European University Institute

Department of History and Civilization

On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century

Arto Kokkinen

Thesis submitted for assessment with a view to obtaining the degree of Doctor of History and Civilization of the European University Institute

Florence, July 2011

Department of History and Civilization

On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century

Arto Kokkinen

Examining Board:
Prof. Giovanni Federico (EUI) - Supervisor
Prof. Youssef Cassis (EUI)
Prof. Jaime Reis (University of Lisbon)
Prof. Markku Lanne (University of Helsinki)

ACKNOWLEDGEMENTS

A number of people, to whom I am grateful, have influenced and inspired me during this research. The first seeds for this study were sown in the late 1990s and early 2000s when I was working in the National Accounts unit at Statistics Finland. I was lucky to be a colleague with Dr. Jukka Jalava, Docent Pirkko Aulin-Ahmavaara and Eeva Hamunen. With Jukka we constantly discussed about the dimensions of National Accounts that intersect academic research. Docent Aulin-Ahmavaara was already a distinguished scholar, and she was the one who introduced to me the branch of research on how to measure human capital in the National Accounts. Later, Eeva was pushing me to IARIW congresses. At the same time when Jukka urged me to join the research seminar by Professor Riitta Hjerppe, I was attending courses of time series analysis at the University of Helsinki. The learning in this period can still be traced in parts of this dissertation.

Getting in touch with Riitta Hjerppe was of course the cornerstone for this study: a person with her kindness, knowledge and remarkable research history can easily draw the attention of a newcomer into a particular field of research. The first part of the study began to materialise while I was employed in her research project and a paper for the XIV World Economic History Congress in Helsinki in 2006 was under construction. In an exemplary way, Riitta was active in introducing me and her other students to a number of leading international scholars and always pushed us to international conferences. Only because of Riitta, I had already early on the great pleasure to listen to and to talk about the research in economic history and economics by/with professors such as Lennart Schön, Jonas Ljungberg, Luis Bértola, Jaime Reis, Stephen Broadberry, Leandro Prados de la Escosura, the late Angus Maddison, Ola H. Grytten, Ulrich Pfister, Carsten Burhop, Sevket Pamuk, Joerg Baten, Giovanni Federico, Gregory Clark, Sakari Heikkinen, Susanna Fellman, Marjatta Rahikainen and with their students. Already in this period, I was happy to be acquainted with Dr. Bas van Leeuwen and Dr. Péter Földvári. Their kindness and our discussions on human capital have meant a lot to me. The support by the Yrjö Jahnsson foundation for the work and for participating in the conferences is greatly acknowledged. The early influence of these learning opportunities is obvious on these pages. The discussions and co-operation with Riitta Hjerppe continued throughout the time for the preparation of this dissertation.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The next important turning point for the study at hand was when I was accepted to the PhD programme of the European University Institute (EUI). Here I have had the chance to work under the intellectual supervision of Professor Giovanni Federico, who, in addition to being a great scholar, has supported in all matters concerning research and life with a family in an international environment. In the first important year at the EUI, when the dissertation was already structured, I was also enjoying the intelligent supervision of Professor Harold James. The learning lessons from already mentioned scholars and such as David Mitch, Anindya Banerjee, Hans-Joachim Voth, Albrecht Ritschl, Claude Diebolt, Timothy Leunig, Kevin O'Rourke, Barbara Fraumeni, Markku Lanne and Antti Ripatti continued both at the EUI in the departments of History and Civilization and of Economics, and in conferences and workshops.

The discussions on all of the matters relating to academic research and life in general with the fellow students at the EUI have been a pleasure and inspired me greatly. Especially, I have to thank Paul Sharp, a visiting fellow at that time, from the University of Copenhagen, who guided me to the first steps of cointegrated VAR analysis, Olivier Accominotti from Sciences Po, Paris, for discussions on economic analysis, and Jacob Weisdorf from the University of Copenhagen for discussions, e.g. on economic analysis and genetics. I also want to thank Miika Tervonen, Samppa Rohkimainen, Jan Kunnas with his family, Jyrki Johannes Lessig, Joonas Korhonen with his family and other friends at the EUI for sharing the life with us and for discussions on everything. In 2009 I participated in the Cointegrated VAR Summer School by Søren Johansen and Katarina Juselius who also kindly commented on the econometrics in my work. The impact of the work of these scholars and of the summer school has essentially shaped the econometric analysis in Chapters 3 and 4.

The work during the EUI time has been financed by the Academy of Finland and the EUI, for which I am deeply grateful. I also want to express my gratitude to Statistics Finland for giving both me and my wife leaves of absence, for providing working possibilities and research data and for sending me to two important IARIW conferences. Director Ari Tyrkkö, my former immediate superior Tuomas Rothovius and Dr. Timo Alanko have been very supportive towards my research work. In the final year, Director General Heli Jeskanen-Sundström encouraged me to offer a paper for the Conference of European Statisticians. I kindly thank all of them.

The ones that I forgot to mention here for their help during the research work please accept my kindest apologies. The list may be too long for the capacity of my memory.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Finally, I would like to thank my parents, Simo and Anja Kokkinen, for supporting me and for encouraging me to educate myself, and for babysitting when feasible. Without the help in organising our life of my parents and my parents-in-law, Seppo and Taru and my sister-in-law Pia, we would not simply have made it. Also, my brother Jari with his family has helped us when possible.

Without Mia, my wife, this dissertation would not have been accomplished. She followed me to Florence, shared my life, and has helped me with everything, even when this has meant trouble and bother. She has also provided constant help with the language.

Along the time at the EUI came Ella, our lovely daughter, who may sometimes have made our nights shorter, but the moments of our life much fuller. She continuously brings sunshine and happiness to our life and teaches us what really matters in the end.

Florence, July 2011

Arto Kokkinen

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

ABSTRACT

Finland is one of the few examples of poor countries' absolute GDP per capita convergence in the 20th century: One hundred years ago it was a poor agrarian country with GDP per capita less than half of that of the United Kingdom or the United States, world leaders at the time. In the beginning of the 21st century it is an industrialised and services emphasised country with a standard of living ranked among the top fifteen to twenty-five countries in the world. In the same time frame Finland has converged with the average income levels of her leading neighbours, Sweden and the EU15.

How did this convergence happen in the geographically large but low population country without being blessed with abundant natural resources? Thinking of today's poor countries it would be important to understand the processes the few catch-up countries worldwide have gone through. The study is conducted in accordance with the following analytical framework: Firstly, the structural change is seen driven by new possibilities (technology) to produce products (old and new). Secondly, this production with new technology will drive labour productivity and GDP per capita up on the national level. Thirdly, to use new production technologies requires human capital. To find out empirically the impacts of investing in and accumulation of human capital by schooling on GDP, investments in human capital are investigated in the same National Accounts framework as GDP. Fourthly, for permanent growth of labour productivity continuous adoption of new production technologies from the evolving world technology frontier is needed. This requires openness and close interaction via foreign trade with the leading countries. The increasing foreign trade and foreign direct investments will render the business cycles of the economies involved more dependent on each other, which should result in increased co-dependence of business cycles. The issues are investigated in the study by econometric techniques with annual long-run data sets, comparing Finnish growth with Sweden and the EU15 and framing the discussion in the growth variation of a broad set of countries. The results in this study suggest a paradigm shift from neo-classical growth and convergence explanation to technology diffusion model with human capital, in which technological progress is embodied in the new varieties (qualities) of fixed capital.

Keywords: economic growth, GDP per capita, labour productivity, convergence, catch-up, human capital, technological progress, technology diffusion, cointegration, business cycle.

TABLE OF CONTENTS

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

1. INTRODUCTION

The convergence and non-convergence of countries on GDP per capita has been one of the major research issues in economic history and economics since the mid-20th century: Why are some countries so rich and so many so poor? Why do some countries catch up and so many of them fall even more behind? According to Alexander Gerschenkron's classical thesis of the advantage of relative backwardness[1] in the 1950s, the low beginning level of GDP should help a latecomer country to generate higher growth rates and catch up leading countries.

Has this prediction become materialised? In Figure A we can see the initial GDP per capita levels for some countries in 1890 on the horizontal axis and average growth rates in 1890–2000 on the vertical axis. The data points of the countries form a downward sloping line and thus the inverse relation of the initial levels and later growth rates of GDP per capita is obvious among these countries. The countries in Figure A are a group of today's OECD countries. The fastest catch-up countries have been Japan, Finland and Norway. Instead, when we look at the countries in the whole world, in Figure B, we cannot find this phenomenon. The catch up of poorer countries is not automatic. In fact, the differences between rich and poor countries' GDP per capita have grown during the last century.[2] However, some of the poor countries have managed to reduce substantially the gap compared with the average income levels of the leading countries and some have even managed to converge with those.

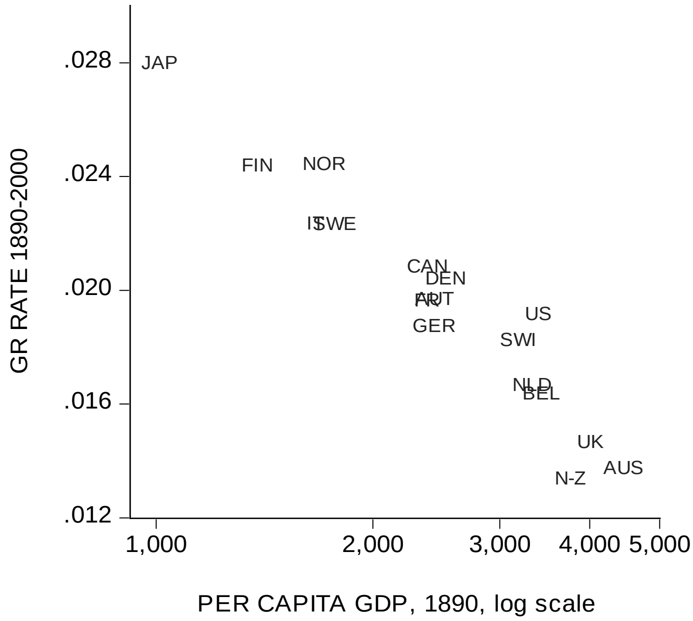
When considering today's poor countries, it would be essential to understand the development and the processes the catch up countries have gone through. In this study the aim is to trace Finland's convergence with the EU15 and Sweden on GDP per capita in the 20th century. The topics to which attention is particularly paid are whether it was simply the later industrialisation with later gains in labour productivity that caused Finland to catch up, whether the substantial investments in human capital by schooling have been one of the factors behind the dramatic change in the economic performance of Finland, and finally, whether the business cycles of Finland have converged to those of the EU15 and Sweden along with the converging average income levels and with the economic integration in Europe.

---

[1] Gerschenkron, Alexander (1952). Economic Backwardness in Historical Perspective. In *The Progress of Underdeveloped Areas*, Ed. B. F. Hoselitz. University of Chicago Press; Gerschenkron, Alexander (1962). *Economic Backwardness in Historical Perspective: A Book of Essays.* Cambridge: Harvard University Press.
[2] De Long, J., Bradford (1988). Productivity Growth, Convergence, and Welfare: Comment, American Economic Review, vol. 78, 5, pp. 1138–1154; Pritchett, Lant (1997). Divergence, Big Time, *Journal of Economic Perspective,* vol. 11, 1997: 3, pp. 3–17.

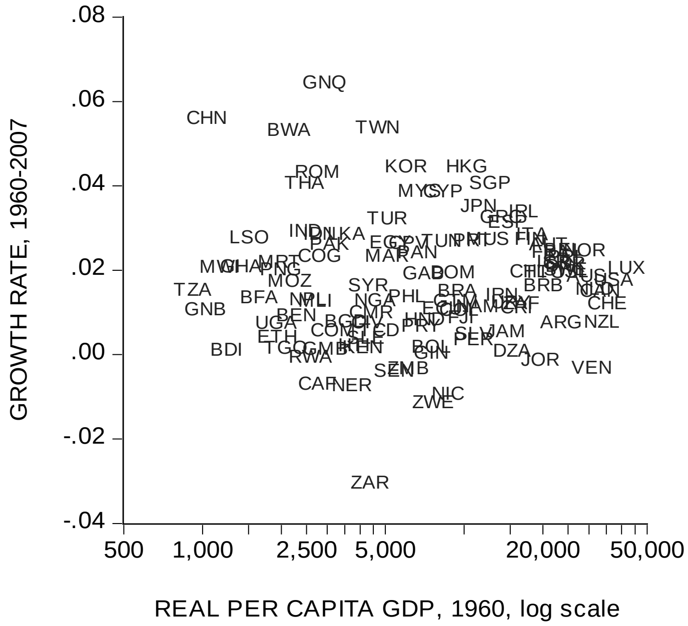
Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure A. Initial GDP per capita levels in 1890 and growth rates 1890–2000, a group of today's OECD countries.



Source: Maddison, Angus (2010). *Historical Statistics of the World Economy*: 1–2008 AD, updated 02-2010. http://www.ggdc.net/MADDISON/oriindex.htm (2010-12-16). Originally a similar figure is presented with older version of Maddison data in Jones, Charles I. (2002). *Introduction to Economic Growth.* 2nd edition, University of California, Berkeley.

Figure B. Initial GDP per worker levels in 1960 and growth rates 1960–2007, countries of the whole world.



Source: *Penn World Tables* 6.3, Heston, Alan, Summers, Robert and Aten, Bettina, *Penn World Table* Version 6.3 (PWT 6.3), Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, August 2009. http://pwt.econ.upenn.edu/php_site/pwt_index.php (2010-12-08) Originally a similar figure is presented with older PWT data in Jones, Charles I. (2002). *Introduction to Economic Growth.*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Before continuing further, it should be discussed how the concept convergence is used in this study. The scientific use of the concept convergence originates from mathematics. For instance, Encyclopaedia Britannica defines the word convergence as "*in mathematics, property (exhibited by certain infinite series and functions) of approaching a limit more and more closely as an argument (variable) of the function increases or decreases or as the number of terms of the series increases*".[3] As an example, the function $f(x) = 1/x$ converges to zero as x increases. This is often denoted as $\lim_{x \to \infty}(1/x) = 0$. In a similar way, we may look at empirically the GDP per capita time series $y_{1,t}$ and $y_{2,t}$ of countries 1 and 2. Now, if the ratio $y_{1,t} / y_{2,t}$ converges to integer 1 along time, the difference of the variables in the logarithmic form $\log(y_{1,t} / y_{2,t}) = \log y_{1,t} - \log y_{2,t}$ approaches zero, $\lim_{t \to T}\left[\log y_{1,t} - \log y_{2,t}\right] = 0$. The strict meaning of the concept implies here that the per capita GDPs of the two countries should at least be very close to meet (and the difference of the logarithmic series to become close to zero) along time at some point T. The use of the concept convergence in the title of this study refers to this strict meaning.

The concept convergence is often used in a somewhat less strict sense, also in economic history and economics, referring to a tendency of the average income levels of the poorer countries to move towards or closer to the ones in the rich countries. For instance, Robert J. Barro and Xavier Sala-i-Martin define absolute convergence by a hypothesis that initially poor countries tend to grow faster than rich ones in per capita terms.[4] This hypothesis can be empirically tested among a large group of countries with the equation $\log(y_{i,t}) = \alpha + (1-\beta) \cdot \log(y_{i,t-1}) + u_{i,t}$, where $y_{i,t}$ is per capita GDP of country i at time t, a and $0 < \beta < 1$ are constants, and $u_{i,t}$ is a residual or a random disturbance term. The condition of β being positive implies absolute convergence since the annual growth rate, $\log(y_{i,t}) - \log(y_{i,t-1})$ is in the equation negatively related to the value of log GDP per capita of the previous year: $\log(y_{i,t}) - \log(y_{i,t-1}) = \alpha + (-\beta) \cdot \log(y_{i,t-1}) + u_{i,t}$. A higher value of the coefficient β corresponds to a greater tendency towards converging (or coming closer to each other) per capita GDPs, hence they also refer to β-convergence in parallel with absolute convergence. Barro and Sala-i-Martin report that the hypothesis of absolute convergence is

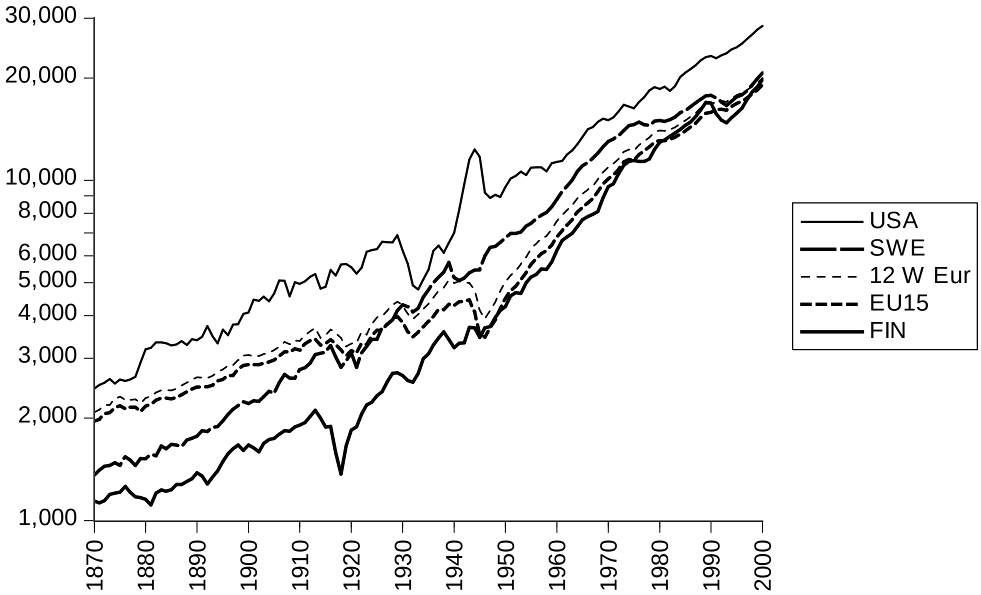
[3] *Encyclopædia Britannica. Encyclopædia Britannica Online*. Encyclopædia Britannica, 2010. http://www.britannica.com.libproxy.helsinki.fi/EBchecked/topic/135706/convergence (2010-12-29).

[4] Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*. The MIT Press, Cambridge, Massachussetts, London, England, pp. 26, 28 Originally published by McGraw-Hill, Inc., 1995.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

rejected among all the countries in the world, as is obvious in Figure B above. On the other hand, as is obvious in Figure A, Finland is one of the relatively few absolute convergence countries.

Figure C. The GDP per capita time series for Finland, Sweden, 12 Western Europe countries and the USA in 1870–2000, in 1990 Geary-Khamis dollars, semi-log scale.



12 W EUR = Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, UK
EU15 = 12 W EUR – (Norway, Switzerland) + Greece, Ireland, Luxembourg, Portugal, Spain

Sources: Maddison, Angus (2010). *Historical Statistics of the World Economy*:1–2008 AD, updated 02-2010 http://www.ggdc.net/MADDISON/oriindex.htm (2010-12-16); data for the EU15: 1860–1995 from Carreras, Albert and Tafunell, Xavier, European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, pp. 63–87, 1996–2000 *Eurostat database* http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (2009-09-09).

In accordance with what was said above, let us focus more closely on the Finnish case with time series data. Figure C delineates the per capita series for the leading economy of the present time, the USA, together with twelve Western European countries, the EU15 area, Sweden and Finland. Inevitably, Finland has converged closely with the twelve Western European countries, with the EU15 and with Sweden on GDP per capita around the turn of the millennium with the data in 1990 international Geary-Khamis dollars. This is an empirical observation without needing any theory at the background. Therefore, Finland is also an example of convergence in the strict sense. Instead, the per capita GDPs of the mentioned

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

economic areas in Europe have not converged to the GDP per capita of the USA, according to the strict meaning of the concept.

Most likely, it is not an accident that Finland has converged to the average income levels of Western Europe and Sweden in the strict sense. This may come from the similar cultural background, institutional settings, high interaction in foreign trade and in foreign direct investments (FDI) and finally from the economic and financial integration of Europe. Correspondingly, Barro and Sala-i-Martin have demonstrated convergence, in this strict sense, in 1870–1990 in groups of capitalistic countries with close interaction and sharing similar institutional and cultural characteristics, Canada, Australia and the USA as one group, the United Kingdom, France, Germany and Italy as another group, and the Nordic countries (without Iceland) as a third example.[5] It is argued here that since the strict convergence in GDP per capita of some groups of countries is observed, this phenomenon should be explored together with the less strict use of the concept. It will also probably give feedback to the vast number of theoretical considerations on growth.

Figure D. The GDP per capita time series for the USA and for the Nordic countries (except Iceland) in 1870–2008, in 1990 Geary-Khamis dollars, semi-log scale.

Source: Maddison, Angus (2010). *Historical Statistics of the World Economy*: 1–2008 AD. http://www.ggdc.net/MADDISON/oriindex.htm (2010-12-16).

[5] Ibid, pp. 332–335.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure D describes the example of the Nordic Countries here (without data for Iceland) together with the US. It is easy to find a convergent point between this group of Nordic countries around the year 1990, after which the financial crises, followed by the liberalisation of the financial markets in the 1980s, hit most severely Finland and Sweden.[6] Rapidly recovering, they have caught up Denmark again around 2006 but have fallen behind from the advancement of the Norwegian levels of per capita GDP and clearly not reached the level of the US. Only Norway could be said to have shown convergence with the US. However, Norway has had special gains from her oil resources in the times of increasing scarcity of this source of energy in the world.

For Finland the road has probably been the most difficult one, with catching up mostly after the Second World War, and being a border country of the West and East in the Cold War era. In her development after WWII, Finland had to ensure more or less constantly that the international relations also in trade would not be interpreted in the Soviet Union as harmful for the Soviet relations.[7] Only after the breakdown of the Soviet Union, in 1991, the political elite of Finland considered applying for the membership to the European Union.[8] In the end, the three neutral zone countries Austria, Finland and Sweden joined the EU at the same time in 1995.

Denmark and Norway had applied for the membership to the EEC together with the United Kingdom and Ireland, first as early as 1960 and then again in 1967. The application procedure originally led to the rejection of the whole group in fear of the US influence along with the United Kingdom in the EEC. Finally in 1969, the accession treaties of the UK, Ireland and Denmark were signed and they joined the EEC in 1973.[9] In Norway, the negative votes formed a majority in the referendum and hence Norway did not join the European Communities at that time or later.

The probable reasons why close economic interaction between the countries and cultural similarities could result in a strict convergence of the levels of GDP per capita is technological diffusion and similarity in the institutional set-up and in preferences.

[6] See Jonung, Lars, Kiander, Jaakko and Vartia, Pentti (Eds) (2009). *The Great Financial Crisis in Finland and Sweden*. Edward Elgar Publishing Ltd., Cheltenham, UK.
[7] Finland declined Marshall aid for political reasons. Similarly, being cautios about the Soviet reactions Finland decided to stay out of the OEEC (OECD), joining only in 1969. Finland managed to accede to GATT in 1949 to secure her export interests.
[8] Jukka Seppinen describes the Finnish road to EU membership in 1995 as "From impossible to possible". See Seppinen, Jukka (2001). *Mahdottomasta mahdollinen. Suomen tie Euroopan unioniin.* Gummerus Kirjapaino Oy, Jyväskylä 2001.
[9] See, e.g. Pihkala, Erkki (2008). *Yhdentyvä Eurooppa. Euroopan unionin taloushistoria.* [Verkkojulkaisu.] Helsinki: Suomalaisen Kirjallisuuden Seura, 2008, http://kirjat.finlit.fi/verkkokirjat/yhdentyva_eurooppa (2011-02-25).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Technological diffusion, often from the leading economies to the followers, involves costs of imitation and adaptation. The costs for adapting a good or a technique are smaller for those who are more familiar with how the new idea operates in the country of origin. In addition, cultural similarities probably also relate to the similarity of preferences in the propensity to save and to smooth consumption over time, and may result as well in the similarity of the institutional framework including property rights and labour market regulations. The patience in choosing consumption between present day and the future, and the property rights for new ideas or patents affect asset accumulation positively in the economy. In some theoretical considerations the time preference in favour of patience even increases with accumulated assets. The correspondence in labour market regulations, in turn, may result in similar labour force participation rates of the population and in similar working hours per day.

Sharing similar values can also result in similar attitudes towards education, and in the case of positive attitudes, the increased human capital in the labour force will facilitate the adaption of new technologies in the country. Advanced and deepened human capital in the research and development activities may as well increase the possibilities to invent new ideas and technologies especially in the leading countries. At the same time, the similarity of the education systems will make it easier to exchange students and labour between countries and boost the interaction.

Foreign direct investments from the leading countries may be especially useful for the follower if foreign involvement reduces the adaptation costs on new technology. However, imitation by local entrepreneurs of products or ideas developed elsewhere may also occur. Although this process can be costly, yet it often escapes any fees paid to the inventor of the good or method in production. Foreign trade in goods and services with and foreign investments from or to the leading countries also increases the knowledge of new goods and of novel technologies in production. Imitation of ideas or even of a production technology may begin by being able to hold a new product in one’s hands. The interaction with the leading countries may form a cornerstone for the followers if they have the ability, human and social capital to follow.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

1.1 Finland's economic interaction with foreign countries after WWI

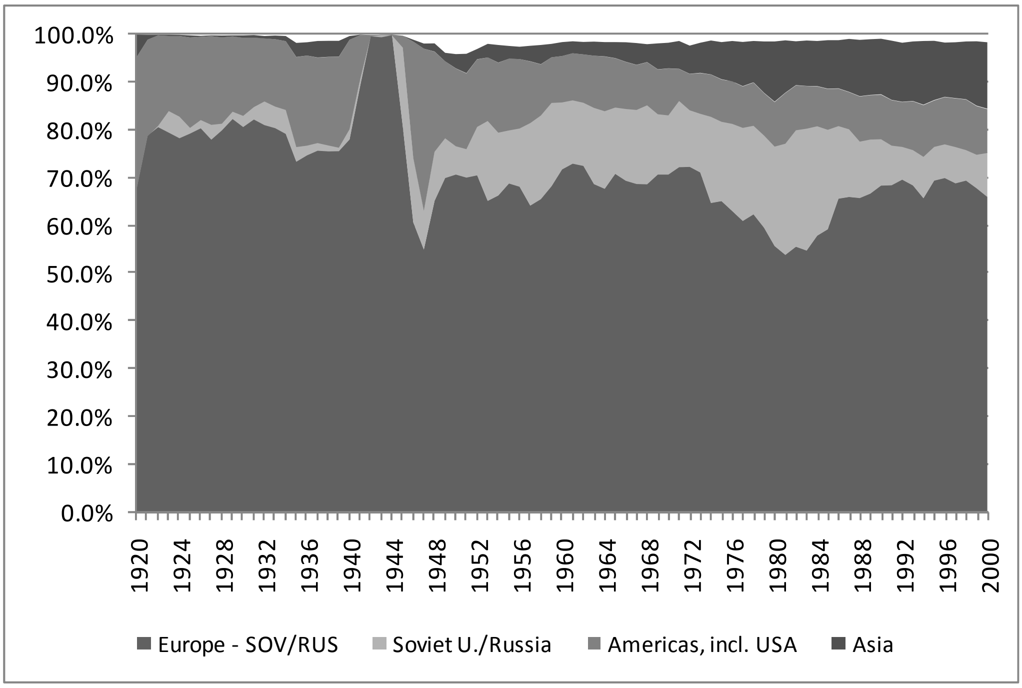
To study the economic interaction with foreign countries, the data on foreign trade and on inward and outward FDIs concerning Finland will be explored in this section. The aim is to shed light on where new technologies and ideas used in the production may have come to Finland after WWI in the 20th century.

Figure E shows the regional distribution of imports to Finland from Europe without the Soviet Union (later Russia), from the Soviet Union (or Russia), from the Americas and from Asia in 1920–2000. It is inevitable that most of the foreign products to Finland have come from Europe other than the Soviet Union, with an average of 71% and the annual share of imports varying from 54% to 82% in peacetime after the First World War. Consequently, technologically advanced products, particularly including machinery and equipment, were mostly imported from Western Europe. The average share of Germany, Sweden and the United Kingdom together was 38% of imports in 1920–2000, and after the Second World War 37%. When adding to this group France, the Netherlands, Denmark, Italy, Norway and Belgium, the average share climbs up to 56% in the whole period, with a same share of imports after WWII. Hence, also in the long run, the average annual shares have been surprisingly stable.

The share of the Soviet Union in Finnish imports grew rapidly from the early 1970s up to the early 1980s in the times of the OPEC oil crises. At this time, in accordance with the bilateral trade agreements with the Soviet Union, Finland obviously gained from importing Soviet oil, and at the same time from being able to export more to the Soviet Union. Since the late 1980s the imports from the Soviet declined while the shares of other Europe and Asia enlarged. The imports from the Americas were the highest between the wars, the average share being 18%. After the Second World War, the average share of the Americas declined to 11%.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure E. The share of Finnish imports from Europe other than the Soviet Union/Russia, the Soviet Union/Russia, the Americas and Asia in 1920–2000.



Source: Database of Riitta Hjerppe on Finnish foreign trade

Foreign direct investments into Finland are perhaps an even more important way for the technology to transfer to Finland. Official statistics on foreign direct investments (FDI) are available from 1965 onwards. FDIs are defined in the Balance of Payment Statistics by a foreign direct investment relation, which arises by foreign corporate acquisition or by purchasing enough shares for controlling (by holding > 50% of the shares) or for having a stabile economic relation with the foreign corporation (by owing 10% – 50% of the shares).

Table A demonstrates the average shares in foreign direct investments inwards to Finland by economic area in 1965–1972 and in 1973–1990. The European Economic Community (EEC) was formed by the original Inner Six countries: France, Germany, Italy, Belgium, the Netherlands and Luxembourg, in 1957. This composition of the EEC stayed the same in the former period here, in 1965–1972. The European Free Trade Association (EFTA) was in turn formed originally in 1960 by the Outer Seven countries: the UK, Denmark, Norway, Austria, Portugal, Sweden and Switzerland. Finland became an associate member of EFTA in 1961 and Iceland joined the EFTA in 1970. In 1973, Denmark, the UK and Ireland, after two application rounds, became members of the EEC. Norway applied at the same time with these countries in 1960 and in 1967, but the result of the referendum in Norway was no, and the country has stayed in EFTA. At the same time, in 1973, the EEC and EFTA areas

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

signed a free trade agreement, which came into force in Finland in 1974. The time periods are chosen in Table A to reflect these changes, allowing for detecting whether the increased integration after 1973 has amplified the inward FDIs to Finland from the EEC area.

Table A. Average annual shares of foreign direct investments inwards Finland from Europe and the Americas in 1965–1972 and in 1973–1990.[10]

	1965-1972
EFTA + EEC	**66.8%**
EFTA	**54.9%**
- SWE	37.5%
- UK	12.4%
- DEN	3.1%
- SWI	1.5%
EEC	**12.0%**
- BENELUX	11.7%
- GER	0.3%
- FRA	0.0%
North Am	**20.0%**
- US	20.0%
Others	13.2%
TOT	100.0%

	1973-1990
EFTA + EEC	**88.1%**
EFTA	**45.1%**
- SWE	37.4%
- SWI	7.8%
EEC	**43.0%**
- BENELUX	16.0%
- UK	15.4%
- DEN	4.7%
- FRA	3.0%
- GER	2.8%
North Am	**9.1%**
- US	9.0%
Others	2.8%
TOT	100.0%

1965–1972:
EFTA (with FDIs reported) = SWE, UK, DEN, SWI, NOR (0.2%), AUS (0%)
EEC (with FDIs reported) = NLD, BEL, GER, FRA, LUX (0%), ITA (0%)
1973–1990:
EFTA (with FDIs reported) = SWE, SWI, AUS (0%), NOR (0%)
EEC (with FDIs reported) = UK (1973–), NLD (9.2%), BEL (6.7%), DEN (1973–), FRA, GER, LUX (1.1%), ITA (0%)

In the first period Iceland joined EFTA in 1970. Portugal was part of EFTA in 1960–1985.
In the second period UK, DEN and IRE joined the EEC in 1973, Greece in 1981, Spain and Portugal in 1986.
UK and DEN have had the most important impact in reported FDIs to Finland of these mentioned countries.

Source: Own calculations, data from Bank of Finland, Balance of Payments Statistics.

The figures in Table A leave no doubt that most of the FDIs into Finland have come from the EFTA and EEC countries. Quite interestingly, Sweden has been the biggest single investor country. In the economically integrating Europe the next biggest investors to Finland have

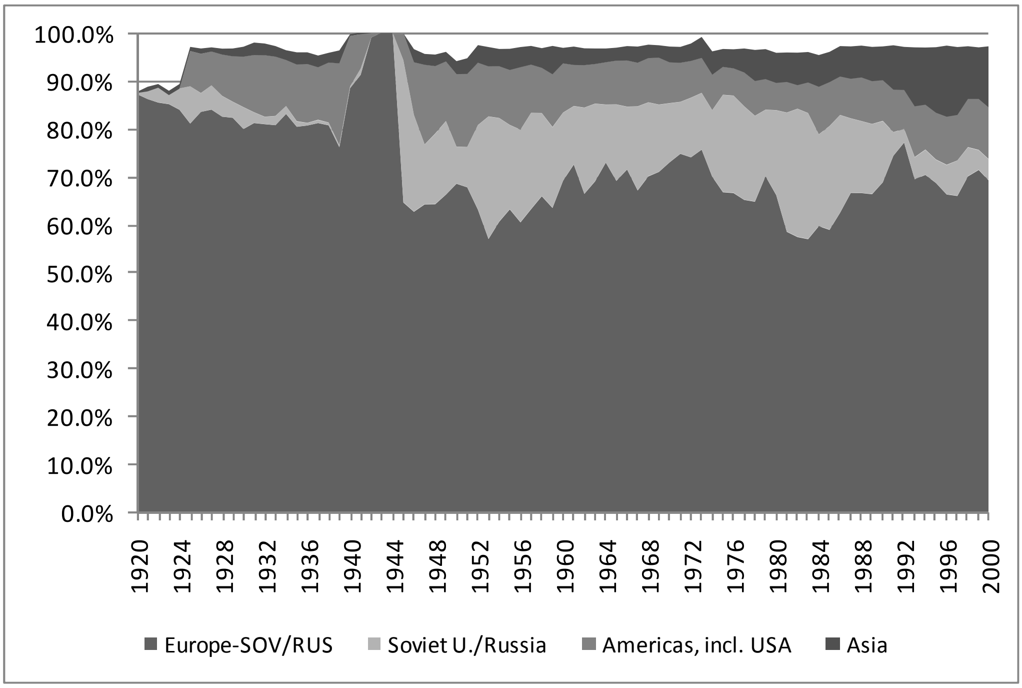
[10] In Table A (and later in Table B)the latter time period is chosen to end in 1990 because in the depression years in 1990–1992 in Finland, both the inward and outward FDIs are reported dramatically negative. Later, in Figures G and H the shares in the cumulated stocks of inward and outward FDIs will be reviewed by economic area in 1994–2009, as the official statistical data for the stocks are available from 1994 onwards. The stocks illustrate how the original investments have cumulated and stayed in the foreign country in the long run up to the stock value at market prices of the observed year. Therefore, only the depression years will be left out of this analysis.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

been the United Kingdom, the BENELUX countries (the Netherlands and Belgium), Denmark, Switzerland and Germany. The more or less same biggest candidates for technology diffusion to Finland are manifested in both imports and in FDIs, however, in the average annual shares for inward FDIs, Sweden steps forth together with the UK and the BENELUX countries and Switzerland. Germany's share in inward FDIs has obviously been minor compared with imports in this time period. The FDIs from the EEC area increased to Finland in the latter period in accordance with the EEC and EFTA free trade agreement.

Another way to get in touch with the technologies abroad are exporting activities and present selling or production activities at the markets in a foreign country. The latter activities can be observed by the outward FDIs from Finland, which will be inspected after focusing on Finnish exports.

Figure F. The share of the Finnish exports to Europe without the Soviet Union/Russia, the Soviet Union/Russia, the Americas and Asia in 1920–2000.



Source: Database of Riitta Hjerppe.

As Figure F shows, most of the exports from Finland have also been sold in the markets of Europe without the Soviet Union or Russia. The average share of this area of Finnish exports has been 72.5% in 1920–2000, between the wars 82.6% and after WWII 67.0%. On average, the exports to Germany, Sweden and the United Kingdom together have formed 44% of exports in 1920–2000, and after the Second World War 37%. Again, adding to this group

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

France, the Netherlands, Denmark, Italy, Norway and Belgium, the average share reaches 65% in the whole period, and 58% after WWII.

The average share of exports to the Americas was in the interwar period 7.7% and in 1946–2000 9.5%, and the average shares to Asia 1.6% and 5.7%, and to the Soviet Union/Russia 2.6% and 14.6%, respectively. Exports to the Soviet Union were expanding especially after WWII because of the war reparations of Finland, and imports in the times of the bilateral trade agreements and the two OPEC oil crises from the early 1970s up to the early 1980s. After the collapse of the Soviet Union, the export share of Russia has become smaller. Since the early 1980s, the share of exports to Asia has particularly grown.

Table B, in turn, gives the possibility to evaluate the more solid presence of Finns in the foreign markets by outward FDIs in 1965–1990. Again most of the outward FDIs, approximately two thirds, were located in the EFTA and EEC areas. The countries with the biggest shares in Europe look familiar, Sweden with her share increasing in the positioning of the Finnish FDIs particularly after the 1980s, the UK, the Netherlands, Belgium and Denmark. France and Switzerland are among the countries with the biggest share in Europe of outward FDIs from Finland, as they are in export shares as well.

Table B also reveals that North America has been somewhat more favoured in the share of the investments from Finland than vice versa. Canada received a good part of the Finnish foreign investments of the paper and pulp industry in the late 1960s, early 1970s, late 1970s and early 1980s. In the 1980s the US increased its average share of investments from Finland. North America was more often a target for the Finnish investments than vice versa. Nevertheless, the vast majority of outward FDIs from Finland were placed in Western Europe. In Europe, France, Germany and Switzerland have had a relatively higher share of Finnish outward investments than in investments inwards Finland.

When inspecting the value of investments in each direction, it becomes clear, however, that it has been an active Finnish strategy to boost investments in foreign enterprises rather than only waiting for the foreign enterprises to invest in Finland. In the first reported period of FDIs above, in 1965–1972, an annual average value of the total investments inwards Finland was EUR 11 million, when in the same period the annual average value of outward investments was EUR 20 million. With the rising foreign investments in the latter reported period, in 1973–1990, the difference is much larger: the average annual inward investments were EUR 88 million a year, while the average annual outward investments were EUR 454 million per year. For receiving knowledge of new technologies, the stable activities of Finns in the foreign markets seem to have been bigger in magnitude than the inward FDIs.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table B. Average annual shares of foreign direct investments outwards from Finland to Europe and the Americas.[11]

	1965-1972
EFTA + EEC	**52.1%**
EFTA	**18.8%**
- SWE	7.7%
- SWI	6.0%
- UK	4.7%
- AUS	0.3%
EEC	**33.3%**
- BENELUX	9.0%
- GER	7.8%
- ITA	7.2%
- FRA	6.3%
North Am	**43.3%**
- CAN	38.6%
- US	4.7%
Others	4.6%
TOT	100.0%

	1973-1990
EFTA + EEC	**72.7%**
EFTA	**23.3%**
- SWE	15.1%
- SWI	4.4%
- NOR	3.7%
EEC	**49.4%**
- UK	13.8%
- GER	10.8%
- BENELUX	10.1%
- FRA	6.8%
- DEN	3.7%
North Am	**20.7%**
- CAN	11.5%
- US	9.2%
Others	6.6%
TOT	100.0%

1965–1972:
EFTA (with FDIs reported) = SWE, SWI, UK, AUS, DEN (0%), NOR (0%), PRT (0%), ISL (1970–, 0%)
EEC (with FDIs reported) = GER, ITA, FRA, NLD, BEL, LUX (0%)
In addition SPA (did not belong to EFTA, joined the EEC 1986–, 3.0%)
1973–1990:
EFTA (with FDIs reported) = SWE, SWI, AUS (0%)
EEC (with FDIs reported) = UK, GER, FRA, BEL (6.8%), DEN, NLD (3.3%), SPA (joined 1986–, 2.4%), IRE (0.7%), ITA (0.6%), LUX (0%), PRT (joined 1986–, 0%), GRC (joined 1981–, 0%)

In the first period Iceland (ISL) joined EFTA in 1970. Portugal (PRT) was part of EFTA in 1960–1985.
In the second period the United Kingdom (UK), Denmark (DEN) and Ireland (IRE) joined the EEC in 1973, Greece (GRC) in 1981, Spain (SPA) and Portugal (PRT) in 1986.

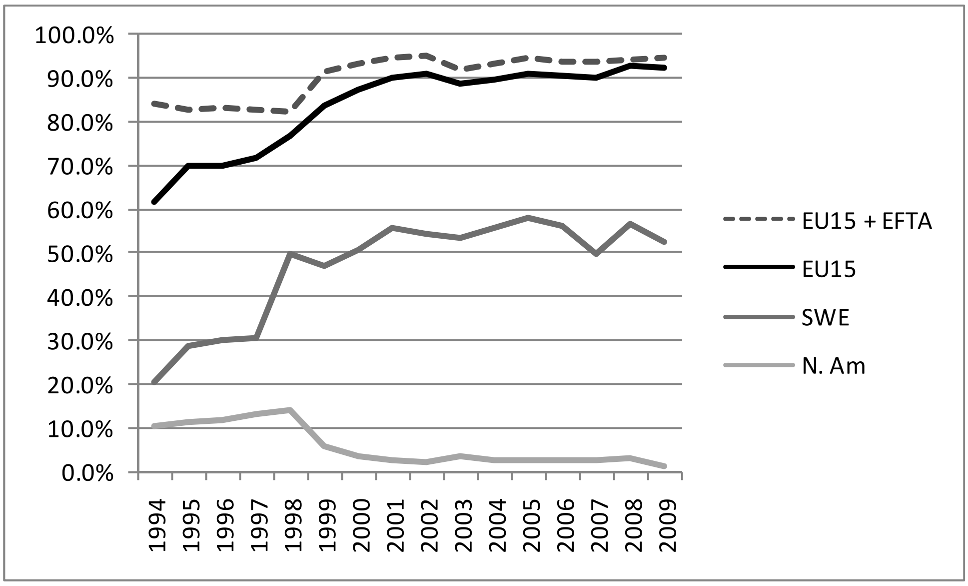
Source: Own calculations, data from Bank of Finland, Balance of Payments Statistics.

Finally, an inspection of the stocks of inward and outward FDIs of Finland is made, with the official statistical data available from 1994 onwards. The stocks give an even more accurate picture since they show how the original investments have cumulated and stayed in the foreign country in the long run up to the stock value of the observed year. In addition, the stocks at the end of the year are revalued to reflect the market value of the holdings in the foreign country each year.

[11] NB: In the Balance of Payments Statistics the direct investment represents both the original investment by which the investor acquires the ownership of the foreign enterprise and after it the other capital by which the investor directly finances the activities of the foreign enterprise. The claims of the owned foreign enterprise from the investor reduce the net value of the investment. Hence, in some years of the FDIs of a country a negative net value is reported in the statistics. The average annual shares over the years take these into account over time.

Figures G and H present the shares of the inward and outward FDI stocks in Finland by economic area in 1994–2009. From the former, Figure G, it becomes even more obvious that Sweden has been the biggest single foreign investor to Finland, as her share of the total inward FDI stock has been around 50% or more since 1998. Correspondingly, the dominance of the joint EU15 and EFTA area is even clearer than above, with an annual average share of the total stock of 90% and with an increasing share towards 2009. The overall picture is quite similar with the stocks of outward FDIs in Figure H, with the EU15 and EFTA having the highest average annual share of 75% and Sweden the biggest average share, 25%, of single countries, although Sweden has not been as dominant as in the inward FDIs.

Figure G. The share of the inward FDI stocks in Finland by economic area 1994–2009.

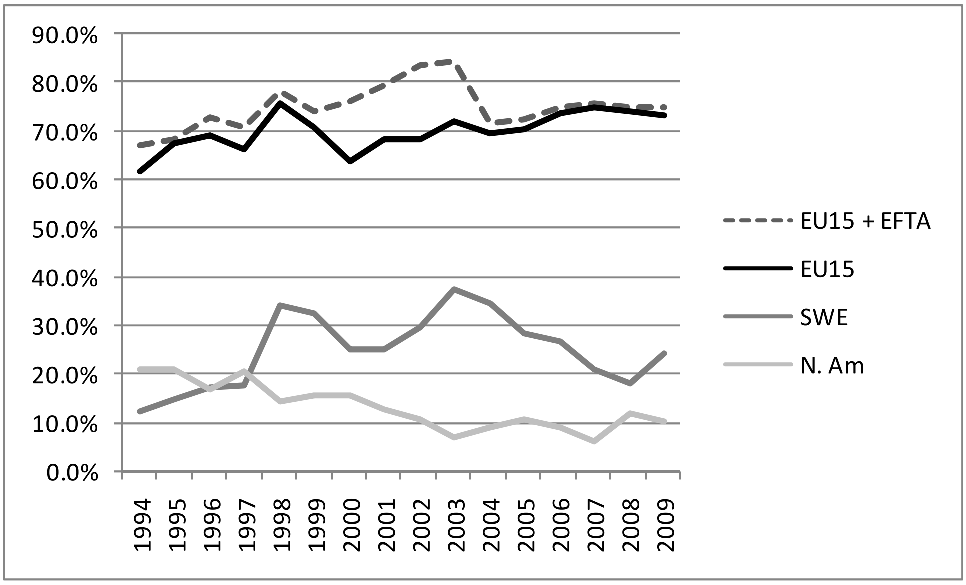


EU15 = Sweden (46.9%), Netherlands (14.3%), Denmark (6.5%), UK (5.5%), Germany (4.0%), Belgium (1.9%), France (1.5%), Luxembourg (1.3%), Ireland (0.6%), Austria (0.4%) , Italy (0.4%), Spain (0.1%), Greece (0.0%), Portugal (0.0%),
EFTA = Switzerland (3.6%), Norway (2.8%), Iceland (0.2%)
N. Am.= US (5.7%), CAN (0.1%)
Annual average shares of the countries reported in parenthesis.

Source: Bank of Finland, Balance of Payments Statistics.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure H. The share of the outward FDI stocks from Finland by economic area 1994–2009.



EU15 = Sweden (25.0%), Netherlands (16.7%), Germany (7.7%), Belgium (5.7%), UK (3.9%), France (3.1%), Denmark (2.7%), Luxembourg (2.0%), Spain (0.9%), Austria (0.8%), Greece (0.0%), Ireland (0.6%), Italy (0.8%), Portugal (0.1%)
EFTA = Iceland (3.2%), Norway (1.9%), Switzerland (0.0%)
N. Am. = US (12.0%), CAN (1.2%)
Annual average shares of the countries reported in parenthesis.

Source: Bank of Finland, Balance of Payments Statistics.

To summarise data on the stocks by country, Sweden, the Netherlands, the UK, Germany, Denmark and Belgium have been the typical countries investing into Finland and receiving FDIs from Finland when judging by the cumulated stocks of FDIs, revalued by the market values each year. North America and the US have had a somewhat higher share in the outward FDIs from Finland than in the inward FDIs from the US. In the direct investments, more or less in both directions the economic interaction with the US relative to others seems to have declined since the EU membership of Finland in 1995 and after the implementation of the euro.

The annual average total stock value of inward FDIs was around EUR 32 000 million in 1994–2009 (EUR 59 000 million in 2009) and in the total outward FDI stocks around EUR 50 000 million in 1994–2009 (EUR 88 000 million in 2009). Hence, relatively more FDIs have flowed to Finland in the period of EU membership, judged by comparing the above figures with the difference in the average annual total inward and outward investment flows in 1973–1990. However, Finnish active investments abroad have been bigger according to the cumulated stocks of FDIs as well. An active role in outward FDIs can be an important

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

way for a follower country to get in touch with new technologies when the agents of the follower country enterprises have enough human capital to be able to learn of new ways of production, new equipment and new ways to do business in activities abroad. The contacts in the foreign outward activities probably increase the interest of the foreign corporations in investing into the follower country.

Unfortunately, the official statistics on foreign direct investments are not available before 1965. Fortunately, Riitta Hjerppe has studied foreign companies in Finland between the world wars.[12] According to the conventional wisdom, the period after WWI was characterised by narrowing activities in international relations and protectionism. However, the author found out that there were more foreign owned enterprises in Finland at the time than anticipated, over 400, at the same time as the proportion of foreign trade to GDP stayed exceptionally high in Finland, by international comparison. Also, the customs and other barriers to foreign trade were smaller in Finland than internationally on average at that time. Therefore, the author concludes Finland had more economic interaction with foreign countries than was previously thought.

In another paper Hjerppe focuses particularly on the Swedish foreign companies in Finland in the same period.[13] She observed the number of the Swedish enterprises and their importance for the Finnish development between the wars to have been bigger than previously known. In Chapter 2 in this dissertation, the interwar period is considered as a take-off time for the Finnish catch-up growth, the observation already made by Olle Krantz.[14] Finland may have been relatively more active than countries on average in economic interaction internationally in the interwar period, which quite probably has also resulted in technology transfer to Finland, helping her way on the way to modernising the economy.

Table C displays the number of companies in Finland between the world wars in Hjerppe's study and their distribution by country and by industrial class. Most of the foreign companies were again Swedish, followed by German, Norwegian, British and Danish companies. The share of these countries forms 80% of the foreign owned enterprises, a share comparable to that of the joined EFTA and EC area FDIs in Finland in 1965–1990. Not only

[12] Hjerppe, Riitta (2004). Monikansallisten yritysten tulo Suomeen ennen toista maailmansotaa. *Kansantaloudellinen aikakauskirja*, 3/2004, pp. 216–238.

[13] Hjerppe, Riitta (2006). Svenska företag i Finland under mellankrigstiden. In Aunesluoma, Juhana, Fellman, Susanna (Eds.) *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet*. Svenska litteratursällskapet i Finland, Helsingfors, 2006, pp. 325–354.

[14] Krantz, Olle (2001), Industrialisation in Three Nordic Countries: A Long-Term Quantitative View, in *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940,* Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters 2001, pp. 23–65.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

the shares in imports to Finland, but also the big picture in the shares of inward FDIs by countries seems to have been quite stabile after WWI in the 20th century.

Table C. The share of foreign companies by country and by industrial class in Finland in the interwar period.

By country	Nr.	%	By industrial class	Nr.	%
SWE	151	35%	**Agriculture and forestry**	**15**	**3%**
GER	79	18%	**Manufacturing**	**156**	**36%**
NOR	43	10%	- textile, clothing	23	5%
UK	40	9%	- forest industries	61	14%
DEN	35	8%	- chemistry	23	5%
US	20	5%	- electrical machines, equipment	28	7%
Sov.U.	11	3%	**Services**	**251**	**58%**
Estonia	5	1%	- trade	152	35%
others	38	9%	- transportation, telecommunication	55	13%
not known	8	2%	- banks and insurance	12	3%
			- real estates	12	3%
Total	430	100%	Total	430	100%

Source: Hjerppe, Riitta (2004). Monikansallisten yritysten tulo Suomeen ennen toista maailmansotaa. *Kansantaloudellinen aikakauskirja*, 3/2004, pp. 216–238.

The idea is not to claim here that Finland would not have benefited from the special relations with the Soviet Union in foreign trade and from the vast Soviet markets in exports in the 20th century. However, except for two nuclear power plants built in the 1970s, Finland was not primarily importing machinery and other production equipment from the Soviet Union. I do not either disagree with the positive effects of the markets in the Russian Empire in the first phase of industrialisation in the 19th century Finland.

It is neither the purpose here to argue that the relations in the foreign trade and in the foreign investments with the US would not have been important for Finland in the interwar period or in the times of the Cold War. As a matter of fact, if not taking into account the economic integration areas of Europe, the EEC and the EFTA, the US would be regarded as the second biggest in 1965–1972, the fourth biggest in 1973–1990 and between the wars the sixth biggest single investor country to Finland. It is also clear that soon after WWII it was the USA that assisted in rebuilding Western European economies by, for instance, the Marshall aid (not received in Finland). Probably at that time Western European countries were copying and implementing, where suitable, production technologies in the machines and equipment employed in the US. However, they were also doing the same with other Western European countries, Japan and later also with other Asian countries along the latter part of the 20th

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

century. Here, the idea is to perceive the big picture in the economic interactions of Finland by economic areas: Judged by the foreign trade and FDIs, it seems clear that the new technology products diffused to Finland above all from Western Europe instead of the US or of the Soviet Union after WWI. For the interdependence of economies and for the convergence pattern of Finland, this is quite probably crucial.

When talking about the technology and physical capital, the focus often turns to the manufacturing industries. What is not so often considered is the new technology and physical capital used in services as well, such as in transportation, telecommunication, trade, banking, finance and insurance. If moving in time for a moment to the early 21st century, it is worth noticing that software programming, the results of which are later embodied in a computer or mobile phone, belongs in the industrial classification to services (see, e.g. the EU's Standard Industrial Classification, NACE Rev. 2). In the present time, the new technology showing up in a computer (or mobile phone) as a new quality is therefore often produced in services. Also, throughout the 20th century electrifying and computerising banking and insurance, the development, e.g. in the equipment for transportation, logistics, storage and planning and inventing business activities have had their impact on the labour productivity of the services. In Chapter 2 in this dissertation, it is shown that for the convergence with Sweden, Finland has gained from the rise in the labour productivity of services as well, not only from the manufacturing and construction industries.

As Finland was vastly agrarian in the early 20th century, and even after WWII, there was also plenty of room for the successful business in the progressing services along with gradual urbanisation and rising income development. This is reflected in the distribution of foreign owned enterprises by industrial class in the interwar period as well, as can be seen in Table C. Foreign companies had seen the business opportunities in the services in Finland already between the World Wars, and 58% of the companies were operating in services. This is also corroborated in the other paper of Hjerppe, focusing on Swedish companies in Finland at that time, as the shares by industrial class form exactly the same picture as with the broader group of countries in Table C.[15]

It is argued here that the diffusion of the new means and equipment to do business from the leading countries was not only taking place in manufacturing and construction but also in the service industries. Table D gives the same picture in FDI inward flows, here in the periods of 1965–1980 and of 1981–1989. The foreign investments into the service industries

[15] Hjerppe, Riitta (2006). Svenska företag i Finland under mellankrigstiden. In Aunesluoma, Juhana, Fellman, Susanna (Eds.) (2006). *Från olika till jämlika..*, pp. 325–354.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

in Finland have been actually at least as big as in manufacturing. What is particularly intriguing is that in 1965–1980 the services and especially trade received, on average, over 60% of the inward FDIs in Finland. In this time period, as demonstrated in Chapter 2 in this dissertation, Finland was catching up Sweden especially because of the gains of labour productivity improvements in services. These gains in service industries have also later done their part together with gains in secondary production, as is explained in Chapter 2.

Table D. Average annual shares of foreign direct investments inward Finland by industrial classes.

	1965-1980	1981-1989
Manufacturing	29.7%	35.4%
- metal	8.3%	3.2%
- chemistry	10.7%	21.9%
- other manuf.	10.6%	10.3%
Trade	61.2%	40.7%
Finance & Insurance	-	8.7%
Others	9.2%	15.3%
TOT	100.0%	100.0%

Source: Bank of Finland, Balance of Payments Statistics.

In addition to the analysis above, it is worth reminding of the close relations of the Nordic countries in the course of the history. Before 1809 Finland was part of Sweden for ca. 600 years. During this time, Denmark and Norway formed a union, and in the times of the so called Kalmar Union, in 1397–1521, Sweden-Finland was also in the state union with Denmark and Norway. After Sweden broke out of the Union, in 1521, Norway remained with Denmark until 1814. At this time, Denmark lost Norway to Sweden and Norway was together with Sweden until gaining her independence in 1905. Sweden lost, in turn, Finland to Russia in 1809, and Finland was given a status of Grand Duchy in the Russian Empire with a fairly large degree of autonomy in terms of its domestic policies in 1809–1917. The advantage of being inside of the highest customs of the vast markets in Russia proper were helping in attracting foreign investors to build the first larger scale factories for industrial production. At the same time, Finland was allowed to keep her institutional structure, including judicial, religious and local government authorities which were established during the Swedish period. Altogether, one has to conclude that Finland has a lot in common with the institutional set-up

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

and cultural and religious heritage of the Nordic countries. Finland gained her indepepence in 1917. After that, in the interwar period, the economic interaction with Sweden and other Western European countries was active once again, as in the times of exporting furs, fish, tar and timber already before 1809. After the independence, foreign trade increased again with Western Europe, this time by saw-mill products, pulp and paper.[16]

In the era of Golden Years of Economic Growth after WWII, there was also a good amount of co-operation between Nordic countries. For instance, the states agreed on common labour markets in the 1950s. Since 1954, the citizens in the Nordic countries have been able to move and work freely in other countries. Finns both migrated and worked for shorter periods particularly in Sweden. The migration was highest from the late 1950s until the early 1970s.[17]

Finland followed quite closely the organising of the society in Sweden and other Nordic countries, and took example for instance of nine-year compulsory comprehensive school reform, which was implemented earlier in Sweden. The policies increasing social and economic cohesion, regarding low income dispersion by collective bargaining and equal opportunities for children, were followed, although sometimes not exactly to same degree as e.g. in Sweden. The economic system in Finland got similar shape, form and features as in other Nordic countries.

A group of business historians, Susanna Fellman, Martin Jes Iversen, Hans Sjögren and Lars Thue, has named this model recently as Nordic capitalism.[18] They characterise the Nordic model by large public sector, generous welfare systems, high level of taxation, successful state owned companies, high degree of consensus, gender equality, equal opportunities to free education and high levels of human capital, low corruption, high degree of consensus, policies supporting labour supply by means of income-based transfers and publicly subsidised welfare services, compromise thinking, corporatism with centralised state but yet open, the bureaucracy professional but not authoritarian. According to the authors, the Nordic countries have been fairly stable societies with little tension and conflict (at least up to these days). They studied the individual countries and their institutional models in more detail as well, and concluded that Swedish and Finnish capitalism are more similar, as are Denmark and Norway. In Sweden and Finland the institutional model has been influenced to support

---

[16] See Kaukiainen, Yrjö (2006). Foreign trade and Transport. In Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura, pp. 127–163.

[17] See, e.g. Meinander, Henrik (2006). *Suomen historia. Linjat, rakenteet, käännekohdat*. WS Bookwell Oy, Porvoo, p. 201

[18] See Fellman, S., Iversen, M. J., Sjögren, H. and Thue, L. (Eds.) (2008). *Creating Nordic capitalism. The business history of a competitive periphery*. Palgrave Macmillan

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

key export manufacturing industries with large-scale manufacturing firms. The key branches have been mainly the forest, metal and electronic industries. Norway and Denmark, in turn, have been influenced by the strong position of small-scale entrepreneurship.[19]

1.2 Convergence and growth in theory

The approach in this study is first of all empirical. However, since a lot of the background on the discussion whether (and should) the poor countries are (be) catching up the rich ones, some main lines in the theories on economic growth in relation to convergence will be briefly discussed. In accordance with the theories, the concept of convergence is often used somewhat less strictly than the mathematical definition, as discussed above.

The theories on economic growth have confronted challenges in including both the non-convergence on (or non-approaching of) average income levels of the countries in the world and the convergence (or approaching with each other) of some of the countries displayed in Figures A and B, and, at the same time, incorporating the sustained long-run economic growth of the world and of the leading economies after the industrialisation.

Perhaps the most analysed growth theory and a reference point to subsequent theories is the neo-classical Solow-Swan model with technology.[20] This theory includes a production function of the neo-classical type, which assumes constant returns to scale, diminishing returns to each input (physical capital and labour), and some positive and smooth elasticity of substitution between inputs. Combining the production function with a constant saving (and investment) rate rule generates a simple general equilibrium model of the economy.[21] Labour, or the number of workers, is determined by the population, as a constant proportion of the population is assumed to participate in the labour force. Hence, labour is said to grow with the same rate as the exogenously evolving population. Diminishing returns to increasing physical capital, the only variable that countries can affect in the model, implicates convergence in per capita income levels of the poorer countries to the rich ones if the saving rate and the population growth equal with the rich countries. With low beginning

[19] Fellman, Susanna, Sjögren, Hans (2008) Conclusion. In Fellman, S., Iversen, M. J., Sjögren, H. and Thue, L. (Eds.) (2008). *Creating Nordic capitalism. The business history of a competitive periphery*. Palgrave Macmillan, pp. 559–560, 563.
[20] Solow, Robert M., (1957). Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, vol. 39, 1957: 3, pp. 312–320.
[21] Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, p. 10.

levels of physical capital in proportion to labour input, higher rates of returns are prevailing, meaning in the model more rapid growth in output per capita compared to rich counties with an already substantially higher ratio of accumulated physical capital to labour. In the long run, the per capita growth would finally cease because of diminishing returns to physical capital.

To match with the long-run steady state growth, exogenous technology, available to all countries and that countries cannot affect, was included in the model. The rate of the exogenous technological progress in the world determines the long-run steady state growth rate of output per capita. The transition process to the steady state ratio of physical capital to labour is the process associated with convergence or catch-up. However, convergence is conditional on the constant saving rate and on the population growth rate, both assumed constant and exogenous along time in each country but allowed to vary between countries. In the long run, two countries with the same saving rate and population growth would reach the same steady state in output per effective unit of labour, after which the countries would grow with the same rate defined by the technological progress outside the model.

It is worth noticing that the neo-classical model introduces a somewhat different concept to the discussion, the concept of conditional convergence. Already in the Solow-Swan basic neo-classical model without technology in 1956, countries converge to their own steady state GDP per capita growth rate, which is caused by their steady state capital per worker ratio.[22] The steady state capital per worker is determined through the country's saving (i.e. investment) rate and through the country's population growth (and depreciation rate of capital). Because of diminishing returns to physical capital, in the long run the growth would have eventually come to an end.

Instead, in the previously referred Solow's neo-classical model with technology, exogenous technological progress can offset the tendency for the marginal product of capital to fall, and in the very long run, countries exhibit per capita growth at the rate of exogenous technological progress.[23] The differences in the growth rates in the shorter run could be interpreted as transition dynamics to each country's steady state capital per worker to technology ratio. During the transition to the steady state among the countries with the same saving rate and population growth, the country with an originally lower capital per worker to technology ratio would grow faster, because of higher rates of return on capital beginning

---

[22] Solow, Robert (1956). A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, vol. 70, 1956: 1, pp. 65–94; Swan, Trevor, Economic Growth and Capital Accumulation, *Economic Record*, vol. 32, 1956 November, pp. 334–361.

[23] Solow, Robert, (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, vol. 39, 1957: 3, pp. 312–320.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

from low levels of capital. While preserving the prediction of convergence conditional on saving rate and population growth, one of the deficiencies of the model is that the long-run growth is determined entirely by the rate of exogenous technological growth, i.e. outside of the model. In the model, technology is freely available to all the countries without depending, e.g. on the country's educational level.

A simple production function, which is often thought to provide a reasonable description of actual economies, is the Cobb-Douglas function. The neo-classical production function with technology, assuming a labour-augmenting technological progress, can be presented using this function type as $Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}$, where Y_t, K_t, L_t are output, physical capital and labour input, $0 < \alpha < 1$ is a constant, $A_t > 0$ is the level of technology assumed to grow at an exogenous rate, $\dot{A}_t / A_t = g$. As mentioned above, labour participation rate in the population is assumed constant, and therefore labour (or number of workers) grows with the same rate, n, as population: $L_t = L_0 e^{nt}$, where L_0 is the initial value of labour, $\dot{L}_t / L_t = n$. The produced output is either consumed or saved, and since saving is assumed to equal investments, $Y_t = C_t + I_t = C_t + (s \cdot Y_t) = C_t + s \cdot (K_t^{\alpha}(A_t L_t)^{1-\alpha})$ where C_t denotes consumption, I_t investments and s is the constant saving rate of the economy. Physical capital is accumulated over time with investments, I_t, taking into account the depreciation of capital, δK_t, where $0 < \delta < 1$ is the constant rate of depreciation: $\dot{K}_t = I_t - \delta K_t = sY - \delta K_t$.

Because of constant returns to scale the production function can be rewritten in terms per unit of labour, $Y_t / L_t = (K_t / L_t)^{\alpha}(A_t)^{1-\alpha}$ or often denoting the per capita variables with small letters, $y_t = k_t^{\alpha}(A_t)^{1-\alpha}$. Furthermore, the production function can be given with variables expressed in terms of per effective unit of labour, $\tilde{y}_t = \tilde{k}_t^{\alpha}$, where $\tilde{y}_t \equiv Y_t / A_t L_t$ and $\tilde{k}_t \equiv K_t / A_t L_t$, respectively. The capital-effective labour ratio, $\tilde{k}_t$, will rise from the low beginning level because of diminishing returns to scale are not yet stepping in. Essentially, this suggests the poor countries to catch up with the rich ones if the condition on the equal saving (and investment) and population growth rates is satisfied.[24]

The convergence properties of the neo-classical model with technology can be evaluated in accordance with the Cobb-Douglas production function. In this form a coefficient for convergence can be derived from the model,

[24] See, e.g. Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, p. 29; Jones, Charles I. (2002). *Introduction to Economic Growth.* 2nd edition , W. W. Norton & Company, New York.

$\beta = (1-\alpha)\cdot(n+g+\delta)\cdot(\tilde{y}_t / \tilde{y}^*)^{-(1-\alpha)/\alpha}$. The convergence coefficient $\beta = (1-\alpha)\cdot(n+g+\delta)$ indicates how rapidly an economy's output per effective worker, $\tilde{y}_t$, approaches its steady state value, $\tilde{y}^*$. In the long-run steady state, $\tilde{y}_t = \tilde{y}^*$, and $\beta = (1-\alpha)\cdot(n+g+\delta)$.[25]

However, Gregory Mankiw, David Romer and David Weil already showed in the early 1990s that the predicted speed of convergence derived from this theory is much too high to accord with the empirical evidence with the narrow concept of capital, physical capital, in the model.[26] Still, with this knowledge at hand, in the relatively few quantitative studies on the Finnish-Swedish GDP per capita or labour productivity convergence with reference to theory, the research has usually been based on the neo-classical model.[27] Building on this model, Jonatan Svanlund has even stated that both Finland and Sweden, and Western Europe as well, have converged with the GDP per capita levels of the US, and not with each other. With regard to the strict meaning of the concept of convergence, as in this study, this view cannot be endorsed (see Figures C and D in Introduction).

In accordance with the above, empirical studies have shown that the variables in the neo-classical model are not adequate to account for the cross-country variation in Figure B, and for convergence by physical capital in the labour input between the countries, conditioned on population growth and saving rate, to hold in reality, as stated in the theory. For instance, Mankiw, Romer and Weil showed in 1992 as well that the neo-classical model with exogenous technology augmented by human capital by schooling (approximated by secondary schooling attainment) makes the model fit much better to the growth performance of a large group of countries in the world in 1960–1985. With the proxy variable for human capital, their results suggested diminishing returns on broad capital prevailing in the production. In this dissertation, in Chapter 4, this is to be studied again on the Finnish case, but with an empirical variable for human capital by schooling measured in the National Accounts as the other core variables for economic growth.

In the same line, Barro and Sala-i-Martin already demonstrated later in the 1990s that conditional convergence can only hold empirically for a large group of countries, once holding fixed variables such as initial levels of human and physical capital, measures of

---

[25] See, e.g. Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, pp. 36–37, 53.

[26] Mankiw, N. Gregory, Romer, David, Weil, David N. (1992). A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics*, Vol. 107, 2 (May), pp. 407–437.

[27] For instance, Lindmark, Magnus, Vikström, Peter (2003). Growth and Structural Change in Sweden and Finland: a Story of Convergence, *Scandinavian Economic History Review*, vol. 51, 1, pp. 46–74; Svanlund, Jonatan (2010). *Svensk och finsk upphinnartillväxt*. Dissertation, Umeå Studies in Economic History No. 38.

governmental policies, the propensities to save and have children, etc.[28] This implicates that if there are differences in other factors outside the neo-classical model, e.g. in human capital levels, government policies and institutions, countries with the same saving (investment) rates and population growths would not converge.

In empirical studies the technological progress of the neo-classical model, A_t, is often approximated by calculating it as a residual in a growth accounting exercise.[29] However, the need for including additional sources of cross-country variation for growth in empirical studies also shows up in this residual. Therefore, this residual, often called Total Factor Productivity (TFP) or Multifactor Factor Productivity (MFP), will include more factors (e.g. all the factors mentioned with perhaps social capital added to the list) than only technological progress presented in the model. In principle, these factors should be included in the theory on economic growth. One line of research has tried to show which factors will affect the MFP growth and therefore, are explaining the MFP growth. Looking at this the other way around, by adding the most important other factors into the model, one would get the MFP either to reflect better the pure technological progress or possibly make the MFP vanish. The latter case would mean that exogenous technological change would not be needed in the model any more. In this dissertation, in Chapters 3 and 4, it is studied whether human capital would be one of the most important factors which would make the MFP to diminish. The long-run economic growth of Finland is explored by including human capital by schooling accumulated in the National Accounts instead of using a proxy variable on school attainment. The results suggest that with this empirical counterpart for human capital, the MFP might not be needed in the production function in the intensive form.

The exogeneity of the saving rate of the model was released in the mid-1960s by Cass and Koopmans. Following Ramsey's work already in 1928, Cass and Koopmans brought consumer optimisation into the neo-classical model, which enables endogenous determination of the saving rate. The time preference in choosing consumption between now and the future will affect the saving rate and the accumulation of capital. While preserving the hypothesis on

[28] Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, Chapter 12.

[29] See Crafts, Nicholas (2004b). Quantifying the contribution of technological change to economic growth in different eras: a review of the evidence, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen & Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers, pp. 205–226; Barro, Robert J. (1999b). Notes on growth accounting. *Journal of Economic Growth* 4, pp. 119–137.

conditional convergence, this extension provides the transition dynamics of the model to be richer.[30]

In the 1980s Paul Romer with a group of other researchers became increasingly unsatisfied with the shortcomings of the neo-classical model, especially with the fact that the long-run growth comes outside the model in the form of exogenous technological progress. The determinants of the long-run growth were again found to be central issues for the theory.

According to Charles I. Jones, the steady exponential economic growth (for instance, for the USA in the last 130 years) is incorporated in the growth theories by assuming some differential equation to be linear in the model and take the form $\dot{X} = \_ X$.[31] However, as argued by Jones and Rodolfo Manuelli, linearity is an asymptotic requirement, not a conclusion that needs to hold at every point in time.[32] In the Solow model with technology, this differential equation is $\dot{A}_t = g A_t$ for the exogenous technology without a motivation.

In the models of Paul Romer (1986), Robert Lucas (1988) and Sergio Rebelo (1991), the growth may continue to eternity because the returns to a broad class of capital, including physical and human capital, do not necessarily diminish with developing economy.[33] Knowledge achieved with learning by doing in production or investing spills over across producers and external benefits from human capital help to avoid the tendency for diminishing returns to the accumulation of capital.

In the models where continuous growth is sustained by constant returns to broad capital, the production function of the economy can be expressed as $Y_t = AK_{T,t}$ where K_T includes both physical capital and human capital.[34] The fundamental differential equation is in these models in the broad capital accumulation $\dot{K}_T = I_{T,t} - \delta K_{T,t} = sY_t - \delta K_{T,t} = sK^{\alpha}_{T,t} - \delta K_{T,t}$ where *s* is the saving (investment) rate. In the model, $\alpha = 1$, and the capital accumulation is linear $\dot{K}_T = sK_{T,t} - \delta K_{T,t}$. Therefore, in these

---

[30] Ramsey, Frank (1928). A Mathematical Theory of Saving, *Economic Journal*, vol. 38, December, 543–559; Cass, David (1965). Optimum Growth in an Aggregative Model of Capital Accumulation, *Review of Economic Studies*, vol. 32, 1965: July, pp. 233–40; Koopmans, Tjalling C. (1965b). On the Concept of Optimal Economic Growth. In *The Econometric Approach to Development Planning*. Amsterdam: North Holland, 1965.

[31] Jones, Charles I (2005). Growth and ideas, in Aghion, Philippe, Durlauf, Steven N. (Eds.) (2005) *Handbook of Economic Grwoth*, vol 1B, Elsevier B.V., Amsterdam, The Netherlands, Chapter 16, pp. 1064–1111.

[32] Jones, Larry E, Manuelli, Rodolfo E. (1990). A Convex Model of Equilibrium Growth: Theory and Policy Implications. *Journal of Political Economy*, 98, 5 (October), pp. 1008–1038.

[33] Romer, Paul M. (1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy*, vol. 94, 1986: 5, pp. 1002–1037; Lucas; Robert E. Jr. (1988). On the mechanics of Economic Development, *Journal of Monetary Economics*, vol. 22, 1, pp. 3–42; Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run Growth, *Journal of Political Economy*, vol. 99, 3, pp. 500–521.

[34] See, e.g. Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run Growth, *Journal of Political Economy;* Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, pp. 172–182.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

models investing in physical and human capital generates steady growth, since diminishing returns to scale with respect to broad capital is not prevailing in the production, at least at the macro economy level. It is worth noticing that A is a constant parameter here. These models have often been doomed unrealistic, since with school attainment data used as a proxy for human capital, diminishing returns to broad capital have been reported prevailing in the production, and hence $\alpha < 1$. However, this may not be the case when human capital is assessed in the same National Accounts framework as the empirical counterparts for the other core variables in the growth theory, Y_t, K_t and L_t are. This is explored in Chapter 4 in this dissertation in the form $Y_t = AK_t^{\gamma} H_t^{1-\gamma}$ where K stands for physical capital and H for human capital. The hypothesis to be tested is: $\gamma + (1-\gamma) = 1$, where $0 \le \gamma \le 1$.

The AK_T model provides an alternative way to look at the data in Figure B above. This model predicts, in the purest form, no convergence between countries, which could very well explain the pattern of divergence in the whole world. However, the convergence of some countries is not either predicted by this model. Yet, it has been shown that the imbalance between physical and human capital, in favour of human capital, together with a non-negative gross investment requirement leads to growth acceleration, and hence could reflect the convergence behaviour of some of the countries. This can also explain, for instance, Europe's fast recovery and catch-up growth with respect to the US after WWII. Although the losses in human capital were unbearable in Europe, physical capital was even more destroyed. In addition, in this theory family, a simple way to extend the model to take into account the conditional convergence hypothesis is to express the production function as $Y_t = AK_t + BK_t^{\alpha} L_t^{1-\alpha}$, where $A > 0, B > 0, 0 < \alpha < 1$ and K_t refers to broad capital. This is a combination of the AK_T and neo-classical models, it exhibits constant returns to scale and positive diminishing returns to labour and broad capital. The model yields endogenous, steady-state growth, but also predicts conditional convergence as the neo-classical model.[35]

Another way to have the conditional convergence hypothesis included without relying on the empirically not quite adequate neo-classical model are the technology diffusion models, which are emphasising the role of human capital in the imitation and adaptation of technology from abroad.[36] The evidence on the strict convergence between countries with high interaction and cultural similarity leads to this direction.

---

[35] Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, pp. 38– 42.

[36] See, for instance, Nelson, Richard R., Phelps, Edmund S. (1966). Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review*, 56, 2 (May), pp. 69–75; Grossman, Gene M.,

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The technology diffusion from the leading countries to followers includes costs of imitation and adaptation. In the growth models of technology diffusion it is assumed that the costs for imitation are lower than the costs for innovating when very little has yet been copied. However, the costs for imitation and adaptation increase along with the pool of uncopied ideas gets smaller. The more technologies the follower has already implemented, the closer it will be to the latest leading edge technologies in the world and the more knowledge and skills in the adaptation is needed. The cost structure implies diminishing returns to imitation and hence generates a pattern of convergence, even if there would be constant returns to scale prevailing in the production with respect to reproducible capital as above.

In this study, as regards the empirical results in Chapter 4, the joint aspects of the models of technological diffusion with human capital and of capital good varieties are proposed to be relevant for the long-run economic growth of Finland in the 20th century. Putting these into a single growth theory model, the model suggested here combines features from the $Y_t = AK_t^{\gamma} H_t^{1-\gamma}$ model above, from the technology diffusion models and from the model with a variety of producer products.[37] In the variety of products model, endogenous technological progress is induced by a variety of capital goods. The new varieties are invented by research and development activities in the whole world. The idea on varieties in the productive inputs is also used in Paul Romer's seminal work in the context of technological change and economic growth.[38] The model with combined features proposed here is described next.

If technology is embodied in the variety of fixed capital equipment, and human capital is crucial for the implementation of technologies, the production function can be expressed as $Y_t = A \cdot (h_t L_t)^{1-a} \cdot \sum_{j=1}^{N} (k_{j,t})^{\alpha}$, where $0 < \alpha < 1$, A is a constant, h_t is the average

Helpman, Elhanan (1991). *Innovation and Growth in the Global Economy*, Cambridge MA, MIT Press, Chs. 11–12; Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, Chapter 8. Benhabib, Jess, Spiegel, Mark M. (2005). Human Capital and Technology Diffusion. in Aghion, Philippe, Durlauf, Steven N. (Eds.) (2005) *Handbook of Economic Growth*, vol 1A, Chapter 13, pp. 936–966, Elsevier B.V., Amsterdam, The Netherlands.

[37] Cf. Ethier, Wilfred J. (1982). National and International Returns to Scale in the Modern Theory of International Trade. *American Economic Review*, 72, 3 (June), pp. 389–405; Barro, Robert J. (1999b). Notes on growth accounting. *Journal of Economic Growth* 4, pp. 119–137; Crafts, Nicholas (2004b). Quantifying the contribution of technological change to economic growth in different eras: a review of the evidence, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen & Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers, pp. 205–226. The model here refers particularly to the specification of Crafts (2004b).

[38] Romer, Paul M. (1987) Growth Based on Increasing Returns Due to Specialization, *American Economic Review*, vol. 77, 2, pp. 56–62; Romer, Paul M. (1990). Endogenous Technological Change, *Journal of Political Economy*, vol. 98, 5, part II, S71–S102.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

human capital of labour input, L_t is quantitative labour input, $k_{j,t}$ is the input of one type of fixed capital good and N expresses the number of capital goods used in that country. Technological progress takes the form of expansions in N. The input of total fixed capital used in the production is equal to the sum of the inputs of variety of capital goods, $K_t = \sum_{j=1}^{N}(k_{j,t}) = Nk_{j,t}$ and human capital is the labour input multiplied by average human capital in the labour, $H_t = h_t L_t$. This implies that the aggregate production function can be given in the familiar form $Y_t = AH_t^{1-\alpha} \cdot N \cdot k_{j,t}^{\alpha}$.

To see the effect from an increase in N, the production function can be rewritten in the form $Y_t = AH_t^{1-\alpha} \cdot N^{1-\alpha} \cdot (Nk_{j,t})^{\alpha}$ or as $Y_t = AH_t^{1-\alpha} \cdot N^{1-\alpha} \cdot (K_t)^{\alpha}$, where $K_t = Nk_{j,t}$.[39] The latter equation expresses that diminishing returns set in when K_t increases for given N but not when N rises for given K_t. In other words, if the number of varieties of capital goods increases in the world over time and an increasing number of capital goods can be adapted in a country, there does not have to be diminishing returns to fixed capital. Instead, if the amount of fixed capital increases only because of increasing use in the same type (and quality) there are diminishing returns to this type of capital. Of course, the diminishing returns do not have to step in with low levels of the same type of capital, and capital accumulation of the same type is productive up to a certain level of intensity in that capital type.

The increase in the variety of capital goods and therefore the technological progress is mostly taking place in the leading economies through research and development with plentiful human capital. In a follower country a crucial question is how to get involved with the new, more productive capital goods along time. The positive development requires close interaction with a group of leading economies to get to know of new varieties of productive fixed capital. Human capital is crucial for a country in understanding the instructions and the way the new capital goods work, in order to implement them, and, in order for the country to be later able to produce new varieties of capital itself. Therefore, the amount of $K_t = Nk_{j,t}$ depends on $H_t = h_t L_t$ in a country. With a positive development in K_t the citizens anticipate

[39] See Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, pp. 213–214; Crafts, Nicholas (2004b). Quantifying the contribution of technological change to economic growth in different eras.. in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, p. 217.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

good prospects for the return in investing in human capital, H_t, and hence the advancement of fixed capital creates demand for human capital and boosts its formation.[40]

The importance of human capital for economic growth in Finland is studied in Chapters 3 and 4 in this dissertation. Instead of using the typical school attainment variables as a proxy for human capital, the empirical counterpart for human capital by schooling is formed in the National Accounts framework, from which the empirical counterparts for the other core variables in the growth theories come. Finally, the Finnish labour productivity is modelled by strict econometric analysis together with physical and human capital in the labour input in 1910–2000.

A follower country such as Finland would of course not have been able to produce all the new capital goods implemented in her production along time. Instead, as suggested above, Finland has imported them or foreign enterprises have implemented them in their production in Finland, or Finnish corporations have adopted them in their foreign activities and have employed them in the production at home as well. As noted in Section 1.1 above, most of the new capital good varieties to Finland have quite probably arrived from Western Europe and Sweden.

The possible increase in the co-dependence of business cycles between Finland and Sweden and between Finland and the EU15 area, along with the development described above, is studied in Chapter 5. According to the definition of the FDI in the Balance of Payment Statistics, a foreign direct investment relation arises by foreign corporate acquisition or by purchasing enough shares for controlling (> 50% of the shares) or for having a stabile economic relation (10% – 50% of the shares) with the foreign corporation. In practice, this often means that the production of the original enterprise now takes place in both countries in separate establishments. The establishment in the foreign country may produce intermediate inputs for the parent company in the home country. Having this type of value added chain or producing the same final products in both countries will make both establishments equally influenced by the fluctuations in the world demand for their final products, and by the fluctuations in prices for raw materials and financing services. The business cycles of the two

[40] In the formulations above, the investments in research and development could be thought to be included in K_t, with regard to the new revised international standard, System of National Accounts 2008, to be implemented in the following years. If these would account for the increase in the traditional physical capital, it could be possible that the expression *N* would not be needed in the formulations. See SNA2008 (2009). The Inter-Secretariat Working Group on National Accounts. *System of National Accounts 2008*, Commission of the European Communities-Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington D.C.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

establishments would become literally alike. Obviously, this type of economic interaction in the two countries will render the economies of the countries more dependent on each other and should breed convergence or synchronicity in their economic cycles.

1.3 About previous research

Many sources for Finland's relatively fast economic progress have been considered by previous research. These have included discussion about the break-through in industrialisation, export-driven growth and benefiting from the vast markets of Russia in the late 19th century and later of those of the Soviet Union, investment policy, specialisation in exports and advantaging therefore on increasing returns to scale in production, forest reserves and the comparative advantage in related industrial production, trade policy, gradual opening of the economy from the war-time inward orientation after 1957, increased agreements in free trade, the role of public sector in building stable infrastructure and institutions[41], the importance of labour productivity growth and implementation of electrification and ICT technology[42], and long-run growth policy[43]. Perhaps the most common explanation for the Finnish long-run growth would be export driven industrialisation, in which a small country is achieving advantages in economies of scale in production by means of specialisation and by the demand in bigger markets. In this explanation the rise of investment in physical capital is often associated with the exporting manufacturing industries, and free trade is a booster for Finnish exports. The discussion has been influenced by the neo-classical theory, at least in the background. In addition, an important direct and sophisticated application of the neo-classical theory is, of course, growth accounting. Perhaps the most notable long-run work in this field is done by Pekka Tiainen[44] and Jukka Jalava[45].

[41] See, e.g. Hjerppe, Riitta (1989). *The Finnish Economy 1860–1985, Growth and Structural Change.* Bank of Finland Publications, Studies on Finland's Economic Growth XIII, Helsinki 1989; Hjerppe, Riitta. (1990). *Kasvun vuosisata*. Valtion painatuskeskus, Helsinki; Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura.

[42] See e.g. Jalava, Jukka (2004). Electrifying and Digitalising the Finnish Manufacturing Industry: Historical Notes on Diffusion and Productivity. In Sakari Heikkinen and Jan Luiten van Zanden (Eds.) *Explorations in Economic Growth*, Aksant Academic Publishers, Amsterdam;

[43] Pekkarinen, Jukka, Vartia , Juhana (1993). *Suomen talouspolitiikan pitkä linja*. WSOY, Juva 1993.

[44] Tiainen, P. (1994). *Taloudellisen kasvun tekijät Suomessa. Työvoiman, pääoman ja kokonaistuottavuuden osuus vuosina 1900–90*. Helsinki. Tiainen was inspired by the work of Edward Denison (1962, 1979) and compiled the series for MFP by industry and total economy from 1900 onwards.

[45] See e.g. Jalava, Jukka (2007). *Essays on Finnish Economic Growth and Productivity, 1860–2005*. Tutkimuksia 248, Tilastokeskus, Helsinki. Jalava studies many aspects on economic growth by growth accounting.

A number of studies on convergence in the Nordic countries and on Finnish-Swedish catch-up growth have been conducted as well. Similarly as in the Finnish research, much of the research is done in the spirit of neo-classical thinking[46]. The focus has been on industrialisation and structural change, on accumulating physical capital per labour input, on exports by manufacturing industries, and in addition on efficient allocation of resources. The early studies have compared per capita GDP levels and the timing of the industrial take-off in the Nordic countries from the mid-19th century to the interwar period. For instance, in the early 2000s, Olle Krantz studied the break-through in industrialisation of Sweden and Finland with respect to the Danish one.[47] He finds that the take-off occurred in Sweden around 1890 and in Finland in the interwar period. In the same time, Riitta Hjerppe investigated labour productivity differences in the manufacturing industries in Sweden, Finland and Denmark, in 1870–1940.[48] According to her labour productivity in the Swedish and Finnish industrial production were growing faster than in Denmark, resulting in catch-up of the former countries with respect to Denmark.

Krantz has also compared Swedish growth with a group of other countries in 1870–2000 and discusses the Swedish relatively slower growth rates in the latter half of the 20th century.[49] He argues that a specific 'Swedish model' in the society restrained effective production factor allocation and the ability for the economy to exploit new technology.

Ola Grytten has analysed GDP per capital levels in the Nordic countries in the 1830–1910 contributing with novel PPP-adjustments.[50] He finds that over the entire period Denmark was best off, followed by Norway which was closing the gap especially in 1850–70. Later, in the first decade of the 20th century Sweden took the second place. Finland and Iceland were well below Norway and Sweden with GDP per capita levels around 50–60% than that of Denmark's.

---

[46] There is at least one notable exception. Camilla Josephson conducts her whole work in the frame of modern growth theories: Josephson, C. (2005). Growth and Business Cycles. Swedish Manufacturing Industry 1952–2001. *Lund Studies in Economic History* 37.

[47] Krantz, Olle (2001), Industrialisation in Three Nordic Countries: A Long-Term Quantitative View. In *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940,* Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters 2001, pp. 23–65.

[48] Hjerppe, Riitta (2001). The Convergence of Labour Productivity. In *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940,* Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters 2001.

[49] Krantz, Olle (2002). Svensk ekonomi under 1900–talet: en omväxlande historia. In Andersson-Skog, L.and Krantz, O., *Omvandlingens sekel. Perspektiv på ekonomi och samhälle i 1900-talet Sverige*. Studentlitteratur, Lund.

[50] Grytten, O.H. (2004). Economic Growth and Purchasing Power Parities in the Nordic Countries 1830–1910. In *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday,* Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers.

Lars-Fredrick Andersson and Olle Krantz compare the development in both countries with 16 other advanced industrialised countries in 2006.[51] The Swedish economy grew more rapidly than the countries on average from 1890 onwards, as a result of the take-off in industrialisation, all the way until WWII. In Finland, the growth pace was lower until the 1920s than on average in this group of countries, after which growth surged. They find that Finland has caught up Swedish income levels from 1950 until the end of the 1990s.

Perhaps the most interesting works in the Finnish-Swedish convergence for this thesis are the studies by Magnus Lindmark and Peter Vikström, in 2003, and by Jonatan Svanlund, in 2010. They both study the Finnish-Swedish convergence framing the analysis to growth theory. In addition, they both conduct empirical analysis with quantitative tools.

In their thorough research Lindmark and Vikström[52] show that the structure of Finnish economy has become similar and income levels converged with those of Swedish economy. The authors find that the shares of primary, secondary and tertiary production have followed a similar pattern with respect to income levels in both countries. Only the timing has been different, as Finland was lagging behind in the structural change. When studying the long-run growth rates, they base their analysis on neo-classical growth theory and concentrate on the contribution of industrial production in both countries. However, with focusing on manufacturing industries the authors cannot exhaustively explain the Finnish convergence with Sweden. In connection with neo-classical theory, they find the TFP growth rates similar in manufacturing industries in both countries, and by this they argue that Finland was not lagging behind Sweden in technology. In this study, in Chapter 2, it is shown that the advances in the labour productivity of services have also contributed to the Finnish catch-up with respect to Sweden.

Jonatan Svanlund (2010) studies carefully the Finnish-Swedish catch-up growth in 1950–2000 along with neo-classical theory.[53] Building on neo-classical model the author argues that both Finland and Sweden, and the Western Europe as well, have all converged towards the US (which is named as the single leading economy), and the convergence of Finland, Sweden and the Western Europe should be viewed only as convergence towards the US in 1950–2000, and not as convergence with each other. The argument is that when

---

[51] Andersson, L-F., Krantz, O. (2006). Tillväxt och konvergens. En jämförelse an den ekonomiska utvecklingen i Finland och Sverige under 1800– och 1900–talen. In Aunesluoma, Juhana, Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet*. Svenska litteratursällskapet i Finland, Helsingfors, 2006.
[52] Lindmark, Magnus & Vikström, Peter (2003). Growth and Structural Change in Sweden and Finland: a Story of Convergence, *Scandinavian Economic History Review*, vol. 51, 2003: 1, pp. 46–74.
[53] Svanlund, Jonatan (2010). *Svensk och finsk upphinnartillväxt*. Dissertation, Umeå Studies in Economic History No. 38.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

plotting the growth rates of Sweden and Finland and the Western European countries in 1950–2000 against their per capita GDP levels in 1950, Sweden and Finland are well in line with other West European countries, and with the US. This can be observed in Figure I. In the Figure, the US is above Switzerland, together with the Western Offshoots (consisting of the USA, Canada, Australia and New Zealand). Therefore, Jonatan Svanlund argues that Sweden, Finland and Western European countries have had the same long-run steady state.

However, thinking of the long-run growth in Finland and Sweden, the period 1950–2000 is quite late and short in their economic development. If doing the same exercise, for instance, in 1870–1913, as in Figure J, it becomes obvious that while Sweden and the Western European countries are in line with each other, Finland is obviously not. Instead, Finland is in the same group with the Eastern European countries in this period.

From Figure J one could perhaps still argue that Sweden and the Western European countries are roughly enough in the same line as the US and the Western Offshoots. Together with Figure I, one might state that they all have shared the same long-run steady state for 130 years. However, this is not the case with Finland and, for instance, with Japan.

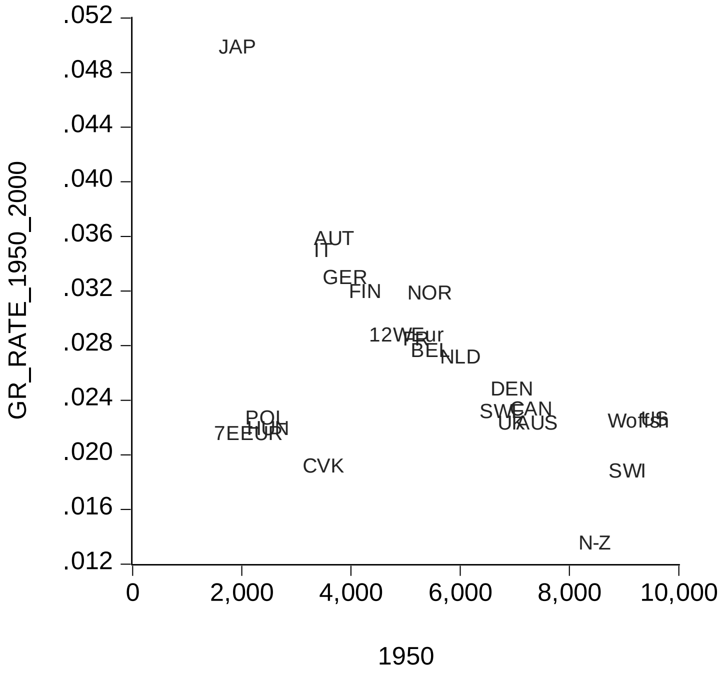
As a matter of fact, in the first period a separate straight line can be drawn through the observations of the UK and the individual Western Offshoots[54], and another through Netherlands and the Western European countries. The Eastern European countries (together with e.g. Japan) form an own group. Therefore, at least three separate groups can be observed from the first period graph (Figure J).

Finland was part of the Russian Empire at that time. Although Finland was allowed to keep the institutions from the Swedish period, the connections to the technologically advancing Western world diminished. Finland was also very agrarian, rural and underdeveloped. Yet, in accordance with the neo-classical theory Finland should have been able to enjoy of the (exogenous) technological progress, which is in the theory freely usable to all countries without costs.

[54] Detecting more carefully both figures, one can notice other interesting features in accordance with the countries the US, CAN and AUS, one of the strict convergence clubs observed by Barro and Sala-i-Martin in the time series direction. One can draw a straight line through their observations in both figures, in the first period far north-east from the origin, and in the second period a horizontal line. This is actually what we should do, since they have converged closely to the same level (around 1990, not diverged significantly thereafter) and seem to grow in the same pace in the latter period. They have been in the same group in both periods. (New Zealand has fallen off from the group of Western Offshoots in the second period.). In the second period, the UK should be interpreted to have moved to the Western European group as strict convergence is found between GER, FRA, ITA and the UK. The slower growth of Sweden in the post-war period, e.g. relative to Finland, may reflect the rising costs in copying and implementing new technologies, once being already close to the most advanced world technology frontier. Sweden had already relatively high levels of human capital for that as well.

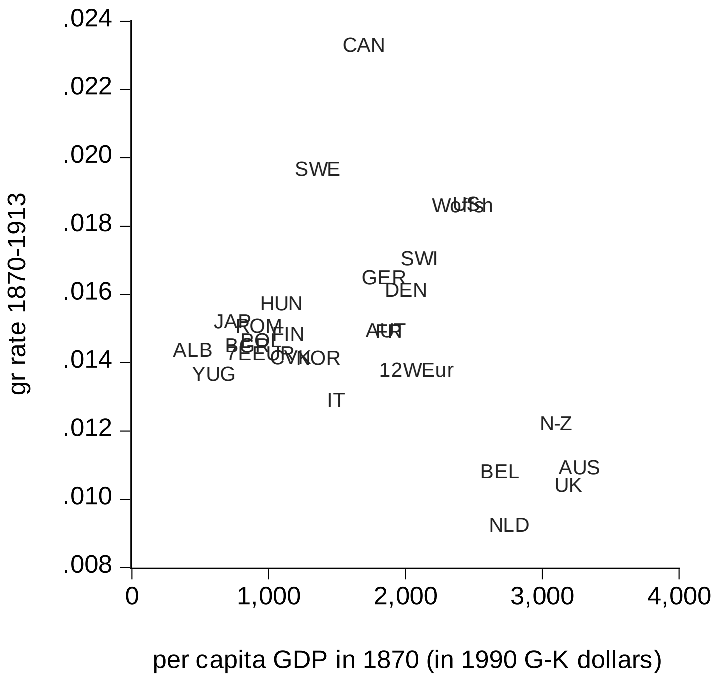
Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure I. Initial GDP per capita levels in 1950 and growth rates 1950–2000, a group of selected countries.



Source: Maddison, Angus (2010). *Historical Statistics of the World Economy*: 1–2008 AD, updated 02-2010. http://www.ggdc.net/MADDISON/oriindex.htm (2010-12-16).

Figure J. Initial GDP per capita levels in 1870 and growth rates 1870–1913, a group of selected countries.



Source: Maddison, Angus (2010). *Historical Statistics of the World Economy*: 1–2008 AD, updated 02-2010. http://www.ggdc.net/MADDISON/oriindex.htm (2010-12-16).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Looking Figure J through the lenses of technological diffusion, one soon notices that those lower income level countries that had close interaction and cultural similarities with the technologically most advanced countries, have had the best chances to get to know, and to implement advancing technology at home. Not surprisingly, Australia, New-Zealand, the US and Canada are in the same line with the UK, and German speaking Austria, Germany, Switzerland, Belgium together with Denmark, Sweden and France are in the same line with the Netherlands.

In the latter part of the 20th century Finland (and e.g. Japan) has moved from the Eastern European group to the same line with the Western European group, while many other countries have not. In the Finnish case, this achievement has to do with the increased economic interaction with this country group by foreign trade and FDIs, and with Finland creating her form of Nordic capitalism and her infrastructure, and opening up the economy. In this period of free trade agreements, world has become much more open regarding technology diffusion for most of the countries, particularly for those with the contacts and the ability to absorb new technologies. An exception is formed, of course, by the Eastern European countries.

For being able to implement more and more complicated technologies, countries have also needed much more human capital in 1950–2000. Finland was a latecomer in economic development, but also in education, as compulsory primary education was not introduced until 1921. It took until the latter part of the 20th century, until post primary education advanced in the labour force rapidly in Finland (see Figure 3.3.4). Human capital is one factor, where the change in Finland, also relative to the Western Europe, has been dramatic since 1870.

In his interesting study, Svanlund considers further aspects of the Finnish-Swedish catch-up growth. In line with Barry Eichengreen's work[55] the author also analyses wage moderation in both countries as a possible source for labour productivity growth. Using the labour share of the national income as an indicator for wage moderation, Svanlund finds more evidence of wage moderation having advanced Finnish growth performance instead of Swedish. According to Svanlund this is one central finding in the study, as Eichengreen originally hypothesised Sweden as a typical candidate for wage moderation. In contrast with the view of the Finnish low interest rate policy the actual interest rate was found lower in Sweden in the post-WWII period.

[55] Eichengreen, B. (1996). Institutions and Economic Growth: Europe after World War II. In Crafts, N. and Toniolo, G. (Eds.) *Economic Growth in Europe since 1945*. Cambridge University Press, Cambridge.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Inspired by the seminal work of Jeffrey Williamson and Kevin O'Rourke[56] Svanlund investigates whether prices, and particularly factor prices converged regarding the Finnish migration to Sweden since the mid-1950s until 1970s. From the mid-1970s both the relative productivity and the relative wage gap started to close. Concerning, exchange rate and price levels, the author finds that the price level was higher in Finland in the 1950s, which is reported as a possible incentive for the Finnish migration. Svanlund hypothesises that the migration pattern may also have followed the exchange rate development, as the Swedish krona increased its relative value until the 1970s, after which the relative value of the Finnish mark surged. Furthermore, Svanlund reports results that especially at an industry level productivity growth is explaining real wage growth over time (with data for the years 1955, 65, 75, 85, 95) in both countries, and therefore finds support for the factor price convergence. According to him, if assuming that the Finnish migrants were looking for a job in the same branch in Sweden[57], migration was probably working towards factor price convergence. Labour supply in the agricultural production dampened wage growth, an effect which was strongest in Finland after the 1950s. In line with Peter Temin's work[58], from this perspective Finland had a higher potential for productivity growth.

In this thesis, one aim is to study the role of human capital in the Finnish growth by constructing new long-run estimate for human capital by schooling in the National Accounts. In Finland, measuring human capital in the National Accounts frame has been studied by Pirkko Aulin-Ahmavaara, particularly from a theoretical point of view. Her proposed complete system of production of human capital and human time in the input-output framework will be reviewed later.[59] Another example of research on human capital in the

[56] See e.g. O'Rourke, Kevin H. and Williamson Jeffrey G. (1999). *Globalisation and History. The Evolution of Nineteenth-Century Atlantic Economy*. MIT Press, London. In the book Williamson and O'Rourke focus on today's OECD countries (plus Argentina) in the period from the mid-nineteenth century to WWI. The period is characterised in the book first by the aspiration to free trade but from 1880 onwards by backlash against it in the form of national protection. Globalisation and History summarises the authors' and their collaborators' vast amount of research work published in many articles in several journals in 1991 - 1998. Williamson and O'Rourke ask big questions about how income distribution between and inside the countries was affected by growing trade, increasing capital and labour movements as well as by different political economy regimes (free trade against different degrees of protection).

[57] This issue should be perhaps explored further, since the rapid structural change and technological progress in primary production in Finland in the 1960s and 1970s, made quite quickly parts of the large population in the rural areas unemployed. Usually, the ones of them that did not find an occupation in the urbanising Finland are seen to have migrated to Sweden.

[58] Temin, P. (2002). The Golden Age of European Growth Reconsidered. *European Review of Economic History*, Vol. 6, No 1: pp. 3–22.

[59] See, e.g., Aulin-Ahmavaara, Pirkko (1987). *A Dynamic Input-Output Model with Non-Homogenous Labour for Evaluation of Technical Change*. Finnish Academy of Science and Letters. Helsinki; Aulin-Ahmavaara, Pirkko (1990). Dynamic Input-Output and Time. *Economic Systems Research*, 2, pp. 239–34; Aulin-Ahmavaara, Pirkko (1991). Production Prices of Human Capital and Human Time. *Economic Systems Research*, 3, pp. 345–65; Aulin-Ahmavaara, Pirkko (2002): *Human Capital as a Produced Asset*. Session Paper Number 1, Session

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

context of national accounting in Finland is the work by Timo Relander in the late 1960s. He was considering the gross value of the stock of educational capital in manufacturing industry by a replacement cost method without depreciation for the years 1950 and 1960.[60] In addition to those, in his study on labour productivity growth in the Finnish manufacturing industries in 1925–1952, Olavi Niitamo used the evolution of the number of graduates from lower secondary schools for an indication of 'the level of knowledge' or human capital.[61]

Other empirical research on human capital in Finland has concentrated more on the role of education in the labour market (e.g. the quality of the labour force), and on lucrativeness of education to individuals, e.g. in Rita Asplund's thorough analyses through rates of return on education[62]. Asplund has also discussed the difference in the social and private return on education.[63] Together with Mika Maliranta, Asplund considers the role of human capital more wide and important for Finnish growth than suggested in standard growth accounting, however, without quantitative evidence or suggestions how to achieve it.[64] In addition, Ulla Hämäläinen and Roope Uusitalo discuss the signalling effects vs. actual skills in polytechnic school reform in Finland. The effects of comprehensive school reform on intergenerational income mobility in Finland are studied by Tuomas Pekkarinen, Roope Uusitalo and Sari Kerr.[65] In this study, the object is to form long-run time series on human capital by schooling on the national level for Finland, in order to study the role of human capital by schooling in the long-run growth in Finland.

6A, 27th General Conference of the International Association for Research in Income and Wealth, Stockholm, Sweden, August 18–24; Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, Helsinki:Tilastokeskus, 2003; Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, series 50, number 2, pp. 213–228.

[60] Relander, T. (1969). *Oppilaitoskoulutuspääoma Suomen tehdasteollisuudessa vuosina 1950 ja 1960*. Taloudellinen tutkimuskeskus. Helsinki.

[61] Niitamo, Olavi (1958). Tuottavuuden kehitys Suomen teollisuudessa vuosina 1925–1952. *Kansantaloudellisia tutkimuksia*, XX, Kansantaloudellinen yhdistys, Helsinki.

[62] See, e.g. Asplund, R. E. (1993), Essays on Human Capital and Earnings in Finland, *The Research Institute of the Finnish Economy, Series A18*; Uusitalo, Roope (1999). Essays in Economics of Education, *Research Reports 79:1999, Department of Economics, University of Helsinki.*

[63] Asplund, Rita (1998). Private vs. Public Sector Returns to Human Capital in Finland, *Journal of Human Resource Costing & Accounting*, Vol. 3 Iss: 1, 11–33

[64] Asplund, Rita, Maliranta, Mika (2006). Productivity growth: The Role of Human Capital and Technology. In Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura, 263–283.

[65] Pekkarinen, Tuomas, Uusitalo, Roope, Kerr, Sari (2009). School tracking and intergenerational income mobility: Evidence from the Finnish comprehensive school reform. *Journal of Public Economics*, vol. 93(7-8), August, 965-973; Hamalainen, Ulla, Uusitalo, Roope (2008). Signalling or Human Capital: Evidence from the Finnish Polytechnic School Reform. *Scandinavian Journal of Economics*, Vol. 110, Issue 4, pp. 755-775.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

1.4 The basic research questions of the study

The basic framework of the analysis in the study is as follows: Firstly, the structural change is seen driven by new possibilities (technology) to produce products (old and new). Secondly, this production with new technology will drive labour productivity and GDP per capita up on the national level. Thirdly, to use new production technologies requires human capital (education, also resulting in the ability for constant learning and skills accumulation). Fourthly, for permanent growth of labour productivity continuous adoption of new production technologies is needed. A poor developing country cannot form new production technologies herself (at least in the early stages) and hence needs continuous absorbance of new technologies from others in accordance with the advances in the world technology frontier. This requires openness and close interaction via foreign trade with a group of leading countries. The increasing foreign trade will render the countries involved more dependent on each other. This type of convergence should breed convergence (or co-dependence) in business cycles.

The research will be conducted in accordance with this basic framework. The first two items of the framework will be analysed in Chapter 2 where structural change and labour productivity growth will be explored as sources of Finland's convergence. The basic research questions are: Did Finland's economic transformation take place in accordance with the classical view of structural change? Did Finland catch up Sweden and the EU15 simply because of later industrialisation in accordance with the classical view? What were the contributions of primary, secondary and tertiary production to the Finnish catch-up? To outline a complete picture of the catch-up process, the value added and labour productivity growth of all the production fields and their contributions to economy-wide level will be examined.

In Chapter 3 the possible connection between investments in human capital and economic growth in Finland will be explored. To find out empirically the impacts of investing in and accumulation of human capital on GDP, investments in intangible human capital by schooling are to be examined in the same Historical National Accounts framework as GDP. The basic research questions are: Has the considerable input in education been one of the sources for Finland's fast GDP per capita growth and speeding up the growth in the 20th century? Do we find a long-run relation between human capital accumulation and economic growth in Finland?

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Chapter 4 studies the role of both human and physical (or fixed) capital in the Finnish long-run growth along with the following research questions: Have there been constant or diminishing returns to scale prevailing in the production with respect to reproducible capital, including both physical and human capital? Is it possible that with human capital estimate from the National Accounts the Solow residual will be significantly diminished or even vanished in the production function? Has the evolution of physical and human capital enhanced the evolution of each other?

In Chapter 5 the possible deepening of business cycle co-dependence among the mentioned economic areas will be studied. The basic research questions for this part are: Do we find convergence of business cycles in the form of increased synchronicity between Finland and Sweden and between Finland and the EU15 after WWII? Has the possible increased synchronicity led even to a common cycle along the development in the latter part of the 20^{th} century?

The main objectives of the whole study are to bring new results on the process, timing and locating of Finland's convergence with Sweden and the EU15 on GDP per capita, to find out the role of human capital by schooling, also together with physical capital, in the economic development of Finland, and to discover whether the business cycles have converged along with the development between the mentioned economic areas and Finland.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

2. CATCHING UP IN EUROPE: FINLAND'S CONVERGENCE WITH SWEDEN AND THE EU15 [66]

Kokkinen Arto, Jalava Jukka, Hjerppe Riitta and Hannikainen Matti [67]

Abstract

Finland is an obvious case of economic convergence in the 20th century. Is this due to the fact that the Finnish industrialisation phase started late compared with Sweden and the EU15 average? In this article the Finnish post-WWII catch-up process is traced by analysing the major – i.e., primary, secondary and tertiary – industries. First we explore whether the Finnish catch-up can be explained only by late industrialisation. Then we delineate the phases of structural change, and finally, we show how primary, secondary and tertiary production and labour productivity growth have contributed to aggregate development and catch up. Our analysis brings new results on timing and locating convergence. Secondary production had its biggest impact on Finnish GDP growth later than in Sweden. However, it was not solely the advantages of secondary production growth that caused Finland's catch up. The labour productivity growth contribution from services was essential for Finland's catch up especially in 1965–80.

2.1. Introduction

The economic convergence of countries has been one of the major research issues since the mid-20th century. In line with Alexander Gerschenkron's classical thesis of the advantage of relative backwardness[68] numerous studies have tried to find empirical evidence on whether productivity growth rates tend to vary inversely with productivity and production levels. The

---

[66] Chapter 2 is published as Kokkinen, Arto, Jalava, Jukka, Hjerppe, Riitta and Hannikainen, Matti (2007). Catching up in Europe: Finland's Convergence with Sweden and the EU15, Scandinavian Economic History Review, 55:2, 153–171. The contribution of Kokkinen was half in the planning, calculations and writing of the paper.

[67] We wish to thank Concepción García-Iglesias for participating in the early ideating of the paper. Warm thanks also belong to the editor, two anonymous referees, Stephen Broadberry, Angus Maddison, Lennart Schön and other participants of the seminar "Convergence and Non-convergence since the Second World War", held on January 20–21, 2006, at the University of Helsinki, and participants of the Vice-Presidential session of the XIV International Economic History Congress, August 21–25, 2006, Helsinki, for their helpful comments without implicating them for any remaining errors. Riitta Hjerppe, Arto Kokkinen and Matti Hannikainen thank the Yrjö Jahnsson Foundation for financial support in this research. Jukka Jalava's research is partly supported by the Research Project "EUKLEMS 2003. Productivity in the European Union. A Comparative Industry Approach" supported by the European Commission, Research Directorate General, within the Sixth Framework Programme, Contract No. 502049.

[68] Gerschenkron, Alexander (1952). Economic Backwardness in Historical Perspective. In *The Progress of Underdeveloped Areas*, Ed. B. F. Hoselitz. University of Chicago Press 1952; Gerschenkron, Alexander (1962). *Economic Backwardness in Historical Perspective: A Book of Essays.* Cambridge: Harvard University Press 1962.

study of long-run development is important because even small differences in growth rates can have enormous long-term consequences for standards of living. However, the catch up of poorer countries is not automatic. In fact the differences between the GDP per capita of rich and poor countries' have grown during the last century.[69]

The convergence literature is linked to growth theories. For instance, the neo-classical theories[70] predict convergence in economic growth among countries that have similar saving rates and population growths. The new growth theories[71] and empirical research emphasise a country's ability to attain technological progress in production with human capital and social capability has been emphasised. For instance, according to Moses Abramovitz's seminal research countries should avoid institutional and technological obstacles to reach faster growth than in the leading countries.[72] When technological progress is achieved, it is accompanied by structural changes in the economy, meaning both changes in the shares of different industries and structural changes inside the same industry when unprofitable old technology firms are replaced with more profitable new-technology firms.

One of the topics related to the convergence discussion has been whether it is possible to find common patterns in economic development in different countries. According to Gerschenkron the early industrialised countries and the latecomer countries develop in different ways.[73] Gerschenkron stressed the importance of manufacturing industries in the progress of latecomer countries – the more backward a country is the faster the potential growth of industrial output. The vitality of industrial production was also emphasised by Nicholas Kaldor who suggested that aggregate economic growth is related to growth in

---

[69] De Long, Bradford (1988). Productivity Growth, Convergence, and Welfare: Comment, *American Economic Review*, vol. 78, 1988: 5, 1138–1154; Pritchett, Lant (1997). Divergence, Big Time, *Journal of Economic Perspective*, vol. 11, 1997: 3, 3–17.

[70] Ramsey, Frank (1928). A Mathematical Theory of Saving, *Economic Journal*, vol. 38, 543–559; Solow, Robert (1956). A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, vol. 70, 1956: 1, 65–94; Solow, Robert (1957). Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, vol. 39, 1957: 3, 312–320; Swan, Trevor (1956). Economic Growth and Capital Accumulation, *Economic Record*, vol. 32, Nov., 334–361; Cass, David (1965). Optimum Growth in an Aggregative Model of Capital Accumulation, *Review of Economic Studies*, vol. 32, 1965: 3, 233–240; Koopmans, Tjalling C. (1965). On the Concept of Optimal Economic Growth. *Pontificae Academiae Scientiarum Scripta Varia*, vol. 28, 1965, 225–300.

[71] Romer, Paul M.(1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy*, vol. 94, 1986: 5, 1002–1037; Romer, Paul M. (1987). Growth Based on Increasing Returns Due to Specialization, *American Economic Review*, vol. 77, 1987: 2, pp. 56–62; Romer, Paul M. (1990). Endogenous Technological Change, *Journal of Political Economy*, vol. 98, 1990: 5, S71–S102; Lucas; Robert E. (1988). On the mechanics of Economic Development, *Journal of Monetary Economics*, vol. 22, 1988: 1, 3–42; Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run Growth, *Journal of Political Economy*, vol. 99, 1991: 3, 500–521.

[72] Abramovitz, Moses (1986). Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, vol. XLVI, 1986: 2, 385–406.

[73] See Prados de la Escosura for a recent examination of this issue. Prados de la Escosura, Leandro (2005) Gerschenkron Revisited. European Patterns of Development in Historical Perspective.*Universidad Carlos III de Madrid, Working Paper 05–79 (10), Economic History and Institutions Series 10,* December 2005.

manufacturing and that manufacturing productivity increases the productivity of other industries.[74] On the other hand, the researchers of the classical overall pattern of economic development and structural change Colin Clark, Simon Kuznets and later on Ronald M. Hartwell, on the other hand, depict economic development as a shift from primary production to secondary production during the process of industrialisation, subsequently followed by the shift from secondary production to tertiary production as the post-industrial stage is entered.[75]

Defining absolute (or unconditional) convergence as the catching up of a poorer country's GDP per capita with that of the leading countries, Finland is an obvious, positive case of economic convergence in the 20th century.[76] However, most of the convergence seems to have taken place after World War II. In Finland the industrialisation phase started late compared with Sweden and the EU15 average. The share of secondary production in GDP did not decrease until the 1970s[77] while in many Western European countries the share of manufacturing had started to decline earlier. Thus it seems that Finland was in a different phase of structural development after WWII. In addition, production shifted from primary production not only to secondary but also to tertiary production in Finland at the same time in contrast with the classical view of separate industrialisation and post-industrialisation phases. Therefore, Finland has had a somewhat different path in her fast structural change after WWII compared with Sweden and the EU15.

Despite the available historical databases there is relatively little research on Finland's convergence with Sweden or/and the EU. The most notable exception is the work by

---

[74] Kaldor, Nicholas (1967). *Strategic Factors in Economic Development*. New York: New York State School of Industrial and Labor Relations, Cornell University 1967.

[75] This classical view has also been challenged as, e.g. Broadberry argued that Germany and the United States surpassed Britain's level of aggregate labour productivity by shifting resources out of agriculture and improving the productivity of services rather than manufacturing. Clark, Colin (1940). *The Conditions of Economic Progress*. MacMillan & Co. London 1940, 395–439; Kuznets, Simon (1961). *Six Lectures on Economic Growth*. Frank Cass & Company, London, 1961; Hartwell, Ronald .M. (1973). The Service Revolution: The Growth of Services in Modern Economy, in *The Fontana Economic History of Europe 3: The Industrial Revolution, Ed. Carlo M. Cipolla*. Glasgow: Fontana/Collins 1973, 358–396; Broadberry, Stephen N. (1998). How did the United States and Germany Overtake Britain? A Sectoral Analysis of Comparative Productivity Levels, 1870–1990, *Journal of Economic History*, vol. 58, 1998: 2, 375–407.

[76] The growth theories have introduced yet another concept – conditional convergence – to the discussion. In conditional convergence countries converge to their own steady state GDP per capita growth rate, which is determined by their steady state capital per worker (to technology) ratio. In this paper the focus is on absolute convergence, since in the case of Finland there has also been absolute convergence to her leading neighbours, which is rather rare worldwide.

[77] Hjerppe, Riitta (1989). *The Finnish Economy 1860–1985: Growth and Structural Change. Studies on Finland's Economic Growth XIII.* Helsinki: Bank of Finland Publications, Government Printing Office 1989; Hjerppe, Riitta & Jalava, Jukka (2006). Economic Growth and Structural Change: A Century and a Half of Catching-up, in *The Road to Prosperity: An Economic History of Finland*, Ed. Jari Ojala, Jari Eloranta & Jukka Jalava. Helsinki: Suomalaisen Kirjallisuuden Seura 2006.

Magnus Lindmark and Peter Vikström.[78] In their thorough research the authors show how the structure of Finnish economy and income levels converged with those of Swedish economy. However, when explaining the Finnish catch-up process Lindmark and Vikström focus on the development of the Finnish manufacturing industry. Unfortunately, with such a focus the authors cannot explain the entire Finnish catch-up process. A second exception is a Nordic research group comparing the Danish, Finnish and Swedish economies from the 1870s to the 1940, with particular reference to convergence.[79]

In this article our aim is to trace the Finnish catch-up process. We will next describe some general features of Finland’s economy and catch-up with Sweden and the EU15. After that we will examine whether the late development of secondary and tertiary production and the different path of structural change have been sources to Finland’s convergence: we will first explore whether the Finnish catch-up can be explained only by the late industrialisation. After that we will focus on how the structural change happened in Finland, and finally, to complete the picture, we will show how primary, secondary and tertiary production and labour productivity growth have contributed to aggregate development and the catch-up process. This analysis will bring new results on timing and locating convergence.

2.2 Some general features of Finland’s economy and catch-up with Sweden and the EU15

Finland in the early 2000s is an industrialised country with a standard of living ranked among the top 15–20 countries in the world. Finland has been a member of the European Union since 1995 and has belonged to the European Economic and Monetary Union since 1999 with the Euro as its currency. One hundred years ago it was a poor agrarian country with a gross domestic product per capita less than a half of that of the United Kingdom or the United States, world leaders at the time. We know Finland’s GDP growth from 1860 onwards from the Historical National Accounts of Finland, which were completed in the late 1980s.[80] We

[78] Lindmark, Magnus & Vikström, Peter (2003). Growth and Structural Change in Sweden and Finland: a Story of Convergence, *Scandinavian Economic History Review*, vol. 51, 2003: 1, 46–74.
[79] Kryger Larsen, Hans, Ed. (2001) *Convergence? Industrialisation of Denmark, Finland and Sweden 1870–1940*, Helsinki: The Finnish Society of Sciences and Letters 2001.
[80] Hjerppe, *The Finnish Economy 1860–1985.*

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

have fairly detailed annual series for the balance of total supply and demand at current and constant prices since 1860, value added and employment by industry, and the structure of foreign trade by commodities and countries, etc.[81]

Though not blessed with abundant natural resources, Finland embarked on the road of industrialisation utilising her forests, her hydropower potential and the rural labour reserve to produce goods to the Russian as well as the western market. The role of electrification and other technical innovations as enablers of productivity increase have been important.[82] Finnish GDP per person grew 12-fold from 1900 to 2000. That means a growth of 2.5 per cent per year. Swedish GDP per person increased 9-fold, that is 2.3 per cent per year, while that of the 15 European Union countries grew almost 7-fold or 1.9 per cent per year in 1900–2000. All these economies experienced incredibly fast growth compared with any other previous period. Figure 2.1 shows that long term economic growth in the 20th century has been an almost continuous process with, however, severe disruptions during the World Wars and the 1930s depression.

Some acceleration of growth can be seen from 1900 to the 1970s in Figure 2.1, but all the curves flatten out to clearly slower growth rates in the 1970s, after the so-called Golden Years of Economic Growth following World War II. In the early 1990s the Finnish economy quite unexpectedly fell into a serious depression for several years and real GDP fell by more than 10 per cent. This was deeper than any other peace-time depression since the middle of the 19th century. European Union countries also experienced recessions or depressions then, but not nearly as bad as that in Finland.

Compared with the EU15 in 1900, Finland started from a level of less than 40 per cent below West European GDP per capita (Figure 2.2). There was slow convergence, but the First World War and the Finnish Civil War reduced Finnish GDP per capita to 60 per cent below that of the EU15. After the war the recovery of the economy was quite fast in Finland compared with Western Europe and during the interwar period the Finnish economy did much better than the western world.[83] The GDP per capita gap narrowed to about 20 per cent and even less before the outbreak of World War II.

---

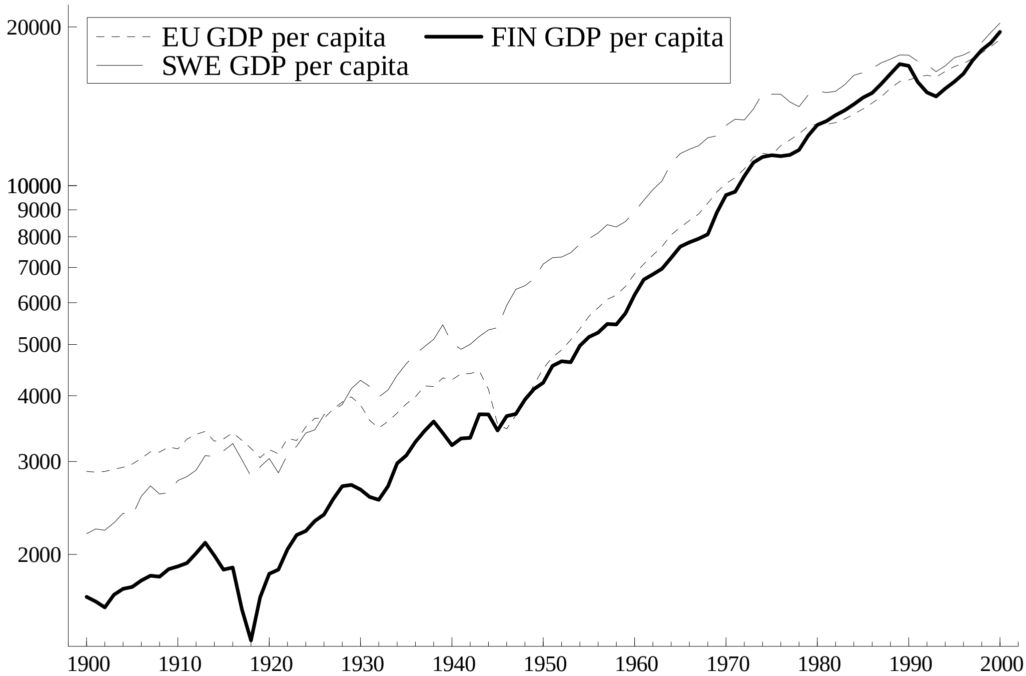
[81] A Nordic database on the Norwegian School of Economics and Business' web pages contains the time series of the Finnish Historical National Accounts. See www.nhh.no/forskning/nnb/.

[82] Jalava, Jukka (2004). Electrifying and digitalising the Finnish manufacturing industry: Historical notes on diffusion and productivity, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Heikkinen, Sakari & Zanden, Jan Luiten van. Amsterdam: Aksant Academic Publishers 2004, 227–244.

[83] According to Krantz this was the period of the Finnish take off. Krantz, Olle, Industrialisation in Three Nordic Countries: A Long-Term Quantitative View, in *Convergence? Industrialisation of Denmark, Finland and*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure 2.1 GDP per capita in the EU15, Sweden and Finland 1900–2000 (logarithmic scale, 1990 Geary-Khamis dollars).
Sources: Own calculations; data from Hjerppe, Riitta, *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* Jyväskylä: Kopi-Jyvä Oy 1996; Statistics Finland; Carreras, Albert and Tafunell, Xavier, European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, 63–87; Krantz, Olle, *Swedish Historical National Accounts 1800–1998: Aggregated Output Series*. Manuscript 2000; Statistics Sweden; Maddison, Angus, *The World Economy: a Millennial Perspective.* Paris: OECD, Development Centre 2001.



Compared with the EU15, the development of the Finnish economy after World War II was more uneven than in the other peace time periods under consideration. First, there was a brisk catch-up immediately after the war, with GDP per capita actually surpassing the EU15 level in 1946–48.[84] The gap widened again until the end of the 1950s. The tide turned only after the devaluations of 1957 and 1967 and easing of foreign trade regulations. The Finnish economy closed the gap with the EU15 throughout the 1970s despite the difficulties caused by the oil crises, exceeding the EU15 level in 1980. The early 1990s depression again changed the situation and caused a collapse of 15 percentage points. This was followed by a rapid recovery during the second half of the 1990s.

Sweden, 1870–1940, Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters 2001, 23–65.

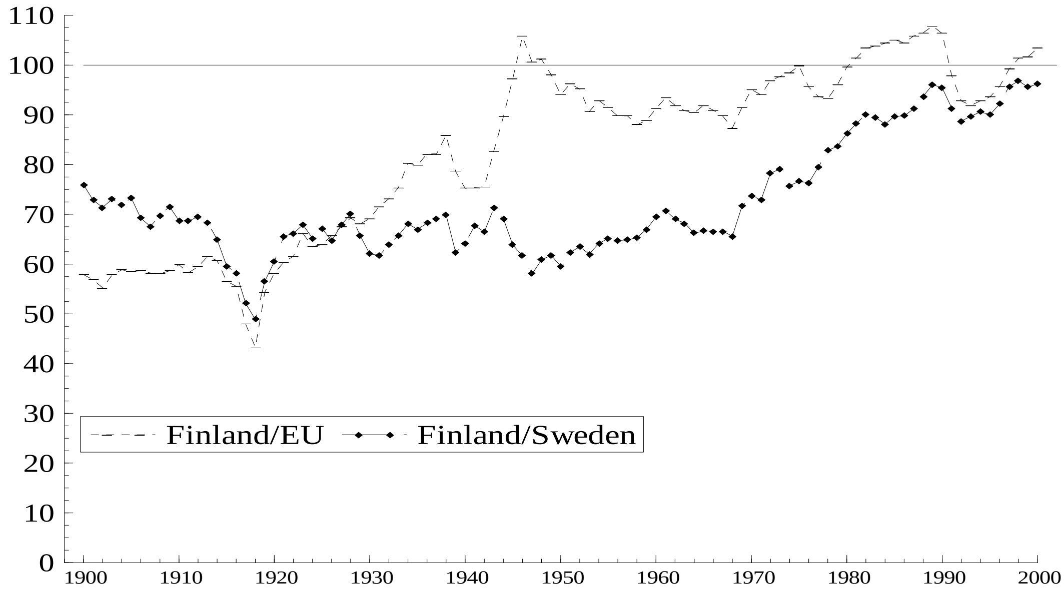
[84] The reconstruction of Finland, settlement of Karelian evacuees and soldiers as well as payment of war reparations to the Soviet Union forced the Finnish economy into fuller speed than the other countries devastated by the Second World War. The physical civil destruction was also less extensive in Finland than it was in many of the other war-faring countries.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure 2.2 Finland's GDP per capita compared with that of the EU15 and Sweden, 1900–2000 (%).

Sources: Own calculations; data from Hjerppe, *Finland's Historical National Accounts 1860–1994;* Statistics Finland; Carreras and Tafunell, European Union economic growth experience, 1830–2000, Krantz, *Swedish Historical National Accounts 1800–1998*; Statistics Sweden.

Note that statistics from different sources (national, OECD, World Bank, etc.) give somewhat different levels of GDP per capita in PPPs around the turn of the millennium. In some GDP per capita in Finland is slightly higher than that of Sweden, in most it is the other way round.



Compared with Sweden (Figure 2.2) the gap in GDP per capita even widened in the early 1900s, due to Sweden's earlier industrialisation. From the early 1920s the gap persisted on average until the 1970s, when the Finnish GDP per capita finally started to catch up. The gap almost closed before the devastating 1990s depression set in and then widened again for many years, with some recovery after 1997. The reasons for this rapid catch-up by more than 20 percentage points from the late 1960s to the late 1980s are not at all clear and under investigation in this article.

Labour input and productivity of labour as factors of Finnish economic growth

GDP per capita can be expressed as the product of two components: labour productivity and labour input per capita. Labour productivity (GDP per hours worked) is often seen as the more important one as it can grow without bounds. For the amount of work that can be done per person there is an upper limit. Therefore economic growth can in the long run be sustained only by labour productivity change. Rephrasing the variables in natural logarithms GDP per capita can be divided as follows:

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

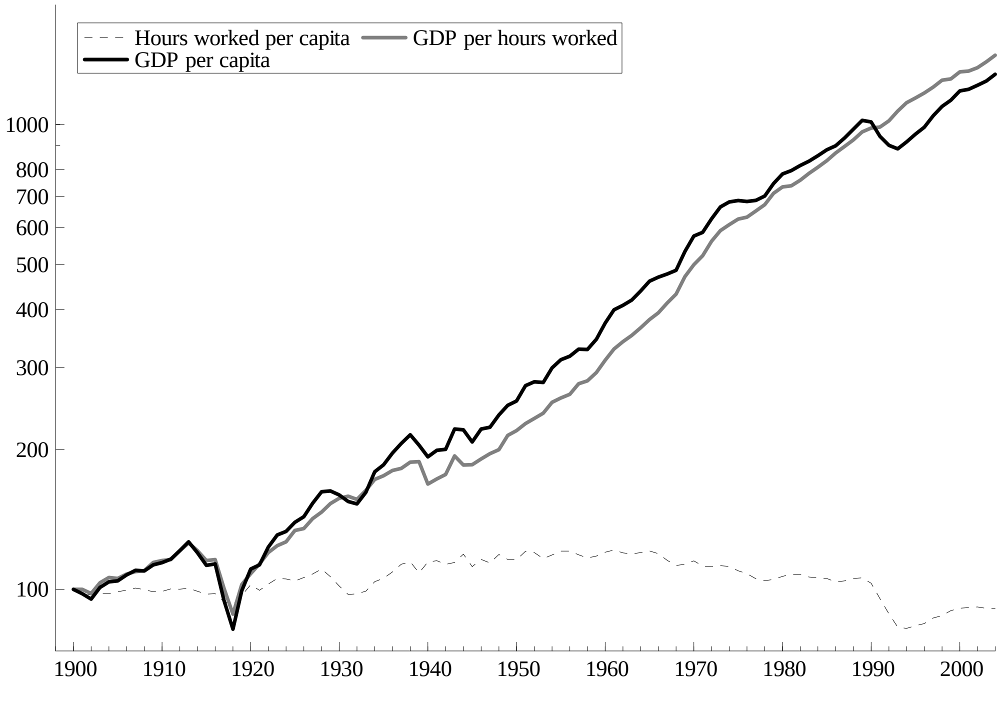
(1) log (GDP / capita) = log (GDP / hours worked) + log (hours worked / capita).

From equation 1 it can be seen that the higher labour productivity is, the more hours that have been worked on the national level (meaning a bigger employment share of population and/or more hours worked by each employee), the higher GDP per capita will be. An increase in labour input (hours worked) per capita has a level effect on GDP per capita. Labour productivity, on the other hand, has an effect on GDP through productivity growth, which acts on the compound interest principle – even a slight change in the long-run productivity growth rate has significant long term implications.

Figure 2.3 shows the levels and evolution of Finnish GDP per capita and its components in index form (natural logarithmic scale) for the years 1900–2004. It is obvious that the main contribution to Finnish GDP per capita growth came from the increase in labour productivity (GDP per hours worked).

Figure 2.3 GDP per capita and its components in Finland, 1900–2004 (GDP at year 2000 prices; indices 1900=100, logarithmic scale).

Sources: Own calculations; data from Hjerppe, *Finland's Historical National Accounts 1860–1994;* Statistics Finland.



Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute
DOI: 10.2870/35887

2.3. Structural change and productivity growth as sources of Finland's convergence

In this section we study whether late industrialisation and a somewhat different path in structural change have been the sources of Finland's faster labour productivity growth, faster GDP growth and convergence. In subsection 2.3.1 we will first explore whether the later fast growth of secondary production explains Finland's catch-up. The vitality of industrial production for economic growth was emphasised, among others, by Nicholas Kaldor.[85] Moreover, the importance of manufacturing growth has been constantly brought up in discussions of Finnish economic policy. We will use Kaldor's growth laws as a framework to test whether the development in secondary production can explain the convergence of Finland after WWII.[86] Later in subsection 2.3.2 we will broaden our examination and explore the impacts of primary and tertiary production on Finland's convergence to Sweden as well as the impacts of secondary production. Using the non-parametric growth accounting approach of the National Accounts framework the contributions of primary, secondary and tertiary production to GDP and labour productivity growth are studied in both countries for the years from 1945 to 2003.

2.3.1 Can GDP and labour productivity growth be explained by secondary production?

In this subsection we will focus on secondary production in explaining economic growth in Finland and Sweden and the EU15. In accordance with Kaldor's growth laws[87] we will test the following hypothesis: with the late fast growth phase in secondary production, can Finnish convergence be explained via its effects on aggregate labour productivity and GDP growth? In other words, we make an assumption here that the fast GDP growth and the essential labour productivity growth in catch-up are due to secondary production growth.

---

[85] Kaldor, *Strategic Factors in Economic Development.*
[86] "There can be little doubt from the empirical evidence…that the pace of long run growth and development is closely associated with the growth of industrial activities". Thirlwall, Anthony P., A General Model of Growth and Development on Kaldorian Lines, *Oxford Economic Papers,* vol. 38, 1986: 2, 199–219.

[87] It is worth noticing that originally Kaldor (1967) suggested his growth laws in a different economic environment in accordance with the UK's relatively slow growth in the post-WWII period. At that time the convergence discussion had barely begun. As mentioned before, we will use these growth laws as a framework for testing if the catch up of Finland can be explained by relatively late but fast secondary production growth. Kaldor, *Strategic Factors in Economic Development;* Kaldor, Nicholas (1978). *Further Essays on Economic Theory*. London: Gerald Duckworth & Co. Ltd. 1978.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

First the possibility to explain economic growth by Kaldor's growth laws is examined. With Ordinary Least Squares (OLS) regressions, the statistical significance and explanatory power of the laws are tested on Finnish, Swedish and EU15 data. After that we focus on the differences in explanatory power and statistical significance of each law in Finland and Sweden in 1945–2003, in order to find out whether Finland really has had different industrialisation phases compared with Sweden and to determine whether the rapid evolution of secondary production evolution can explain Finland's catch up.

Kaldor (1967) stressed that a precondition for the growth of secondary and tertiary production is that primary production generates a surplus above the bare subsistence minimum. As a country passes from economic immaturity to maturity, by which Kaldor (1978) meant a state where real incomes per head in each part of the economy are comparatively similar, the role of secondary production is crucial due to increasing returns to scale. Kaldor (1967, 1978) suggested that 1) aggregate economic growth is related to growth in manufacturing, and that 2) manufacturing productivity increases the productivity of the other sectors. These observations are often called Kaldor's growth laws.[88]

OLS regressions were carried out to cast some light on the applicability of Kaldor's laws to the economic history of Finland and Sweden during 1945–2003 and to the EU15 during 1980–2003. The comparison of Finland and Sweden is also done in the sub-periods 1945–79 and 1980–2003.

regression (1) $\Delta Y_{GDP} = \alpha_1 + \beta_1 \Delta Y_{SEC} + \varepsilon_1$,

regression (2) $\Delta LP_{GDP} = \alpha_2 + \beta_2 \Delta Y_{SEC} + \beta_3 \Delta E_{PRIM\&TERT} + \varepsilon_2$, [89]

[88] Not to be confused with Kaldor's stylized facts. Kaldor did actually propose several growth laws. One of them stated that manufacturing productivity growth is related to manufacturing output growth (also called Verdoorn's law). We will concentrate here on the two laws mentioned in order to assess the impacts of secondary production on GDP and aggregate level labour productivity growth on Finland's catch up. Jalava has estimated the applicability of Verdoorn's law on Finnish data as well. Jalava, Jukka (2006). Production, Primary, Secondary, and Tertiary: Finnish Growth and Structural Change, 1860–2004, *Pellervo Economic Research Institute, Working Papers* No. 80, 2006: January; Stoneman, P. (1979). Kaldor's law and British economic growth: 1800–1970, *Applied Economics*, vol. 11, 1979: 3, 309–319; Bairam, Erkin (1990). Verdoorn's Original Model and the Verdoorn Law Controversy: Some New Empirical Evidence Using the Australian Manufacturing Data, *Australian Economic Papers*, vol. 29, 1990, 107–112; Mamgain, Vaishali (1999). Are the Kaldor-Verdoorn Laws Applicable in the Newly Industrializing Countries?, *Review of Development Economics*, vol. 3, 1999: 3, 295–309; Wells, Heather & Thirlwall, Anthony P. (2003). Testing Kaldor's Growth Laws across the Countries of Africa, *African Development Review*, vol. 15, 2003: 2–3, 89–105.

[89] All the variables in both regressions are differenced and logarithmised and stationary, thus the possible spuriousness problem in time series regression (connected to regression of unit root time series) is not present. Heteroskedastic and autocorrelation consistent standard errors are used in both regressions to avoid wrong statistical inference.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

where

Δ	=	*the absolute change of the variable (here variables are expressed in natural logarithms and Δ approximates closely a relative change, e.g. in per cents, sometimes marked with log%)*
Y	=	*real value added, the subscript implies the part of the economy under review,*
ΔY	=	*the change of real value added*
LP	=	*labour productivity, real value added / hours worked,*
ΔLP	=	*the change of labour productivity*
E	=	*number of hours worked,*
ΔE	=	*the change in number of hours worked*
α	=	*a constant in the regression equation*
β	=	*a regression coefficient for the explanatory variable, if $\beta \neq 0$ according to statistical tests with the data, the variable has explanatory power for the left hand side variable in the equation*
ε	=	*residual or error from the regression equation, the part of variation of the left hand side variable in the equation that could not be explained*

Kaldor's first proposition is assessed with regression 1,[90] where GDP growth was explained by the growth of real value added of secondary production in each country or area (Table 2.1). According to the results some confirmation can be given to Kaldor's first law. The model fits each country's data fairly well in each time section available and all the variables' coefficients are statistically significant. The model's explanatory power (adjusted R squared) is 70 per cent for Finland and 80 per cent for Sweden in 1945–2003. However, comparing Sweden and Finland in two subsections of time (1945–79, 1980–2003), differences in the model fit can be found: the variation in secondary production value added explains only 57 per cent of Finland's GDP variation in the first period, but at the same time it explains as much as 90 per cent of Sweden's GDP variation. In contrast, in the latter period the secondary production variation explains more for Finland (as much as 85 per cent). Thus, the contribution of secondary production to GDP has been more important in Finland in 1980–2003. Therefore, according to these results as well, Finland's benefits from full industrialisation came later compared with Sweden. For the latter period, the model receives confirmation from the EU15 (91 per cent R squared) data as well. One must remember that tertiary production also contributed to GDP growth, which was not argued in Kaldor's first law and not tested with regression 1.

[90] With the first regression we are primarily interested in how much we can predict (or explain) GDP growth by secondary production growth in each economic area, thus for equation 1 we look merely at the adjusted R^2 instead of ß coefficient values. However, to be sure that the simultaneous causation of secondary production growth to GDP growth does not lead us to wrong conclusions with OLS regression coefficients, the simple correlations between ΔY_{GDP} and ΔY_{SEC} are also shown in Table 3.1 and they clarify simply the same results – without parameter estimation. In addition to regression 1, we also ran regressions in which we explained ΔY_{GDP} with $\Delta Y_{PRIM,}$ ΔY_{SEC} and ΔY_{TERT}: in this case the regression coefficients (with explanatory power close to 1) give the average contribution of each production class in each period and these results, too, verified the conclusions made with regression 1. Later, in sub-section 3.2, we will use growth accounting techniques – again without parameter estimation – to achieve even annual contributions to economy-wide GDP and labour productivity growth of primary, secondary and tertiary production.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table 2.1 Results for regression 1.

	1945–2003	*1945–1979*	*1980–2003*	*1945–2003*	*1945–1979*	*1980–2003*	*1980–2003*
Country	FIN	FIN	FIN	SWE	SWE	SWE	EU15
N	58	34	24	58	34	24	24
equation	1	1	1	1	1	1	1
constant	0.008*	0.013**	0.004	0.011***	0.012***	0.010**	0.014***
	(2.63)	(2.83)	(1.11)	(6.89)	(6.79)	(3.16)	(20.15)
$\beta_1 (\Delta Y_{SEC})$	0.556***	0.493***	0.627***	0.506***	0.580***	0.371***	0.502***
	(6.07)	(3.84)	(17.92)	(10.80)	(19.09)	(7.67)	(12.10)
Adj. R^2	0.70	0.57	0.85	0.80	0.90	0.72	0.91
D.W.	1.21	1.42	1.20	1.24	2.35	1.27	1.63
F	134.2***	44.1***	129.9***	223.1***	304.6***	58.9***	230.1***
Correlation (ΔY_{GDP}, ΔY_{SEC})	0.84	0.76	0.92	0.89	0.95	0.85	0.96

Sources: Own calculations**;** data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Rodney, *Growth, Accumulation, Crisis: With New Macroeconomic Data for Sweden* 1800–2000. Stockholm: Almqvist & Wiksell International 2005; Groningen Growth and Development Centre, 60-Industry Database, October 2005, **http://www.ggdc.net**.

***= significant at the 0.1% level. **=significant at the 1% level. *=significant at the 5% level. +=significant at the 10% level. The t-statistics and F-statistics have been obtained using the Newey-West (1987) heteroskedastic and autocorrelation consistent standard errors in the software EViews 5.1. The error structure is expected to be heteroskedastic and autocorrelated up to a number of lags. The truncation lag was chosen by q = floor(4(T/100)$^{2/9}$) following the suggestion of Newey and West. This means 3 lags for periods 1945–2003 and 1945–1979 and 2 lags for period 1980–2003. Newey, W. K. and West, K. D. A Simple, Positive Semi-definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix, *Econometrica*, vol. 55, 1987: 3, 703–708.

As an assessment of Kaldor's second proposition, aggregate labour productivity growth was explained by the growth of value added of secondary production and non-secondary labour input growth (regression 2). According to our regression results in Table 2.2, the growth in the non-secondary labour input at first glance seems to have a clear negative relationship with labour productivity change at the economy-wide level, as Kaldor expected: the β_3-coeffiecients are negative. However, with a more careful scrutiny of the results, one notices that with our data, β_3 is not statistically significant (at the 5 per cent level) in Finland in 1945–79 and the explanatory power (11 per cent) is dramatically low. Kaldor's second law does not seem to hold for Finland during 1945–79, although it receives confirmation in all the other time periods and countries. For the whole period the explanatory power is clearly weaker for Finland than for Sweden. On the other hand, the explanatory power is the strongest for Finland in the second time period, while its biggest impact on Swedish aggregate labour productivity growth was in 1945–79. This corroborates the later continuing industrialization phase in Finland. However, non-secondary labour input growth did not decrease aggregate labour productivity in Finland in 1945–79, which implies primary and tertiary production contributions to aggregate labour productivity as well.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table 2.2 Results for regression 2.

	1945–2003	*1945–1979*	*1980–2003*	*1945–2003*	*1945–1979*	*1980–2003*	*1980–2003*
Country	FIN	FIN	FIN	SWE	SWE	SWE	EU15
N	58	34	24	58	34	24	24
equation	2	2	2	2	2	2	2
constant	0.022***	0.026***	0.019***	0.019***	0.021***	0.017***	0.023***
	(7.11)	(4.41)	(8.43)	(9.05)	(6.25)	(9.61)	(17.28)
$\beta_2 (\Delta Y_{SEC})$	0.232*	0.185	0.319***	0.352***	0.411***	0.186***	0.334***
	(4.22)	(1.20)	(11.51)	(6.21)	(8.32)	(4.31)	(4.67)
$\beta_3(\Delta E_{PRIM\ \&TERT})$	-0.464**	-0.315+	-0.778***	-0.772***	-0.580**	-0.586***	-0.880***
	(-3.04)	(-1.94)	(-10.81)	(-7.61)	(-3.57)	(-6.36)	(-6.54)
Adj. R^2	0.29	0.11	0.73	0.61	0.69	0.51	0.64
D.W.	1.27	1.24	0.94	1.14	1.63	2.38	0.90
F	12.41***	3.01+	31.86***	44.95***	37.65***	12.74***	21.19***

Sources: Own calculations**;** data from Hjerppe, Finland’s Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database.

***= significant at the 0.1% level. **=significant at the 1% level. *=significant at the 5% level. +=significant at the 10% level. The t-statistics and F-statistics have been obtained using the Newey-West (1987) heteroskedastic and autocorrelation consistent standard errors in the software EViews 5.1. The error structure is expected to be heteroskedastic and autocorrelated up to a number of lags. The truncation lag was chosen by q = floor($4(T/100)^{2/9}$) following the suggestion of Newey and West. This means 3 lags for periods 1945–2003 and 1945–1979 and 2 lags for period 1980–2003. Newey and West, A Simple, Positive Semi-definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix.

To conclude, we found that Kaldor’s laws can be used only partially to analyse economic growth in Finland. Secondary production had the biggest impacts on Finnish GDP growth in 1980–2003. Thus we must reject our first hypothesis that Finnish growth and convergence with Sweden, and consequently with the EU15 as well, could be explained solely with the late phase of rapid growth in secondary production through its impact on speeding up aggregate labour productivity change.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

2.3.2 The contributions of primary, secondary and tertiary production to Finland's catch-up

In order to find out more about the roles of structural change and aggregate labour productivity growth as explanatory sources of Finnish convergence to Sweden during 1945–2003, we will explore the growth of value added growth and the labour productivity in major industries of the economy. Special attention is given to service production. From now on, we will use the non-parametric growth accounting techniques of National Accounts to attain a deeper analysis of the contribution of primary, secondary and tertiary production within the time periods used previously.[91] To shed more light on growth and convergence during 1945–1980 we will divide this period into two sub-periods, i.e. 1945–65 and 1965–80.

The evolution of the production structures of Sweden and Finland are shown in Table 2.3 and in Figures 2.4 and 2.5. Sweden had a more industrialised and more service-oriented economic structure already in 1945, whereas Finland, although rapidly changing, was a much more agricultural society in the first years of the period. Looking at the shares in Table 2.3, one notices that while Sweden's primary production share diminished from 14 to 2 percentage points from 1945 to 2003, Finland's primary production share decreased from 42 to 3 percentage points. The fastest structural change seems to have taken place in Finland from 1945 to 1965 when the share of primary production declined from 42 to 16 percentage points and at the same time both secondary and tertiary production shares increased. However, from 1980 to 2003 the services share grew substantially again in Finland at the same time as the shares of primary and secondary production diminished. In Figures 2.4 and 2.5 it is worth noticing that the highest share of secondary production in Sweden was in the early 1960s and in Finland in the mid-1970s.

Table 2.3 Production structure of the economy in Sweden and Finland, in 1945, 1965, 1980 and 2003.

SWE	1945	1965	1980	2003	FIN	1945	1965	1980	2003
PRIM	14%	7%	4%	2%	PRIM	42%	16%	10%	3%
SEC	39%	42%	32%	27%	SEC	27%	36%	38%	32%
TERT	47%	51%	64%	71%	TERT	31%	48%	52%	65%

Sources: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database**.**

[91] With growth accounting techniques we can get not only average contribution coefficients (or explanatory powers) in each time period but obtain the annual contributions of primary, secondary and tertiary production to the economy-wide level. Using logarithmical changes in the variables under review we can calculate the average growth contributions (including the compound interest effect) for shorter time periods.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure 2.4 Percentage shares of primary, secondary and tertiary production in Swedish GDP, 1945–2003.

Sources: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database.

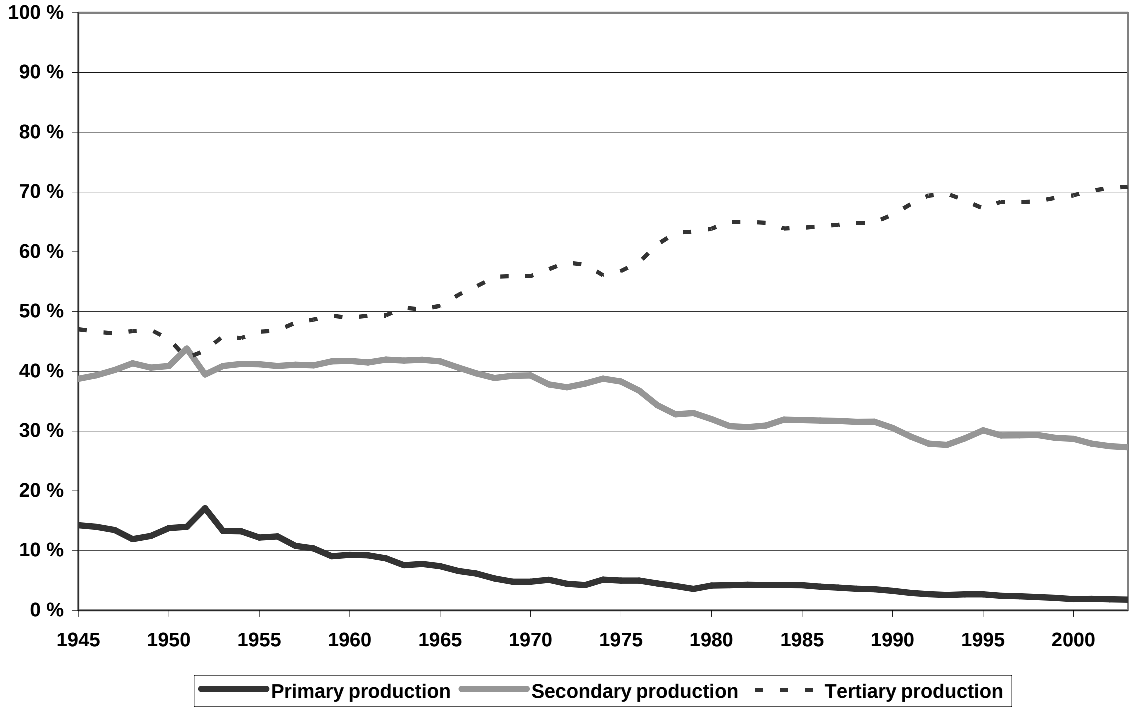
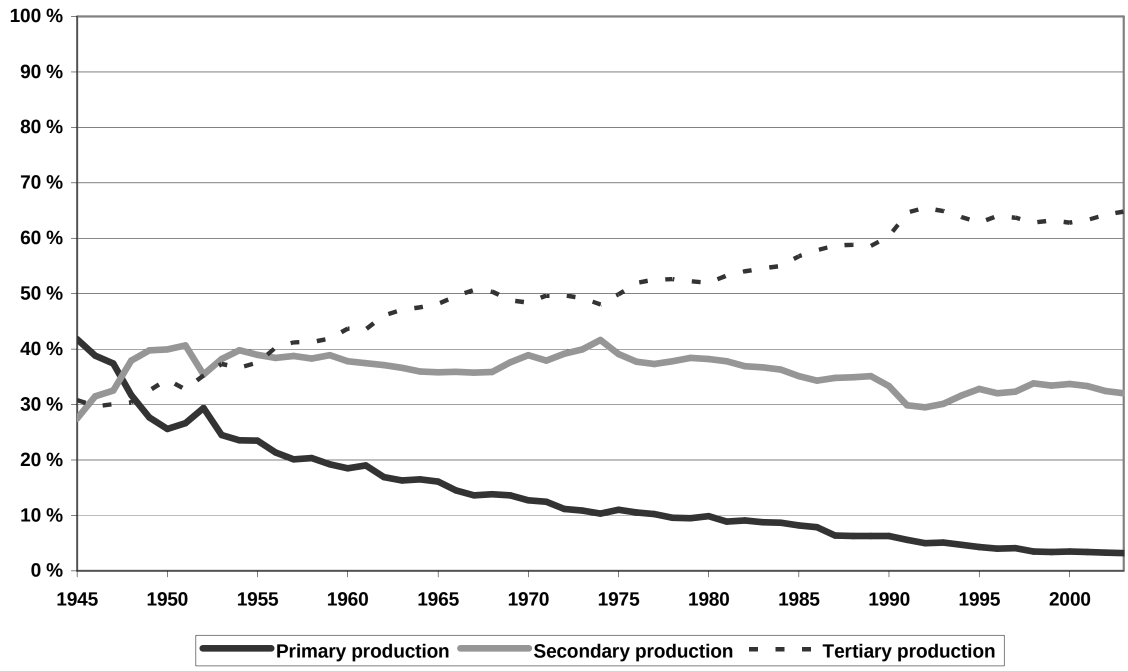


Figure 2.5 Percentage shares of primary, secondary and tertiary production in Finnish GDP, 1945–2003.

Sources: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland.



Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Value added growth contributions

Table 2.4 shows that the value added in secondary and tertiary production grew rapidly in Finland in the first two periods. This confirms – together with previous results – that production shifted from primary production to secondary and tertiary production at the same time in Finland. This shows that Finland has gone through a good part of its industrialisation phase after WWII, but Sweden deepened its industrialisation in the first period under review as well. The growth in secondary and tertiary production in Finland (Table 2.4) has been faster than in Sweden in all of the periods. Hence, Finland experienced structural change later than Sweden, but its transformation from an agricultural to an industrialised and post-industrialised country was more rapid and more simultaneous than that of Sweden.

Table 2.4 Average growth in Finland and Sweden by period (log%).

	1945-1965		1965-1980		1980-2003	
	FIN	SWE	FIN	SWE	FIN	SWE
PRIM	0.9%	0.7%	0.5%	-0.6%	-0.2%	0.7%
SEC	6.7%	5.5%	4.4%	2.0%	3.4%	2.8%
TERT	5.3%	4.1%	4.2%	3.3%	2.4%	1.8%
GDP	**4.4%**	**4.2%**	**3.7%**	**2.6%**	**2.5%**	**2.1%**

Sources: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database**.**

How much then did the growth of primary, secondary and tertiary productions contribute to GDP growth in Finland and Sweden? In Figure 2.6 the contributions of primary, secondary and tertiary production growth to GDP growth are calculated by multiplying the annual current price production share by the annual volume log per cent growth in each production class in each time period.[92] Because the growth contribution rates are expressed in logarithms, they exhibit the average period growth contribution rates (including the compound interest effect) in each major industry as well.

As can also be seen from Table 2.4, the average GDP growth rate was almost similar in both countries in the first period, which confirms the fact that to a large extent, Finland did not catch up with Sweden in GDP per capita during 1945–65 (see also Figure 2.2). In both countries, the growth came from both secondary and tertiary production, with the emphasis on

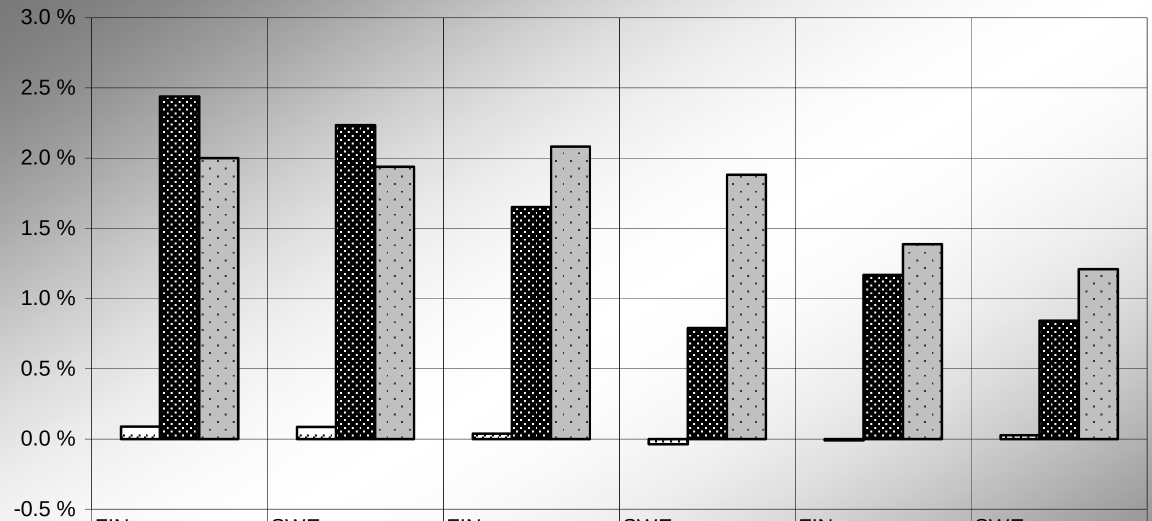
[92] The annual volume growth rates in primary, secondary and tertiary production were aggregated from more detailed sub-classes by using Törnqvist aggregation in accordance with Törnqvist-index methodology.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

secondary production growth in 1945–1965. Observing Table 2.4 it is clear that Finnish secondary production growth rate was higher (6.7 per cent) than the Swedish (5.5 per cent). However, because of the essentially larger share of secondary production (Table 2.3) secondary production's growth contribution was not that different.

Figure 2.6 The contributions of growth of primary, secondary and tertiary production to GDP growth in Finland and Sweden (log%, annual average by period; average of yearly growth rates multiplied by current price annual share (current price annual share is t and t-1 years' average share)).

Sources: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database**.**



	FIN	SWE	FIN	SWE	FIN	SWE
	1945-1965		1965-1980		1980-2003	
PRIM	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
SEC	2.4%	2.2%	1.7%	0.8%	1.2%	0.8%
TERT	2.0%	1.9%	2.1%	1.9%	1.4%	1.2%

It is important to note that both Finland's secondary and tertiary production grew more rapidly (Table 2.4) in all periods and contributed more particularly in the last two periods (Figure 2.6), in Finland than in Sweden. In the first period the GDP growth rates of both countries were high, but from Finland's point of view the difference in GDP per capita remained almost as big at the end of this period as it had been at the beginning. Figure 2.6 reveals that the contributions of the growth of service production to GDP in Finland have been even bigger than the contributions of secondary production in the second and third periods when Finnish growth was faster and most of the convergence with Sweden mostly took place.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Labour productivity growth contributions

Above we noticed that it was not only the rise of secondary production but also the rise of tertiary production that caused Finland's faster GDP growth in 1965–80 and 1980–2003. Figure 2.3 in section 2.2 showed the vitality of labour productivity growth in contributing to GDP per capita growth. This is why we will conclude this discussion by evaluating primary, secondary and tertiary labour productivity growth and their contributions to aggregate labour productivity in Finland and in Sweden.

Table 2.5 Labour productivity in Finland and Sweden, average growth by period (log%).

	1945-1965		1965-1980		1980-2003	
	FIN	SWE	FIN	SWE	FIN	SWE
PRIM	2.3%	4.4%	5.1%	4.9%	3.5%	3.5%
SEC	4.0%	4.8%	4.1%	4.1%	4.7%	3.7%
TERT	2.0%	2.4%	3.0%	1.9%	1.3%	1.0%
TOT economy	**3.1%**	**3.9%**	**4.2%**	**3.1%**	**2.8%**	**1.9%**

Sources: Own calculations; data from Hjerppe, Finland’s Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database**.**

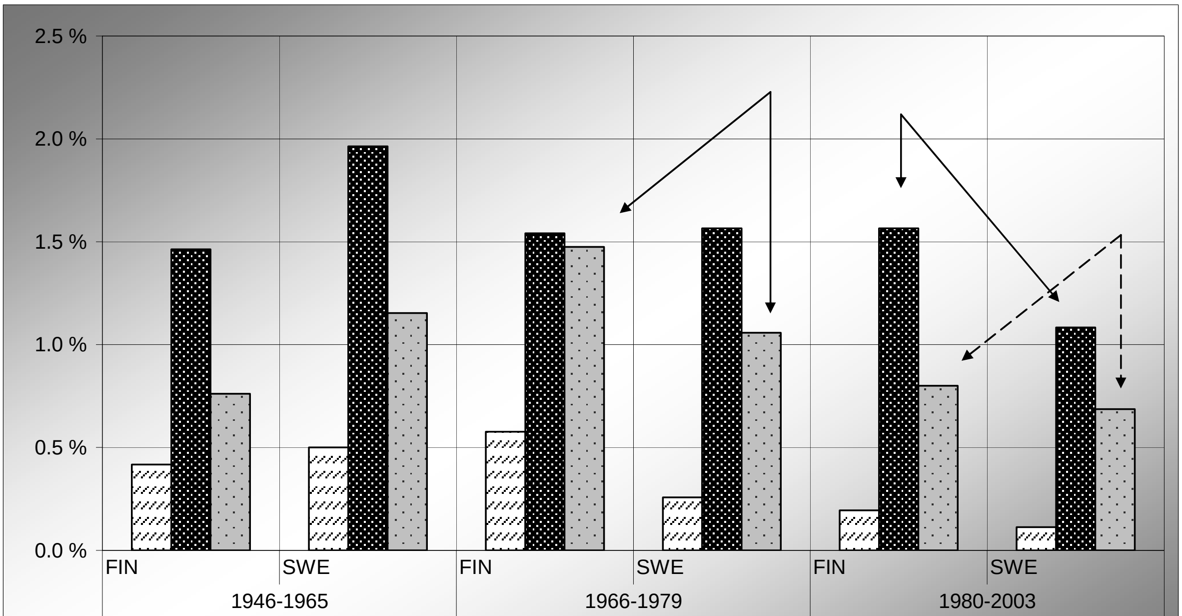
From Table 2.5 it can be seen that labour productivity grew faster in Sweden in 1945–65 both at the aggregate level and in each major industry. This also shows why Finland did not catch up with Sweden in that period, although labour input grew after WWII in Finland together with labour productivity. The faster structural change and labour input growth in secondary and tertiary production during the first period helped Finland respond to Sweden’s fast GDP growth and avoid falling behind in GDP per capita in those years.

In 1965–80 Finland’s labour productivity grew at the aggregate level at a higher rate than Sweden’s. The rate of labour productivity growth in secondary production was the same in both countries, but Finnish labour productivity in services grew more rapidly. In Sweden productivity growth in services decelerated already in this period. This reveals the fact that the rapid labour productivity growth in services was indispensable for Finland’s catch-up in the period of 1965–80.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Particularly in the third period (1980–2003) aggregate level productivity and secondary production productivity[93] grew faster in Finland than in Sweden. At this point the productivity growth of tertiary production slowed down in Finland as well, although it was still growing faster than in Sweden. It seems that by the last period Finland had reached a similar service-oriented economic structure as Sweden (see Table 2.3).

Figure 2.7 Primary, secondary and tertiary labour productivity growth contributions to aggregate labour productivity growth in Finland and Sweden, average by period (log%; average of yearly productivity growths multiplied by current price annual share (current price annual share is t and t-1 years' average share)).
Sources: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Edvinsson, Growth, Accumulation, Crisis; Groningen Growth and Development Centre, 60-Industry Database**.**



	1946-1965 FIN	1946-1965 SWE	1966-1979 FIN	1966-1979 SWE	1980-2003 FIN	1980-2003 SWE
PRIM	0.4%	0.5%	0.6%	0.3%	0.2%	0.1%
SEC	1.5%	2.0%	1.5%	1.6%	1.6%	1.1%
TERT	0.8%	1.2%	1.5%	1.1%	0.8%	0.7%

Finally, the primary, secondary and tertiary labour productivity growth contributions to aggregate labour productivity growth are presented in Figure 2.7. Comparing developments in the labour productivity contributions in both countries it can be detected that Finland's labour productivity growth contribution in services exceeded the Swedish one in 1965–80 and 1980–2003. Especially in 1965–80 this was decisive for Finland's catch-up as Sweden had a larger secondary production labour productivity contribution than Finland. In the last period,

[93] In 1980–2003 Finnish manufacturing productivity growth was very polarised. It was mainly due to the so-called Nokia effect. Jalava, Jukka (2006b).Catching up with the Technology Frontier: Finnish Manufacturing Productivity, 1975–2003, *Scandinavian Economic History Review*, vol. 54, 2006: 1, 47–63.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

1980–2003, Finland surpassed Sweden's labour productivity contribution in secondary production for the first time. In this period the difference between the two economies was biggest in secondary production and therefore secondary production labour productivity growth had the biggest impact on Finland's faster GDP per capita growth in 1980–2003.

The bigger value added growth contributions in 1965–2003 and faster than Sweden's labour productivity growth in 1965–80 in Finnish services may also be partly a consequence of the later phase in structural change – probably there was more room for new economic production in services as well. In addition we have to note that the share of services produced by the public sector has been bigger in Sweden. In National Accounts public sector production is valued through the costs of production and consequently its labour productivity growth becomes zero in the calculations. This means that labour productivity growth in services in both countries has come from privately produced services, in which there must have been more growth in Finland during 1965–1980.[94]

In the end, a word of caution: when examining only the effects on GDP per capita growth separately in both countries, it is important to note that looking at the whole time period 1945–2003 the biggest (but not the only) contributions to aggregate labour productivity in Finland and Sweden came from secondary production. Thus, if we were explaining only the GDP per capita growth separately in each country, we might state that compared with primary and tertiary production, secondary production seems to have had the largest impacts on Finland's and Sweden's labour productivity and GDP per capita growth during 1945–2003. It probably has had its effects through innovations (e.g. electricity in the first period and ICT in the last period) on labour productivity growth in services as well. Nevertheless, taking into account Sweden's strong secondary production performance and Finland's inability to overcome it in terms of labour productivity contributions until 1980–2003, the contributions of tertiary production have played a significant role in Finland's catch-up in GDP per capita, particularly during 1965–80.

[94] Surely due to a lack of historical producer price indices for service industries there are also difficulties in measuring the productivity of private services exactly.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

2.4 Conclusions

The main task of this chapter was to trace Finland's economic catch-up with the EU15 and especially with Sweden. We also wanted to see whether the late industrialisation and different path of structural change were sources of Finland's faster labour productivity growth and convergence. We found that despite considerable catching up with the EU15 in the interwar period, the gap in GDP per capita between Finland and the EU15 was closed mainly in the 1960s and the 1970s. Sweden's lead was only closed in the 1970s and the 1980s, and again in the 1990s. Sweden was ahead of the EU15 average in GDP per capita already in 1945 and at the beginning of the 21st century as well. Therefore when converging to Sweden, Finland has consequently caught up and overtaken the EU15 average income level.

GDP per capita has grown considerably both in Finland and Sweden during 1945–2003. A comparison of the countries shows that the difference in GDP per capita remained almost constant during 1945–65 and that Finland's catch-up with Sweden mostly took place during 1965–2003. During the whole period reviewed, it seems that there was more room to expand to new economic activities in the Finnish economy. Thus, in compliance with the classical view, beginning from a low production level Finland gained from the latecomer position and from faster structural change.

Alexander Gerschenkron, Nicholas Kaldor and the classical view of structural change (Colin Clark, Simon Kuznets, Ronald Hartwell)[95] emphasised the importance of manufacturing industries to the latecomer country's catch-up process. Therefore, we wanted to find out whether late industrialisation and secondary production growth would explain Finland's convergence after WWII. We used Kaldor's growth laws as a framework to test this. We found that Kaldor's laws could be used partially in explaining economic growth. Secondary production had its biggest impacts on Finnish GDP growth as late as 1980–2003, whereas its major effect on Swedish GDP growth came as early as 1945–79. However, labour input growth in non-secondary production did not have a statistically significant negative influence on aggregate labour productivity in Finland during 1945–79. Thus we rejected our first hypothesis that Finnish growth and convergence with Sweden, and consequently with the EU15 as well, could be explained solely with the later growth phase in secondary production via its impacts on speeding up aggregate labour productivity. Contrary to the classical view

[95] Gerschenkron, Economic Backwardness in Historical Perspective. In *The Progress of Underdeveloped Areas*; Kaldor, *Strategic Factors in Economic Development*; Clark, *The Conditions of Economic Progress*; Kuznets *Six Lectures on Economic Growth*; Hartwell, The Service Revolution: The Growth of Services in Modern Economy, in *The Fontana Economic History of Europe 3: The Industrial Revolution*.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

and Kaldor's growth laws, it was not solely the advantages of secondary production growth that caused Finland to catch up.

To shed more light on the roles of non-secondary parts of the economy as well, we explored the growth of value added and labour productivity in primary, secondary and tertiary production and their contributions to the aggregate level. Additionally, we compared Sweden and Finland in major industries in three sub-periods: 1945–65, 1965–80 and 1980–2003. The analysis showed that the service production growth contributions to GDP in Finland have been even larger than secondary production contributions in the second and third periods when Finnish growth was faster and most of the convergence with Sweden took place. However, we must bear in mind that convergence is assessed in terms of GDP per capita and labour productivity growth is an important factor for GDP per capita growth. From the analysis of labour productivity contributions we saw that labour productivity growth contribution in services exceeded the Swedish one during 1965–80. Thus, the labour productivity growth contribution from services was essential for Finland's GDP per capita catch-up during 1965–80 since Sweden gained slightly more from secondary production labour productivity even in that period. In the last period, 1980–2003, Finland finally exceeded Sweden's labour productivity growth contributions in secondary production and the most important effect for the faster Finnish GDP per capita growth came from secondary production at that time.

The importance of services, as already emphasised by Broadberry (1998) for the US and Germany with respect to the UK, in the catch-up is a new result for Finland and worth considering also when analysing the catching up or lagging behind of other countries. Such an exercise requires historical data on a more disaggregated level than of the total economy, which is of course more difficult to obtain, but the extra effort is worthwhile.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3. INTANGIBLE HUMAN CAPITAL BY SCHOOLING AND ECONOMIC GROWTH IN FINLAND IN THE 20TH CENTURY

In the basic framework of this study structural change is seen driven by new possibilities (technology), to produce products (old and new). To implement and use new production technologies along time requires human capital, which in this analysis is associated with more and better educated labour. Structural change is seen arising from the new possibilities (new technology) to produce products.

The structures of production particularly in the advanced economies have changed dramatically in the 20th century and continue changing: First, the phase of industrialisation of the countries continued. Second, from the last decades of the 20th century an increasing share of the national product was and is produced in the service industries. And in the late 20th century, a whole new branch – the industries of information and communication technology, ICT – has emerged and its products are used as final consumption (e.g. mobile telephones) and as intermediate consumption or investments (e.g. mobile telephone networks to telephone operators). ICT can also be used to produce either physical products or services. These structural changes can be described as moving from society predominated by primary production to the industrialised society and onwards to the post-industrial and information society.

As noted in Chapter 2, Finland can be seen as one of the latecomer countries in structural change although the industrialisation had already started in the 19th century. According to National Accounts[96], in 1920 the share of primary production (agriculture and forestry) was only slightly less than one half, 47%, of the whole economy with the shares of secondary (manufacturing and construction) and tertiary (services) production 24% and only 30%, respectively. The fractions of the secondary and tertiary production increased in the interwar period. However, after the resettlement of the Karelian people from the areas lost in the war and the young men who returned from the war mostly into the rural areas of Finland, the share of primary production increased again. Therefore, as late as in 1948, the primary production share of GDP was still 32%, the share of tertiary production still only 30% while that of secondary production had already increased to 38% in accordance with the production

[96] Hjerppe, Riitta (1996). *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* University of Jyväskylä, Department of History, Suomen historian julkaisuja 24. Jyväskylä 1996; Statistics Finland, (2005). National Accounts, Population Statistics, Education and Research. *Statistical Yearbook 2005,* Helsinki.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

for the war reparations to the Soviet Union. The highest share of secondary production, 41%, was reached in 1974 (at same time the share of primary production had already fallen to 11% and that of services had increased to 48%). At the turn of the millennium, in the year 2000, the share of services was recorded at 65% (primary production 4% and secondary production 34%) and the share of services has continued its increase. Hence, during the time period under review Finland has gone through a considerable transition from a country characterised by primary production, through the era of manufacturing industries' rise and opening of the economy, to the information society emphasised by service industries. The main question of this part of the study is: Have the substantial inputs in education played a role in this rapid transition and fast change of economic performance in Finland?

In general, the growth and differences in growth of GDP per capita have been one of the major research issues in economic history and economics since the early 20th century. As noted in the Introduction of this study, in the neo-classical growth theories the inputs used in production are physical capital (*K*) and labour (*L*).[97] The more a country invests in physical capital (e.g. machines), the more there is physical capital in relation to labour (if the labour force and population do not grow faster than the stock of physical capital[98]). The growing labour productivity in production will lead the country to a higher GDP per capita. Thus, the countries that invest more and have a low population growth will have a higher GDP per capita than countries that invest less and have a fast population growth. At the same time, the neo-classical growth theories predicted convergence in economic growth among countries that have similar saving (and thus investment) rates and population growths.

Perhaps the most used neoclassical model is the Solow model with technology[99], which introduced technological change that prevents the economic growth eventually to cease under the diminishing marginal rate of return on physical capital. While diminishing returns to scale on physical capital would have damped down the economic growth, the exogenous technological progress (like "manna from heaven") caused sustained per capita growth. This model predicted converging growth rates to the countries with similar saving rates and

[97] Solow, Robert M. (1956). A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, vol. 70, 1956:1, pp. 65–94; Solow, R.M. (1957): Technical Change and the Aggregate Production Function, *Review of Economics and Statistics* 39, 1957:3, pp. 312–20; Swan, Trevor W. (1956). Economic Growth and Capital Accumulation, *Economic Record*, vol. 32, 1956: November, pp. 334–61; Cass, David (1965). Optimum Growth in an Aggregative Model of Capital Accumulation, *Review of Economic Studies*, vol. 32, 1965:July, pp. 233–40; Koopmans, Tjalling C. (1965b). On the Concept of Optimal Economic Growth, in *The Econometric Approach to Development Planning.* Amsterdam: North Holland 1965.

[98] It is also assumed that the labour force participation rate in the population does not change when the population grows.

[99] Solow (1957) Technical Change and the Aggregate Production Function. *Review of Economics and Statistics.*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

population growths. The prediction came from the assumption of more productive physical capital per labour input in the low levels of capital before the diminishing returns come into force. Finally, in the long run all the countries would grow at the same rate with exogenous technological change that is freely available to all countries and that country could not affect. However, the empirical applications of these models have shown that a big part of the reasons and factors explaining economic growth is left in the model to a residual (in the so-called Solow residual).

According to Alexander Gerschenkron's classical thesis of the advantage of relative backwardness[100], the lower the GDP per capita is at the beginning, the higher economic growth is expected. In practice, this usually means that after the automation of primary production a large number of people working for agriculture will enter the labour market and will be available for increasing intake of manufacturing industries. In other words, when the level of manufacturing industries' value added increases most from the low beginning level, the whole economy grows at the fastest pace. This coincides with Finland: the economy has grown at the quickest rate (4.9% a year, on average) in recorded history in 1946–1972. This also coincides with China in the 1990s and early 2000s. In the empirical applications of growth models with panel data the initial GDP per capita level of the countries is usually added to the analyses as an explicative variable.

Moses Abramovitz in his famous article "Catching up, forging ahead, and falling behind" stressed countries' differences in social capability as one of the important factors behind different performances in economic growth[101]. Using the definition of Abramovitz, social capability means that developed infrastructure and institutions as well as the attitude and education of people, contribute to the country's ability to absorb more advanced technologies. The discussion about the empirics of convergence and divergence surged among economic historians and economists.

In the modern economic growth theories the country's ability to technological progress in production with human capital has been emphasised somewhat in line with Abramowitz.[102] Many of these models suggest technological change to be endogenised by

[100] Gerschenkron, Alexander (1952). Economic Backwardness in Historical Perspective. In *The Progress of Underdeveloped Areas*, Ed. B. F. Hoselitz. University of Chicago Press 1952; Gerschenkron, Alexander (1962). *Economic Backwardness in Historical Perspective: A Book of Essays.* Cambridge: Harvard University Press 1962.
[101] Abramovitz, Moses (1986). Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, vol. XLVI, 1986: 2, pp. 385–406.
[102] E.g. Romer, Paul M. (1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy*, vol. 94, 1986:5, pp. 1002–37; Romer, Paul M. (1987). Growth Based on Increasing Returns Due to Specialization, *American Economic Review*, vol. 77, 1987:2, pp. 56–62; Romer, Paul M. (1990). Endogenous Technological

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

research and development (R&D) activities and some of them introduce the diffusion of technology across the countries in accordance with human capital. Economies that invest more in physical capital will be richer, as in earlier growth models. In addition, economies that invent more ideas and technology and accumulate more skills that can help them either to adopt or invent new technologies will be richer. In these models human capital (*H*) is seen either as a main production factor together with physical capital (*K*) enhancing labour input, or as a factor used in inventing new technology or facilitating the implementation and adaptation of new technologies.

Thus, the modern theories of economic growth have begun to treat technological change endogenously including innovation by R&D and knowledge or human capital in the models. The idea is to explain the factors for and the dynamics of the technological change with the accumulation and spillover of knowledge, with specialisation in its areas and with its externalities. Fundamentally, the new models in the essence are giving up the diminishing marginal rate of return assumption. Often in the models, low accumulation of human capital may even prevent the growth.

Unfortunately, there is shortage of data on investments in and stocks of human capital especially comparable with physical (or fixed) capital, as human capital is not included inside the asset boundary of the System of National Accounts. This has made it difficult to test the new theories properly. In empirical research attempts have naturally been made to solve the lack of such data in different ways. A common solution has been to use a replacing variable outside the National Accounts framework (for instance, numeracy or literacy rate, schooling enrolment ratio, average years of schooling, etc.) in the growth regressions.

Characteristically these traditional measures are used in cross-sectional comparisons of countries – for instance, in growth regressions the initial enrolment ratio is linked with the initial GDP level when explaining later economic growth performance as in Robert Barro's thorough research.[103] In the end, according to Barry Bosworth's and Susan Collins' update of empirical growth studies in economics, by using these types of variables, either in the cross-sectional or panel data regressions, no unambiguous agreement has been achieved on the role

Change, *Journal of Political Economy*, vol. 98, 1990:5, pt. II, S71–S102; Lucas, Robert E. Jr. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22, 1 (July), pp. 3–42; Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run Growth, *Journal of Political Economy*, vol. 99, 3, pp. 500–21; Grossman, Gene M., Helpman, Elhanan (1991). *Innovation and Growth in the Global Economy*, Cambridge MA, MIT Press.

[103] See Barro, Robert J. (1991). Economic Growth in a Cross Section of Countries, *Quarterly Journal of Economics*, vol. 106, 1991:2, pp. 407–33.

of increased education in explaining differences in economic growth across countries and time.[104]

However, the empirical counterparts of the other key variables in the growth theories come from inside of the systematic National Accounts frame (GDP, physical capital stock, hours worked). One of the problems with the conventional measures is that it is difficult to say whether these variables are comparable with investments in physical capital or with accumulated stock of physical capital, or the services of the stock. Or in other words, what is an investment in these approaches and how investments accumulate to the stock of human capital. Another problem with the conventional empirical human capital variables is that they are not measured similarly as the other key variables: GDP and investments in physical capital are monetary flows in National Accounts. And when monetary investments (the volumes are also expressed in monetary terms, i.e. when the price inflation is properly deflated out) are accumulated to the physical capital stock, the stock is also a monetary valued variable (at fixed prices as accumulated by deflated volumes of investments).

The aim of Chapter 3 in this study is to explore whether there would be a straight-forward cointegration relation to be empirically found between human capital by schooling and long-run economic growth in Finland. Human capital by schooling is to be assessed in the same National Accounts framework as the other variables examined in it, such as GDP, investments in physical capital and accumulation of physical capital stock. The expenditures in formal education per year are separated from final consumption and treated as investments in human capital in Finland in 1877–2000. The human capital stock is accumulated through investments in a similar way to physical capital, i.e. through invested monetary flows in education. As a result, investments in and stock of human capital are valued in monetary terms as GDP and physical capital, at fixed prices. After this, the impact of annual human capital investments on GDP can be analysed and the long-run connection between human capital accumulation and GDP growth can be evaluated.

There are few empirical examples of measuring human capital in the context of National Accounts in the literature as well. The proposed well-known setups of modified National Accounts Systems will be studied in Section 3.2. The two best-known are the work of John Kendrick in 1976 and the work of Dale Jorgenson and Barbara Fraumeni in the late 1980s. In the former, John Kendrick built an entire new System of National Accounts for the

[104] Bosworth, Barry P. & Susan M. Collins (2003). The Empirics of Growth: An Update. *Brookings Papers on Economic Activity*, 2:2003.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

United States and assessed human capital by accumulated inputs for the U.S. in 1929–1969.[105] In the latter, Dale Jorgenson and Barbara Fraumeni did the same for the U.S. in 1948–1984, however, basing their approach on the lifetime labour income including in their analysis household work and leisure.[106] In addition, Pirkko Aulin-Ahmavaara has proposed a dynamic input-output approach, which includes a complete system of production including the production of human capital and human time (the services of human capital). In her system production is based on the total available time-bill of active population.[107] The differences in the evolution between the suggested two best-known National Accounts measures of Kendrick and Jorgenson and Fraumeni with the conventional proxy measures based on school attainment will be reviewed. However, both of these as well as Aulin-Ahmavaara's National Accounts measures have broadened the scope of National Accounts far beyond the standard GDP.[108] Their measures for human capital can only be compared with the 'new' GDP or output in their systems.

At the same time, an overwhelming majority of empirical examinations have explored the connection of schooling with the standard GDP without receiving unambiguous results on the role of human capital in standard GDP growth. Measuring human capital in the National Accounts framework could reveal better the impact of human capital on growth and possibly result in a more straightforward long-run relation of human capital and GDP than with the proxy measures. In this part of the study, the main object is to investigate whether the results with a National Accounts estimate would be different with regard to standard GDP growth. Therefore, a measure on intangible human capital by schooling is formed in the modified National Accounts frame in which GDP does not change.

Finland was a latecomer both in economic development and in schooling as well. Compulsory education was not introduced in Finland until 1921, while it was introduced in

---

105 Kendrick, John W. (1976). *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York.

106 Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*, Studies in Income and Wealth, Vol. 52, Chicago, IL, University of Chicago Press; Jorgenson, Dale W., Fraumeni, Barbara M. (1992a). The Output of Education Sector. *Output Measurement in the Service Sector*, in Z. Griliches,(Ed.) Studies in Income and Wealth, Vol. 55, Chicago, IL, University of Chicago Press; Jorgenson, Dale W., Fraumeni, Barbara M. (1992b). Investment in Education and U.S. Economic Growth, *Scandinavian Journal of Economics*, 94. Supplement, pp. 51–70.

107 Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced* Asset; also in, e.g. Aulin-Ahmavaara, Pirkko (1987). *A Dynamic Input-Output Model with Non-Homogenous Labour for Evaluation of Technical Change*. Finnish Academy of Science and Letters. Helsinki; Aulin-Ahmavaara, Pirkko (1990). Dynamic Input-Output and Time. *Economic Systems Research*, 2, 239–34; Aulin-Ahmavaara, Pirkko (1991). Production Prices of Human Capital and Human Time. *Economic Systems Research*, 3, 345–65.

108 Standard GDP refers here to the GDP calculated in accordance with international standard of National Accounts, the System of National Accounts.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Denmark 1814, in Sweden in 1842, in Norway 1848, in Italy 1878, in France in 1882 and in parts of Germany already in the late 17th century.[109] Even after 1921 in Finland, many local decision makers favoured ambulatory schools as they were cheaper to run than proper folk schools. Hence, it took at least until WWII before mostly everywhere in the rural areas children could go to fixed school.

Before proceeding further, it is worth clarifying that I do not claim here that human capital would be the only factor behind Finland's (or any other nation's) economic growth. However, the development in educating Finns has been substantial in the latter part of the 20th century. For instance, before World War II and right after it, the average educational level of the population was still quite low. In previous analysis, the total expenditure on education per year by the government has been estimated to have increased ten times the level 50 years ago and in Finland nearly all of the formal education is provided by the public sector.[110] Nowadays, Finland has often been considered an exemplary country of education[111]. The number of matriculations per year was eight times higher in 2000 than in 1945, while excluding physical capital[112] other usual inputs on national product in the long run have not increased in a similar way (land – not increased, population 1.4 times higher than in 1940). At the same time the volume of GDP has increased 7.8 times higher a year in 2000 than in 1945[113]. One would assume that the accumulation of knowledge, know-how and skills would have contributed to the changes of the Finnish economy and also become one of the important factors in producing the national product of Finland in the 21st century's information society.

---

[109] Antikainen, Ari, Rinne, Risto and Koski, Leena (2006). *Kasvatussosiologia*. WSOY Oppimateriaalit Oy, Helsinki, p. 71.

[110] Pekkala, Sari, Intonen , Nina, Järviö, Maija-Liisa (2005). Education Expenditure in Finland in the Twentieth Century and in the Future, *Discussion Papers 365, Government Institute for Economic Research*, Helsinki 2005, p. 44.

[111] E.g. OECD (2003). *Education at a glance 2003*. OECD, Paris.

[112] Physical capital (or fixed capital) is a basic variable in the growth theory models as well. Its impact on growth is obvious and inevitable, but perhaps the whole story of long-run growth cannot be explained only with it and labour input, and possibly added land and energy into the production function.

[113] Hjerppe, Riitta (1996). *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables*; Statistics Finland, (2005). National Accounts, Population Statistics, Education and Research. *Statistical Yearbook 2005.*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The research problem

The research problem of this chapter can be expressed with the following questions: Can human capital by schooling be estimated and presented in the systematic framework of Finland's National Accounts in the 20th century together with other standard real macro-economic variables calculated in it? What have been its investments flows per year and how have they accumulated to human capital stock?

If the preceding questions have been answered, the goal of forming the data has been attained. In that case further questions can be asked: How have investments in human capital by schooling contributed to annual GDP of Finland in the 20th century? Has there been a straight-forward long-run relationship between human capital and GDP per capita growth in Finland?

3.1 The system of production of the SNA

Human capital is not treated as an asset according to the asset boundary of the international standard of National Accounts (System of National Accounts, SNA) in the currently applied 1993 version (SNA1993). The revised SNA2008 to be implemented in coming years excludes it from assets in the core accounts as well, but proposes to handle it in an additional voluntary satellite account outside the core system.[114] Excluding human capital from the SNA is not an accident. A decision has been made to treat final consumption, including education expenditures, as a contribution to welfare.[115]

The question of treating, for example, education expenditures as investments was already considered by the early developers of National Accounts. However, they decided not to go to that direction. For instance, Kuznets asked whether some of the consumption is in fact wanted by the consumers in their capacity as producers. But in his point of view the distinction is tenuous. "For if education is conceived simply as preparation for livelihood not

---

114 See SNA93, The Inter-Secretariat Working Group on National Accounts (1993), *System of National Accounts 1993*, Commission of the European Communities-Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington D.C; SNA2008 (2009). The Inter-Secretariat Working Group on National Accounts. *System of National Accounts 2008*, Commission of the European Communities-Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington D.C.

115 See SNA93, (1993) SNA2008, (2009); Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 15.

 DOI: 10.2870/35887

as the enhancement of living, and if a man's residence and its appurtenances are counted simply as the domestic equipment appropriate for the production of his income, then, since satisfaction of the consumer is inextricably bound up in the circle of means and ends with the needs of the producer, the whole category of ultimate consumption disappears."[116]

In her in-depth research in the early 2000s, Pirkko Aulin-Ahmavaara clarifies the accounts of assets in the SNA: Non-financial assets are in the system either produced assets or nonproduced assets.[117] In order to treat human capital as an asset it has to belong to either one of these categories. At the same time, acquiring different skills demands inputs (as well as even raising children). And if producing of output resulting in this case in asset accumulation (or capital formation) requires inputs, there seems to be a process in transforming inputs to output. Thus, Aulin-Ahmavaara reasons that "If human capital is wanted to be seen as an asset, it has to be produced." But production of human capital falls outside the production boundary of the SNA. According to her, "leaving human capital outside the asset boundary of the System of National Accounts is a logical consequence of its definition of production".[118]

This can be seen, e.g. in paragraph 6.15 of the currently applied SNA93 in which economic production is defined as an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital and goods and services to produce outputs of goods and services. Processes that produce goods can be identified without difficulty according to the SNA93 in paragraph 6.16, but the distinction between the production of services and other activities is not always easy, as mentioned in the same paragraph. Activities that are not considered productive in an economic sense include basic human activities such as eating, drinking, sleeping, taking (physical) exercise, etc. that are impossible for one person to obtain another person to perform instead. Paying someone else to take exercise is no way to keep fit. This means that production of human capital through participating in education cannot be included in production delimited by the SNA93 although paragraph 6.16 does not mention this special case. On the other hand, activities such as washing, preparing meals, caring for children, the sick or aged are all activities that can be

---

[116] See, for instance, Kuznets, Simon (1946). *National Income: A Summary of Findings*, New York: National Bureau of Economic Research, p. 20; Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset.* Session Paper Number 1, Session 6A, 27th General Conference of the International Association for Research in Income and Wealth, Stockholm, Sweden August 18–24, 2002, p. 3.

[117] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 3. Aulin-Ahmavaara was originally describing the system of production of the SNA93, however, the reasoning here does not change in the SNA2008. Concerning the system of production the biggest change in the SNA2008 is that research and development expenses will be subtracted from intermediate uses and treated as investments.

[118] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, pp. 3, 14–15.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

provided by other units, and, therefore, fall within the general production boundary according to paragraph 6.16. [119]

Nevertheless, as Aulin-Ahmavaara states, economists have often requested that National Accounts would cover the recording of human capital and include it in the GDP calculations. They see that some present expenditure linked to human beings yields returns over the future.[120] Also, in modern economic growth theories the role of human capital has been approved over the last decades. The National Accounts are constantly criticised for not incorporating all the important factors for modern economic growth. This cannot be simply ignored since, for instance, in the SNA93 it is argued that "The design and structure of the System relies heavily on economic theory and principles as well as business accounting practises. ... When business accounting practices conflict with economic principles, priority is given to the latter, as the System is designed primarily for purposes of economic analysis and policy making."[121]

To conclude, according to Aulin-Ahmavaara "… if investment in human capital is to be included in the GDP, it has to be produced."[122] "…And whenever human capital and its services are treated as outputs of a production system, it naturally has to be done within the framework of a coherent, explicit or implicit, description of that system." [123] Next, the implicit system of production of the original SNA is discussed in accordance with Aulin-Ahmavaara's representation in 2002. Later the system of production in this study is introduced with regard to this representation.

According to Aulin-Ahmavaara, the description of the production system of the System of National Accounts is internally consistent at the national level. It satisfies the following simplified equations (the equations are simplified in the sense that taxes and subsidies are ignored and that a simple geometric rate of depreciation is assumed):[124]

[119] SNA93, (1993). The Inter-Secretariat Working Group on National Accounts, *System of National Accounts* (paragraphs 6.15, 6.16).
[120] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 3.
[121] SNA93 (1993). The Inter-Secretariat Working Group on National Accounts, *System of National Accounts* (paragraph 1.59).
[122] Ibid, p. 2.
[123] Ibid, p. 4.
[124] Ibid, p. 6; Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, Helsinki:Tilastokeskus, 2003, pp. 13–14.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$$O + M = U + C + I + E \quad (3.1)$$
$$GDP = O - U = C + I + E - M \quad (3.2)$$

$$O = U + W + R \quad (3.3)$$
$$GDP = O - U = W + R \quad (3.4)$$

$$\frac{dK}{dt} = I_t - \delta K_t \quad (3.5)$$

$$L = \overline{L} \quad (3.6)$$

Where

O = gross output	W = labour compensation
M = imports	R = operating surplus (or mixed income)
U = intermediate uses / intermediate inputs	δ = rate of depreciation
C = final consumption	K = capital stock
I = gross capital formation	L = labour input
E = exports	

NB: Goods and services used for own gross fixed capital formation and change in inventories are included in the output. The gross capital formation contains change in inventories and own capital formation as well.

In the system of production of the SNA, the first equation (3.1) defines the supply and demand in the economy in a time unit: Output (O) is the value of produced goods and services at home, including goods and services used for own fixed capital formation and changes in inventories (for unfinished, or finished but not yet sold, goods and services). Imports (M) include the value of goods and services imported to the country. The use or demand of these products is on the right hand side of the first equation (3.1): Part of these products has been reused as intermediate inputs (U) or as in formation of gross fixed capital (I_K) which also includes changes in inventories and own fixed capital formation. A good part of them is used as final consumption (C, including here both private and general government final consumption) or exported (E). As already mentioned, changes in inventories and goods and services used for own gross fixed capital formation are included in the output. Aulin-Ahmavaara notes that this means that goods and services that are used outside the time unit during which they are produced are also included in the output.[125] All the variables are expressed in monetary terms, often in fixed prices, where the price changes have been

[125] Ibid, p. 6.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

deflated. The second equation (3.2) shows how GDP (or value added) can be calculated through output minus intermediate inputs or through net-demand, i.e. C + I + (E-M).

The third equation (3.3) emphasises that the value of output can also be calculated through incomes generated in the production process, namely through intermediate inputs plus the compensations for labour (W) and capital (R, operating surplus of the producers). As a consequence, in the fourth equation (3.4) the same GDP can be calculated by the incomes generated in the production process as the sum of compensation for labour and for capital. The original fifth equation (3.5a) describes the accumulation of gross fixed capital: investments in (fixed) capital increase the accumulated stock and the depreciation decrease the value of the stock. The labour input (equation 3.6) is treated as an exogenous variable as households decide whether they are available in the labour market and how much they are willing to work.

3.2 About previous research on human capital in the National Accounts framework

Two main well-known approaches of estimating human capital stocks and flows for a nation's economy in the context of national accounting are the retrospective (or resource-cost) method and the prospective (or present value of lifetime incomes) method. The first is usually related to the work of John Kendrick in the late 1970s (see also the work of Abramowitz and David in 1996).[126] The latter is most often associated with the thorough work of Jorgenson and Fraumeni (J-F) in the late 1980s and early 1990s (or with the work of Graham and Webb in the late 1970s).[127] The methods of Kendrick and Jorgenson and Fraumeni (J-F) are referred to in this study as the two best-known measurement methods for human capital in the National

[126] Kendrick, John W. (1976). *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York; Abramovitz, M. and David, P. A. (1996). Technological Change and the Rise of Intangible Investments: The U.S. Economy's Growth-path in the Twentieth Century. *Employment and Growth in the Knowledge-based Economy*. OECD, Paris, pp. 35–50.
[127] Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*, Studies in Income and Wealth, Vol. 52, Chicago, IL, University of Chicago Press; Jorgenson, Dale W., Fraumeni, Barbara M. (1992a). The Output of Education Sector. *Output Measurement in the Service Sector*, in Z. Griliches,(Ed.) Studies in Income and Wealth, Vol. 55, Chicago, IL, University of Chicago Press; Jorgenson, Dale W., Fraumeni, Barbara M. (1992b). Investment in Education and U.S. Economic Growth, *Scandinavian Journal of Economics*, 94. Supplement, pp. 51–70; Graham, J. W., and Webb, R. H. (1979). Stock and Depreciation of Human Capital: New Evidence from a Present-Value Perspective. *The Review of Income and Wealth*, Series 25, June, pp. 209–224.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Accounts. In the early 2000s, Pirkko Aulin-Ahmavaara made an important contribution by bringing these approaches comparably together with a representation of the implicit system of production of the SNA.[128] Aulin-Ahmavaara analysed the underlying production systems of these methods in relation to the production system of the SNA93. She has also proposed a dynamic input-output representation of a complete production system that includes the production of human capital and human time (services of human capital).[129] My aim in this study is to form long time series on intangible human capital by schooling based on paid monetary flows on education. This would give the possibility to compare the estimate for human capital from the National Accounts frame with the conventional proxy variables based on school attainment. The overwhelming majority of empirical research has used variables of the latter type without receiving an unequivocal agreement on the role of human capital by schooling on growth.

Aulin-Ahmavaara's work is followed in this study to discuss the production system of the System of National Accounts (Section 3.1) and for comparing the implicit systems of production of the two best-known proposed systems in the National Accounts framework, where human capital is included (Sections 3.2.1 and 3.2.2). The input-output model for the complete production system with human capital and its services by Aulin-Ahmavaara will be reviewed in Section 3.2.3. Also, the underlying production system for intangible human capital by schooling in the empirical application in this work is later introduced by following Aulin-Ahmavaara's representation of the system of production. In addition to those mentioned, a "short-cut" procedure for estimating human capital stock proposed by Harry Postner will be discussed (Section 3.2.3) using the same notation as in the systems above.

The differences in the evolution of the two best-known National Accounts measures and the conventional school attainment measures for human capital will be delineated for the U.S., in the case of Kendrick in 1930–1970, and in the case of Jorgenson and Fraumeni in 1950–1986 when discussing each method. However, both of these two renowned National

[128] Aulin-Ahmavaara, Pirkko (2002): *Human Capital as a Produced Asset*. Session Paper Number 1, Session 6A, 27th General Conference of the International Association for Research in Income and Wealth, Stockholm, Sweden, August 18–24; Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, Helsinki:Tilastokeskus, 2003; Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, series 50, number 2, pp. 213–228.

[129] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced* Asset; also in, e.g. Aulin-Ahmavaara, Pirkko (1987). *A Dynamic Input-Output Model with Non-Homogenous Labour for Evaluation of Technical Change*. Finnish Academy of Science and Letters. Helsinki; Aulin-Ahmavaara, Pirkko (1990). Dynamic Input-Output and Time. *Economic Systems Research*, 2, pp. 239–34; Aulin-Ahmavaara, Pirkko (1991). Production Prices of Human Capital and Human Time. *Economic Systems Research*, 3, 345–65.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Accounts systems have broadened the National Accounts far beyond the standard GDP and their estimates on human capital are only comparable with the new GDPs in their systems.

Later, the estimate in this study for intangible human capital by schooling in the National Accounts will be compared with the conventional school attainment measures and with the standard GDP in Finland in 1935–2000. This forms a strictly fair comparison since both the National Accounts estimate and the school attainment variables are measuring human capital by schooling, and both can be used to study the role of human capital in the standard long-run GDP growth.

3.2.1 A retrospective approach – human capital as accumulated costs

In his seminal and thorough approach, John Kendrick separates tangible and intangible human capital. In Kendrick's total system, investment in intangible human capital includes investments in education and training, and also investments in health, mobility and R&D.[130] Here the focus is on Kendrick's estimates on tangible and intangible human capital by education and training. Investment in tangible human capital is equal to the rearing cost of children up to the age of 14, including the full value of their consumption. Investment in intangible human capital by education and training includes the costs of schools and the foregone earnings of students 14 years and over.[131] Including the foregone earnings changed GDP substantially in Kendrick's system, since it has not been an actual monetary flow and is not included in GDP in the international standard of National Accounts (SNA93)[132].

Aulin-Ahmavaara's interpretation of the underlying production system of John Kendrick's resource-cost approach is presented with her simplified equations as follows: [133]

[130] Kendrick (1976). *The Formation and Stocks of Total Capital.*
[131] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 6.
[132] SNA93 (1993). The Inter-Secretariat Working Group on National Accounts, *System of National Accounts*, Commission of the European Communities-Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington D.C.
[133] Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, Helsinki:Tilastokeskus, p. 14; Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 6–8.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The new equation of 3.1:

O + produced human capital + M
= U + consumption of children less than 14 years + cost of schooling
+ C − consumption of children less than 14 years - cost of schooling
+ I + produced human capital
+ E

The new equation of 3.3:

O + produced human capital
= U + consumption of children less than 14 years
+ cost of schooling
+W
+ foregone earnings of students
+ R

The new *GDP = GDP + foregone earnings of students*

where

Produced human capital
= consumption of children less than 14 years
+ cost of schooling
+ foregone earnings of students

NB: labour input (or number of hours worked) is the services of human capital

Kendrick reclassifies the cost of schooling and also the cost of rearing children as investments after subtracting them from final consumption expenditure. According to Aulin-Ahmavaara, in her representation "… in fact ... in equation (1) (NB: here 3.1) these costs are first deducted from final consumption and added to intermediate inputs. These intermediate inputs are used in the production of human capital. The value of this human capital is added to output and to investment in equation (1) (NB: here 3.1)." In the third equation, 3.3, "... the value of the produced human capital is added to output and the value of intermediate inputs to intermediate inputs. Since in this case the value of human capital is equal to the value of intermediate inputs used to produce it the GDP remains unchanged."[134]

The foregone earnings of students are added to output in the first two equations 3.1, 3.2 and to investment in both equations 3.1, 3.2 and in the fifth equation 3.5. In the third equation 3.3 (and fourth 3.4) they are added to output and labour compensation. Thus GDP is

[134] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 7.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

adjusted with foregone earnings of students (GDP = O − U = W + R = C + I + E − M has changed with the amount of foregone earnings of students, added in O, W and I). Hence, Kendrick has broadened the scope of standard accounts by imputing a value for the foregone earnings of students. The number of hours spent in formal schooling is added to the labour input in the sixth equation 3.6, consistently with taking the foregone earnings in to the analysis.

Thereby, in Aulin-Ahmavaara's reasoning: "… investment in both tangible and intangible human capital are part of the adjusted GDP and can be interpreted to be outputs of production processes, with explicitly defined inputs."[135]

In Kendrick's system the labour input (or hours worked) is considered as services of human capital. Unskilled labour corresponds with the services of tangible human capital and skilled labour with services of intangible human capital. According to Kendrick, the possible inputs (or maintenance costs) for the services of human capital in the final consumption, such as costs of eating and drinking, etc. do not have to be deducted from consumption for this purpose, because the same activities afford satisfaction and contribute to the welfare of human beings as consumers. On the other hand, Aulin-Ahmavaara criticises this by questioning whether the consumption of children less than 14 years old, used in the system for the production of tangible human capital, did then not afford satisfaction. In her point of view, the welfare criterion may be inaccurate when deciding whether consumption expenditures should be treated as intermediate inputs in the production of human capital and its services or as final consumption.[136] In her dynamic input-output model, she has gone all the way in treating all the consumption of the labour force as inputs for the services of human capital, and has also deducted it from labour compensation. This inevitably shows that common agreement has not been achieved in deciding what all should be separated from final consumption.

In the end, when calculating the rates of return on capital Kendrick deducts the maintenance costs of human capital based on minimum budget estimates for families of various sizes. In Aulin-Ahmavaara's view, this means that the maintenance costs should be treated as intermediate inputs in the production of the services of human capital.[137] Aulin-Ahmavaara's argument is based on the strictly similar treatment of both fixed and human capital services. On the other hand, the argument on Kendrick's welfare criterion may also

---

[135] Ibid, p. 7.

[136] Ibid, p. 7; Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, p. 14; Kendrick (1976). *The Formation and Stocks of Total Capital*.

[137] Ibid, p. 7–8; Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, p. 14; Kendrick (1976). *The Formation and Stocks of Total Capital*.

have its logic in the basic system. At the same time as the standard SNA excludes human capital, hours worked is already included in the system, but the costs for maintenance of man's ability to work are not separated from final consumption. If following Kendrick's argument on the welfare criterion, however, then the consumption of children less than 14 years old should not have either been deducted from final consumption.

Aulin-Ahmavaara obviously emphasises the production of human capital services as well with a strict reference to fixed capital services. However, Kendrick may have begun his reasoning from hours worked, which are already included in the system, but which education and training are not affecting in the standard system as they are in reality. Later in the empirical application in this dissertation, for me the biggest question is how to get the education services used by the cohorts of students connected to hours worked in a system with reference to standard GDP. As is obvious from the Introduction in this study, some modern growth theories have in fact suggested that intangible human capital by education in the labour force is enhancing the hours worked of the educated individuals.[138]

Aulin-Ahmavaara also bases her critique on the fact that the rate of return to human capital becomes substantially higher on the aggregate economy level than that to fixed capital in the system of Kendrick.[139] This is of course a valid point if the capitals are assumed to yield the same returns as in the neoclassical growth theory with perfect competition, and if separate calculations for the rates of return are not allowed in line with Kendrick. However, the assumptions of perfect competition and enterprises as price takers also have to be relaxed in the growth accounting exercises along with the SNA2008, in which the research and development (R&D) expenses are capitalised. The decision for capitalising R&D in the SNA has a connection to the new growth theories referred to in the Introduction of this study. In accordance with this change in the SNA and in the theory, the assumption of equal rates of return on both types of capital, at least always and in every occasion, have to be released in

[138] Aulin-Ahmavaara argues that labour is a primary input in the SNA. According to her, in her input-output model, when human capital and also its services are treated as outputs of production processes, there is no longer any primary input of labour to be compensated. (Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, p. 224). But what if labour input is considered as services of human capital, and labour input would be weighed by the education in the labour force in line with the work of, e.g. Jorgenson and Griliches (1967). However, in my reasoning, the weighting should be done by taking into account the volume of the inputs each cohort of students has used in their education. If accomplishing this analysis requires a small change to the SNA's definition of production, and an exception for not necessarily treating the services of human capital as produced in a strictly same way as with fixed capital, these modifications should be done. In the real world, education services have enhanced the skills of the educated labour, and this has its effects on hours worked. This is not reflected in the hours worked of the SNA although it obviously should, as National Accounts is supposed to represent the real world. Also, Aulin-Ahmavaara herself suggested a radical change to the definition of production in the SNA.

[139] Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, pp. 221–222.

the derived analyses. When investments in R&D on successful projects by an enterprise have led to important technological innovations, the monopoly power for the years under the patent protection must have yielded a much higher rate of return on these investments compared with other fixed capital. In this case, the human capital of the employees engaged in these R&D projects will probably be proven to have yielded a much higher rate of return compared with traditional fixed capital in the same time. The gained monopoly power by successful R&D projects is emphasised in the modern growth theory as an important incentive for investments in R&D and, at least implicitly, for human capital.

Another question is the difference between private rate of return and social rate of return. The first one is the one usually calculated for fixed capital, but in the case of human capital the latter has also been emphasised and it is again connected with imperfect competition. What if the private rate of return to human capital would be seen to be calculated, for instance, as Aulin-Ahmavaara argues, but in the calculations for the social rate of return the focus would be on the more direct expenses of education for the society (or together with direct health, social, etc. expenditures,)? Children have been brought up and nourished without regard to whether they have had a chance to participate in education, for instance, in the early 20th century Finland. Also, when comparing with earlier developed accounting systems, one soon notices that opportunity costs in general are not taken into account in the calculations in those parts of, e.g. business accounting in which the bookings are to a great extent based on paid transactions.

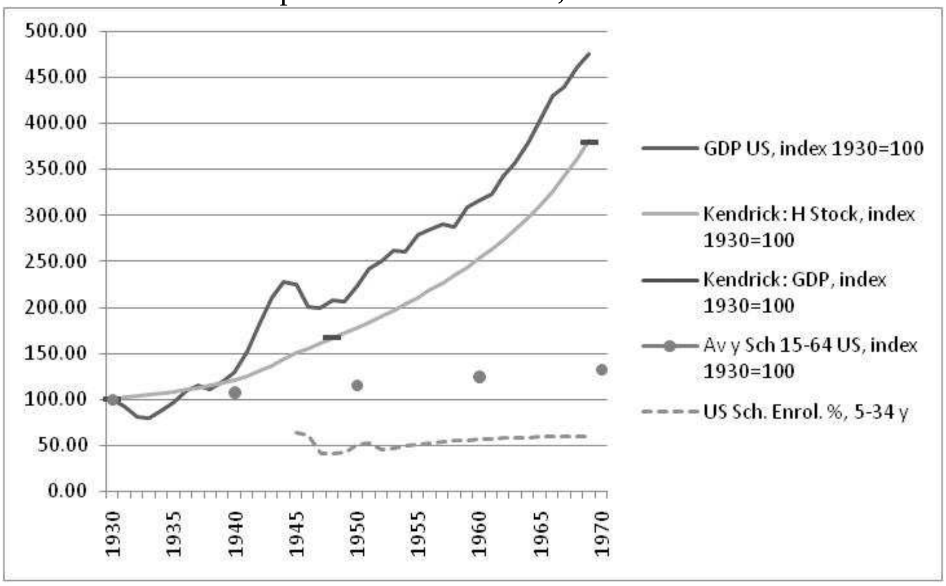
In fact, the accounting systems for enterprises and other communities are divided to external accounting (or accountancy) and to internal (or managerial) accounting. External accounting is done for providing information on the financial situation to groups of interest outside the community/enterprise (for tax authorities, share holders, etc.), and it is supposed to be as transparent, unambiguous and as instantly recognisable as possible. The external accounting consists typically of the profit and loss account, financial account and balance sheet. Similarly, the basic information content in the core accounts of the SNA includes the production and income accounts, the institutional sector accounts, the financial accounts and balance sheets, and has obviously a direct analogy with the external accounting based on paid transactions. The direct linkage in the SNA to the structure in the earlier developed accounting systems cannot be a coincidence.

In the accounting systems for communities/enterprises, the purpose of the internal accounts part is to provide information to the managers, e.g. for making decisions. In this part, the rates of return on investments, with different assumptions on returns in future, are also

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

calculated. I am arguing that the similar division should be spelled out when considering taking human capital into account in the calculations in the National Accounts. With this division in mind, the analysis on human capital by education and its effects on hours worked could be conducted in the basic form, based on paid monetary transactions, in the core accounts of the SNA. Other analysis including the foregone earnings of students, lifetime labour incomes including forecasts for the rest of the lifetime, dynamic input-output analysis based on human time, and the calculations, e.g. of the rate of return possibly strictly comparably with fixed capital would be done in the satellite accounts. If this division in the accounts is not spelled out, the information on the advantages for the society on educating people with reference to standard GDP cannot be provided at all in the core accounts of the SNA, i.e. in the most analysed accounts by the interest groups.

Figure 3.1 The United States 1930–1970: Real GDP (chained 1996 billions of dollars), Kendrick's human capital stock by education and training, Kendrick's estimate for 'new' real GDP 1930 (1929), 1948, 1969, average years of schooling in the working age population (15–64), school enrolment % at the ages 5–34, NB: all variables except school enrolment ratio are expressed in index form, 1930=100.



Sources: Carter, Susan B., Sigmund G. Scott, Michael R. Haines, Alan L. Olmstead, Richard Sutch, Gavin Wright (Eds.) (2006). *The Historical Statistics of the United States*. New York: Cambridge University Press, 2006; real GDP for the U.S., school enrolment rate at the ages of 5–34; Kendrick, John W. (1976). *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York, Kendrick's stock of H by education and training; Godo, Yoshihisa and Hayami, Yujiro (1999). Accumulation of Education in Modern Economic Growth; Comparison of Japan with the United States, *ADBI Working Paper No. 4*, Tokyo: Asian Development Bank Institute; average years of schooling in the working age population for the U.S.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

In accordance with his system, Kendrick made empirical calculations for the U.S. for the years 1929–1969. This included a massive data gathering and compiling process, and finally the building up of a modified National Accounts system. With all the vast amount of work done, one may wonder whether Kendrick's estimate on human capital differs from the conventional school attainment proxies for human capital.

To observe this, Figure 3.1 delineates the evolution of average years of schooling (15–64 year-old population), school enrolment ratio (at the ages 5–34) and real GDP in the U.S. in 1930–1969. In addition, the figure gives Kendrick's estimates for the stock of human capital by education and training through accumulated costs, and his new estimate for GDP in the U.S. (in 1930 (1929), 1948, 1969), as he has imputed foregone earnings of students as being part of investments in education, which are included in the new GDP. The foregone earnings of students formed a major part of investments in education and training and changed the level of GDP dramatically. The time frame in the figure comes from the calculation period of Kendrick. The figure shows inevitably that the proxy variables for schooling exhibit linear growth at the same time as GDP (with or without Kendrick's adjustments) and Kendrick's estimate for the stock of education and training through accumulated inputs grow exponentially. In addition to Kendrick's own work, Hak Pyo and Sooil Jin (in 2000) and Bas van Leeuwen (in 2007) have used this approach, the first ones estimating the stocks of human capital for Japan and Korea[140] and the latter one for India, Indonesia and Japan[141]. Their estimates for human capital indicate an exponential evolution as Kendrick's estimate for the U.S.

[140] Pyo, Hak. K., Sooil Jin, (2000). A Comparative Profile of Human Capital: US, Japan and Korea. In I. Hwang and K. Odaka (Eds), *The Long-Term Economic Statistics of Korea 1910-1990*, Institute of Economic Research. Hitotshubashi University, 2000, pp. 289–311.

[141] Leeuwen, Bas van (2007), *Human Capital and Economic Growth in India, Indonesia, and Japan. A quantitative analysis, 1890–2000*, ISBN: 978 90 8891 003 6. Doctoral dissertation, Utrecht University: Utrecht. http://www.basvanleeuwen.net/Papers.htm (2011-03-30).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.2.2 A prospective approach – human capital as lifetime labour incomes at present value

In the perhaps most referred prospective approach nowadays, Dale Jorgenson and Barbara Fraumeni begin their analysis stating that the concept of human capital is based on an analogy between investment in physical capital and investment in human beings. The common element is that present expenditures yield returns over the future. They define in their system the investment in human capital (tangible and intangible) as the present value of lifetime labour incomes for all individuals in the U.S. population. In order to accomplish calculations based on this definition and taking into account lifetime labour income in nonmarket activities of the individuals, they suggest a new system of National Accounts for the U.S. private sector economy in their paper in 1989.[142] Since human capital is inversely derived by labour income, this approach assumes that labour compensation equals in every occasion exactly marginal product of labour, and therefore the approach is based on the neo-classical theory with perfect competition in product and production factor markets.

In this system, the scope is much broader than in the standard accounts. Nonmarket activities, such as household work and leisure and consumption of nonmarket services are brought into the analysis. The value of time spent in household work is imputed, by using the market wages in the occupation of these services as an opportunity cost, and included in the labour income. Free time is also valued by the market wages. The imputed labour compensation for a year of time spent in schooling is equal to the difference between the lifetime labour incomes of an individual having completed the number of years of education with the year under consideration included, and an individual with one year less in education with the same sex and age. Following this procedure, the value of the time spent in formal schooling can be calculated for all individuals enrolled in education, and it is included in the total labour income. Because the analysis is based on the lifetime labour income, the incomes for the years of the rest of the lifetime are forecast and discounted back to the present year.

The total product in their system includes investment in human and nonhuman capital and consumption of market and nonmarket goods and services. Full investment is defined as the sum of investments in human and nonhuman capital, and full consumption as the sum of human and nonhuman investments. Full product is then the sum of investment and

[142] Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

consumption. The relative importance of investment turns out to be around 50% of full product, a share much greater than in the standard National Accounts.[143]

The value of outlays on the services of human plus nonhuman capital gives the value of full product. The outlays mentioned take the form of labour and property compensation. Jorgenson and Fraumeni define full labour compensation as the sum of market labour compensation for activities in the labour market and of nonmarket labour compensation for activities resulting in investment in education and direct consumption of labour services outside the labour market. In a similar manner, full property compensation is the sum of market and nonmarket property compensation. Full factor outlay is defined as the sum of labour and property compensation.[144]

The imputed nonmarket labour compensation forms more than 80% of labour compensation in this system. Full labour compensation includes the value of nonmarket activities, including investments in education, household production and leisure time. Because of this, in the system of Jorgenson and Fraumeni, full labour compensation is 90% of factor outlay (property compensation 10%, respectively), and the relative importance of labour compensation is obviously higher than in standard accounts.

In incomes accruing to individuals the taxes reducing and subsidies increasing incomes are taken into account. Therefore, full income is defined as the sum of labour compensation after taxes (i.e. labour income) and property compensation after taxes (i.e. property income). According to the authors, ... “Property income in constant prices corresponds to the services of nonhuman capital, and labour income corresponds to the services of human capital”.[145]

The authors also calculate estimates on wealth of the private national sector of the U.S. economy in 1949–1984 as the sum of nonhuman wealth and human wealth. The change in wealth in a year is defined as the sum of investment in human and nonhuman capital (net of depreciation and revaluation of the capitals). The share of human wealth has ranged between 0.94 and 0.92 and therefore has formed definitely the most important part in total wealth in this system.[146]

The beginning point for the measurement of lifetime labour incomes for all individuals in their analysis has been to obtain average hourly labour compensation annually for individuals classified by sex, sixty-one age groups (ages 14–74) and eighteen education

[143] Ibid, p. 274.
[144] Ibid, p. 274.
[145] Ibid, pp. 275, 303.
[146] Ibid, pp. 276, 318.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

groups (educational attainment from no education to 1 to 17 or higher). According to the authors, the second step was to impute labour compensation and hours devoted to nonmarket activities. The time available for all market and nonmarket activities by an individual is assumed to equal fourteen hours per day. The time spent in satisfying physical needs is classified as maintenance and is excluded from time spent in nonmarket activities. By using the information of the studies of time allocation, Jorgenson and Fraumeni have allocated the annual time available for all individuals among work, schooling, household production and leisure, and maintenance.[147]

The third step, as stated by the authors, was to impute the value of labour compensation for nonmarket activities. For estimating lifetime labour incomes for all individuals in the population, Jorgenson and Fraumeni divide the life cycle into three stages. In the first stage, individuals participate in formal schooling, in the second stage individuals may enrol in school and also in work, and in the third stage they may only participate in the labour market. For individuals in the first stage of the life cycle the imputed value for the time spent in schooling forms the labour compensation. In the second stage, individuals are compensated for their possible labour input in the labour market or for the time spent in schooling. In the third stage, total labour compensation for individuals is the sum of compensation for market labour activities (after taxes) and for nonmarket labour activities (household work and leisure).

For an individual in the third stage the expected incomes in future periods are forecast. This is done, firstly, by assuming that the expected incomes are equal to the incomes of an older age individual with the same sex and education. Secondly, the future real incomes are assumed to increase at the estimated rate of Harrod-neutral technical change, at the rate of 2% per year. The income for each future year is weighed by the probability of survival by sex. Ultimately, the present value of future income is achieved by discounting them at a real rate of return, using an estimate of 4% per year.[148]

In calculations for the rest of the lifetime labour income for the individuals in the second stage, the authors impute the value of time spent in schooling through its effect on lifetime labour income. For instance, for the person who is completing the highest level of schooling, 17 or higher, lifetime labour income is the discounted value of expected future labour incomes for a person of that sex and age and seventeen or more years of schooling. The imputed labour compensation for the time spent in schooling is equal to the difference

[147] Ibid, pp. 277, 278.
[148] Ibid, p. 279.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

between the lifetime labour incomes of an individual with seventeen or more years of education and an individual with the same sex and age and one less year of education (less tuition and fees for that grade). In a similar manner, the imputed labour compensation for the time spent in schooling for individuals in lower grades can be achieved. In this third stage of the life cycle, the value of time spent in schooling plus labour compensation for market and nonmarket activities forms the total labour compensation. When participation in the labour market is ruled out, i.e. in the first stage of the life cycle, the value of labour compensation is formed only by the imputed value of schooling. For those too young to be at school, imputed labour compensation is zero, but according to Jorgenson and Fraumeni, lifetime labour incomes are well defined. For instance, the value of a newborn baby is equal to the lifetime labour income at age zero.[149]

In their 1989 paper Jorgenson and Fraumeni define investment in human capital in a year as the sum of lifetime incomes for all individuals born in that year and all immigrants plus the imputed labour compensation for all individuals enrolled in school. The authors define depreciation of human capital as the sum of changes in lifetime labour incomes with age for all individuals remaining in the population and lifetime labour incomes of all individuals who die or emigrate. Revaluation for human capital is defined in terms of changes in lifetime labour incomes for individuals in the same group of age, sex and education.[150]

Next, Aulin-Ahmavaara's interpretation of the implicit system of production in Jorgenson and Fraumeni's approach is presented in accordance with her representation of the production system in the SNA (cf. Section 3.1).[151] In this system the value of a newborn entrant into the population is equal to the lifetime labour income of that individual at age zero. Investment in human capital in any year is the sum of lifetime incomes of individuals born that year and all immigrants plus the imputed labour compensation for formal schooling for those enrolled.

In Aulin-Ahmavaara's interpretation, human capital is (and must be) produced and therefore she first defines the produced human capital in a year in accordance with investment in human capital. Secondly, she clarifies the services of human capital. And finally, before proceeding to her interpretation on the underlying system of production, she defines the value of market work and of schooling time.

[149] Ibid, p. 280.
[150] Ibid, pp.276, 280.
[151] Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, Helsinki:Tilastokeskus, p. 15; Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 8–11.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Produced human capital
= lifetime incomes of individuals born that year + lifetime incomes of immigrants
+ impact of schooling on lifetime labour income

Produced human capital services =
market work + household work + free time + schooling time

The value of market work = labour compensation for market work
The value of schooling time = the impact of schooling in lifetime labour incomes

The new equation of 3.1:

O + produced human capital + produced human capital services +M
= U + incomes from market work + time spent in schooling + 8 hours/day sleep
+ C + imputed incomes from household work + rest of free time hours
+ I + produced human capital
+ E

The new equation of 3.3:

O + produced human capital + produced human capital services
= U + incomes from market work + time spent in schooling + 8 hours/day sleep
+W − incomes from market work
+ produced human capital services - 8 hours/day sleep
+ lifetime labour incomes of babies born that year
+ lifetime labour incomes of immigrants
+ R

The new *GDP*
= GDP + produced human capital + imputed incomes from household work
+ imputed incomes from the rest of free time hours

= GDP + schooling time + imputed incomes from the household work
+ imputed incomes from the rest of free time hours
+ lifetime income of babies born that year + lifetime income of immigrants

Investment in human capital, valued by the lifetime labour income of both market and nonmarket activities for newborn babies and immigrants and by the impact of schooling on lifetime labour income, is added to investments in equation 3.1, and since Aulin-Ahmavaara sees it must have been produced, to output in equations 3.1 and 3.3. Time spent in schooling (valued by the impact of schooling on lifetime income) is used as an input in the production of human capital, and is hence added to intermediate inputs in 3.1 and 3.3. Lifetime labour income of the newborn babies and immigrants are added to the labour compensation in 3.3 as well.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

In equation 3.1 the standard final consumption is marked with C, here the consumption of nonmarket goods and services are added to it. They are valued by the imputed labour compensation for household work and for the rest of the free time hours.

According to Aulin-Ahmavaara, human capital produces services in this system 16 hours per every day. These services are used in market work, household work, in free time and in the production of intangible human capital. The services of human capital are compensated for in the compensation for labour (attached with *W* in 3.3), however by subtracting the eight hours' sleeping time per day. These eight hours of sleeping time per day are seen as an input for human capital services and are adjoined in intermediate inputs with U in 3.1. Part of the human capital services are used in consumption of nonmarket good and services in the form of household work and free time in 3.1, as already noted. The labour income in the system is based on the service activities of human capital as spelled out by Jorgenson and Fraumeni "labour income corresponds to the services of human capital".[152]

Aulin-Ahmavaara does not explicitly give a reason in her representation for moving the original compensation for market work, denoted by *W* above, from labour compensations to intermediate uses in her representation of the system. My interpretation to this is that when market work (valued by the compensation for it) is included in the produced human capital services, according to Aulin-Ahmavaara's reasoning, it has to be produced and hence it is moved to intermediate inputs. The same amount is included in the produced human capital services in the output (and in the labour compensation).

It is obvious from Aulin-Ahmavaara's interpretation as well that the system of Jorgenson and Fraumeni is comprehensive: they calculate both the formed human capital and the services of human capital. One of the ways to rationalise the system by the authors is that both the investments in and the services of human capital are comparable to those of nonhuman capital. The services of human capital (or human beings) are used in all the activities of the individuals, in market work, in household work, in free time (except for sleeping) and at school in producing human capital. The other side of the coin is that the system involves quite sizable imputations for the value of nonmarket activities including forecasts on the rest of the lifetime labour incomes, both from market and nonmarket activities. Also, as Aulin-Ahmavaara notes, even the babies born in that year have a positive value of human capital.

[152] Ibid, pp. 275, 303.

In Aulin-Ahmavaara's[153] analysis of this system, the profound work is appreciated. Because she has obviously had in mind a precisely similar treatment of human capital and its services as in the case of fixed capital, she criticises the J-F system with the following points: First, in the production system underlying the Jorgenson and Fraumeni[154] accounts some of the outputs appear to be created without any inputs (the human capital of newborn babies and immigrants). Second, the system is also very sensitive to assumptions made in the calculations. Third, the time spent satisfying physical needs is assumed to be used as maintenance input, but it is never considered that some other goods or services, e.g. food, might also be needed to satisfy physical needs. From the point of view of Aulin-Ahmavaara the possibility that leisure and household work might actually be indispensable to the individuals' ability to participate in market labour activities and education is neither considered. According to Aulin-Ahmavaara, the value of goods and services used as maintenance input should be deducted from GDP, as she stresses again the calculations of rate of return between the different capitals as a consistency check. In my point of view, Jorgenson and Fraumeni may have begun their analysis by thinking of the shortcomings of the National Accounts in reflecting the reality in this matter: By associating all of the lifetime labour incomes with labour input by individuals, the value of human capital can be estimated. However, as in the system proposed by Kendrick, in this system human capital and its services can only be compared with the new Output or with the new GDP from the revised system. At the same time most of the empirical studies have explored the role of human capital in the standard GDP production with the conventional school attainment variables.

Again, after such a substantial amount of work, as in Kendrick's calculations, one might wonder, whether there was a difference in the human capital estimate by J-F compared with the conventional school attainment measures. Figure 3.2 illustrates the evolution of standard GDP and the average years of schooling together with Jorgenson and Fraumeni's (1992a, 1992b) estimate for quality adjusted labour input and new output of the economy, in accordance with their lifetime labour income approach for estimating the impact of investment in education on growth.[155] In their calculations, they first estimated *educational*

---

[153] Ibid, p. 8–11.

[154] Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*.

[155] Jorgenson, Dale W., Fraumeni, Barbara M. (1992a). The Output of Education Sector. *Output Measurement in the Service Sector*, in Z. Griliches,(Ed.) Studies in Income and Wealth, Vol. 55, Chicago, IL, University of Chicago Press; Jorgenson, Dale W., Fraumeni, Barbara M. (1992b). Investment in Education and U.S. Economic Growth, *Scandinavian Journal of Economics*, 94. Supplement, pp. 51–70; See also Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

output as the impact of education on an individual's lifetime labour income including labour income in market and non-market activities (time spent outside the labour market, e.g. parenting and leisure time). Therefore *the output of the education sector is defined as a measure of investment in education*. Secondly, they measured the inputs of the education sector including the outlays of educational institutions as inputs and inputs in the form of time enrolled in formal education. In their analysis, a major part of the value of the output of educational institutions accrues to students in the form of increases in their lifetime labour incomes. By treating these increases as compensation for student time, they state that it is possible to evaluate this time as an input into the educational process. Given the outlays of the educational institutions and the value of student time, the growth of the education sector can be allocated to its sources.

Finally, they aggregated the output of the education and non-education sectors of the U.S. economy to obtain a new measure of the U.S. economic output for estimating the impact of investment in education on growth. The J-F output in Figure 3.2 refers to this new output. They calculated the capital input and the labour input, both in the non-educational sector[156] and the educational sectors[157], and aggregated them, to allocate the growth of this new output growth of the U.S. to its sources. The quality adjusted labour input in Figure 3.2 is the new labour input for the U.S. economy comparable with the new output including investments in education as they have defined. The human input in this new system evolves obviously exponentially as the 'old' and 'new' output while the typical school attainment proxy variables exhibit only a linear evolution.

The result in Jorgenson and Fraumeni's (J-F) (1992b) growth accounting for the sources of growth was that the average rate of productivity growth declined from 1% p.a. to 0.5% p.a. in 1948–1986 in the U.S. economy and its contribution to growth from 31% to 17%, respectively. Labour input now contributed 61% (before 29%) and capital input 22% (before

---

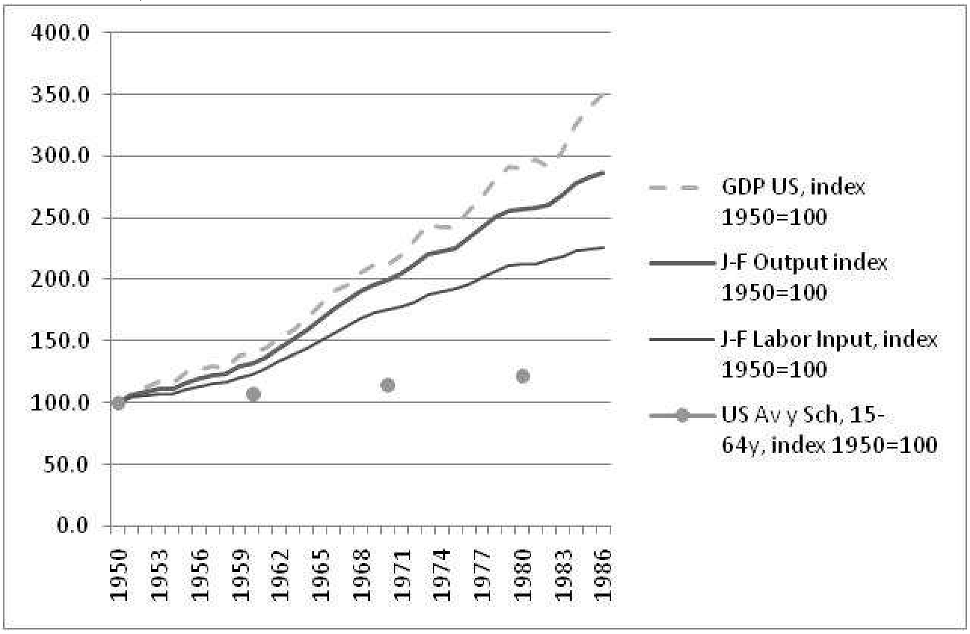
and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*, Studies in Income and Wealth, Vol. 52, Chicago, IL, University of Chicago Press.

[156] The capital input involves weighting components of capital input by rental price. Assets were cross-classified by age, class of the asset, and legal form of organisation. Different ages were weighted in accord with profiles of relative efficiency. For the non-education sector a total of 160 components of capital input were measured separately. Hours worked for each sex were cross-classified by individual year of age and individual year of education for a total of 2 196 different types of hours worked in estimating the contribution of labour input in the non-education sector. Each type of hours worked was weighted by the corresponding wage rate.

[157] In the education sector capital input is defined as educational buildings and equipment. Labour input incorporates the value of the time teachers and other employees of the educational system and student time. Intermediate goods include the purchases of educational institutions, and are included in final demand. The contributions of these inputs are obtained here as in the non-educational sector by weighting the growth rates by the corresponding share of the inputs in educational output.

40%) for growth. Therefore, the quality adjusted labour input accounted now considerably more than before and accounted for most of the growth. *Together capital input and labour input accounted now for almost all of the growth.* They concluded that the accumulation of human and non-human capital accounts for the predominant share of economic growth.

Figure 3.2 The United States 1950–1986: Real GDP (chained 1996 billions of dollars), Jorgenson-Fraumeni's new output, Jorgenson-Fraumeni's labour input, average years of schooling in the working age population (15–64), NB: all variables are expressed in index form, 1950=100.



Sources: Carter, Susan B., Sigmund G. Scott, Michael R. Haines, Alan L. Olmstead, Richard Sutch, Gavin Wright (Eds.) (2006). *The Historical Statistics of the United States*. New York: Cambridge University Press, 2006; real GDP for the U.S., school enrolment rate at the ages of 5–34; Jorgenson, Dale W., Fraumeni, Barbara M. (1992b). *Investment in Education and U.S. Economic Growth*, Scandinavian Journal of Economics, 94. Supplement, pp. 51–70, J-F Output, J-F Labour input; Godo, Yoshihisa and Hayami, Yujiro (1999). Accumulation of Education in Modern Economic Growth; Comparison of Japan with the United States, *ADBI Working Paper No. 4*, Tokyo: Asian Development Bank Institute; average years of schooling in the working age population for the U.S.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.2.3 A dynamic input-output model with a complete production of human capital and human time

Pirkko Aulin-Ahmavaara has criticised both Kendrick's and Jorgenson and Fraumeni's proposed measures for human capital because both studies do not take into account all of the goods and services in the standard final consumption needed as inputs in the production of human capital and human capital services.[158] Her main argument is that this may lead to a very high net (private) rate of return on human capital, whereas according to her, in a market economy the rates of return should be quite close to those of fixed capital. Aulin-Ahmavaara has herself introduced a dynamic input-output system, where the production of human capital and the services of human capital are treated precisely analogously to fixed capital. In her system, human capital and its services are strictly treated as produced as in the case of any other capital good.[159]

The production of human capital consists of both tangible and intangible human capital. In the production of the tangible part, all the goods and services consumed by people below active (or working) age are taken into account. In the production of intangible human capital, educational services, consumed by the individuals enrolling in schooling after basic education, are used as an input. Human time, or the services of human capital in the system, is produced by using goods and services consumed by the labour force. The difference to the best known systems introduced above is that both in the production of human capital and human capital services the goods and services consumed by individuals are used as an intermediate input. This system is an important contribution since it can be seen as giving the upper bound to the extent to which the analysis should be broadened and the SNA changed if sharing the goal of treating human capital precisely as fixed capital.

For being able to do this, Aulin-Ahmavaara has changed the whole definition for production. To begin with, Aulin-Ahmavaara has defined active human time as "...any use of time by individuals who have passed their basic education and have not become unable to

[158] See, e.g. Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*; Aulin-Ahmavaara, Pirkko (2004). Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, series 50, number 2, pp. 213–228.

[159] See also, e.g. Aulin-Ahmavaara, Pirkko (1987). *A Dynamic Input-Output Model with Non-Homogenous Labour for Evaluation of Technical Change*. Finnish Academy of Science and Letters. Helsinki; Aulin-Ahmavaara, Pirkko (1990). Dynamic Input-Output and Time. *Economic Systems Research*, 2, pp. 239–34; Aulin-Ahmavaara, Pirkko (1991). Production Prices of Human Capital and Human Time. *Economic Systems Research*, 3, pp. 345–65; Aulin-Ahmavaara, Pirkko (1997). Measuring the productivity of nations. In Simonovits, A. and Steenge A. E. (Eds.), *Prices, Growth and Cycles: Essays in Honour of AndrásBródy*, London, Macmillan.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

work”. The time of those incapable for work and children below working age in the production cannot be used outside the production unit, and hence the time of these is not treated as output. Instead, finished units of human capital (i.e. those graduated), or unfinished (those who are still continuing in schooling after basic education) can be used and are used outside the time unit during which they are produced and are part of the output.[160]

Then production can be defined “as direct or indirect utilisation of active human time to bring about something that can be used up or transformed into another form in a process using human time directly or indirectly.” According to the author this definition allows obviously for both human capital and human capital services (human time) to be produced.[161] The author admits that this definition of production is a radical change compared to that in the standard accounts. However, she argues for this definition by stating that “...in the end time is the only scarce resource of a human being”.[162]

Aulin-Ahmavaara also changes the definition of an establishment by treating every individual as a separate establishment, when human capital and human time is produced, as the basic producing unit is an establishment in the SNA. The author states that “... output consists of those products than can be delivered or provided outside the producing establishment or are used by the establishment itself outside the time unit during which they are produced” referring both to the SNA and to input-output model.[163] To simplify the production process of human capital, those products that are used to produce another unit of the same product are included, although they typically become available outside the establishment.

According to the author, “... Anything that has been produced can, at least in principle, be used as input in the production process. All the produced inputs can appear both in the form of flows and in the form of stocks.”Therefore the dynamic input-output model is a natural way to describe the general production process. In the model the flow coefficients, a_{ij}, are representing a quantity-flow of a material input used in the production process up to a year. Stocks of these inputs are also needed, either as such or tied up in the inventories of semi-finished or finished products and they are represented by the stock coefficients, b_{ij}.

[160] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 12.
[161] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 12.
[162] Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, series 50, number 2, p. 216.
[163] Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, p. 216.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Inputs in any kinds of services, human time included, can also be tied up in the inventories of semi-finished and finished products.[164]

Fixed assets are tied in the production process for more than a year, and their productive capacity will decrease. These losses in the productive capacity have to be replaced in order to produce the same amount on the aggregate level. Therefore, flow coefficients of replacement of fixed capital, a^R_{ij} are introduced in the terms of the stock coefficients and the rates of replacement of fixed capital, v_{ij} as: $a^R_{ij} = v_{ij} b_{ij}$.[165]

According to Aulin-Ahmavaara, the production system can be represented by means of a dynamic input-output model where the matrix $\mathbf{A}$ of flow coefficients, a_{ij}, also contains the coefficient for replacement of fixed capital. The matrix $\mathbf{B}$ for the stock coefficients, b_{ij}, also includes the coefficients of inventory. Both of the matrices is formed by the following blocks

$$\begin{pmatrix} GG & GE & GT \\ 0 & EE & ET \\ TG & TE & TT \end{pmatrix}.$$

The system distinguishes three types of "industries" or categories involved in the production process: *G* = the industries producing market and nonmarket goods and services as in the SNA; *E* = the industries producing different types of human capital and *T* = the industries producing different type of human time (services of human capital).[166]

Aulin-Ahmavaara describes the contents in the blocks of the matrix representation: In the first row, GG represents the coefficients of goods and services in the production of goods and services; GE consists of the coefficients for consumption on all goods and services by the individuals below working age and, in addition, the consumption of educational services of the individuals who are producing additional units of intangible human capital which is embodied in them. In GT the coefficients for the rest of the consumption of goods and services by the active age individuals is used as an input in their production of human time. (The consumption of retired individuals is included in the coefficients of the respective category in the active age population).[167]

[164] Ibid, p. 216.
[165] Ibid, p. 216.
[166] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, pp. 12–13.
[167] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 13.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

In the second row, EG is zero, since human capital is not directly involved in the production of goods and services in this system; "EE represents the inputs from one stage of gestation of human capital to the next one in the gestation of the same unit of human capital." In matrix **B** ET includes the coefficients of human capital in the production of human time, in matrix **A** the same block covers the respective coefficients in replacement. In the third row, TG includes the coefficients of human time in the production of goods and services. TE consists of coefficients for active human time used in rearing children within the households as well as the time used in formal schooling after basic education. TT expresses the input coefficients of human time used in the production of human time referring to leisure and household work in the active population.[168] In the 2004 paper, she describes in chronological order how the production of human capital and human time proceeds from a newborn baby up to the time of being retired, showing the comprehensiveness of the system.[169]

Equilibrium prices can be used to analyse the relative prices of investment and stocks of human capital in accordance with the balanced rate of growth of the economy. The price unit is the price of simple human time. According to Aulin-Ahmavaara, the principal use of the model is in allowing for to analyse the potential rate of balanced growth of economy using technology represented by the matrices. Aulin-Ahmavaara has made calculations in benchmark years for Finland, giving the rate of balanced growth 2.1% in 1970, 1.7% in 1980 and 1.25% in 1985. The balanced rate of growth can be interpreted as the rate of total factor productivity, referring to neo-classical growth theory. The reasons for the changes in the potential rate of balanced growth can be analysed within the system by the production prices of the different industries.[170]

This system has apparently gone all the way to treat human capital and particularly its services as produced and precisely similarly to fixed capital, and also takes into account all of the costs and maintenance inputs for the services, as defined in the system. The change in the definition of production, as well as the change in the scope of the accounts compared with the standard accounts, is dramatic, though. The use of this system to test the ideas in modern growth theories, discussed in Introduction in this study, seems to be difficult.

[168] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 13.
[169] Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, pp. 217–218.
[170] Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 14; Aulin-Ahmavaara, Pirkko (2004): Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, p. 2220.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.2.4 A "short-cut" procedure in estimating human capital stock and flows

In this section a "short-cut" procedure proposed by Harry H. Postner in estimating human capital stock and flows is discussed.[171] One of the most interesting features in this approach is that it is applicable to the core accounts of the SNA framework in accordance with the standard production of goods and services without changing GDP. This approach would also be much easier and cheaper to implement in practice than the ones introduced above. Moreover, I will use the same symbols as were used in describing the production system of the SNA in summarising the derivation of this proposed method by Postner.

The author motivates his approach by stating that the two main approaches, the resource-cost (usually associated with Kendrick) and the present value method (typically associated with the works of Jorgenson and Fraumeni in 1989 and Graham and Webb in 1979) can and do yield widely different empirical estimates on human capital, even though some degree of reconciliation is possible as in Eisner's work in 1988.[172] Also, depending on the application of various assumptions in each method, significant differences in the results can arise within each method.

The author begins by denoting the total return to human capital by W (compensation for labour in Section 3.1) and the total return to nonhuman capital by R (compensation for nonhuman capital in Section 3.1, i.e. operating surplus or mixed income): Let W represent the total return to human capital and R represent the total return to nonhuman capital. Then, according to Postner, "in the spirit of Irving Fisher", since income can be seen as a return to at least some form of capital, the total national income, Y, is the sum of the returns to capitals (cf. also equation 3.4 in Section 3.1), i.e.

$$W + R = Y \qquad (3.2.4.1).$$

[171] Postner, Harry H. (1989). *Estimation of Human Capital Stocks and Flows: Is There a "Short-Cut" Procedure?* Session Paper, Session 8B, Twenty-first General Conference of the International Association for Research in Income and Wealth, Lahnstein, West Germany, 20–26 August 1989.

[172] Kendrick (1976). *The Formation and Stocks of Total Capital*; Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*; Graham, J. W., and Webb, R. H. (1979). Stock and Depreciation of Human Capital: New Evidence from a Present-Value Perspective. *The Review of Income and Wealth*, Series 25, June, pp. 209–224; Eisner, R. (1988) Extended Accounts for National Income and Product. *Journal of Economic Literature*, Vol. 26, 4, Dec., pp. 1611–1684.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Next, Postner defines the observed share of the return to human capital in total national income and denotes it with α: $W / Y = \alpha$. Now, the total return to human capital in relation to total return to nonhuman capital can be derived with simple algebraic manipulation to be

$$W / Y = \alpha \qquad \Rightarrow \qquad W/R = \frac{\alpha}{1-\alpha} = \alpha^{*} \quad (3.2.4.2)$$ [173]

In the further discussion, Postner is denoting, for simplicity, the expression of α /(1− α) with α*. Next, the author continues to the stocks by defining *H* to represent the total value of human capital stock and *K* to represent the total value of nonhuman capital stock. The total income-producing wealth of a nation, *T*, is the sum of these two: $H + K = T$.

The rates of return to each type of capital are by definition:

W / H = the rate of return to human capital stock
R / K = the rate of return to nonhuman capital stock.

According to Postner, without loss of generality it may be supposed that the rates of return in each type of capital are in proportion to each other

$$W / H = \beta \cdot R / K \qquad (3.2.4.3),$$

in which β is the ratio of the rate of return to human capital stock as compared to the rate of return to nonhuman capital stock. According to Postner, β is essentially unobserved, but a reasonable range of estimates for β can be simulated.[174]

With these ingredients, and by beginning the further derivation from equation 3.2.4.3, Postner continues with his derivation in order to formulate an expression for *H/T*. This expression would denote the relative importance of human capital stock compared with total capital stock for a nation's economy.

---

[173] Postner (1989). *Estimation of Human Capital Stocks and Flows: Is There a "Short-Cut" Procedure?*, p. 3. The derivation of the formulas is omitted in order to save space as in Postner (1989). *Estimation of Human Capital Stocks and Flows: Is There a "Short-Cut" Procedure?* The results have also been derived by the author of this study, and are available upon request.
[174] Ibid, pp. 4, 9–10.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$$W/H = \beta \cdot R/K \qquad \Rightarrow \alpha^* = \beta \frac{H}{K}$$

$$\Rightarrow H = \left(\alpha^* / \beta\right) K \qquad (3.2.4.4)$$

As can be seen above, if an estimate for *K* is available, an estimate for *H*, the total value of human capital stock, can also be obtained. Nevertheless, Postner continues with his derivation to get to the expression of H/T: [175]

$$\alpha^* = \beta \frac{H}{K} \qquad \Rightarrow \qquad \alpha^* \left(K / \beta T\right) = H/T$$

Now, for the first time, there is an expression for *H/T*. The focus is put on the term *K/ βT* to reduce the expression and finally the following is achieved:

$$\Rightarrow \quad \frac{\alpha^*}{\left(\alpha^* + \beta\right)} = H/T \quad . \qquad (3.2.4.5)$$

Therefore, the ratio of human capital stock to the total income-producing wealth of a nation can be estimated with using only the parameters *α* and *β*. This derived expression in equation (3.2.4.5) is a major goal for Postner's "shortcut" procedure's first part. It is notable that a prior estimate for *K*, the total value of nonhuman capital stock, is not needed in deriving *H/T*. On the other hand, an estimate for *H* can be obtained if an estimate for K is available (equation 3.2.4.4).

In the second part of his derivation, Postner reconsiders the fact that α is assumed to be the "observed" share of the total return to human capital in total national income. But what is really observed is the share of total labour income in total national income, where national income is defined as the summation of all labour income and all returns to nonhuman capital. The author recognises that it is not correct to claim that total labour income is equivalent to the total return to human capital. Instead, a "minimum maintenance subsistence return" to raw labour must be subtracted out of total labour income, in order to correctly measure the total return to human capital. According to Postner, this follows the tradition of David Ricardo and

[175] Ibid, pp. 4–5.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

still shows up in the literature of human capital.[176] Pure "maintenance expenses" have already been removed in the observed measurement of total return to nonhuman capital. On the other hand, all returns to human capital are already included as part of total labour income and no imputations for income from human capital are required.[177]

The author continues by keeping the basic identity of equation 3.2.4.1: $W + R = Y$. From now on W represents the observed total labour income of a national economy and R remains unchanged. Now it can be supposed without loss of generality that the total return to human capital is:

$$W^* = \delta W \qquad (3.2.4.6)$$

where $0 < \delta < 1$ and where δ is essentially unobserved, though, Postner clarifies again that a reasonable range of estimates δ can be simulated.[178]

Now it can be defined:

$$W^* + R = Y^* \qquad (3.2.4.7)$$

where Y^* represents an adjusted total national income and is unobserved since W^* is unobserved. When developing further the equations above, it turns out

$$\Rightarrow \quad W - (1 - \delta)W + R = Y - (1 - \delta)W = Y^* \qquad (3.2.4.8)$$

so that:

$$W^* / Y^* = \delta W / [Y - (1 - \delta)W].$$

As a next step the interest of Postner is in creating an expression for W^*/Y^* based only on observed and unobserved parameters. The derivation of the expression builds upon the observed parameter $\alpha = W/Y$. By manipulating and deriving further from $W^* / Y^* = \delta W / (\delta W + R)$ Postner ends up with a formulation:

---

176 Ibid, p. 6.
177 See also Eisner, Robert (1989). The Total Incomes System of Accounts, Chicago and London, Chicago University Press, pp. 1628, 1640
178 Ibid, pp. 6, 9–12.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$$\Rightarrow \quad W^* / Y^* = \quad \frac{\alpha\delta}{1-\alpha(1-\delta)} \equiv \alpha_A \tag{3.2.4.9}$$

Now using the new α_A notation and using the knowledge for deriving α^* in 3.2.4.2, the author receives

$$\Rightarrow \quad \mathrm{W^* / R} = \quad \frac{\alpha_A}{(1-\alpha_A)} \equiv \alpha_A^* \tag{3.2.4.10}$$

and finally from the new starting point (3.2.4.7) it can be shown with α_A^* that

$$\Rightarrow \quad H/T = \frac{\alpha_A^*}{\left(\alpha_A^* + \beta\right)} \ . \tag{3.2.4.11}$$

In his paper Postner clarifies the straight-forward simulation of unobserved parameters β and δ. [179] He also makes estimations with his approach that Canada’s human capital share of total capital in 1988 would have been between 0.57 – 0.61.

The interesting aspect in this approach is that it is relatively easy and clearly not expensive to provide. It does not demand any changes in the core of the SNA and the GDP is not changed as mentioned. As shown above, the two rates of return to each type of capital need not be equal. Human capital here refers to all the returns from labour input (hours worked).

Criticism on this approach can addressed to the fairly simple assumptions, e.g. that all human capital would generate returns instead of productive part of human capital, a way of thinking that is common in the analysis of returns on physical capital. Another obvious problem is that any information will not be achieved on the composition of human capital stock or flows.

[179] Ibid, pp. 6, 8–12.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.3 Empirical assessment of intangible human capital by schooling in Finland in the 20th century

The role of human capital in economic growth, in national production of goods and services and in the incomes generated in the production process has been constantly discussed in economics and economic history, especially since the 1960s[180]. Briefly said, the importance of human capital in economic growth has been duly noted and approved in a variety of modern growth theory models.[181] Human capital is seen either as an input for production together with physical capital enhancing labour input or as a facilitating factor for technical change.

However, in empirical studies no unambiguous agreement has been achieved on the role of increased education in explaining differences in economic growth across countries and time. Some of the cross-country empirical explorations document a positive and significant impact on schooling on real GDP per capita.[182] On the other hand, some find either a non-significant or negative effect.[183] It has also been questioned whether other factors would drive the technical change, and would therefore be more important for growth than reproducible

---

[180] E.g. Schultz, Theodore W. (1961). Investment In Human Capital. *The American Review of Economics*, Vol. LI, March 1961, Number one, pp. 1–17; Abramowitz, M. (1986). Catching Up, Forging Ahead, and Falling Behind. *Journal of Economic History*, Vol. 46, Issue 2, The Tasks of Economic History (Jun., 1986), pp. 385–406; Lucas, Robert E. Jr. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22, 1 (July), pp. 3–42; Mankiw, N. Gregory, Romer, David, Weil, David N. (1992). A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics*, vol. 107, 1992:2, pp. 407–37; Chaudhuri, Kausik and Maitra, Pushkar (2008). School Attainment, Completion, and Economic Development: A Cross-Country Analysis. *Review of Development Economics*, 12(1), pp. 90–105.

[181] See, e.g. Nelson, Richard R., Phelps, Edmund S. (1966). Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review*, 56, 2 (May), pp. 69–75; Romer, Paul M. (1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy*, vol. 94, 1986:5, pp. 1002–37; Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run Growth, *Journal of Political Economy*, vol. 99, 3, pp. 500–21; Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*. The MIT Press, Cambridge, Massachussetts, 1999. Originally published by McGraw-Hill, Inc., 1995; Galor Oded (2005). From Stagnation to Growth: Unified Growth Theory. In Aghion P., Steven N. Durlauf (Eds), *Handbook of Economic Growth*, vol 1A, Elsevier B.V., Amsterdam, The Netherlands, Chapter 4, pp. 171–293; Benhabib, Jess, Spiegel, Mark M. (2005). Human Capital and Technology Diffusion. In Aghion, P., Durlauf, S. N. (Eds.) *Handbook of Economic Grwoth*, vol 1A, Elsevier B.V., Amsterdam, The Netherlands, Chapter 13, pp. 936–966; Truong, Công N. and Tran-Nam, Binh (2007). Endogenous Growth and Publicly Funded Knowledge Accumulation. *Review of Development Economics*, 11(2), pp. 421–435.

[182] E.g. Barro, R. J. (1991). Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics.* 106, 1991:2, pp. 407–43; Levine, R. and D. Renelt (1992). A Sensitivity Analysis of Cross-Country Growth Regressions. *American Economic Review.* 82, pp. 942–63; Barro, R. J. and X. Sala-i-Martin (1999, 1995) *Economic Growth*. The MIT Press, Cambridge, Massachussetts, 1999. Originally published by McGraw-Hill, Inc., 1995.

[183] E.g. Lau, L. J., Jamison, D.T. and Louat, F.F. (1991). Education and Productivity in Developing Countries: An Aggregate Production Function Approach. *Policy Research Working Paper # 612*, World Bank; Islam, N. (1995) Growth Empirics: A Panel Data Approach. *Quarterly Journal of Economics*, 110, No. 4, pp. 1127–70; Bosworth, Barry P., Collins, Susan M. (2003). The Empirics of Growth: An Update. Brookings Papers on Economic Activity, 2:2003, pp. 113–179.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

capital accumulation.[184] In the time longitudinal aspect an unequivocal straightforward empirical long-run relationship between human capital accumulation and average income levels has proven not to be easy to detect, particularly without imposing an exponential structure for the empirical variable for human capital.

The reason for the controversy could be that direct measuring of human capital is not an easy task. The proxies for human capital used are typically school enrolment ratio, average years of schooling and literacy rate. However, the empirical counterparts of the other core variables in the growth theories come from inside of the systematic National Accounts frame (GDP and physical capital stock) and are valued in monetary terms. One of the problems with the proxies for human capital is that it is difficult to say whether these variables are comparable with investments in physical capital or with accumulated stock and services of physical capital. An obvious problem is that they do not have a logical connection to GDP as investments in physical capital.

The aim in this study is to explore empirically the impacts of investing in and accumulation of human capital by formal education on Finland's fast GDP growth in the 20th century. Human capital by schooling is assessed in the same National Accounts framework as the other variables examined in it, such as GDP, investments in physical capital and accumulation of physical capital stock. Education expenditure per year is separated from final consumption and treated as investments in human capital in Finland in 1877–2000. The stock of human capital by schooling is accumulated through these monetary valued investments when students have graduated and finally enter the labour markets. As a result, investments in and stock of human capital are valued in monetary terms as GDP and physical capital.

Finland is one of the few examples of poor countries' absolute convergence in GDP per capita levels in the 20th century: One hundred years ago it was a poor agrarian country with a gross domestic product per capita less than half of that of the United Kingdom or the United States, world leaders at the time. In the 2000s it is an industrialised and services emphasised high technology country with a standard of living ranked among the top fifteen to twenty-five countries in the world. From the late 19th century to the change of the millennium Finland has been one of the fastest growing countries among today's OECD countries together with Japan and Norway.[185] In the same time frame Finland has converged to the

[184] E.g. Hall, Robert E. and Jones, Charles I. (1998). Why Do Some Countries Produce So Much More Output Per Worker Than Others? *The Quarterly Journal of Economics*, Vol. 114, No. 1, (Feb., 1999), pp. 83–116.
[185] Cf. Jones, Charles I. (2002). *Introduction to Economic Growth.* University of California, Berkeley, 2nd edn., W. W. Norton & Company, New York, p. 65.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

average income levels of her leading neighbours, Sweden and the EU15.[186] This has happened in a low population density country without abundant natural resources. Industrialisation, investing early in physical capital especially in the paper and pulp industries, and the role of electrification and other technological innovations as enablers of productivity increase have been important.[187] In addition, as a part of the cultural climate of Scandinavia education has been seen important for bettering the living conditions in the future, since the latter part of the 19th century. Nowadays Finland has often been considered an exemplary country of education[188]. The fundamental question of this study is: Have the substantial inputs in education played a role in this dramatic change of economic performance in Finland?

Section 3.3.1 studies the long-run relation of GDP per capita and education in the population. It is structured as follows: Sub-section 3.3.1.1 focuses on how to assess human capital by schooling in the National Accounts framework in order to test the connection between education and standard GDP. Section 3.3.1.2 continues on the empirics on how investments in education were formed and Section 3.3.1.3 introduces how human capital was accumulated in this study and ends with analysing the development of the accumulated stock of human capital by schooling together with GDP and GDP per capita. In Section 3.3.2 the long-run relation of the development of human capital and real GDP per capita in Finland in the 20th century will be explored.

---

[186] Cf. Kokkinen, Arto, Jalava, Jukka, Hjerppe, Riitta and Hannikainen, Matti (2007). Catching up in Europe: Finland's Convergence with Sweden and the EU15, *Scandinavian Economic History Review*, 55:2, pp. 153–171.
[187] Jalava, Jukka, Electrifying and digitalising the Finnish manufacturing industry: Historical notes on diffusion and productivity, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen & Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, pp. 227–244.
[188] See, e.g. OECD (2003). *Education at a glance 2003*. ISBN: 9264102353 , OECD, Paris. OECD (2007) PISA study 2006, ISBN: 9789264040007, www.pisa.oecd.org/ (2011-03-30).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.3.1 Assessing human capital by schooling in the National Accounts frame

In this section, firstly, the methodology on how human capital by schooling is included in the National Accounts framework in this study is presented. Secondly, the constructed series of long-term final education expenditures, employed as investments in human capital, will be introduced and the changes to the Finnish Historical National Accounts in this study will be reviewed.[189] Finally, the evolution of the formed empirical stock of human capital by formal education will be illustrated and compared with the conventional school attainment variables.

3.3.1.1 Methodology for measuring human capital by schooling

In the latest revision process of the SNA the issue of measuring human capital in the context of the SNA was widely discussed with the conclusion that this was not feasible for the time being. It is stated in the SNA2008 (par 3.48) that "Human capital is not treated by the SNA as an asset. It is difficult to envisage "ownership rights" in connection with people, and even if this were sidestepped, the question of valuation is not very tractable".[190] At the same time, an overwhelming majority of empirical examinations on human capital and economic growth have used school attainment variables without receiving unequivocal results on the role of human capital in standard GDP growth. This obviously leads to the question whether assessment of human capital by schooling in the same National Accounts framework as the other core variables would be viable and would lead to different results.

However, as noted in Section 3.2, in the two best-known suggested approaches, as well as in Aulin-Ahmavaara's approach on how to incorporate the analysis of human capital in the National Accounts, the scope is broadened far beyond the standard accounts and the standard GDP. In addition, an example by Harry S. Postner on taking human capital into account in the standard National Accounts was reviewed. Another possibility for the analysis in accordance with standard accounts is to weight labour input by the levels of educational

---

[189] Hjerppe, Riitta (1996). *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* University of Jyväskylä, Department of History, Suomen historian julkaisuja 24. Jyväskylä 1996; Statistics Finland, National Accounts, 2005.

[190] This statement may have a connection to the main proposed methods including imputed non-paid monetary flows as investments or as services of human capital (see Section 3.2). An agreement has not been reached on how to incorporate human capital into the core accounts.

categories which is done, for instance, already in the work by Jorgenson and Griliches in 1967 and by Jalava and Pohjola in 2002.[191]

In the real world, hours worked has been enhanced with the knowledge and skills by education of the individuals in the labour force when producing the standard GDP. This is not reflected in the standard National Accounts figures. The primary goal in this part of research is to explore whether or not there has been a connection between schooling in the working age population and the standard long-run GDP growth in Finland in the 20th century. With this goal, human capital by schooling has to be taken into account with reference to the standard GDP in the National Accounts. In fact, the currently implemented System of National Accounts 1993 (par 1.57) implies to such a system by stating "*The decision whether to classify certain types of expenditure by households or government, such as education or health services, as final consumption expenditures or gross fixed capital formation does not affect the size of GDP, as both are final expenditures*."[192]

This study follows the statement above and develops a system of National Accounts which concentrates on paid monetary flows in education for Finland for the long-term assessment of human capital by schooling together with standard GDP, GDP per capita and later GDP per hours worked. Therefore, the focus is on the knowledge and skills accumulation achieved by the used education services of the cohorts of students and thus on intangible human capital by schooling. This intangible human capital by schooling has enhanced the labour input of those enrolled in each type of schooling in the standard GDP production in the real life. It should therefore be taken into account in the National Accounts.

The quality of labour with respect to education is embodied in the individuals in the labour force. Intangible human capital by schooling is therefore used in the form of hours worked. In reality, in the long run, total hours worked have included hours worked of the labour without any formal schooling and hours worked of those enrolled in different types and levels of schooling. Therefore, the human input in the standard GDP production in the National Accounts should be the hours worked adjusted by the education of the labour force. This refers to the view often considered in the economic theory where human capital is seen as the skill premium compared to raw labour. The hours worked of those enrolled in schooling could be simply called as hours worked by labour with education. As mentioned, this same idea of weighing labour input by the levels of education is used already, for

[191] Jorgenson, D. W and Griliches, Z. (1967). The Explanation of Productivity Change. *Review of Economic Studies*, July 1967; Jalava, J. and Pohjola, M. (2002). Economic Growth in the New Economy, Evidence from Advanced Economies. *Information Economics and Policy*, 14, pp. 189–210.
[192] SNA93, (1993). Paragraph 1.57.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

instance, in the works by Jorgenson and Griliches and for Finland by Jalava and Pohjola.[193] In their analyses labour input is classified by the categories of educational level. However, in my point of view, the differences in the volume of the education services used by the cohorts of students in different times, has to be taken into account as well. I am stating that this analysis would be possible to include inside the core of the accounts, as the works by the mentioned authors are.

This would not prevent doing analyses with broadening the scope of the SNA in the satellite accounts. These could include imputed non-monetary flows (such as foregone earnings as in Kendrick's system or forecasted incomes for the rest of the lifetime as in Jorgenson and Fraumeni's system) or dramatic changes to the definition of production by taking into account imputed non-monetary flows (as in Aulin-Ahmavaara's system).

In accordance with the analysis in Section 3.2 and particularly with the point of view of Aulin-Ahmavaara, the hours worked of those enrolled in schooling could also be called as "the services of intangible human capital". With reference to Aulin-Ahmavaara's reasoning, if problems would arise from the fact that these services are not suggested to be produced similarly as the rest of the hours worked in the system, the total hours worked can be simply called as human input, or quality adjusted labour input, in the production of goods and services. In my point of view, the naming of these hours worked is, however, more a matter of convenience.

Also with respect to the previous analysis in Section 3.2, I am following the welfare criterion in consumption as Kendrick, and not deducting the final consumption of goods and services as maintenance inputs for "the services of human capital". However, by following rationally the same welfare criterion I am not subtracting either the consumption of children below the age of 14 from final consumption in the empirical analysis. In my point of view, the children have been fed and nourished with the same goods and services in Finland in the 20th century without regard to whether they have enrolled in schooling or not, and also even if they have not been able to participate later in the labour force.

The costs for education services, instead, will be deducted from final consumption and treated as investments in intangible human capital by schooling. Schooling in my view, at least as practiced in Finland, cannot be seen as consumption resulting in instant welfare in the same sense as the consumption of other goods and services. Schooling in the basic level is

[193] Jorgenson, D. W and Griliches, Z. (1967). The Explanation of Productivity Change. *Review of Economic Studies*, July 1967; Jalava, J. and Pohjola, M. (2002). Economic Growth in the New Economy, Evidence from Advanced Economies. *Information Economics and Policy*, 14, pp. 189–210.

obligatory in Finland, and the enrolment in further schooling is done for gaining better future possibilities for receiving labour income in the labour market years later. As typical to all investments, the gains in the future are uncertain, but on average are high enough to act as an incentive for schooling.[194]

In this study, students will produce and embody human capital in the learning process by using education services as intermediate inputs. They will use their mental and physical capability to learn new knowledge and skills and accumulate their human capital, to be able to participate later in the production of GDP by their working hours in the economy. This requires time, rehearsal, reading and practising but without getting paid, i.e. no monetary transactions that are not already traced in the SNA are taking place. The incentive for students is the possibility to use their abilities and generate incomes in the future: the trouble and bother for educating themselves are seen as an investment that will yield in time. The human input in the production of GDP has been the hours worked by the people without education and people with different types and level of education in Finland in the 20th century. All of the human input is owned and controlled by the individuals in the working ages of the household sector. They are offering human input to be used in the production by the producers of goods and services, and they are negotiating for the compensation for the use of it. On the national level human input can be presented as $H_t = h_t L_t$, i.e. by labour input (L_t) multiplied with average human capital in the labour input ($h_t = H_t / L_t$), as suggested by the modern growth theories, discussed in the Introduction of the study at hand.

The valuation problem mentioned above as a one given reason for not incorporating human capital in the SNA2008, may have something to do with the best-known proposed systems including human capital, also suggesting flow variables without monetary transactions to be accounted either as investments or as services of human capital (see Kendrick, 1976, Jorgenson and Fraumeni, 1989, 1992a, 1992b, Aulin-Ahmavaara, e.g. in 2002, 2004). For instance, treating foregone earnings of students as investments in the core system would make GDP to include this same amount, for which no transactions occurred. It should also be added to the balance sheet of households, in which the wealth of households should be comparable with that of the financial accounts in the system. While foregone earnings (or the present value of the forecasts for the lifetime labour incomes) can be justified from the input-output view, it may be unjustified from the point of view institutional sector

[194] Following the same line of thoughts, on the national level, health and perhaps social expenditures could be seen as investments in human capital, but this is out of the scope of the analysis here concentrating on formal education.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

accounts, which aim at giving the financial position (the net lending/borrowing to/from other institutional sectors) of the institutional sectors and how they have financed their production and investments. If foregone earnings (or the present value of the forecasts for the lifetime labour incomes) were added in the output of the household sector (/of the sector where educational institutions belong in each country), this would have to change the financial position of the household sector (/the respective sector) even without any transactions occurred. At the same time, thinking of GDP per capita as a measure for material living standard, in the long-run analysis the inclusion of foregone earnings in the core accounts would not perhaps make sense, since no one has eaten with foregone earnings (or with future incomes). Imputations affecting GDP would also decrease the transparency of the calculations, which would not likely be appreciated, for instance, in the financial markets. It is not likely that these systems would be incorporated in the core of the SNA, even when they can be quite thorough.

In addition, without arguing that foregone earnings of students would not be important in education decisions in the micro-level, this study introduces a system concentrating on paid monetary flows as investments in formal education for two particular reasons: First, the aim here has been to explore whether schooling has had a role in the standard GDP growth. All the empirical studies with the proxy variables for human capital have sought for the connection with the standard GDP. Second, if foregone earnings are added to both investments and to GDP, it results in an approx. 20-30% increase in the level of GDP and hence would make a much bigger part of investments (Kendrick, 1976). When the connection of human capital in accordance with such investments would be explored with GDP, a long-run equilibrium type of cointegration relation would be empirically much easier to achieve. Therefore, in empirics, at least to start with, it would be good to make sure that the connection human capital by education can strictly be found with the standard GDP. Inversely, if finding a long-run cointegration relation by concentrating on paid monetary flows, the relation is probably to be found as well with adding the same imputed figure to investments (accumulated to the corresponding stock) and to GDP.

Next, the changes to National Accounts in this study will be reviewed with reference to the discussion in Section 3.2 by following Aulin-Ahmavaara's interpretation of the implicit system of production in the SNA.[195] The revisions to the production system are shown with the bolded variables and with equation 3.5b).[196]

[195] Aulin-Ahmavaara was originally describing the system of production of the SNA93, however, to my best knowledge, the reasoning here with respect to human capital by schooling does not change in the SNA2008. The

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.1 *[O+**O$_H$**] + M = [U **+ education expenditure**] + [C **- education expenditure**] + [I$_K$ **+ I$_H$**] + E*

3.2 *GDP = [O+**O$_H$**] - [U **+ education expenditure**] = [C **- education expenditure**] + [I$_K$ **+ I$_H$**] + E - M*

3.3 *[O **+ O$_H$**] = [U **+ education expenditure**] + W + R*

3.4 *GDP = [O **+ I$_H$**] - [U **+ education expenditure**] = W + R*

3.5a $\frac{dK}{dt} = I_{Kt} - \delta_K K_t$ 3.5b $\frac{dH}{dt} = I_{Ht} - \delta_H H_t$

3.6. $L = \bar{L}$

Where
O = gross output,
M = imports
U = intermediate uses / intermediate inputs
C = final consumption expenditure
I_K = gross physical capital formation
I_H = gross human capital formation
K = stock of fixed capital
H = stock of intangible human capital stock by schooling
E = exports
W = labour compensation
R = operating surplus (or mixed income)
L = labour input
δ_K = rate of depreciation of physical capital
δ_H = rate of depreciation of human capital

NB: Goods and services used for own gross capital formation and change in inventories are included in the output. The gross capital formations contain change in inventories and own capital formation.

In order to include intangible human capital by schooling in the produced assets the production system is revised in this study (the bolded variables). In equation 3.1, the education expenditures are deducted from final consumption (in the Finnish case from general government) expenditures and reclassified as intermediate inputs (education services are used in the learning process of students). The new skills the students have embodied within a year are treated as produced human capital by schooling (O_H), which is valued through expenses in education. In the demand side, each year when a student continues at schooling, the amount of produced human capital by schooling is recorded in gross human capital formation (I_H) (in the form of change in inventories in own capital formation).

---

biggest change with regard to the system of production in the SNA2008 is that research and development expenses will be subtracted from intermediate uses and treated as investments.
[196] The system is simplified in a way that taxes and subsidies are ignored and simple geometric rates of depreciation are assumed. The components in the equations are expressed at constant prices.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Since the intermediate inputs, the new produced human capital and the gross human capital formation (so far in the form of change in inventories in own capital formation) all equal the value of education expenditures. This means that the accounts are balanced and GDP does not change in the equations 3.2 and 3.4. It is worth noticing that in equations 3.3 and 3.4 the compensation for labour includes compensation for skills and knowledge by education used in the production. The depreciation of human capital by schooling of the labour force is assumed to be included in their wages and salaries as part of the compensation for the skills accumulated and used in the labour market.

When a student has finally graduated from his/her highest education and enters the labour force, all the produced human capital up to that date will be moved from the intermediate inventories to investments inside the component gross human capital formation (I_H). At that time, the stock of intangible human capital by schooling is accumulated with perpetual inventory method by investment, i.e. by the amount of all accumulated education expenditures the student have used up to that date (I_{Ht} , in equation 3.5b). Therefore the long graduation times in education are taken into account in accumulating the stock of human capital by schooling. *The entire stock reflects people in the working ages with different education along time, taking into account the volume of the resources put to education each cohort with different educational path has used.*

The productive stock of intangible human capital by schooling is decreased by the rate of depreciation of human capital by schooling with the assumption of geometric age-efficiency profiles, calculated separately in basic, upper secondary, professional and university education in accordance with the average service lives, assuming that the average retirement age is 65. The stock of human capital is adjusted by those deceased in wars and by net migration.

It is worth mentioning that the educational system in Finland up to the present day has been by far mostly financed by general government. Therefore, the minute part of privately financed education has been neglected in estimating the evolution in education expenditures backwards until 1877.[197] In the countries with private educational system the education expenditures in the private final consumption would be, of course, used as investments. In the empirical analysis in this study, school buildings and other fixed capital are included in the fixed (or physical) capital. They will be taken into account in the analysis in Chapter 4 inside of fixed capital.

[197] See more of the estimation of the evolution of education expenditures backwards in Section 3.3.1.2.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

To summarise, human capital by schooling can be seen treated as a produced asset following the defined asset categories of the standard System of National Accounts. However, no imputed non-paid monetary flows are included in this analysis in order not to change the GDP or the financial positions of the institutional sectors with respect to the current international standard. The time devoted to learning at and outside the school is seen to be used to produce human capital but it is not given a monetary value because there has not been a monetary flow paid for it in the real world. The broad capital accumulation in the revised system will include fixed capital and human capital by schooling.

As mentioned earlier, intangible human capital by schooling (or the accumulated knowledge and skills) is used finally in the process of production and income generation in the labour market in the working ages since it is embodied in the labour force. The human input in the production of goods and services is the labour input adjusted (or weighed) by the intangible human capital by schooling in the labour force. In the real world, the labour is compensated for the human input as defined above. The wages and salaries that are accounted in GDP are paid for people participating in the production. In a modern economy an increasing part of their labour income is compensation for their skills and knowledge. The purpose of this system at hand is to take this into account, by quality adjusting the labour input by intangible human capital by schooling. This does not imply in any way that the accumulated human capital – especially of people working in research and development – could not affect technical change separately. Rather, the reasoning here implies the existence of both channels on how human capital enhances economic growth.

3.3.1.2 Investments in human capital by schooling

In this sub-section, first, the centre of attention is on the gathered long time series of education expenditures used for gross capital formation (or more briefly here as investments) in human capital by schooling. Secondly, the changes to the original National Accounts variables in the modified system in current and constant prices will be demonstrated.[198]

The annual monetary flow that has been invested in education is included in National Accounts in every country following the SNA. In Finland's case this monetary flow is included in the general government expenditures. The modern National Accounts, presenting

[198] Finland's Historical National Accounts, database: Hjerppe, Riitta (1996), *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* Statistics Finland updates and chains these series to be in accordance with today's figures of Finland's National Accounts from 1975 onwards.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

data from 1975 onwards, contains a more detailed breakdown of the general government final consumption expenditures, including final consumption education expenditures, than the older versions of National Accounts and the Historical National Accounts for Finland. Firstly, the main task was to separate the education expenditures from the general government expenditures in Historical National Accounts for the years before 1975, since nowadays' National Accounts give them separated from 1975 onwards, (see DATA APPENDIX 3.1). Secondly, for aiming to take into account the long graduation times in education, the division of education expenditures in basic and secondary (secondary refers here to lower secondary and upper secondary, i.e. grammar, schools), university and professional education had to be estimated (see DATA APPENDICES 3.2, 3.4–3.8) and, respectively, the number of students in each type of education had to be collected (see DATA APPENDIX 3.12).

Concerning the modern National Accounts period, in 1975–2000, education expenditures for comprehensive education (previously primary plus lower secondary), upper secondary, professional (including vocational, commercial and technical schools) and university education could be further separated using the same data sources as have been used for compiling the National Accounts figures. In this time period the general government expenditures in the National Accounts are broken down to the classes of industrial classification, education as one of the classes, and to producing sectors: central government sector and local government sector. The central government sector (or the state) has produced all university education in this time period. Local government sector units – i.e. municipalities and joint municipal authorities (the latter from 1959 onwards) – are producing basic & upper secondary (grammar school) and professional education services. Thus, to achieve education expenditures in each type of education for the years 1975–2000, the education expenditures of local government sector were to be divided into basic & secondary and professional education expenditures. The central government education expenditures are the expenditures of the universities including also a smaller amount of expenditures of research institutes owned by the state. For simplicity, these are often named in this study as university education expenditures. The constant price figures of the university expenditures are then given by the National Accounts as well.

The statistics on financial statements of municipalities and joint municipal authorities have been used comprehensively in the compilation of local government education expenditures in the National Accounts in 1975–2000. Therefore, the total education expenditures of basic & secondary and professional education are very reliable. For dividing the local government education expenditures into sub-groups, basic & secondary and

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

professional education expenditures, the exactly same sources were used. However, in this time period there have been major changes in the book-keeping laws regarding municipalities and the joint municipal authors. In the compilation of the continuous time series of the local government accounts in the National Accounts the respective changes in the contents of the variables concerning intermediate expenditures have been carefully taken into account each year. With the time frame and resources of this study, the calculations at such a detailed level would not have been possible. Wages and salaries proved to be almost the only variable whose content has not changed in this time period and they form two thirds of education expenditures of the local government. I chose to use the wages and salaries of the sub-groups in proportion to all wages and salaries of education in the local government sector for dividing the education expenditures into sub-groups in current prices (see DATA APPENDICES 3.2 and 3.3A)).[199] The cost inflation in the current price figures were deflated in each class by the implicit price index of local government education expenditures (see DATA APPENDIX 3.1) to get to constant price (also called fixed price or volume) figures (see DATA APPENDIX 3.3B).[200] As a result the sum of the basic & secondary and professional education expenditures both in current and constant prices follow the National Accounts figures in 1975–2000.

Now I had the total of education expenditures as well as the breakdown of them in accordance with National Accounts in the late 20th century. Next the task was to estimate the evolution of the expenditures backwards from 1975 preferably as far back in time with comparable annual fluctuation data. First I will aim at explaining what figures I should be estimating backwards: The output of the general government units (and non-profit seeking organisations) is derived by the costs in the National Accounts since they are not selling the goods and services in the markets, and hence not receiving market sales revenues that could be used in output calculations. Therefore, output consists of wages and salaries (including fees for employee pension, etc. social security fees directly attributable to the compensation of labour) plus intermediate inputs (materials and services bought from other producers to be used in the production of the education services). When the received non-market fees (for instance partial payments of households for the meals at the school, not covering over 50% of the costs of the meal production) are subtracted from the output, we will get to final

[199] The figures for polytechnics in 1997–2000 (in DATA APPENDIX 2) have been summed up to the class professional education, since the lines in technical institutes, commercial schools, etc. that formed the polytechnic schools have been included in professional education in all of the previous history in this study. The aim here is to accumulate the stocks in as long a time period as possible.

[200] The implicit price index of the education expenditures reflects the changes in the costs of different items, wages and salaries and items in intermediate uses.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

consumption education expenditures. Thus, the education expenditures in the case of a public sector producer describe the costs that are covered by the collected taxes. In practice, in Finland this refers to almost all of the costs in accordance with the education at schools itself. It is worth noticing that investments in buildings and in other physical capital and equipment used in production for more than one year are not included in final consumption expenditures, but in investments in physical capital.

In the backwards estimation, in the optimal state of matters I would have all the data of the different items of at least the costs of the organisers of producing education services in different types of education. If using state's financial accounts data, in which all the state's monetary transactions in education are given, together with the cost data of the organisers of schooling, to avoid double accounting I should be able as well, to consolidate the state subsidies out of the costs of the producer, when the producer has not been the state itself. In addition, because the aim in this part of the study is to study by time series econometrics whether there has been a connection between inputs in education and economic performance in Finland, continuous annual fluctuation data should be available.

I considered different strategies and gathered data from different data sources. For basic & secondary education expenditures, forming the majority of the expenditures, the first idea was to use both state's financial accounts data and statistics on the financial accounts of the municipalities and joint municipal authorities following the procedure in 1975–2000. While local government has produced in practice all of the primary education services, the duties for organising lower and upper secondary and professional/vocational education had changed many times between the central and local government before the early 1970s in Finland, and therefore I should have been carefully able to distinct, year by year, the subsidies from the state included in the total costs of reported education expenditures in the local government statistics. To be able to do this every year the data was not available. In addition, the statistics on the finances of municipalities (and joint municipal authorities from 1959 onwards) was first published only for towns for the years 1910–1912 (SVT XXXI: 1, 2) without statistics published for the years 1920–1924. Only from 1930 (SVT XXXI: 5–6) onwards the statistics of all municipalities, including towns, townships and rural municipalities were published yearly. Moreover, the content of the statistics, and the reported variables based on financial accounts of each municipality and therefore on book-keeping laws and practices at each time, has changed along time and probably only the wages and salaries could have been used for estimating the development backwards in the local

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

government sector. For achieving long enough annual education expenditure development the use of this data with partial coverage proved not to be the most productive.

Another possibility was to use the statistics for primary schools and secondary schools (lower secondary and upper grammar schools), which have reported the total costs of the schools, including the investments in school buildings and other physical capital (not separated and therefore not possible to subtract from the total). For secondary schools this data source was promising, since the statistics gave a possibility to form a continuous annual series for 1909–1963. Instead, the statistics for primary schools reported the costs annually only for 1930–1948, and the data for the years before 1930, reported in three to five or six year intervals, did not include the costs of lower primary schools in the countryside.

For achieving annually comparable development data in the estimation of the backwards development in basic & secondary education I ended up using the data on the total costs of the state in the state's financial accounts, reported in Statistical Yearbooks of Finland (SYF). The yearbooks have been published from 1879 onwards including data beginning from 1877.[201] This data includes all of the costs of the state's schools, and the considerable state's subsidies from the tax revenues for local government (and private) units to organise the schooling in primary (also in professional education in the early years) and later also in secondary education. The local government units did participate themselves to the costs of schooling, however I am stating that the backbone of the development of the monetary education expenditures in Finland was formed by the state subsidies. Budgetary laws and decisions of the state in putting more money to education were the initiative, the main incentive. They often included an obligation for the municipalities to do their part in the schooling expansion as well. Concerning the expenditures, this can be seen empirically in Figure 3.3.1 where the evolution of the total costs in primary and secondary education in school statistics are compared to state's total costs in the respective two types of schooling. The reason for the very close development of the figures is that the total costs of the municipal (and private) schools include the subsidies from the state. The state subsidies to other producers are in turn part of state's total expenditure in education in the financial accounts of the state.

The advantage for using state's expenditure in basic and secondary education (forming most of the education expenditures) for estimating the evolution backwards in this

[201] Erkki Pihkala has also studied state's income and expenditure in the late 19th century. However, he did this in ten-year intervals, in 1860, 1870, 1880, 1890 and 1900. For the purposes of this study I had to use annually as comparable source material as possible. See Pihkala, Erkki (1977). Valtion tulojen ja menojen rakenne 1800-luvun jälkipuoliskolla. *Helsingin kauppakorkeakoulun julkaisuja*, B-23.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

type of education was first that annual continuous data was available, secondly the data was comparable in the sense that it came from the same source and hence there was no risk of double accounting, thirdly the data was available all the way back to 1877 and fourthly by using the exactly same source included data for the development of the expenditures of university and professional education. The oldest and biggest university, University of Helsinki, has been owned by the state, and the following smaller ones were strongly subsidised by the state. By the late 1960s and early 1970s, in accordance with the expansion in the university education and state founding new universities at that time, all of the university education was moved under the state in Finland. The schools in professional education have as well been subsidised by the state in late 19th and 20th century, and in the time of the expansion of this type of education, after WWII, the state by itself founded large vocational institutions and encouraged the municipal authorities to organise this type of education with state subsidies. By the early 1970s the duty for organising professional education was given to municipal authorities in Finland.

The data available in the statistics on the financial accounts of the state, published in the Statistical Yearbooks of Finland (SYF) can be seen in DATA APPENDICES 3.4, 3.5, 3.6, 3.7. The data of the statistics for the state costs or subsidies of the schools in professional education is summarised in DATA APPENDIX 3.8. The latter is used for deriving the evolution of the professional education expenditures in 1885–1938, as for this period the statistics on state's financial accounts did not give separated information on the costs of state in professional education.

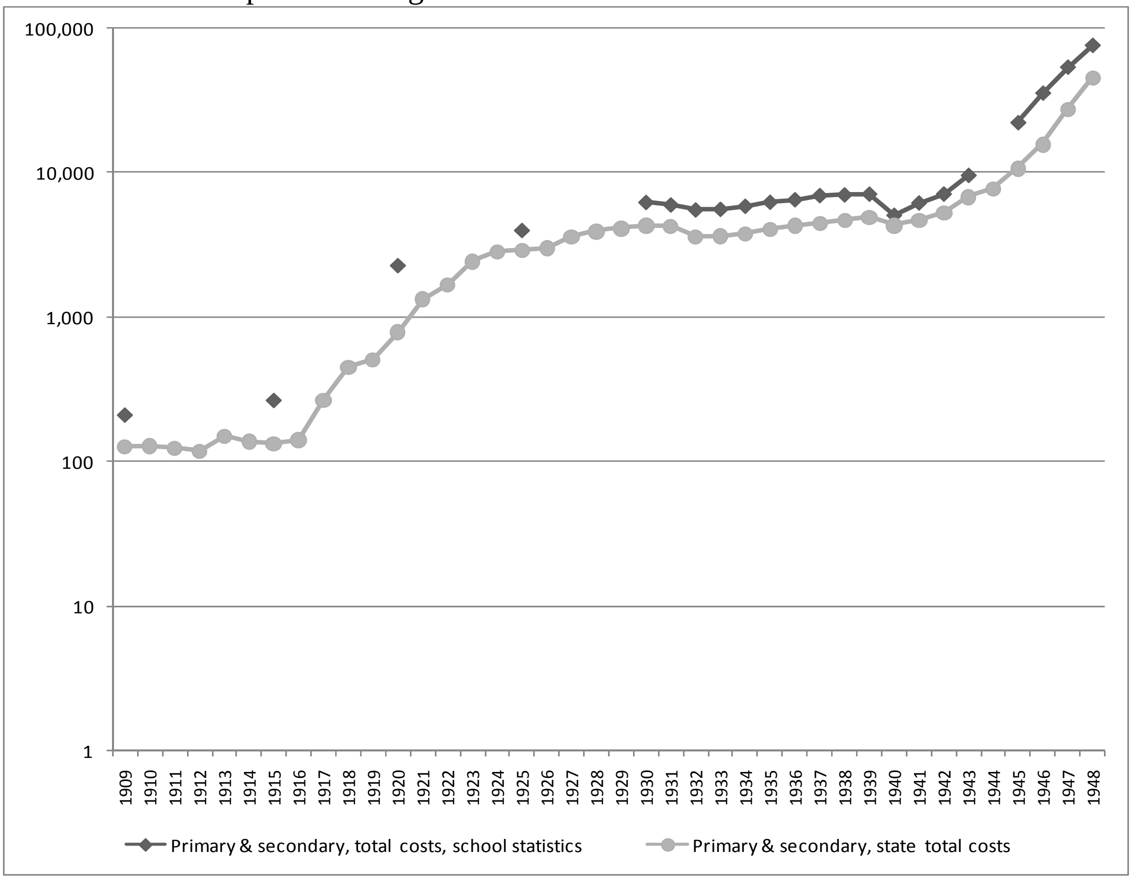
The data on the state's expenditures in education was available at the most detailed level for the years 1938–1975 (see DATA APPENDIX 3.5). From 1938 backwards to 1877 changes in the broader classes in the state's financial accounts that include the mentioned types of education, but include some administration as well, had to be used (see DATA APPENDIX 3.6). However, the education types formed the majority of the expenditures in the accounting classes and therefore the changes backwards should be quite reliable. Next, more detailed information on the data in the DATA APPENDICES will be given.

DATA APPENDIX 3.4 gives the data for the development of the current price education expenditures in state's financial accounts in 1967–1975: for basic & secondary education the class used was primary schools and lower and upper secondary schools (yleissivistävä opetus,), for professional education vocational schools (ammattiopetus) and for university education universities & other higher education (yliopistot ja muut korkeakoulut) (see DATA APPENDIX 3.4). It is worth to note that the costs for primary and secondary

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

schools were not separated in this period. Probably this would have been too difficult in the statistics, as the primary (classes 1–4–8) and lower secondary education (classes 5–9 for those elected to secondary school after the 4th class) were joined together to comprehensive education (classes 1–9 in the new system) gradually school by school from North Finland to South Finland in 1970–1978.

Figure 3.3.1 The comparison of the development of total costs of primary and secondary schooling in the data sources in 1909–1948. The total costs of schools in the primary and secondary school statistics compared with the total costs of the state on each type of schooling in the state's financial accounts, thousands of new Fmk (new Finnish Marks) current prices, the variables are expressed in logarithms.



Source: Own calculations, data sources: total costs of primary schools in school statistics: SYF 1921: XIII, 182, 183; SYF 1930: XIII, 178, 179; SYF 1935: 171, 173; SYF 1938, XIII, 179, 181; SYF 1940, XIV, 179, 181; SYF 1942: XIV, 183, 185; SYF 1944–45: XIX, 193, 195; SYF 1948: XIX, 294, 296; SYF 1950: XIX, 287, 289, *NOTE: In years 1909, 1915, 1920, 1925 only upper primary school costs in the countryside included*; total costs of secondary schools in school statistics: SYF 1920: XIV, 179; SYF 1930: XIII, 185; SYF 1935: XIII, 183; SYF 1938: XIII, 189; SYF 1950: XIX, 301; SYF 1953: XXII, 313 *NOTE: total costs of secondary schools in 1939 are that of the year 1938*; total costs by state in the state's financial accounts: for sources see DATA APPENDICES 3.4, 3.5, 3.6, 3.7.

For the development of current price expenditures in 1959–1966 (see DATA APPENDIX 3.5) the following budgetary classes were employed: for changes in basic & secondary education expenditures, the sum of the classes for primary schools (in Finnish:

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

kansakoululaitos) and for secondary schools (oppikoulut), for professional education sum of the expenditure in the following classes (under the Ministry of Agriculture and the Ministry of Trade and Industry at that time); institutes for agricultural education (maataloudelliset oppilaitokset), navigation and schools for navigation (merenkulkulaitos ja merenkulkuoppilaitokset), technical instruction (other than at the institute of technology, in Finnish: muu teknillinen opetus), vocational training (ammattiopetus) and commercial training (kauppaopetus). For university education expenditures the class universities and other higher education (korkeakoulut) was used.

For the years 1938–1958 the data for the evolution of the current price education expenditures in basic & secondary education and in professional education was formed as above (see DATA APPENDIX 3.5). Instead, in the university education the broad class, such as above, was not reported, and the changes in the sum of the following classes were used; University of Helsinki (Helsingin yliopisto), Veterinary College (eläinlääketieteellinen korkeakoulu) and Institute of Technology (teknillinen korkeakoulu).

The statistics for the financial accounts of the state report the expenditures in a somewhat broader budgetary classes before WWII, and the expenditures of professional education institutes were not reported separately under the Ministry of Agriculture and Ministry of Trade and Commerce as above (see DATA APPENDIX 3.6). Therefore, detailed information on the data used in each type of education for the years 1887–1938 is given below.

In basic & secondary education the budgetary classes were basically the same as above. Here, the level of education expenditures in 1938 was derived backwards with the changes of the sum of classes of primary schools (kansakoululaitos) and of secondary schools together with the national board of education (oppikoulut ja kouluhallitus).

Instead, for the estimation of the evolution in expenses of university education a broader budget class, including churches (kirkot), university (yliopisto), other civilization (ym. sivistystoimi) had to be employed for calculating the changes backwards in the education expenditures from 1938. This forms a slight falling-off in the quality for the evolution of university expenditure, however, at this time period there was not a dramatic expansion in the university education, (as in the primary and more slowly in secondary education) and the development of the university expenditures in this long period could be seen reasonably plausibly have grown with the average pace of this broader budgetary class. The share of university expenditure of the finally achieved total education expenditure was 12% in 1887 and 8% in 1938, which illustrates that the use of the changes in the higher level

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

budgetary class could not have had a big effect on the total backwards estimated education expenditures.

DATA APPENDICES 6 and 7 give the available data for the years before 1887. For the years 1882–1886 (see DATA APPENDIX 3.6) only the principal group on expenditures of the state in education and other civilisation was available. The principal group is consisting of the sum of the budgetary classes of primary schools (kansakoululaitos), of lower and upper secondary schools with the national board of education (oppikoulut ja kouluhallitus) and of a broader budgetary class, including churches (kirkot), university (yliopisto), other civilisation (ym. sivistystoimi). The figures for the expenditures in the sub-classes, basic & secondary and university, were estimated with the proportions of the sub-classes of this principal budgetary class in 1887, a procedure which at the same time gives equivalent annual changes in these sub-classes to the principal class.

Before 1882 the classes reported in the statistics on financial accounts of the state differ again slightly from the budgetary classes above. The strategy used was to fill in the years 1877–1881 backwards to the schedule in DATA APPENDIX 3.6, using as closely as possible similar information.

DATA APPENDIX 3.7 describes the data available for the estimation of the sub-classes in 1877–1879. The good news was that the same classes could be found for the year 1887, the year which I already above used as a benchmark for the division to the sub-classes in 1882–1886. First, I estimated the figure for the same principal class for 1879 as in 1882–1886 by the proportion of the sum of secondary, primary, university and funding for research and arts in the years 1879 / 1887 (see DATA APPENDIX 3.7) and multiplied this proportion with the figure for the principal class for 1887 in DATA APPENDIX 3.6.[202] With now having the estimated figure of the expenditures of the principal class in 1879 and the figure given in 1882 (see above and in DATA APPENDIX 3.6), I used linear interpolation for the total expenditures in the years 1880 and 1881. For achieving the data in the sub-classes as in the DATA APPENDIX 3.6, in 1881, I used again the proportions in 1887 in DATA APPENDIX 3.6. For the year 1880, the figures for the sub-classes in basic & secondary education were derived again by the proportion of the expenditures in 1887, but the figure for university expenditure was achieved as a residual, the principal class figure minus expenditures in basic

[202] Before the multiplication I estimated the expenditures of the institute of technology (polytechnic school at the time), 239.5, and subtracted them from the university class in 1887. This figure was derived by using the proportions of the sum of the classes university and industry, commerce, navigation schools, subsidies for handicraft schools in 1879/1887 in DATA APPENDIX 7.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

& secondary. The same was done to achieve the university expenditure in 1879, but now the basic & secondary classes were given in DATA APPENDIX 3.7.

The figures in the principal category for 1877 and 1878 could be estimated backwards by the changes in the sum of the sub-classes in DATA APPENDIX 3.7 (with leaving the class industry, commerce, navigation schools and subsidies for handicraft schools out). The figures in the sub-class churches, university, other civilisation (as in DATA APPENDIX 3.6) were estimated in a similar manner, by using the changes in the university category in DATA APPENDIX 3.7. The figures for the basic & secondary sub-classes in 1878 were given (see DATA APPENDIX 3.7) and the figures in 1877 respectively, when subtracting out the estimated expenditure for the professional schools (later under the Ministry of Trade and Industry) which were here included in secondary schools and the national board of education (DATA APPENDIX 3.7).

As mentioned before, DATA APPENDIX 3.8 summarises the data of the statistics for the state subsidies of the schools in professional education in 1885–1938, employed for deriving the evolution of the professional education expenditures in the mentioned period. The data was reported in five year intervals in 1885–1910 and the observations inside the intervals were estimated by linear interpolation. For the annual changes in 1882–1885 the evolution of the sum of basic & secondary and university education had to be used. For the year 1879, the ratio of the budgetary class industry, commerce, navigation schools and subsidies for handicraft schools over the sum of all of the budgetary classes in DATA APPENDIX 3.7 (primary school, secondary schools and the national board of education, university, funding for research and arts, and commerce, navigation, etc.) was multiplied with the derived figure of the principal class above, basic & secondary plus university education. The annual changes of the same principal budgetary class mentioned in 1879/1878 and 1878/1877 were used to derive the development for professional education as well. At this point the figures for the indicator for professional education in the years 1880 and 1881 could be linearly interpolated using the derived figures in 1879 and 1882.

As a result of above, I had a series for annual development of education expenditures in basic & secondary, professional, university education for 1877–1975. These estimated annual changes of current price education expenditures of each type of education, were deflated to volume changes by the implicit price index of general government expenditures in Historical National Accounts. The general government expenditures have been originally deflated by constructing a particular cost index taking into account the cost inflation of wages and salaries in general government activities and of typical products in intermediate

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

consumption. The changes of the constant price figure changes were calculated by using the changes of current price and changes of implicit price index by using the following formulas 3.3.1.2.1 and 3.3.1.2.2.[203]

$$(1+dV/V) = (1+dp/p)*(1+dq/q) \qquad (3.3.1.2.1)$$

$$\Rightarrow (1+dq/q) = (1+dV/V) / (1+dp/p) \qquad (3.3.1.2.2)$$

where dV/V = the relative change of Value (here the relative change at current prices)

dp/p = the relative change of price (here the change of price index)

dq/q = the relative change of quantity (here relative change at fixed prices).

At this moment, I had the constant price education expenditures on the levels of National Accounts in Finland for 1975–2000 and the estimated annual constant price changes in each type of education in 1877–1975. I linked these series, resulting in a continuous series at constant prices in 1877–2000, as follows:

Let Y_t be a figure of fixed price education expenditures in 1975 and Y_{t-1} in 1974, respectively. The rate of change, r, can be calculated simply by $Y_t / Y_{t-1} = r$. Now, if the previous year's figure Y_{t-1} and the rate of change r, is known, the figure for the moment t is simply given by $Y_t = r * Y_{t-1}$. Similarly, if the figure for Y_t and the rate of change, r, is known, the previous year's figure can be achieved simply with the formula:

$$Y_{t-1} = Y_t / r \qquad (3.3.1.2.3).$$

Figure 3.3.1 displays finally the achieved series for education expenditures at constant prices in 1877–2000. According to these figures the fixed price education expenditures in Finland have grown to be 123 fold in 1877–2000 and in 1945–2000 14 fold, while GDP at fixed prices has grown 43 and 7.86 fold, respectively, and the volume of GDP per capita 16 and 5.7 fold, respectively. These annual figures of education expenditures were employed as investments in human capital by schooling in 1877–2000.

According to the classics[204] of National Accounting, one of the reasons not to include human capital inside of the System of National Accounts has been that it is difficult to

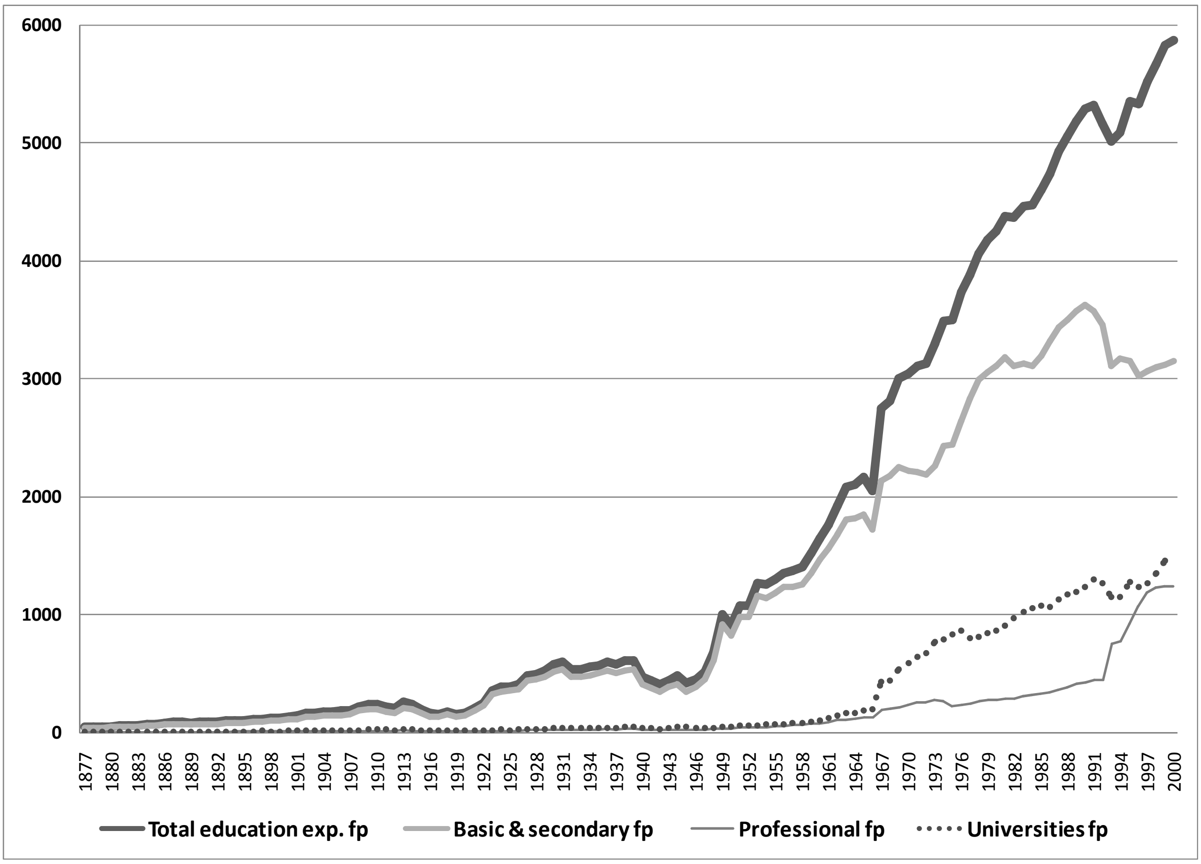
[203] I would like to express my gratitude to Dr. Matti Estola for clarifying these formulas precisely.

[204] Cf. Kuznets, Simon (1946). *National Income: A Summary of Findings*, New York: National Bureau of Economic Research, p. 20; Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset*, p. 3.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

decide what part of the substantial portion of the flows of goods and services to consumers should be treated as investments in human capital. For instance, if all health, social, education, cultural and recreational services were classified as investments in human capital, the category of final consumption would diminish dramatically. In this study the focus is on skills and knowledge accumulation by education that is believed here to be the core of human capital in economic analysis without regard to whether human capital is seen as an input in production by enhancing labour or as a catalyst for technical change.

Figure 3.3.2 The estimated education expenditures and their division to sub-classes in Finland in 1877–2000, millions of euro, constant prices (fp, reference year 2000).



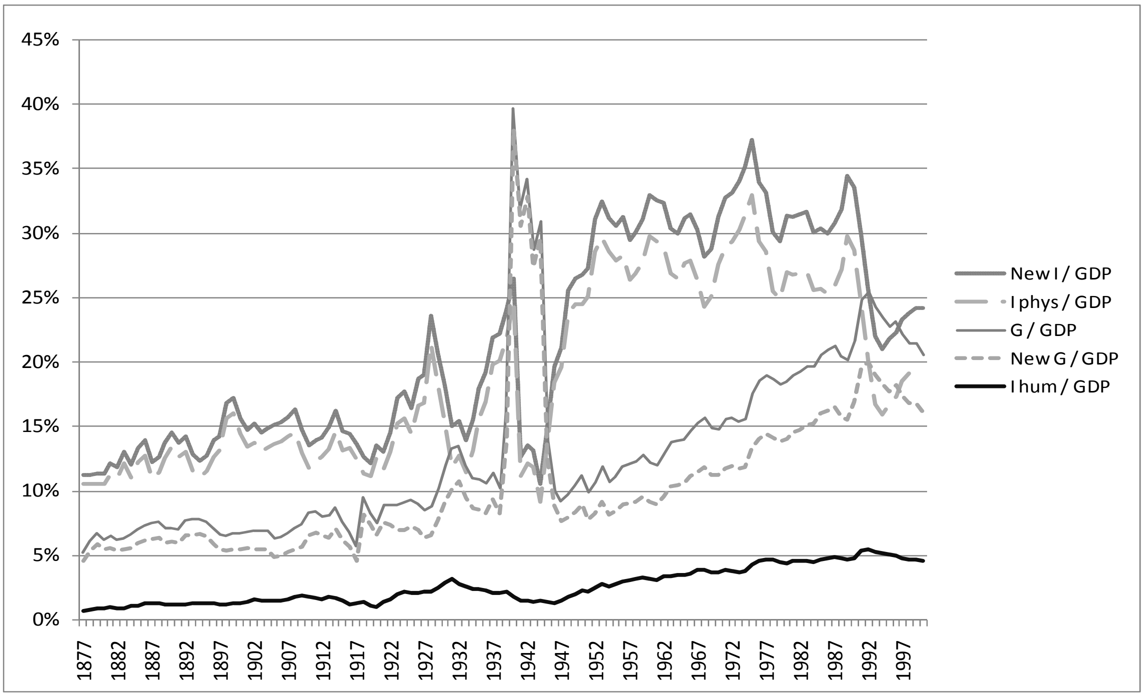
Source: Own calculations, data from statistics on financial accounts of the state, Statistical yearbooks 1879–1975, Statistics Finland; National Accounts publications: 1948–1965, database of National Accounts 1975–; Statistics of the financial statements of municipalities and joint municipal authorities, *Suomen taloushistoria 3. Historiallinen tilasto*. (1983) (in Finnish: Finland's economic history 3, Historical Statistics) (Ed.) Kaarina Vattula. Tammi, Helsinki 1983.

How much did the main aggregates of National Accounts change when the education expenditures above were employed as investments and the modifications to other variables were done respectively? The most important changes to National Accounts current price

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

variables in relation to GDP can be viewed in Figure 3.3.3. Original general government expenditures' share of GDP (G/GDP) has varied between 5.2% and 25% in peace time Finland, the new general government expenditures (New G/GDP) between 4.6% and 20%, when the education expenditures have been subtracted. The difference between these variables' shares of GDP can be seen in investments in education ratio of GDP (I hum/GDP) that has varied between 0.7% and 5% of GDP. The physical capital investments' ratio of GDP (I phys/GDP) has varied from 10% to 33% and the new physical plus human capital investments' ratio (New I/GDP) from 11% to 37% in relation to GDP. The new and old variables shares of GDP fluctuate in respect to each other. As a result in the modified system 1% to 5% more of monetary flows are treated as investments that reduce – with the same percentages – the general government expenditures in Finland's case. Therefore, the direct impact of investments in human capital by schooling on current price GDP has varied between 1% and 5%.

Figure 3.3.3 The original and changed National Accounts variables as a proportion of GDP at current prices in 1877–2000.



Source: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; statistics on financial accounts of the state, Statistical yearbooks 1879–1975, Statistics Finland; National Accounts publications: 1948–1965 and database of Finland 1975–; Statistics of the financial statements of municipalities and joint municipal authorities, *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

At constant prices (see Figures 1 and 2 in APPENDIX 3.2) old general government expenditures grew on average by 3.5% a year in 1877–2000, new general government expenditures have grown at an average pace of 3.4%. Old investments (investments in physical capital) have grown on average by 3.26% a year and new total investments by 3.35% on average per year. The average growth of investments in formal education has been 3.9% a year, which is a higher average growth rate than that of physical capital investments. However, investments in physical capital formed 90% in the early years and in the late years still around 80% of the total investments and therefore the level of annual investments in physical capital has been substantially higher in the modified system. The direct impact of investments in intangible human capital by schooling on constant price GDP has varied from 1.5% to 6%, whereas the direct impact of physical capital investments on constant price GDP has been from 10% to 35% in Finland (see Figure 3.3.3 above). Eventually, the changes to the system of production of National Accounts – when concentrating on actual monetary flows paid for education – were fairly modest.

3.3.1.3 The stock of human capital by schooling

The stock of human capital by schooling was accumulated each year by all the used education expenditures of the students graduating that year from their highest education, and hence becoming employable in the labour markets. For this purpose, data on the number of students in each type of education in 1880–2000 had to be gathered (see APPENDIX 3.2 and DATA APPENDIX 3.12) and divided further to school classes.[205] Consequently, the constant price education expenditures were firstly gathered in primary, secondary (divided by the proportion of the number of students to lower secondary and upper secondary up to the 1970s), professional/vocational and university education. Secondly in each type of education the expenditures were distributed to pupils in the school classes with respect to the number of

[205] Data sources are given in the mentioned Data Appendix. One of the difficult tasks was to divide the number of students in secondary schooling to lower secondary and upper secondary (as well as the basic primary schooling from the extension classes) before the comprehensive school reform in the 1970s, in order to achieve comparable figures with the nine-year compulsory comprehensive schooling since the 1970s. Luckily, Osmo Kivinen (1988) had gathered both lower and upper secondary figures in five-year intervals (and primary school figures up to the sixth class and beyond that in the extension classes). By interpolating linearly the relative shares of lower and upper secondary (and basic primary and the extension classes) in the number of students in the whole secondary (primary) schooling, I was able to estimate the annual figures for lower secondary (and the extension classes of primary schooling) up to the 9th class in comprehensive schooling nowadays. See Kivinen, Osmo (1988), *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini Suomessa 1800- ja 1900-luvuilla*. Turun yliopisto, Annales Universitatis Turkuensis, 68, Turku.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

pupils in each class. This way the number of students and the education expenditures they have used in different years at different stages of their education could be followed (or at least systematically estimated) annually, all the way until they were graduating and becoming employable in the labour markets. The years of the pupils in education, the level of schooling and all the education expenditures used in their schooling history were all traced following the major changes in the schooling system.[206]

As an example, Table 3.3.1 illustrates how the education expenditures were distributed to the number of students in upper secondary schools in 1880–1882. On the left hand side, above the year labels, the total number of students in upper secondary schools is displayed. In the first year, here in 1880, I used the distribution of the number of people in each age, 16–18, in the population statistics, for dividing the number of students to first, second and third class (or grade) with respect to their ages. However, since an individual can only enter the second class after having passed the first year in the school, in the following year, 1881, the number of students in the second class has to be derived from the number of first class students previous year. Similarly, the number of the third class students in 1882 has to be in line with the second class students in the preceding year. At the same time, some of the students have failed to pass the class of the previous year and unfortunately some have also deceased, although the failure in passing to the next year has been in the schooling system even more important, and this has to be somehow taken into account. I approximated this phenomenon by a 5% failure ratio each year in the upper secondary schooling.[207] Hence, in Table 3.3.1, the number of second (or third) class students in, 1881 (or in 1882), is achieved with multiplying the number of first (second) year students, in 1880 (in 1881), by 0.95. Now, the next year, (1881 in the example), has already the number of students in the second and third class, and the number of students in the first class can be calculated by subtracting the sum or the second and third class from the total number of students, (in 1881;

[206] On the major changes in the schooling system, see, e.g. Kivinen, Osmo (1988), *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini Suomessa 1800- ja 1900-luvuilla*. Turun yliopisto, Annales Universitatis Turkuensis, 68, Turku; Klemelä, Kirsi (1999), *Ammattikunnista ammatillisiin oppilaitoksiin: ammatillisen koulutuksen muotoutuminen Suomessa 1800-luvun alusta 1990-luvulle*, Turun yliopisto, Koulutussosiologisen tutkimuskeskuksen raportti 48, Turku.

[207] The failure ratio for successfully passing a year in schooling was set in lower secondary schooling to 0.97, in professional/vocational schooling to 0.97, in upper secondary to the mentioned 0.95 and in university education to 0.95. The use of the failure ratios also aims to reflect the reality in that not all students have completed the schooling in question, and that the passing from one year to another is assumed here to be more difficult in upper secondary and in university education. In primary schooling I chose not to use the failure ratio assuming that in this most primary form of schooling eventually all have passed. This is of course a simplification, however, the primary schooling has been obligatory since 1921. Before this, without the ability to read one did not get permission from a clerk to getting married. Of course, a vast majority in the countryside was learning to read in schools by the church or at home, both of which I have not been able to take into account in the calculations here.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

1512), in upper secondary schooling. The number of students in each class (or grade) was estimated in a similar way in primary, lower secondary, professional and university education.

In our example, in the same table, on the right hand side, the row above the year labels presents the estimated education expenditures in upper secondary schooling in 1880–1882. Now, the figure for the expenditures each year (e.g. EUR 2.1 million in 1880) was distributed to the classes 1–3 with respect to the number of students in the same year (e.g. in 1880). Now, with this set-up, I was able to follow how much each age cohort of students has used the education expenditures along time.

A comparison between the number of students in the final grade and the number of students in the first year in the next level of schooling, and population in that age cohort in the same year, enabled to estimate the proportion of the graduates from upper secondary schooling which did not continue schooling, and was therefore available for the labour markets.[208] In this case in accordance with this proportion, I accumulated the stock by the education expenditures they had used in the first, second and third class in upper secondary school in each different year, and similarly, by all of their used education expenditures in previous schooling. In our example, the education expenditures used by the cohort with age 16 in 1880 in upper secondary schooling is highlighted in the table for 1880–1882 (on the right). The aim, of course, has been to trace the volume of education expenditures used by the students in cohorts.

Table 3.3.1 An example of distributing the education expenditures to the number of students in age cohorts in upper secondary schooling (at the ages 16–18).

Number of Students				**Education expenditure**			
Total N	1415	1512	1551	Tot Mio Eur	2.1	2.3	2.2
	1880	**1881**	**1882**		**1880**	**1881**	**1882**
age/class				Exp / class_age			
16	498	608	524	16	$\boxed{0.7}$	0.9	0.7
17	454	473	578	17	0.7	$\boxed{0.7}$	0.8
18	463	431	449	18	0.7	0.7	$\boxed{0.6}$

[208] The population in each age cohort every year in 1877–1944 was estimated by using the statistics on babies born alive and population in five year age groups (0–4, 5–9, etc.). With the former, theoretical one-year age cohorts without deaths and migration were formed. A survival-migration ratio was calculated by dividing the reported number of people in five-year age groups (0–4, 5–9, etc.) each year with the formed theoretical one-year age groups without deaths and migration. By multiplying the theoretical one-year age cohort with the survival-migration ratio in the respective age group each year, I received estimates for the actual number of people in one-year age cohorts. For the years from 1945 onwards Statistics Finland provides the number of people in one-year age cohorts.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The typical years of schooling and the level of education when entering the labour markets have changed dramatically in Finland in 1880–2000. In the early years under review the majority of pupils entered labour markets after primary school, whereas in the late 1990s almost all of the students went after the 9 years comprehensive education either to professional school or to upper secondary and after that to a polytechnic school or to university. This can be detected as well in the estimated school enrolment ratios in APPENDIX 3.2 and in DATA APPENDIX 3.13. At the same time, the volume of resources used in producing the education services (described by the volume of education expenditures) each year has changed even more dramatically, as is obvious in DATA APPENDIX 3.11.

Following the procedure described above, I was first able to estimate the number of students in the final year in each type of education. In accordance with the independently estimated number of students in the first grades of the next higher types of education, I was able to follow (at least to approximate) on the whole the educational paths of the cohorts of students from the primary education to lower secondary (both included in comprehensive schooling since 1970s) and to vocational/professional schools, from lower secondary to upper secondary (gymnasium here) and to vocational/professional schooling, and finally from the upper secondary to universities and later in time also to upper lines of professional education. As a consistency check, the number graduated from the lower level fitted quite nicely with the separately calculated first-year students in the next level(s). As already mentioned above, comparing the number of the ones beginning in the next level and the number of graduates from the previous level with the number of people in the appropriate age cohort enabled to assess the number of people entering the population in the working ages with each type of schooling.

The above procedure also allows for assessing the number of people with their highest education in the population in the ages 16–64, i.e. in the working ages. The first year of which I had the number of pupils was 1877. The pupils entering the first class of primary school were assumed to be seven years old (in towns), and hence they reached the age of 64 in 1934.[209] Respectively, Figure 3.3.4 gives the overall picture of the evolution of the education in the working age population in Finland in 1934–2006. It is important to note that these figures do not yet take into account the volumes of education expenditures attached with

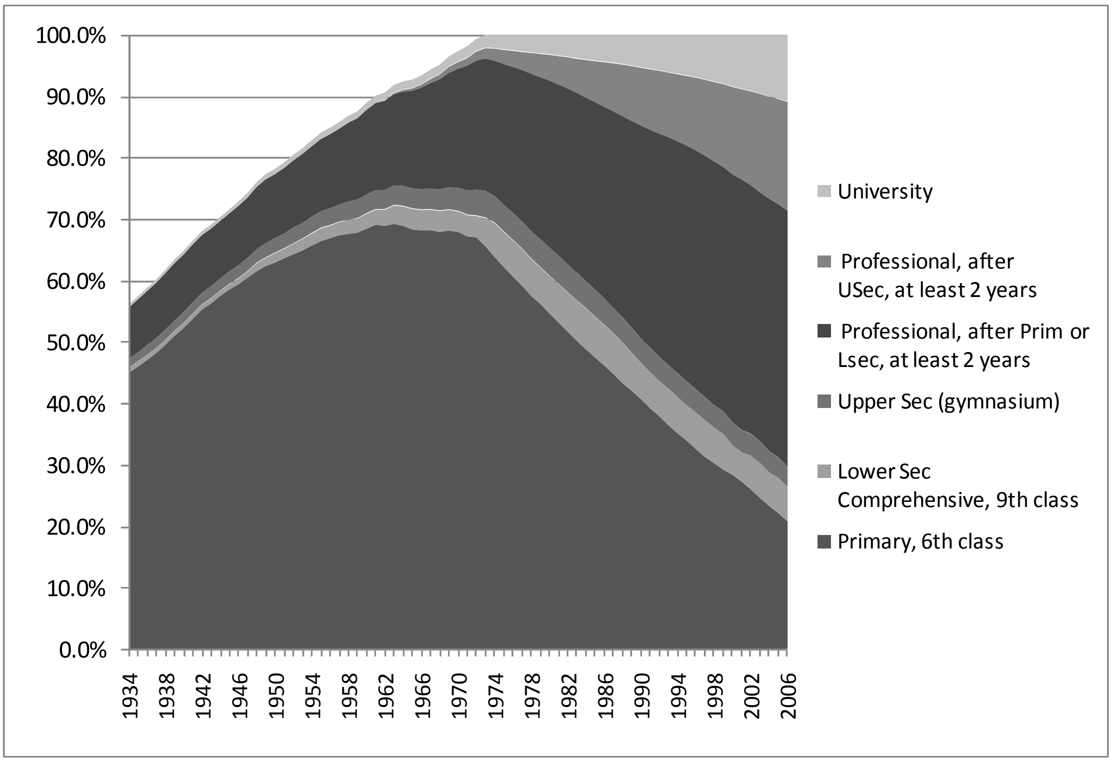
[209] In towns children were assigned to begin at the age of seven in the first class, in the countryside they were assigned to begin in the 3rd grade at the age of nine in 1877–1915. See Kivinen, Osmo (1988), *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini Suomessa 1800- ja 1900-luvuilla.* Turun yliopisto, Annales Universitatis Turkuensis, 68, Turku.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

students and not either the depreciation of the income generating capacity of the aging schooling.

As can be observed in Figure 3.3.4, people with primary and lower secondary education, have formed by far most of the educated people in the working age population up to the late 1960s and early 1970s. Along with the increased demand for lower secondary schooling in the 1950s and 1960s, and with the comprehensive school reform the dominance began to decline rapidly in the 1970s. At the same, with the retirement of the employees without the level of sixth class of primary schooling, gradually all of the working age people are estimated to have attended up to the level of sixth class of primary schooling around the mid-1970s. As can be seen in the composition of people with highest education, most of the graduates from the expanded lower secondary and upper secondary schooling have continued their studies since the 1970s. In the estimated figures below around the early 1990s the people with professional or university education have begun to dominate the working age people.

Figure 3.3.4 The estimated shares of people by their highest education in the working age population (in ages 16–64) in Finland 1934–2006, (%).



Sources: Own calculations, see data sources in DATA APPENDIX 3.12.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Depreciation in the analysis

The accumulation of the stock was done with the perpetual inventory method by taking into account the long producing time of human capital by formal education before it will be used in the human input in the labour markets. The stock was decreased by depreciation. Without renewing the skills (by new education or learning at work) along with evolving labour markets and technology, old investments in human capital by schooling are considered to diminish their income generating capacity along time. The retirement profiles of the cohorts with different types of education were taken into account in accordance with depreciation.

Geometric depreciation rates were used because they typically combine the age-price/age-efficiency and the retirement profile for a cohort of assets. As shown in OECD's manual for measuring capital, various age-efficiency profiles for individual assets, when combined with retirement profiles for entire cohorts, generate profiles that are more or less convex to the origin so that the geometric model can be used as an approximation to a combined age-efficiency/retirement pattern.[210] In addition, an important computational feature is that the value of depreciation can be obtained directly by applying the rate of depreciation to the net capital stock (instead of computing it separately for every vintage). Furthermore, the productive capital stock and the net capital stock coincide in the case of geometric depreciation rates because age-price and age-efficiency profiles coincide.

The depreciation rates for each type of education were approximated by using the declining balance method. In the late 1990s Hulten and Wykoff[211] made a suggestion for converting an average service life of a cohort, T^A, into a depreciation rate, with formula $\delta = R / T^A$, where R is the declining-balance rate. Under the double declining balance formula, R is set to equal 2, but generally it would be best to turn to empirical estimation results for the shape of the geometric depreciation pattern. Later, Baldwin et al.[212] have reported econometric estimates of declining balance rates for traditional capital in the range between 2 and 3.

Here the average retirement age was set to 65. The average age for entering the labour markets with basic education (for the years after 1975 comprehensive schooling and before it primary schooling) was set to 16, with upper secondary education to 19 and with

---

[210] OECD (2009). *Measuring Capital: OECD Manual 2009*, ISBN 978-92-64-02563-9, OECD.

[211] Hulten, Charles R. and Wykoff, Frank C. (1996). ”Issues in the Measurement of Economic Depreciation: Introductory Remarks”. *Economic Inquiry*, 34, pp 10–23.

[212] Baldwin, John, Gellatly, Guy, Tanguay, Marc (2007). *The Cost of Capital Input: Calculation Methods*, revised version of a paper presented at the Capital Measurement Workshop, Ottawa, 22 May 2006.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

university education to 28[213], yielding the average service lives for the mentioned types of education 49, 46 and 37 years, respectively. Because of the lack of empirical estimates for the declining balance rate of human capital by schooling, the rounded depreciation rates were set by calibrating with the declining balance formula: 5% depreciation for basic education, 5.5% for upper secondary and 7.5% for university education,[214] giving the respective declining balance rates 2.45%, 2.73 % and 2.8%, falling in the range between 2 and 3. The decline rate in basic and upper secondary is assumed to be lower than in the university (and professional) education because of the basic knowledge and skills giving nature of this type of education. For university and professional education the declining balance rate is assumed to be somewhat faster (and similar in respect to each other) because they include specialisation directed to the labour market at the time and the evolution of labour markets has been fast in connection with fast transformation of the society and rapid technological change in Finland.

For the professional education different paths in entering the schools and completing the education were considered: For the years up to the mid-1950s the typical way to professional education was considered through lower secondary or primary education at the average age of 16. Most of the lines on this type of education were lasting for two years, however, 20% of the students were considered to have continued a third year (e.g. in upper engineering schools). After 1955 until 1990 an additional 4th year was set to be available to 25% of the third class students, referring to the further training and specialisation in the higher professional schooling.[215] After the polytechnic reform in the early 1990s the proportion of the 4-year professional education was allowed to increase gradually to 70% of students. Together with similar declining balance rate to university education and in accordance with the service lives of 47, 46 and 45 years, the depreciation rates were set to 6%, 6.1% and 6.2%.

The number of graduates from upper secondary schools rose dramatically in Finland after WWII (see APPENDIX 3.3). Most of the upper secondary school graduates continued to the expanding university education. However, some of these graduates began to fill the most wanted lines in the professional education especially from 1970s onwards, which in its part led to the changes in the educational system, in the form of polytechnic school reform, in Finland in the 1990s. Here, since 1960 first a small part, but later gradually increasing

---

[213] This refers to the master degree, which has been the aim in the Finnish university system. On average, the graduation times from the universities have been traditionally high in Finland.
[214] Actually, with these geometric depreciation rates the basic and upper secondary education investment has lost 92% of its value in its average service life and university education investments 94% in their average service lives.
[215] In real life, in practice, sometimes the students had already been in the working life and then attended a specialising or further educating period.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

proportion of the upper secondary school graduates were allowed to go to two, three or four years' professional education after upper secondary school at the age of 19. With approximately similar declining balance rate and service lives of 44, 43 and 42 years, the depreciation rates were set to 6.3%, 6.45% and 6.6% for the human capital of these students when going to work.

Typical to other forms of productive capital, the depreciation describes the gradual loss of income generating capacity due to aging (taking also into account the retirement of the vintages). From what was said above, it should become obvious that I do not think that people in the working ages will finish their efforts in investing in their knowledge and skills after they have graduated from their highest education. Instead, I assume that higher formal education will increase the ability of individuals to update their knowledge and skills along with evolving technology in the labour markets. This should lead to a long-run dependence relation between human capital by formal schooling and economic growth.

Adjusting the stock for those deceased in wars and for net-migration

After accumulating the stocks with respect to persons entering the population in the working ages with different educational paths, these stocks were adjusted for people deceased in the civil war in 1918 and in WWII in 1939–1944. Depending on what is included for the dead in the war, the figures vary to some extent in different sources. I was using the following figures for those deceased: 36 640 in the civil war in 1918, 26 600 in the Winter War in 1939–40, and 60 200 in the Continuation War in 1941–1944. In the last two wars, I divided the number of deceased evenly to each year, resulting in 13 300 per year in 1939–1940 and in 15 050 per year in 1941–44. Riitta Hjerppe has presented figures for the economically active population in proportion to the whole population in ten year intervals beginning for 1860–1980 and 1985.[216] At the same time, Statistics Finland provides annual figures for population and changes in it since 1749.[217] By using Hjerppe's proportion on economically active population over the whole population in 1920 (0.476) and 1940 (0.546), I was able to estimate the economically active population for the Civil War year 1918 and for the years in WWII, 1939–1944. At this point, it was feasible to calculate the ratio of those deceased for each war year in

[216] Hjerppe, Riitta (1989). *The Finnish Economy 1860–1985: Growth and Structural Change. Studies on Finland's Economic Growth XIII.* Helsinki: Bank of Finland Publications, Government Printing Office 1989, Table 13, p. 100.
[217] See Population statistics by Statistics Finland, http://www.stat.fi/til/synt/tau_en.html (2009-03-17)

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

proportion to the economically active population. These ratios are 0.0247 in 1918 and 0.0066 in 1939–1940. In 1941–1944 the ratios with the same rounding came to be 0.0074 each year. I have assumed that people with different education were deceased equally in the war. Hence, the values with respect to the ratios were subtracted from the productive stocks of human capital in each type of education each mentioned year. The percentage of deceased people in wars was at maximum 2.5% in 1918.

In order to take into account migration, similar lines of thought were followed: a ratio of net migration (- or +) in proportion to economically active population was calculated, and the human capital stocks were adjusted respectively in accordance with this ratio. The data for population, those born alive, deaths, natural change in population (those born alive minus those deceased in a year) and the actual change in population was available in the population Statistics by Statistics Finland in 1749–2000.[218] The number of those emigrated and immigrated was available in the mentioned statistics from 1945 onwards. For the period 1877–1944, I calculated the net migration by subtracting the natural change in population from the actual change in population. At this point, I had annual population figures, and figures for net migration in 1877–2000. By using again the ratios of economically active population to the whole population presented in Hjerppe's work in ten-year intervals in 1860–1980 and in 1985, I was able to estimate annual economically active population in 1880–1985.[219] Labour force statistics by Statistics Finland was used for calculating the similar ratio of active population (i.e. labour force) over the whole population for 1990–1995 and 2000.[220] The assumption included here was that, on average, people emigrating from and immigrating to Finland have had similar education to the population in the working ages in Finland at the time. This is of course a rough way to estimate the effect of migration, however the target here is to illustrate an average migration effect, and with this procedure the fluctuation caused by migration in the stocks of human capital by schooling can be described. In addition, in Finland the effects of migration have been minor, noting however, the emigration to the America in the late 19th and early 20th century and particularly to Sweden by the 1960s and the 1970s.

[218] See http://www.stat.fi/til/synt/tau_en.html (2009-03-17).
[219] Hjerppe, Riitta (1989). *The Finnish Economy 1860–1985: Growth and Structural Change. Studies on Finland's Economic Growth XIII.* Helsinki: Bank of Finland Publications, Government Printing Office 1989, Table 13, p. 100
[220] Strictly speaking, I did use, for instance, the ratio of economically active population by Hjerppe in the 1880 for the first five years in that decade (1880–1884), and the ratio of 1890 for the last five years in that decade (1885–1889). The labour market statistics by Statistics Finland are available here http://pxweb2.stat.fi/database/StatFin/Tym/tyti/tyti_fi.asp (2011-04-15).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Together the adjustments were minor compared to the accumulation effects with domestic tremendous expansion of education as can be seen in APPENDIX 3.4. Table 3.1 gives the adjustment ratios (in per cent) of net migration and wars. The ratio of deceased people in wars to economically active population was at highest 2.5% in the civil war year 1918. The ratio of net migration to active population has its minimum value, -1.9%, in 1969, and hence emigration reached its peak at that time. Immigration has been highest after gaining the independence in 1921, with the ratio of net migration 0.7%, respectively.

Table 3.3.1 The adjustment ratios of net migration and wars for human capital, per cent.

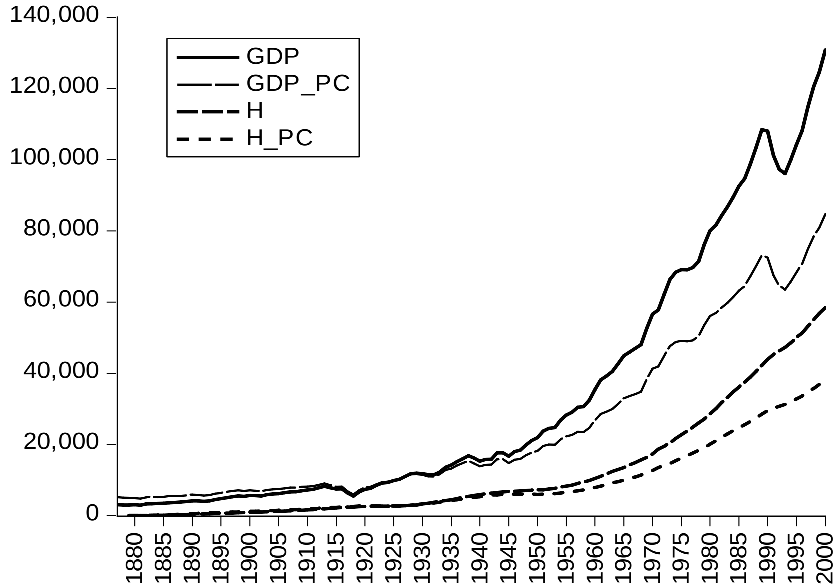
	Net migration	War		Net migration	War		Net migration	War		Net migration	War
1877	0.16%		1908	0.59%		1939	0.10%	-0.660%	1970	-1.72%	
1878	0.07%		1909	-0.98%		1940	0.09%	-0.661%	1971	0.03%	
1879	0.16%		1910	-1.03%		1941	-0.20%	-0.744%	1972	0.26%	
1880	0.24%		1911	-0.23%		1942	-0.22%	-0.743%	1973	0.29%	
1881	0.13%		1912	-0.39%		1943	-0.14%	-0.739%	1974	0.06%	
1882	0.15%		1913	-1.13%		1944	-0.21%	-0.738%	1975	-0.18%	
1883	0.11%		1914	-0.24%		1945	-0.26%		1976	-0.45%	
1884	0.12%		1915	-0.29%		1946	-0.38%		1977	-0.48%	
1885	0.11%		1916	-0.48%		1947	-0.52%		1978	-0.41%	
1886	0.10%		1917	-0.14%		1948	-0.60%		1979	-0.30%	
1887	0.07%		1918	-0.23%	**-2.4709%**	1949	-0.45%		1980	-0.05%	
1888	0.13%		1919	0.12%		1950	-0.79%		1981	0.26%	
1889	0.13%		1920	-0.12%		1951	-0.89%		1982	0.32%	
1890	0.10%		1921	**0.71%**		1952	-0.19%		1983	0.30%	
1891	-0.31%		1922	0.24%		1953	-0.22%		1984	0.19%	
1892	-0.45%		1923	-0.23%		1954	-0.16%		1985	0.12%	
1893	-0.73%		1924	0.19%		1955	-0.14%		1986	0.07%	
1894	0.02%		1925	0.31%		1956	-0.20%		1987	0.03%	
1895	-0.28%		1926	0.23%		1957	-0.40%		1988	0.05%	
1896	-0.32%		1927	0.09%		1958	-0.46%		1989	0.16%	
1897	-0.04%		1928	0.16%		1959	-0.38%		1990	0.30%	
1898	-0.05%		1929	0.10%		1960	-0.45%		1991	0.56%	
1899	-0.87%		1930	0.02%		1961	-0.58%		1992	0.36%	
1900	-0.66%		1931	0.23%		1962	-0.35%		1993	0.36%	
1901	-0.82%		1932	0.22%		1963	-0.38%		1994	0.12%	
1902	-1.71%		1933	0.20%		1964	-0.95%		1995	0.14%	
1903	-0.98%		1934	0.20%		1965	-1.00%		1996	0.11%	
1904	-0.42%		1935	0.17%		1966	-0.58%		1997	0.15%	
1905	-1.14%		1936	0.15%		1967	-0.27%		1998	0.14%	
1906	-0.80%		1937	0.10%		1968	-0.70%		1999	0.11%	
1907	-0.35%		1938	0.11%		1969	**-1.91%**		2000	0.10%	

Finally, Figure 3.3.5 illustrates the accumulated human capital stock by schooling together with constant price GDP and GDP per capita and Figure 3.3.6 the same variables and human capital stock per capita in logarithmic forms, respectively. In the first figure the exponential growth in all of the variables emerges very clearly. Particularly the latter of the figures reveals interesting fluctuation of the human capital by schooling in respect to GDP series: A decrease in the stock in the early 1920s due to the civil war in the late 1910s is discernible, although

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

the investments in education (cf. Figure 3.3.2) increased strongly in the early 1920s. Human capital by schooling began to grow faster only after the mid-1920s, growing swiftly all the way to 1939 when the Winter War began. Olle Krantz has considered this interwar period as the Finnish take-off period.[221] Similarily, after WWII, the stock of human capital by schooling started to grow substantially only after 1952 and especially from the mid-1950s onwards. GDP per capita at constant prices begins its fastest growth after this. The simultaneous timing of the growth of human capital by schooling in respect to GDP variables in the Golden Years of Finnish growth after the 1950s is obvious.

Figure 3.3.5 GDP, GDP per capita, human capital by schooling and human capital by schooling per capita in constant prices in 1877–2000.



Source: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Statistical yearbooks 1880–1975, National Accounts publications: 1948–1965 and database of Finland 1975–; Statistics of the financial statements of municipalities and joint municipal authorities; *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

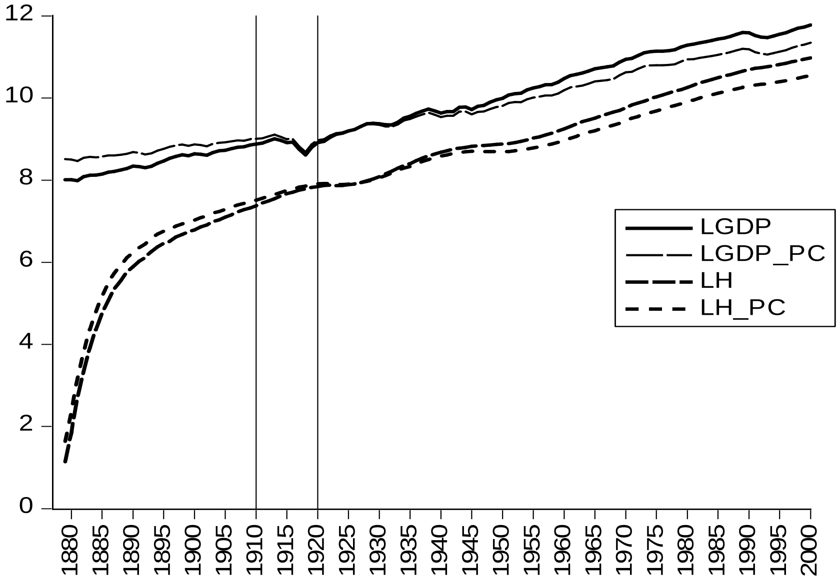
In turn from Figure 3.3.6, with the variables in logarithmic form, the fact that the accumulation of the stock has been started from zero in 1877 can be observed. Indeed, the aim here in gathering education expenditures as far back as possible was to avoid the problem of the initial value of the stock. However, the accumulation of the stock has taken approximately 20 to 30 years before the cumulated stock variable has reached its own fluctuation level.

[221] Krantz, Olle (2001). Industrialisation in Three Nordic Countries: A Long-Term Quantitative View. In *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940*. Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters, 2001, pp. 23 – 65.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Therefore, the long-run connection of economic growth and the stock of human capital by schooling is to be studied later only as late as in 1910–2000, 1920–2000 and 1946–2000. From Figure 3.3.2 it can be observed that the volume of the expenditures in formal education have been such dramatically small in 1877s that the expenditures before that cannot be thought plausibly have affected enormously the accumulated stock in 1910 and in 1920 (or in 1946) and onwards. Hence the stock of human capital after 1910, 1920 or 1946 should be plausible for the empirical analysis.

Figure 3.3.6 GDP, GDP per capita, human capital by schooling and human capital by schooling per capita, constant prices in 1877–2000, logarithmic (LN) scale.



Source: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; Statistics Finland; Statistical yearbooks 1880–1975, National Accounts publications: 1948–1965 and database of Finland 1975–; Statistics of the financial statements of municipalities and joint municipal authorities, *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

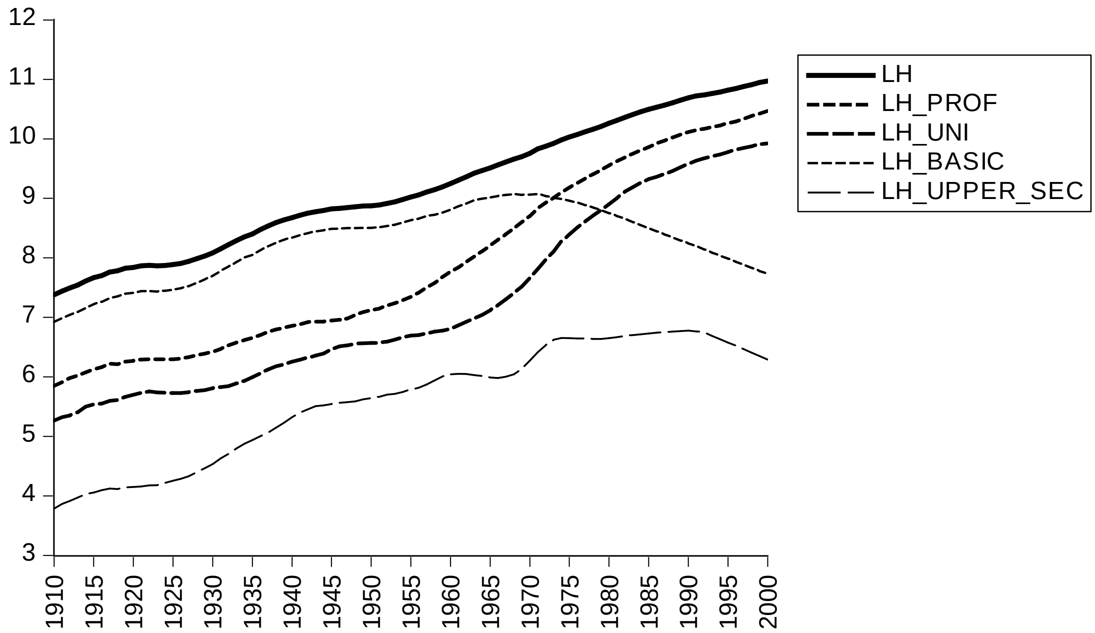
The evolution of the human capital stocks by types of schooling deployable in the labour markets can be seen in Figure 3.3.7 in logarithmic form. The levels and evolutions of the stocks by each type of education reveal the changes in the composition of human capital and they are associated with all of the accumulated education expenditure volumes used by the number of people up to their highest education.

As in Figure 3.3.4, people with basic education in the working ages, referring here to primary (6^{th} class) and lower secondary education, has been the dominating the total stock up to the 1960s and early 1970s. After that the impact of the basic education stock on the total stock has declined rapidly. The depreciation and retirement of the older vintages of the stock

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

has begun first to equal and later to exceed the decreasing number of new people entering the labour markets with only this education at hand. Similarly, the upper secondary human capital stock in the working age population gave first signs of its decline first in the 1960s and later especially in the 1990s. In the 1960s, the expansion of the professional schools increased possibilities to choose professional education instead of gymnasium. However, after the comprehensive school reform in the 1970s the demand for higher education increased and more and more pupils wanted to get the matriculation certificate. Nevertheless, continuously a bigger part of them continued further to universities and also to higher professional education. Finally, in the 1990s the depreciation and the retirement effects of the older vintages exceeded the cumulated education expenditures of the diminishing part of the upper secondary graduates entering the population in the working ages.

Figure 3.3.7 The composition of human capital by schooling in the population in the working ages in Finland in 1910 – 2000.



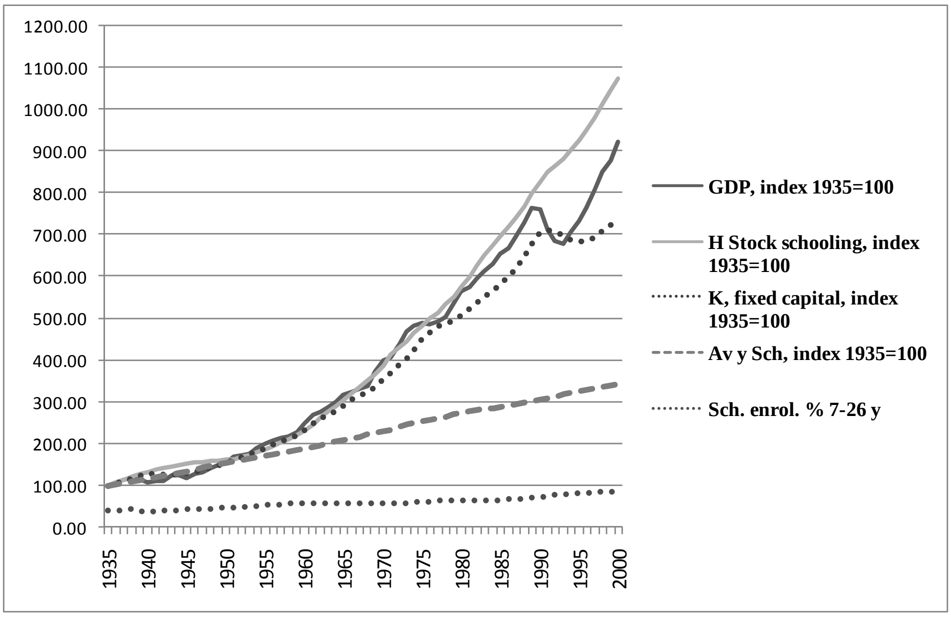
Source: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; statistics on financial accounts of the state, Statistical yearbooks 1879–1975, Statistics Finland; National Accounts publications: 1948–1965 and database of National Accounts 1975–; Statistics of the financial statements of municipalities and joint municipal authorities, *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

In the total stock these changes have been more than compensated with the boost in the number of people entering the labour markets with professional and university education. The growth of the professional education stock began to speed up substantially around 1960 and

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

especially after 1965. From 1965 to 2000 the professional and university education stocks have increased the most compared with the previous history. Interestingly enough, Finland did not catch-up the rapidly growing Sweden in 1945–1965, but only after 1965. Up to 1961, this same time period can be characterised as one of the most inward oriented period with respect to other economies since the independence in 1917, as Finland had to carefully build the peace time relationship with the Soviet Union including the war remunerations ordered to Finland.[222] Later the dominance of primary education in the Finnish labour market has dramatically changed to the dominance of professional and university education towards the end of the 20th century – the age of Finland's ICT revolution. At the same time, the Finnish economy was opened up and integrated to Western European markets.[223] Thinking of the possibilities for exploiting fully the potential gains from integration and implementing new technologies, in terms of human capital, Finland seems to have been ready to the integration process in the 1990s.

Figure 3.3 Finland 1935–2000: Real GDP (constant 2000 ref. year Millions of Euro), Intangible Human Capital stock by schooling, fixed capital, average years of schooling in the working age population (16–64), school enrolment % at the ages 7–26. NB: all variables except school enrolment ratio are expressed in index form, 1935=100.



Source: own calculations, see data sources in Main Data Sources and in the DATA APPENDICES.

[222] Cf., Paavonen, Tapani (1998). *Suomalaisen protektionismin viimeinen vaihe*. Suomen Historiallinen Seura. Historiallisia Tutkimuksia 198, Helsinki.
[223] Cf., Paavonen, Tapani (2008). *Vapaakauppaintegraation kausi. Suomen suhde Länsi-Euroopan integraatioon FINN-EFTAsta EC-vapaakauppaan.* Suomalaisen Kirjallisuuden Seura. Historiallisia Tutkimuksia 235, Helsinki.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Finally, Figure 3.3 depicts the evolution of the National Accounts estimate on intangible human capital by schooling in this study for Finland in 1935–2000 together with real standard GDP, physical capital and the conventional schooling measures (the average years of schooling in 16–64 year-old population, school enrolment ratio at the ages 7–26 for Finland). As discussed above, the estimate for human capital by schooling is formed through accumulated volume of monetary inputs in education in accordance with a modified system of National Accounts including human capital by schooling in which the GDP does not have to change. Therefore, ultimately, in this case the conventional measures and the National Accounts estimate can be compared with the same standard GDP, which makes the examination exact. Intangible human capital by schooling through the volume of accumulated costs based on paid transactions on education is growing exponentially and very similarly to GDP, while average years of schooling and school enrolment ratio are not.

The growth theory models aim to reflect the empirical reality. The linear growth of average years of schooling is likely at least one of the reasons why the human capital variable often enters with an exponential structure in various growth models. In empirical studies, an exponential transformation for the average years of schooling at working ages, e.g. in accordance with Mincerian equations, has been carried out for receiving an estimate for human capital.[224] In the time series studies, GDP and physical capital have been log-linearised while average years of schooling not, referring again to an exponential transformation on the schooling variable in a non-logarithmic form (see, e.g. Self and Grabowski 2003)[225]. However, without a similar transformation in the other core variables, GDP and physical capital, this refers implicitly to increasing returns to schooling itself in the production of GDP. With an estimate in the National Accounts frame (by Kendrick, by J-F or by the proposed method in this study) this type of transformation does not seem to be needed. Therefore, the human capital variable assessed in the National Accounts can probably be entered straight-forwardly in the production function, without any assumptions. This can be seen as a first feedback for theory models of assessing human capital in the National Accounts frame.

The National Accounts measure for human capital grows exponentially in the long run as the standard GDP does, with exhibiting an evolution much more similar to GDP than

---

[224] For instance, in the form $H = e^{\phi u}L$. In this formulation u is the fraction of an individual's time spent learning skills, approximated, e.g. by average years of schooling, and ϕ is a positive constant, in turn approximated by an overall average wage increase rate for an additional year of schooling (e.g. 0.10) in accordance with Mincerian equations. (See, e.g. Jones 2002, pp. 54–56, Bils and Klenow 2000).

[225] Self, Sharmistha and Grabowski, Richard (2003). Education and long-run development in Japan. *Journal of Asian Economics*, 14 (2003), pp. 565–580.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

the conventional measures. Therefore, assessing human capital in the National Accounts might suggest: 1) Human Capital could have a more straight-forward relationship with standard GDP than assessed with average years of schooling in the working age population. The exponential structure of H in entering the production function might not be needed with a National Accounts estimate. 2) There seems to be a long-run steady state equilibrium relationship between the evolution of human capital and GDP, and possibly also with the exponentially growing physical capital. 3) Human capital could get a higher weight in explaining the evolution of standard GDP than what the conventional measures have suggested. Together with physical capital, the unexplained residual, multifactor productivity or the Solow residual could be diminished significantly in the production function. These suggestions will be econometrically tested in Chapter 4 with the data for Finland in 1910–2000, as the variable for intangible human capital by schooling was constructed in the National Accounts frame for Finland in such a way that the standard GDP did not change. In the next section the focus is first on the possible long-run relation of the proposed measure for human capital per capita in this study with standard GDP per capita.

3.3.2 The long-run relation of GDP per capita and human capital by schooling per capita

The possible long-run relation of human capital by schooling and economic growth is explored in this section by cointegration analysis. It is perhaps not reasonable to expect that education has an instant effect on economic growth. Accumulating human capital by formal education takes time. The students are not participating in the production of national income, i.e. they are not earning wages or salaries which are part of the incomes generated in the production and accounted to GDP.[226] Therefore, one would expect that in the long-run the accumulated human capital and average income levels would rather be candidates for having a relation with each other. The long-run relation was tested from 1910, 1920 and 1946 onwards, because as mentioned before, the accumulation of the human capital stock by schooling was initiated from zero in 1877. The stock has reached its own fluctuation level at least around these years (cf. Figure 3.3.4) and hence the testing of the long-run relation with

[226] The subsidies from the state (either a direct monetary subsidy or a subsidy for interests on study loans from the state) are social transfers from general government to the household sector recorded in the institutional sector accounts in the SNA. They are not included in production and GDP.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

parameter estimates is not expected to be violated. The cointegration approach is used, because it is particularly designed for the analysis of interaction of the levels of the variables in the long run.

The economic variables are often non-stationary as are the variables in this analysis. When wishing to regress the levels of non-stationary time series, for avoiding spurious regression results, the cointegration of the variables has to be ensured. If two non-stationary variables do cointegrate, there is a long-run equilibrium between the variables. The variables share a common stochastic trend and they cannot depart from each other for a long time. When a shock occurs to one of the variables, at least one of the variables adjusts in the following periods so that the equilibrium in their development is sustained. However, cointegration is a strong condition: The linear combination of non-stationary time series is non-stationary in general. Cointegration is defined as a special case where the linear combination of such series is stationary. This implies that there exists an error correction representation of how the equilibrium between the variables is sustained.

The variables under review – GDP per capita and human capital per capita – are integrated of order one, which means that the first differences of them are stationary. This enabled an *I(1)*-analysis in the cointegration framework. The vector error correction model to be analysed has the following form[227]:

$$\boldsymbol{\Delta x_t = \alpha\beta' x_{t-1} + \Gamma\Delta x_{t-1} + \mu + \Phi D_t + \alpha\beta_0' t + \varepsilon_t} , \qquad \varepsilon_t \sim iid \ N_p(0, \Omega) \qquad (3.3.2.1),$$

where $\mathbf{x_t} = (y_t, h_t)'$, with small letters referring to a variable divided by population index and expressed in natural logarithms (e.g. y_t is LN [GDP/(population index/100)]), μ is a vector of constants, t is a possible time trend restricted to cointegration relation. The transposed vector ***β'*** includes the long-run cointegration coefficients and the vector **α** adjustment coefficients for the variables under review. Together **α** ***β'*** is referred to as **Π**-matrix defining the common trend(s) and stationary cointegration relations in the model. In the case of *I(1)*-analysis the rank of the coefficient matrix **Π** can be used to test and to determine the number of cointegration relations (which is the rank, *r*) in the dynamic system and the number of unit roots or common trends (in the analysis with p variables, the number of variables minus the rank of **Π**; $p - r$).

[227] See, for instance, Dennis, J.G., Hansen H., Johansen S. and Juselius K. (2005). *CATS in RATS, version 2*, Estima 2005.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Let us open the above notation with the variables in the following analysis (two variables y_t, h_t; p=2, *I(1)*). When r=1, $\mathbf{\Pi x_{t-1}}$ is given by

$$\mathbf{\Pi x_{t-1}} = \alpha\beta'\mathbf{x_{t-1}} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \left(\beta_1 y_{t-1} + \beta_2 h_{t-1} \right) = \begin{pmatrix} \alpha_1(\beta_1 y_{t-1} + \beta_2 h_{t-1}) \\ \alpha_2(\beta_1 y_{t-1} + \beta_2 h_{t-1}) \end{pmatrix}$$

It is often useful to normalise by the coefficient of one of the variables. If we normalise on y_t:

$$\Pi\mathbf{x_{t-1}} = \alpha\beta'\mathbf{x_{t-1}} = \begin{pmatrix} \alpha_1\beta_1(y_{t-1} + \frac{\beta_2}{\beta_1} h_{t-1}) \\ \alpha_2\beta_1(y_{t-1} + \frac{\beta_2}{\beta_1} h_{t-1}) \end{pmatrix} = \begin{pmatrix} \overline{\alpha}_1(y_{t-1} + \overline{\beta}_2 h_{t-1}) \\ \overline{\alpha}_2(y_{t-1} + \overline{\beta}_2 h_{t-1}) \end{pmatrix}$$

With normalising the cointegration relation on y_t and opening up the matrix notation for the whole VECM-model, we will get to a system of two equations. The whole vector error correction model is then given as:

$$\begin{cases} \Delta y_t = \overline{\alpha_1}(y_{t-1} + \overline{\beta_2} h_{t-1}) + \Gamma_{11}\Delta y_{t-1} + \Gamma_{12}\Delta y_{t-2} + \Gamma_{13}\Delta h_{t-1} + \Gamma_{14}\Delta h_{t-2} + \varepsilon_{1t} \\ \Delta h_t = \overline{\alpha_2}(y_{t-1} + \overline{\beta_2} h_{t-1}) + \Gamma_{21}\Delta y_{t-1} + \Gamma_{22}\Delta y_{t-2} + \Gamma_{23}\Delta h_{t-1} + \Gamma_{24}\Delta h_{t-2} + \varepsilon_{2t} \end{cases} \quad (3.3.2.2),$$

where $\overline{\alpha_i}(y_{t-1} + \overline{\beta_2} h_{t-1})$, *i=1,2* is the cointegration relation for each of the variables. The cointegration relation in 3.3.2.2 is stationary, which is why it is often interpreted as the long-run equilibrium for the levels $\mathbf{x_t} = (y_t \;\; h_t)'$. If $\beta'\mathbf{x_t} \neq 0$, it is interpreted as a long-run disequilibrium error and for fixed lags, the loading $\overline{\alpha}_i$ captures its effect on each of the variables (y_t and h_t). In 3.3.2.2 the growth of GDP per capita (Δy_t) and the growth of human capital per capita (Δh_t) are explained I) by the stationary cointegration relation of y_t with human capital by schooling per capita and II) by the two lagged differenced values of y_t and human capital per capita.

The parameters α_1 and α_2 are called adjustment parameters for telling how the system adjusts to the equilibrium. With them the direction of Granger causality in the long run can be tested as well. In the case of two variables for y_t to error correct it is often required

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

that $\alpha_1 < 0$, and for h_t to error correct $\alpha_2 > 0$. If both of them are statistically significant, both of the variables adjust to maintain the long-run equilibrium. If one of them is not significant while the other is, the latter adjusts to the shocks of the other but not vice versa.

Table 3.3.2: Cointegration test and VECM estimation results

	1910-2000	1920-2000	1946-2000
Trace test: "No co-int.relations", p-value	0.003**	0.003**	0.000**
Trace test: "At most one co-int.relation", p-value	0.89	0.60	0.22
Max Eig.val. Test: "No co-int.relations", p-value	0.0019**	0.002**	0.000**
Max Eig.val. Test: "At most one co-int.relation", p-value	0.89	0.60	0.22
β_2 [T-value]	-0.86 [-36.4]	-0.85 [-33.7]	-0.75 [-48.0]
α_1 (for y_t) [T-value]	-0.04 [-1.1]	-0.03 [-0.8]	-0.23 [-3.3]
α_2 (for h_t) [T-value]	0.043 [4.7]	0.046 [4.8]	0.06 [3.3]
Residual Joint Normality (J-B)	0.62	0.37	0.26
Residual autocorr. (LM (1-4), α=0.05)	-	-	-
DUMS:		NO	NO
Transitory Dum 1917-1919	Y		
Permanent Impulse Dum 1918	Y		

The cointegration test results together with the most important vector error correction model estimation results for the long-run analysis are shown in the Table 3.3.2. The unrestricted cointegration rank tests (trace test and maximum eigenvalue test) were carried out for the time periods 1910–2000, 1920–2000 and 1946–2000[228]. The cointegration rank test results are shown in the first four rows in the Table 3.3.1. The hypothesis of “no cointegration relations” was statistically highly significantly rejected for all of the time periods in accordance with both cointegration rank tests, and the hypothesis for “at most one cointegration relation” was clearly accepted. In the first period the cointegration was tested first without dummies (p-value 0.001** for “no cointegration relations” and *p*-value 0.62 for “at most 1 relation”), but for the requirement of the residual normality a transitory intervention dummy was used for the WWI and civil war period 1917–19 (at 1917: -1 and at 1919: 1) and a permanent impulse

[228] This estimation was done in the context of the Johansen approach in EViews 6. Cf. Johansen, S. (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, 2nd. edn*., Advanced Texts in Econometrics, Oxford University Press: Oxford; Juselius, K. (2006) *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*. Advanced Texts in Econometrics, Oxford University Press: Oxford.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

dummy for the actual civil war year 1918 in Finland. In other periods no dummies were needed as the residuals of the system were normally distributed with no autocorrelation on the first four lags.

When exactly one cointegration relation between GDP per capita and human capital by schooling per capita was detected, the VECM system shown in 3.3.2.2 (with a constant in the cointegration relation and with two differenced lags on y_t and h_t) was estimated for each time period. Table 3.3.2 summarises the most important estimated coefficients with T-values in brackets. The coefficient (β_2) for human capital in the cointegration relation of the levels of y_t and h_t in the previous year (t-1) is obviously highly significant with parameter values around -0.85 in the first two estimation periods and -0.75 in the last estimation period. After the feasibility of cointegration in the vector error correction model has been corroborated with all of the above results, it is possible to move on to perhaps the most interesting part of the analysis: how have y_t and h_t been adjusting to the shocks in each other in order to get back to the equilibrium between them. This can be studied with the alpha coefficients and with impulse-response function analysis.

As can be seen from Table 3.3.2, the alpha coefficients have their expected signs in all of the estimation periods. Interestingly, in the first two estimation periods only the adjustment coefficient for human capital, α_2, is statistically significant. This means that only human capital by schooling in the population has adjusted to the shocks in GDP per capita (with a speed of 4.3% of a deviation of the equilibrium in every period estimated in the first time frame (with a speed of 4.6% in the second estimation period)). The Granger-causality seems to have run from average income levels to human capital by formal education. The possible way to interpret this would be the more the average income levels have grown, the more there has been money to put into education and/or the more the average income level has risen the more the demand for education has grown.

However, in the estimation period after WWII both of the alphas have been statistically highly significant, revealing that both of the variables have adjusted to the shocks in the other: α_1 has now the estimated value of -0.23 referring to GDP per capita adjusting to the shocks in human capital by schooling in the population with quite a rapid speed of 23% in every year, while human capital by schooling is adjusting much more slowly with a pace of 6% a year.

The change in the response of GDP per capita to human capital by schooling per capita in the system can be detected from the impulse-response functions as well in Figure

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.3.7. An impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables: A shock to the *i*-th variable not only directly affects the *i*-th variable but is also transmitted to all of the other endogenous variables through the dynamic (lag) structure of the VAR. Figure 3.3.7 reveals that the response of y_t to one unit innovation in h_t has been obviously smaller than to its own innovation when the early years are included in the estimation (the upper part of the left hand figure). Instead when focusing on the period after WWII, the response of GDP per capita to one unit innovation in h_t has turned to be much bigger than a response to its own innovation (the upper part of the left hand figure). The lower parts of the figures show that human capital by schooling is increasing with both an increase in y_t and in itself, with the response on its own innovation being bigger in the post-war estimation period as well.

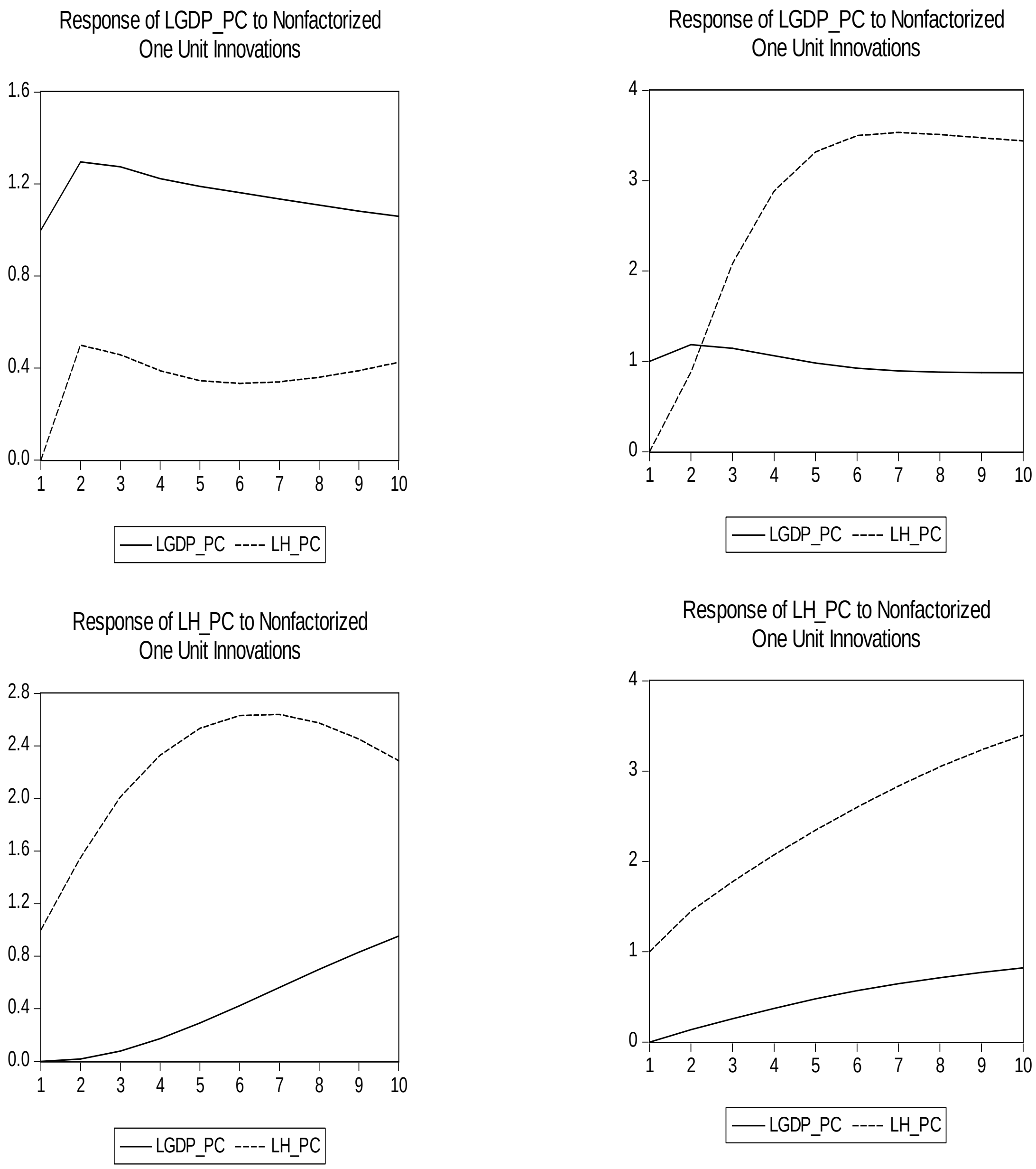
The timing corresponds with the educational expansion in Finland, since especially the professional and university education began to boost up from the 1950s and particularly from 1960s onwards with an accelerating speed towards the end of 20th century, when in practice almost all of the graduates from the schooling system have either a professional or a university degree when entering the labour markets. Before WWII perhaps the biggest concern was to get a reasonably long basic education financed and available to all of the citizens particularly in the rural areas. The econometric results above seem to be in line with this fact.

According to the results of the analysis above the importance of human capital by schooling in the economic development of Finland has noticeably increased after WWII and the interaction between y_t and h_t has transformed into a simultaneous and endogenous development, where human capital is affecting both the development of GDP per capita and the development of its own. However, human capital by schooling adjusts slowly to changes in GDP per capita as well. In accordance with the analysis on these two variables, economic development and human capital seem to enhance the development of each other in the advanced stage of the economic development. Before reaching this stage of the development and this level of human capital, the growth in average incomes has enhanced the growth of human capital, but not vice versa. It is worth noticing, though, that the effects of human capital interacting together with physical capital remain unknown in the analysis so far.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure 3.3.7 Impulse-response graphs for 1920–2000 (on the left) and 1946–2000 (on the right), estimated in EViews6.

1920–2000: **1946–2000:**



Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

3.4 Conclusions

The aim of Chapter 3 of this study was to explore whether the considerable input in education has had a connection to the dramatically changed economic performance in Finland in the 20th century.

In this study the investment flow series of human capital by schooling in 1877–2000 and the stock of intangible human capital by schooling were formed for Finland in the 20th century inside the systematic National Accounts frame. The advantage of this approach is that investments are valued in monetary terms as GDP and physical capital and they have a logical connection to GDP and to other variables in the National Accounts. It is worth noticing as well that the empirical counterparts of the core variables in the growth theories (GDP, physical capital and hours worked) come from the National Accounts. However, this brings changes to the National Accounts, since human capital is not included inside the asset boundary in the international System of National Accounts 1993.

In the two best-known earlier presented systems of this kind, the level and evolution of GDP also changed (partly due to broader concepts of human capital). In this study, the focus was on the human capital by formal education and on the actual monetary flows paid for them. This enabled to introduce a system of production where the accumulation of intangible human capital by schooling can be estimated inside the National Accounts without changing GDP, and to test the long-run relation with accumulated inputs in education and the standard GDP per capita. In fact, the SNA93 (par 1.57) implies the same kind of system as in this study by stating ”*The decision whether to classify certain types of expenditure by households or government, such as education or health services, as final consumption expenditures or gross fixed capital formation does not affect the size of GDP, as both are final expenditures*.” Following this statement, the analysis could be broadened to cover health (and social, etc.) expenditures as investments in human capital as well. The analysis here is done for Finland but following the same lines of thought, a similar approach could be done for any other country, since in the SNA all monetary flows in the economy should already have been traced – also the monetary flow invested in the education of citizens.

The inclusion of investments in (or gross capital formation of) human capital by formal education changed the National Accounts of Finland in this thesis. Using the annual final education consumption expenditures as investments in education resulted in that they have varied from 1% to 5% in relation to GDP at current prices in Finland in peacetime,

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

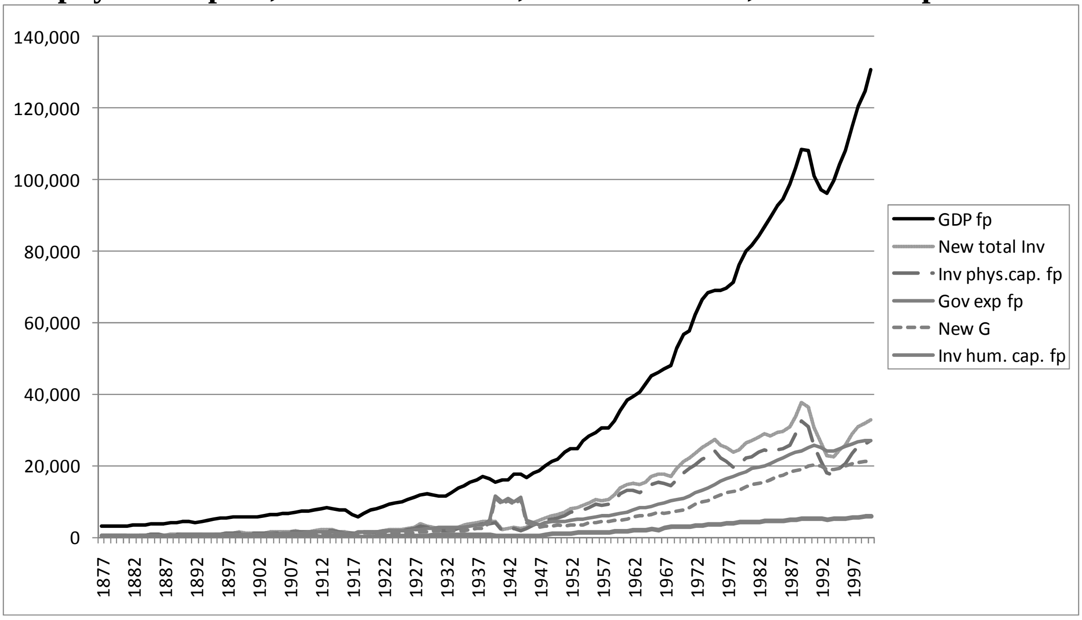
1877–2000. For comparison, the relation of investments in physical capital to GDP has varied at current prices between 10% and 33%. According to these calculations, Finland has invested more in total, and the new investment ratio (including investments in physical capital and in intangible human capital by schooling) of GDP at current prices has ranged between 11% and 37%. Investments in physical capital have grown, on average, by 3.3% a year and investments in education at a higher 3.9% rate a year, on average, in 1877 to 2000. However, investments in physical capital formed 90% in the early years and in the late years still around 80% of the total investments and therefore the level of annual investments in physical capital has been substantially higher in the modified system.

The long-run relation of human capital by schooling and economic performance in Finland was tested with cointegration analysis in the VAR framework. First, the cointegration between GDP per capita and human capital stock by schooling per capita was tested by the Johansen approach in a vector error correction system in 1910–2000, 1920–2000 and 1946–2000. The results showed that the variables are statistically highly significantly co-integrated. Secondly, a vector equilibrium correction model (by Johansen, originally by the Nobel prize winners Engel and Granger) between GDP per capita and human capital stock by schooling per capita was estimated in the time periods mentioned to analyse how the variables adjust to the long-term equilibrium between them. Based on the analysis of the two mentioned variables, the results suggest that when the early stage of economic development was included in the first two estimation periods, only human capital per capita was adjusting to the deviations from the equilibrium in the development of the variables. With the more advanced stage of economic development in 1946 –2000, both of the variables have been adjusting to the shocks in the other. GDP per capita was adjusting to the shocks in human capital by schooling in the population with a rapid speed of 23% every year, while human capital by schooling was adjusting much more slowly with a pace of 6% a year. The change in the response of GDP per capita to human capital per capita in 1946–2000 was detected with the impulse-response function analysis as well. The results showed that after WWII, the response of GDP per capita to an innovation in human capital by schooling has turned to be much bigger than a response to its own innovation. At the same time, human capital has been growing with both an increase in GDP per capita and in itself, but the response on its own innovation has been bigger. What remains so far not studied, is the interaction of human and physical capital, and their impact together on economic growth. This will be explored in the next chapter.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

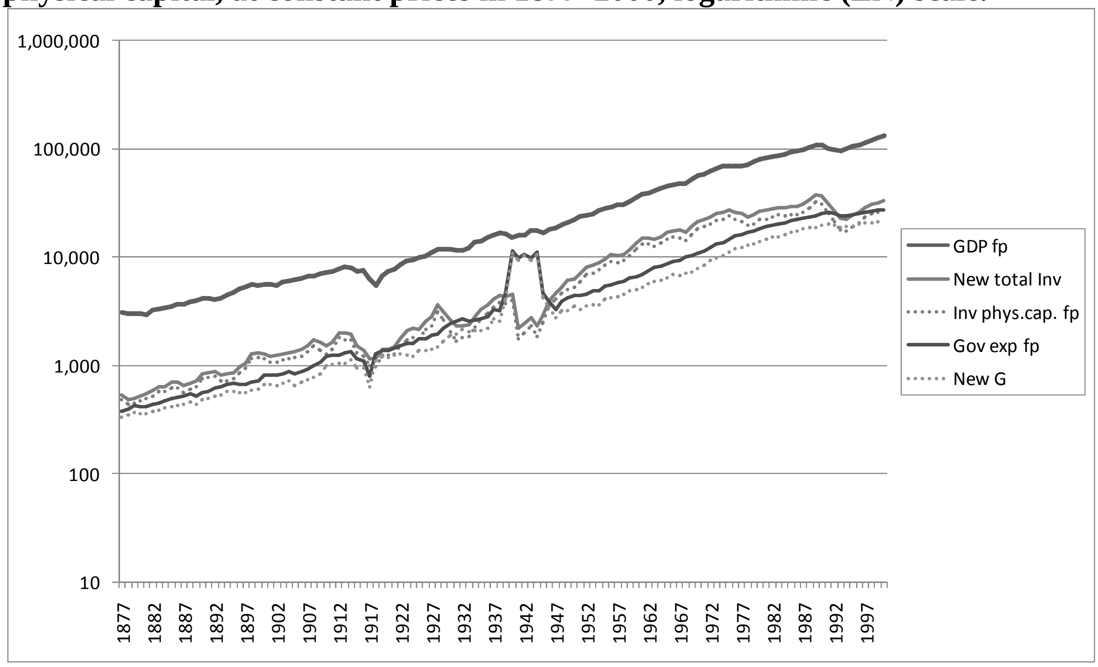
APPENDIX 3.1 The changes in the National Accounts main aggregates at constant prices

Figure 1: GDP, old and new general government expenditures, investments in human and physical capital, total investments, millions of euro, at constant prices in 1877–2000.



Source: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; statistics on financial accounts of the state, Statistical yearbooks 1879–1975, Statistics Finland; National Accounts publications: 1948–1965 and database of Finland 1975–, Statistics of the financial statements of municipalities and joint municipal authorities; *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

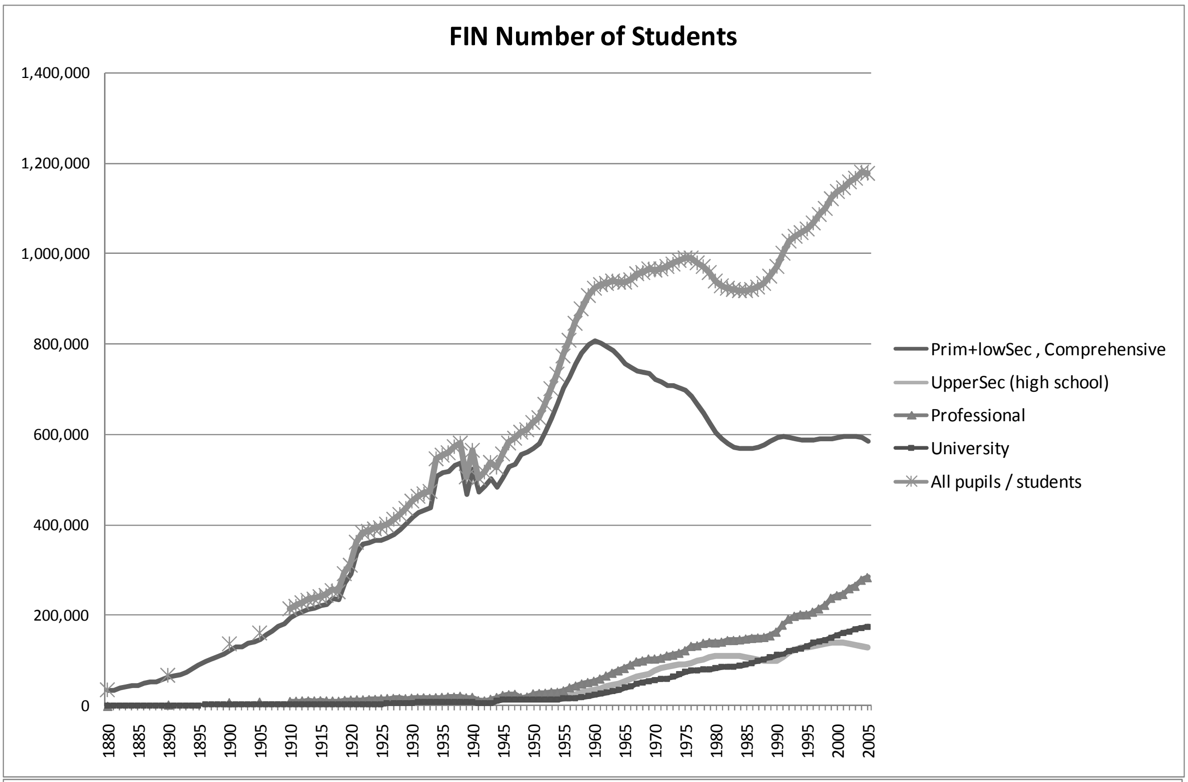
Figure 2: GDP, new total investments, investments in human capital by schooling and in physical capital, at constant prices in 1877–2000, logarithmic (LN) scale.

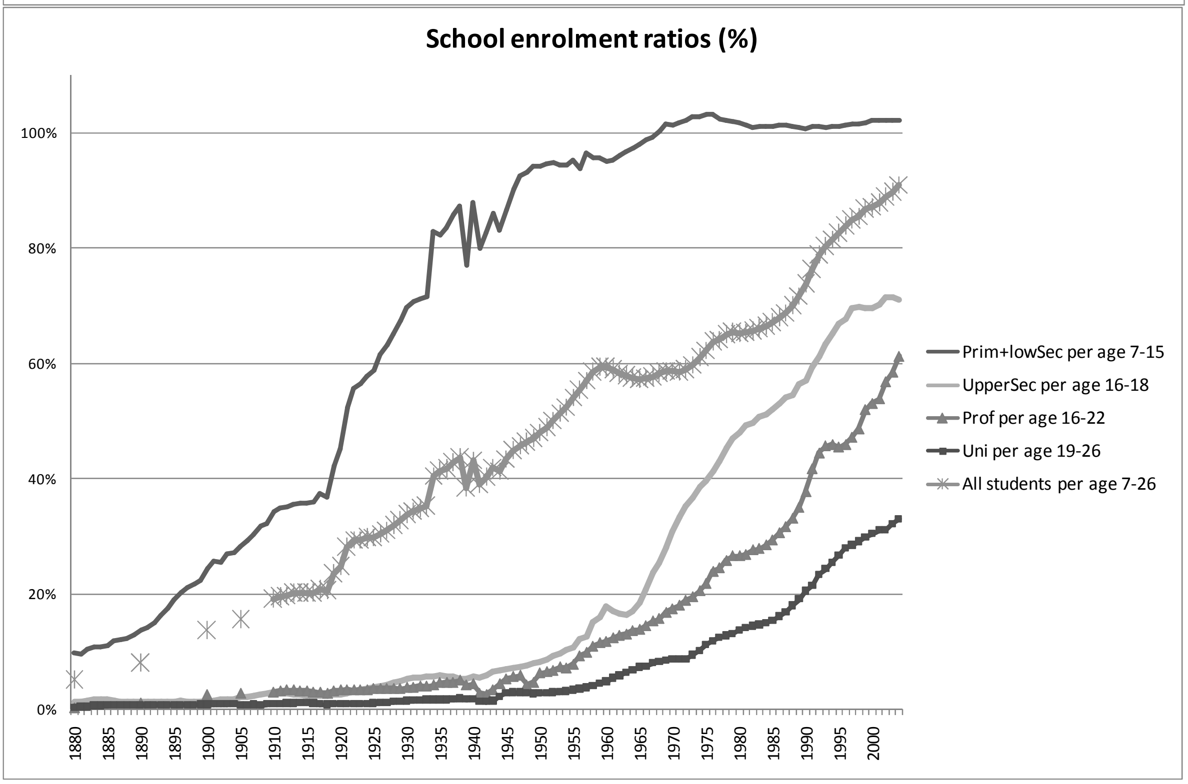


Source: Own calculations; data from Hjerppe, Finland's Historical National Accounts 1860–1994; statistics on financial accounts of the state, Statistical yearbooks 1879–1975, Statistics Finland; National Accounts publications: 1948–1965 and database of Finland 1975–, Statistics of the financial statements of municipalities and joint municipal authorities; *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

APPENDIX 3.2 Graphs on the number of students and on school enrolment ratios in 1880–2005





Source: Own calculations; data from Statistics Finland, Statistical yearbooks 1880–, Official Statistics of Finland (SVT): Educational Institutions 1971–2009; Havén Heikki (Ed.), Education in Finland, SVT 1998:1; Population Statistics; Kivinen, Osmo (1988), *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini Suomessa 1800- ja 1900-luvuilla.* Turun yliopisto, Annales Universitatis Turkuensis, 68, Turku; Klemelä, Kirsi (1999), *Ammattikunnista ammatillisiin oppilaitoksiin: ammatillisen koulutuksen muotoutuminen Suomessa 1800-luvun alusta 1990-luvulle*, Turun yliopisto, Koulutussosiologisen tutkimuskeskuksen raportti 48, Turku.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

APPENDIX 3.3 The adjustment of human capital stock for wars and migration

Figure 1. The stock of human capital by education before (Log H) and after (Log H wars and migration) the adjustment for people deceased in wars and for migration, in natural logarithms in 1890–2000.

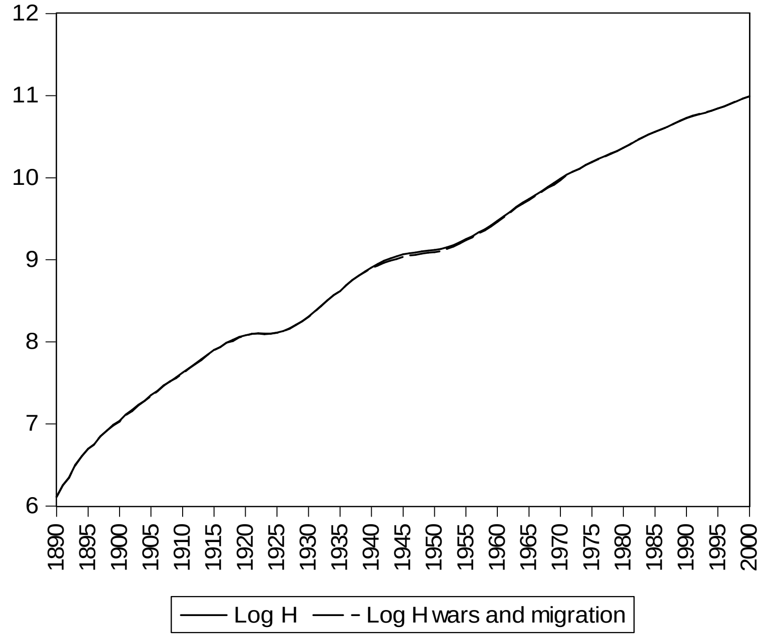
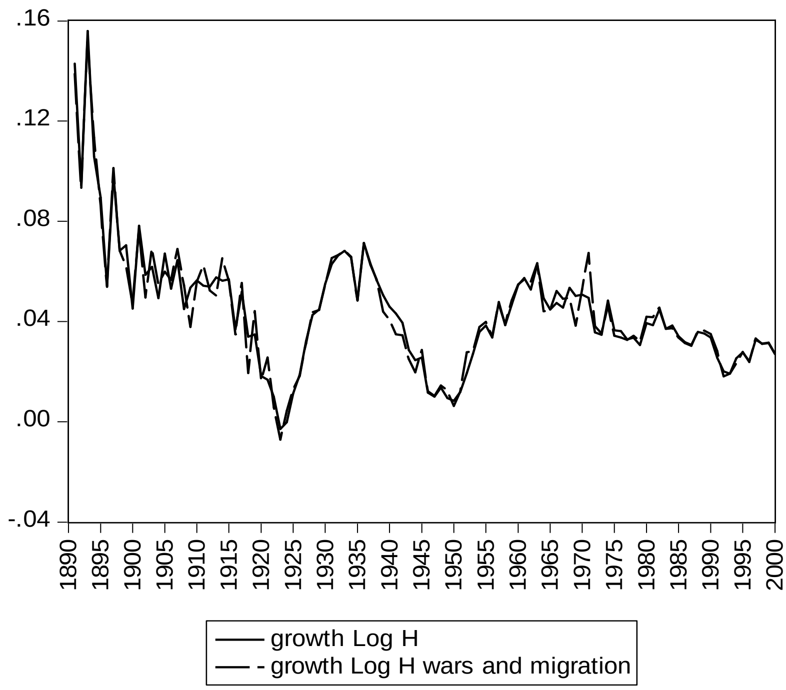


Figure 2. The growth rate of the stock of human capital by education before (Log H) and after (Log H wars and migration) the adjustment for people deceased in wars and for migration, growth in natural logarithms in 1890–2000.



Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.1 General government final consumption expenditures on education 1975–2000

A) General government final consumption expenditures on education in the National Accounts 1975–2000. B) General government consumption expenditures by purpose, education, in the National Accounts 1948–1975, EUR million at current prices.

Source: 1975–2000: National Accounts database, Statistics Finland, Jan 2006; 1948–1975 Finland's National Accounts 1948–64, Tilastollisia tiedonantoja 43. Statistics Finland; National Accounts 1964–77. KT 1978:7, Statistics Finland from the book *Suomen taloushistoria 3. Historiallinen tilasto*. (1983) (in Finnish: Finland's economic history 3, Historical Statistics) (Ed.) Kaarina Vattula. Tammi, Helsinki 1983.

A)

	Central government			**Local government**		
	Universities and resesearch	Universities and research 2000p		Basic, secondary, professional	Basic, secondary, professional 2000p	implicit p index 2000=100
1975	193	831		559	2665	21.0
1976	228	859		689	2874	24.0
1977	226	800		798	3076	25.9
1978	242	806		887	3254	27.3
1979	276	841		990	3332	29.7
1980	312	864		1124	3384	33.2
1981	367	908		1299	3473	37.4
1982	433	969		1437	3399	42.3
1983	497	1022		1619	3437	47.1
1984	547	1051		1762	3423	51.5
1985	610	1076		1989	3526	56.4
1986	632	1068		2232	3666	60.9
1987	713	1126		2438	3796	64.2
1988	814	1169		2685	3881	69.2
1989	883	1192		2963	3987	74.3
1990	977	1235		3229	4052	79.7
1991	1122	1303		3366	4014	83.9
1992	1113	1261		3342	3894	85.8
1993	1003	1148		3383	3866	87.5
1994	1007	1145		3473	3939	88.2
1995	1142	1278		3711	4072	91.1
1996	1135	1238		3802	4089	93.0
1997	1175	1261		3949	4255	92.8
1998	1303	1353		4103	4320	95.0
1999	1411	1461		4239	4365	97.1
2000	1479	1479		4394	4394	100.0

B)

	Education expenditure
1948	91.7
1949	112.1
1950	157.5
1951	220.4
1952	258.8
1953	285.3
1954	296.7
1955	350.8
1956	424.0
1957	476.3
1958	534.0
1959	595.1
1960	634.5
1961	714.8
1962	823.8
1963	915.7
1964	1,046.6

	Education expenditure
1965	1,149.1
1966	1,291.1
1967	1,505.2
1968	1,746.2
1969	1,898.0
1970	2,089.5
1971	2,414.8
1972	2,802.1
1973	3,323.0
1974	4,308.0
1975	5,596.8

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.2 Wages by type of education, local government sector, 1975–2000

Wages and salaries by type of education, local government 1975–2000, EUR thousand at current prices.

Source: Statistics on financial statements of municipalities and joint municipal authorities, database, Statistics Finland 2006.

	Local government			
	Basic educ	Upper Sec	Professional	Polytechnics
1975	247.756	33.446	25.508	
1976	303.529	44.193	30.729	
1977	345.494	50.005	34.326	
1978	371.526	55.145	37.812	
1979	419.392	63.592	43.123	
1980	470.590	74.364	48.718	
1981	535.879	86.236	56.241	
1982	600.471	102.570	66.077	
1983	674.637	120.600	77.868	
1984	726.274	134.023	88.229	
1985	802.936	148.540	98.779	
1986	915.415	157.704	111.079	
1987	986.446	166.074	122.119	
1988	1088.668	184.092	139.808	
1989	1188.836	199.276	158.985	
1990	1276.631	212.648	176.535	
1991	1340.685	221.551	193.752	
1992	1310.837	225.147	196.897	
1993	1218.356	216.109	347.754	
1994	1201.758	218.676	346.337	
1995	1257.958	231.365	438.325	
1996	1292.666	242.774	543.630	
1997	1308.587	248.660	521.699	83.2
1998	1341.177	254.240	482.620	148.4
1999	1384.907	260.083	470.616	183.6
2000	1421.987	269.992	459.647	206.3

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.3 Final consumption expenditure by type of education 1975–2000

A) Education final consumption expenditure by type of schooling 1975–2000, EUR mil.

	Local government, Basic & secondary	Local government, Professional	Central government, University, research	Total Educ exp
1975	513	46	193	752
1976	633	56	228	917
1977	734	64	226	1024
1978	815	72	242	1129
1979	909	81	276	1266
1980	1032	92	312	1436
1981	1191	108	367	1666
1982	1314	123	433	1870
1983	1475	144	497	2116
1984	1598	164	547	2309
1985	1802	187	610	2599
1986	2023	209	632	2864
1987	2204	234	713	3151
1988	2419	266	814	3499
1989	2659	304	883	3846
1990	2887	342	977	4206
1991	2995	371	1122	4488
1992	2962	380	1113	4455
1993	2723	660	1003	4386
1994	2792	681	1007	4480
1995	2867	844	1142	4853
1996	2808	994	1135	4937
1997	2844	1105	1175	5124
1998	2940	1163	1303	5406
1999	3033	1206	1411	5650
2000	3153	1241	1479	5873

B) Education final consumption expenditure by type of schooling 1975–2000, at 2000p, EUR mil.

	Local government, Basic & secondary fp	Local government, Professional fp	Central government, University, research fp	Total Educ exp fp
1975	2443	222	831	3496
1976	2641	233	859	3733
1977	2830	246	800	3876
1978	2989	265	806	4060
1979	3059	273	841	4173
1980	3106	278	864	4248
1981	3185	288	908	4381
1982	3107	292	969	4368
1983	3130	307	1022	4459
1984	3105	318	1051	4474
1985	3194	332	1076	4602
1986	3322	344	1068	4734
1987	3432	364	1126	4922
1988	3497	384	1169	5050
1989	3577	410	1192	5179
1990	3623	429	1235	5287
1991	3571	443	1303	5317
1992	3452	442	1261	5155
1993	3112	754	1148	5014
1994	3167	772	1145	5084
1995	3146	926	1278	5350
1996	3020	1069	1238	5327
1997	3065	1190	1261	5516
1998	3096	1224	1353	5673
1999	3123	1242	1461	5826
2000	3153	1241	1479	5873

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.4 State expenditure by function, education 1967–1975

State expenditure by function 1967–1975, new FIM thousand (State accounts)
Source: Statistical Yearbooks of Finland (SYF).

		Primary schools and grammar schools	Vocational schools	Universities and other higher education
SYF 1968 XVI: 244	1967	762,000	276,000	161,000
SYF 1970 XVII: 246	1968	864,000	319,000	184,000
SYF 1970 XVII: 246	1969	938,000	346,000	236,000
SYF 1972 XVII: 240	1970	977,000	408,000	274,000
SYF 1972 XVII: 240	1971	1,057,000	481,000	327,000
SYF 1974 XVI: 229	1972	1,146,000	534,000	374,000
SYF 1974 XVI: 229	1973	1,336,000	645,000	480,000
SYF 1976 XVI: 221	1974	1,759,000	768,000	607,000
SYF 1976 XVI: 221	1975	2,154,000	779,000	772,000

DATA APPENDIX 3.5 State expenditure in education 1938–1966

State expenditure (in the final accounts of the State) by budget categories 1938–66,
Source: Statistical Yearbooks of Finland (SYF).

			Ministry of Education				Ministry of Agriculture		Ministry of Trade and Industry				
	Fmk		Universities and higher education	University of Helsinki	Secondary schools	Primary Schools	Agricultural institutes	Veterinary College	Navigation and schools for navigation	Institute of Tech-nology	Other technical instruction	Vocational training	Commercial training
SYF 1958 XV: 230	old 1000 Fmk	1938		40,543	117,489	349,715	32,388		49,473	7,852	7,069	8,898	5,950
SYF 1940 XIX: 235	old 1000 Fmk	1939		40,609	124,898	368,145	33,794		49,898	8,088	7,460	9,812	6,341
SYF 1948 XVII: 265	old 1000 Fmk	1940		39,292	109,837	324,286	30,328		57,344	7,794	6,522	8,527	6,399
SYF 1942 XX: 241	old 1000 Fmk	1941		39,638	118,141	350,203	30,977		63,307	7,835	7,366	8,939	6,498
SYF 1943 XX: 244	old 1000 Fmk	1942		40,648	127,592	401,772	33,446		106,837	8,256	6,347	11,874	6,835
SYF 1944-45 XX: 251	old 1000 Fmk	1943		50,991	155,979	526,243	35,794		85,183	13,272	9,173	16,291	9,876
SYF 1944-45 XX: 251	old 1000 Fmk	1944		91,116	194,560	582,397	44,686		89,102	15,937	11,084	24,362	14,297
SYF 1946-47 XVII: 262	old 1000 Fmk	1945		135,504	240,500	833,758	58,559		127,876	21,219	23,214	69,060	21,465
SYF 1948 XVII: 265	old 1000 Fmk	1946		124,346	283,273	1,286,776	79,526		186,788	30,154	30,553	80,008	30,239
SYF 1948 XVII: 265	old 1000 Fmk	1947		200,817	461,289	2,272,224	119,024	5,719	202,584	41,441	52,728	137,379	51,625
SYF 1950 XVII: 256	old 1000 Fmk	1948		228,667	773,836	3,753,166	201,835	8,572	339,953	71,109	95,733	200,547	94,877
SYF 1950 XVII: 256	old 1000 Fmk	1949		313,618	1,269,286	5,888,618	288,813	10,502	381,547	89,038	96,641	229,178	80,027
SYF 1952 XVII: 254	old 1000 Fmk	1950		417,307	1,630,970	6,562,583	359,633	12,067	457,419	105,575	135,112	312,021	142,508
SYF 1952 XVII: 254	old 1000 Fmk	1951		591,538	2,514,540	10,156,959	577,626	17,197	647,318	148,634	198,620	495,920	214,188
SYF 1953 XV: 230	old 1000 Fmk	1952		669,408	2,783,820	10,695,736	640,561	18,677	734,178	168,158	214,419	566,138	250,000
SYF 1954 XV: 234	old 1000 Fmk	1953		714,371	3,337,033	13,024,905	691,718	21,463	784,887	176,420	224,903	645,184	292,566
SYF 1955 XV: 236	old 1000 Fmk	1954		722,558	3,272,612	12,819,168	694,824	92,004	782,783	184,881	228,156	723,089	313,687
SYF 1956 XV: 229	old 1000 Fmk	1955		803,427	4,061,301	13,558,377	837,546	24,059	810,174	204,245	263,702	857,170	351,672
SYF 1957 XV: 231	old 1000 Fmk	1956		989,042	5,025,749	16,232,208	960,726	27,548	977,787	254,224	310,760	1,090,588	430,242
SYF 1958 XV: 230	old 1000 Fmk	1957		1,164,107	5,958,983	16,789,856	1,091,946	34,146	1,037,635	289,309	373,616	1,412,043	544,174
SYF 1959 XV: 231	old 1000 Fmk	1958		1,298,998	6,766,349	17,834,771	1,241,397	42,525	1,210,541	317,130	405,954	1,586,733	589,958
SYF 1960 XV: 232	old 1000 Fmk	1959	1,952,646		7,817,988	19,801,715	1,387,052	51,823	1,261,420	337,714	460,323	1,987,556	712,261
SYF 1961 XV: 231	old 1000 Fmk	1960	2,383,130		9,126,332	21,945,146	1,453,886	66,844	1,386,841	371,231	510,255	2,399,610	752,687
SYF 1962 XV: 234	old 1000 Fmk	1961	2,847,060		10,905,133	23,929,671	1,609,856	79,759	1,360,394	405,119	696,465	3,254,808	948,739
SYF 1963 XV: 239	new 1000 Fml	1962	35,223		131,651	265,277	19,732	997	16,002	5,168	10,359	41,063	11,967
SYF 1964 XV: 236	new 1000 Fml	1963	43,594		156,401	308,052	25,662	1,293	18,061	6,655	11,212	46,819	13,321
SYF 1965 XV: 230	new 1000 Fml	1964	51,290		180,090	338,141	27,881	1,560	21,370	7,671	14,644	55,897	16,214
SYF 1966 XV: 230	new 1000 Fml	1965	59,638		206,069	359,979	29,756	1,903	23,512	9,051	16,865	67,660	19,509
SYF 1967 XV: 229	new 1000 Fml	1966	69,870		226,893	338,471	32,653	2,203	25,903	10,967	18,345	72,325	16,738

DOI: 10.2870/35887

DATA APPENDIX 3.6 State expenditure in education 1882–1944

State expenditure (State final accounts), Old FIM 1000.

Source: Statistical Yearbooks of Finland (SYF).

		Secondary schools and Board of schools	Primary schools	Churches, University, other civilization	Total: Education and other civilisation, under Ministry of educ.
SYF 1944-45 XX: 249	1882				3,709
SYF 1920 XX: 216	1883				3,890
SYF 1920 XX: 216	1884				4,305
SYF 1944-45 XX: 249	1885				4,509
SYF 1920 XX: 216	1886				5,049
SYF 1920 XX: 216	1887	2,404	1,218	1,565	5,187
SYF 1920 XX: 216	1888	2,420	1,267	1,583	5,270
SYF 1920 XX: 216	1889	2,416	1,320	1,614	5,350
SYF 1944-45 XX: 249	1890	2,480	1,370	1,653	5,503
SYF 1920 XX: 216	1891	2,549	1,464	1,676	5,689
SYF 1920 XX: 216	1892	2,586	1,601	1,708	5,895
SYF 1920 XX: 216	1893	2,678	1,690	1,838	6,206
SYF 1920 XX: 216	1894	2,693	1,783	1,729	6,205
SYF 1944-45 XX: 249	1895	2,749	1,874	1,805	6,428
SYF 1920 XX: 216	1896	2,815	2,099	1,907	6,821
SYF 1920 XX: 216	1897	2,883	2,319	1,987	7,189
SYF 1920 XX: 216	1898	2,996	2,790	1,937	7,723
SYF 1920 XX: 216	1899	3,131	2,994	2,013	8,138
SYF 1944-45 XX: 249	1900	3,313	3,255	2,159	8,727
SYF 1920 XX: 216	1901	3,270	3,416	2,372	9,058
SYF 1920 XX: 216	1902	3,897	3,879	2,597	10,373
SYF 1920 XX: 216	1903	4,099	4,000	2,606	10,705
SYF 1920 XX: 216	1904	4,250	4,218	2,636	11,104
SYF 1944-45 XX: 249	1905	4,454	4,428	2,845	11,727
SYF 1920 XX: 216	1906	4,582	4,582	3,192	12,356
SYF 1944-45 XX: 249	1907	4,838	5,018	3,412	13,268
SYF 1944-45 XX: 249	1908	5,090	6,762	3,816	15,668
SYF 1944-45 XX: 250	1909	5,325	7,561	4,263	17,149
SYF 1944-45 XX: 251	1910	5,612	7,436	4,379	17,427
SYF 1944-45 XX: 252	1911	5,768	6,829	4,583	17,180
SYF 1944-45 XX: 253	1912	5,904	6,144	4,139	16,187
SYF 1944-45 XX: 254	1913	6,162	9,069	5,713	20,944
SYF 1944-45 XX: 255	1914	6,431	7,620	5,412	19,463
SYF 1944-45 XX: 256	1915	6,483	7,022	5,050	18,555
SYF 1944-45 XX: 257	1916	6,700	7,607	5,261	19,568
SYF 1944-45 XX: 258	1917	8,385	18,669	7,038	34,092
SYF 1944-45 XX: 259	1918	13,063	32,325	11,121	56,509
SYF 1944-45 XX: 260	1919	15,441	35,716	14,887	66,044
SYF 1944-45 XX: 261	1920	26,332	53,610	20,315	100,257
SYF 1944-45 XX: 262	1921	32,096	103,176	26,749	162,021
SYF 1944-45 XX: 263	1922	35,518	133,348	29,713	198,579
SYF 1944-45 XX: 264	1923	64,228	181,936	48,642	294,806
SYF 1944-45 XX: 265	1924	78,107	209,478	62,141	349,726
SYF 1944-45 XX: 266	1925	83,646	212,549	53,964	350,159
SYF 1944-45 XX: 267	1926	87,951	215,912	57,377	361,240
SYF 1944-45 XX: 268	1927	92,001	273,810	60,162	425,973
SYF 1944-45 XX: 269	1928	96,022	301,172	65,399	462,593
SYF 1944-45 XX: 270	1929	100,112	316,320	75,076	491,508
SYF 1944-45 XX: 271	1930	103,158	331,257	92,114	526,529
SYF 1944-45 XX: 272	1931	114,134	316,134	86,130	516,398
SYF 1944-45 XX: 273	1932	103,825	262,295	81,646	447,766
SYF 1944-45 XX: 274	1933	104,689	262,723	78,400	445,812
SYF 1944-45 XX: 275	1934	105,731	276,449	82,218	464,398
SYF 1944-45 XX: 276	1935	107,910	302,717	90,589	501,216
SYF 1944-45 XX: 277	1936	114,364	320,805	92,491	527,660
SYF 1944-45 XX: 278	1937	116,127	333,938	107,743	557,808
SYF 1944-45 XX: 279	1938	120,852	349,715	130,392	600,959
SYF 1944-45 XX: 280	1939	127,745	368,145	116,334	612,224
SYF 1944-45 XX: 281	1940	112,646	334,286	98,578	545,510
SYF 1944-45 XX: 282	1941	120,936	350,204	98,958	570,098
SYF 1944-45 XX: 283	1942	130,408	401,772	120,074	652,254
SYF 1944-45 XX: 284	1943	159,123	526,243	141,589	826,955
SYF 1944-45 XX: 285	1944	199,246	582,398	193,869	975,513

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.7 State expenditure, education in 1877–1879, 1887

State expenditure (in final State accounts), Old FIM 1000.

Source: Statistical Yearbooks of Finland (SYF).

		General schools and Board of schools	Primary schools	University	Industry, commerce, navigation schools and subsidies for handicraft schools	Funding for research and arts
SYF 1879 Table 48	1877	1662.1*	563.4	545.2		103.5

		Secondary schools and Board of schools	Primary schools	University	Industry, commerce, navigation schools and subsidies for handicraft schools	Funding for research and arts
SYF 1880 Table 56	1878	1323.9	564.5	550.9	285.8	95.5
SYF 1881 Table 55	1879	1360.5	636.8	580.0	492.3**	99.5
SYF 1887 Table 76	1887	2,404	1,218	820.3***	253.5	209.8

* Includes schools under the Ministry of Trade and Industry; estimated 278.8

** Includes the Institute of Technology

*** Includes the Institute of Technology; estimated 239.5

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.8 Professional education, State subsidies 1885–1938

State subsidies or costs, old FIM 1000.
Sources: SYF 1926 XIII: 185; SYF 1935 XIII: 189; SYF 1944–45 XIV: 213.

	Sum, total state subsidies	Seafare	Commerce	Agriculture	Forestry, sawing industry	Technics	Vocational	Cottage industry	Household economics
1885	312.6	71.7	21.7	218.7	-	-	0.55	-	-
1886									
1887									
1888									
1889									
1890	569.7	69.2	49.2	274.4	10.2	134*	32.3	-	-
1891									
1892									
1893									
1894									
1895	852.1	80.3	71.9	390.9	10.2	160*	41.5	85.2	12.3
1896									
1897									
1898									
1899									
1900	1,324.2	99.2	103.5**	694.2	11.1	231*	59.0	110.5	16.1
1901									
1902									
1903									
1904									
1905	1,657.8	98.9	179.6	740.7	93.0	235.2	133.1***	158.0	19.4
1906									
1907									
1908									
1909									
1910	2,307.0	104.5	467.9	765.1	177.4	330.2	179.4	186.4	96.0
1911	2,341.0	109.6	449.8	818.6	158.2	311.4	184.9	207.7	100.9
1912	2,485.8	111.0	472.8	832.1	178.1	370.9	208.7	201.4	110.9
1913	2,611.9	111.9	471.4	889.6	165.5	461.7	209.0	189.8	113.0
1914	2,617.6	108.4	475.1	858.9	146.7	497.6	222.0	198.4	110.5
1915	2,657.5	109.5	480.9	888.6	175.3	472.0	227.7	195.1	108.5
1916	2,781.3	109.0	484.0	908.6	245.7	466.4	262.5	194.9	110.0
1917	3,381.1	109.2	548.9	1,096.8	329.4	569.5	271.0	212.2	244.0
1918	4,963.7	244.8	685.9	1,600.9	611.4	800.5	328.8	285.7	405.8
1919	7,371.4	471.9	1,213.7	2,604.0	581.8	907.7	457.5	450.3	684.4
1920	10,794.1	733.8	1,588.2	3,486.2	639.0	1,769.4	801.6	1,012.0	763.9
1921	13,854.6	771.6	2,078.8	4,472.0	1,058.3	2,390.1	1,133.2	1,085.8	865.0
1922	17,909.1	853.6	2,204.0	6,488.8	1,090.1	2,662.6	1,684.5	1,595.7	1,329.8
1923	20,415.9	791.0	2,345.1	7,773.0	1,455.7	3,067.7	1,989.3	1,172.6	1,821.7
1924	23,213.1	648.4	2,591.9	9,016.4	1,397.0	3,383.2	2,201.6	1,850.0	2,124.7
1925	24,888.0	663.2	2,905.5	9,699.3	1,308.7	3,707.6	2,623.4	1,590.3	2,390.0
1926	27,114.6	552.9	3,155.6	9,936.0	1,279.3	4,841.7	3,105.3	1,780.4	2,463.4
1927	30,155.8	549.9	3,328.0	12,331.0	1,438.9	4,207.6	3,449.4	1,805.5	3,045.5
1928	33,105.2	538.4	3,466.0	13,822.2	1,554.7	4,476.6	4,079.2	1,943.3	3,224.9
1929	42,442.7	689.2	3,914.0	16,121.1	1,511.2	5,512.3	4,291.3	4,050.3	6,353.4
1930	44,029.0	710.3	3,958.5	16,118.2	1,713.9	6,017.8	4,521.0	4,344.4	6,645.0
1931	42,786.2	603.3	3,654.2	15,652.4	1,465.6	5,477.0	4,873.6	4,208.3	6,851.8
1932	42,440.5	601.1	3,422.0	15,563.8	1,448.7	5,392.6	4,860.0	4,403.8	6,748.6
1933	42,647.4	632.1	3,243.5	15,501.8	1,448.7	5,494.6	5,200.7	4,403.1	6,722.8
1934	44,804.7	612.5	3,700.0	15,879.3	1,597.2	5,782.1	5,656.8	4,621.9	6,954.9
1935	45,601.7	601.5	4,050.0	16,105.2	1,128.5	5,780.7	6,173.0	4,693.0	7,070.0
1936	48,263.4	675.5	4,342.0	16,742.7	1,317.8	6,163.9	6,818.0	4,866.0	7,337.5
1937	51,023.6	718.1	4,437.0	17,976.2	1,653.2	6,147.6	7,425.9	5,146.0	7,519.7
1938	53,582.5	836.2	4,699.0	17,918.8	1,607.1	7,069.5	8,257.1	5,400.4	7,794.5

* Lower schools of technique, missing values 1890, 1895, 1900: value for 1900 estimated with the proportion of state subsidies per number of teachers 1905 times teachers 1900 times (nominal wage index of civil servants;1900/1905), similarly values for 1895 and 1890 using t+5 proportions.
** Schools for commerce assistants missing value 1900: estimated with the proportion of state subsidies per number of students 1905 times teachers 1900 times (nominal wage index of civil servants;1900/1905).
*** Preparing vocational schools, missing value 1905: estimated with (the proportion of state subsidies per number of teachers 1910) times (teachers 1905) times (nominal wage index of civil servants;1900/1905).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.9 Professional education, Number of teachers 1885–1938

Sources: SYF 1926 XIII: 185; SYF 1935 XIII: 189; SYF 1944–45 XIV: 213.

	Sum of teachers	Seafare	Commerce	Agriculture	Forestry, sawing industry	Technics	Vocational	Cottage industry	Household economics
1885	167	43	32	90	-	-	2	-	-
1886									
1887									
1888									
1889									
1890	351	-	62	97	-	47	145	-	-
1891									
1892									
1893									
1894									
1895	569	43	85	124	2	55	157	103	-
1896									
1897									
1898									
1899									
1900	730	54	95	167	2	72	219	114	7
1901									
1902									
1903									
1904									
1905	945	53	141	190	10	68	303	161	19
1906									
1907									
1908									
1909									
1910	1,106	46	207	204	11	87	276	172	103
1911	1,204	47	240	215	11	82	297	183	129
1912	1,204	47	237	222	11	84	283	186	134
1913	1,240	47	248	213	10	121	294	171	136
1914	1,273	47	263	207	10	129	299	193	125
1915	1,256	49	261	223	11	117	299	168	128
1916	1,247	50	267	215	11	139	305	168	92
1917	1,187	39	250	211	10	142	301	159	75
1918	1,244	59	304	227	10	124	261	146	113
1919	1,343	73	312	212	10	141	298	156	141
1920	1,416	72	312	237	10	142	345	165	133
1921	1,469	72	291	291	19	140	318	160	178
1922	1,416	14	281	319	19	153	300	159	171
1923	1,469	14	263	358	26	155	307	158	188
1924	1,508	13	275	393	27	154	294	155	197
1925	1,571	12	290	420	27	145	306	152	219
1926	1,577	12	245	436	25	139	352	151	217
1927	1,687	12	334	428	25	150	355	154	229
1928	1,679	12	279	463	25	159	366	164	211
1929	1,756	13	292	459	25	161	401	164	241
1930	1,912	13	305	554	25	168	432	160	255
1931	1,847	13	290	445	25	182	450	162	280
1932	1,836	13	282	455	26	181	445	165	269
1933	1,918	13	282	463	32	182	494	174	278
1934	1,964	13	282	501	32	203	480	168	285
1935	2,038	13	285	518	32	208	515	171	296
1936	1,877	13	293	484	30	190	526	177	164
1937	2,010	13	289	558	30	207	567	181	165
1938	2,072	13	292	567	41	205	607	180	167

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.10 Professional education, Number of students 1885–1938

Sources: SYF 1926 XIII: 185; SYF 1935 XIII: 189; SYF 1944–45 XIV: 213.

	Sum of students	Seafare	Commerce	Agriculture	Forestry, sawing industry	Technics	Vocational	Cottage industry	Household economics
1885	723	114	171	392	-	-	46	-	-
1886									
1887									
1888									
1889									
1890	3,011	156	443	539	-	223	1,650	-	-
1891									
1892									
1893									
1894									
1895	6,160	156	445	661	12	232	1,617	3,037	-
1896									
1897									
1898									
1899									
1900	8,300	217	754	1,053	14	449	2,605	3,173	35
1901									
1902									
1903									
1904									
1905	9,375	178	964	1,147	130	349	3,185	3,337	85
1906									
1907									
1908									
1909									
1910	10,896	170	1,975	1,783	157	552	3,351	2,065	843
1911	11,600	132	2,121	1,940	158	867	3,244	2,142	996
1912	12,176	105	2,047	1,945	181	419	3,256	3,159	1,064
1913	12,348	121	2,120	2,089	143	474	3,243	3,098	1,060
1914	12,160	110	2,155	2,158	144	481	2,908	3,174	1,030
1915	12,590	81	2,213	2,207	163	482	2,990	3,239	1,215
1916	12,085	57	2,394	1,887	163	449	2,848	3,073	1,214
1917	11,990	48	2,369	1,908	139	517	2,934	3,379	696
1918	11,339	70	2,481	1,875	175	395	1,890	3,071	1,382
1919	13,283	88	3,010	1,844	160	418	3,089	3,233	1,441
1920	13,992	124	3,160	1,910	167	503	3,438	3,502	1,188
1921	14,747	138	3,085	2,235	213	624	3,566	3,653	1,233
1922	14,530	130	2,977	2,163	216	725	3,346	3,608	1,365
1923	15,076	100	3,046	2,171	219	762	3,429	3,899	1,450
1924	15,439	121	3,139	2,768	220	753	3,261	3,655	1,522
1925	16,726	121	3,294	3,040	206	764	3,763	3,887	1,651
1926	17,523	130	3,336	3,270	199	878	4,146	3,799	1,765
1927	17,725	173	3,046	3,664	221	1,031	4,134	3,653	1,803
1928	17,704	145	3,097	3,393	217	1,252	4,450	3,394	1,756
1929	17,064	194	3,199	3,568	221	1,536	4,247	2,363	1,736
1930	18,170	249	3,525	3,997	172	1,574	4,657	1,934	2,062
1931	18,540	207	3,252	3,788	165	1,548	5,050	2,689	1,841
1932	19,029	213	2,901	3,808	151	1,525	5,360	2,943	2,128
1933	17,993	243	2,515	3,738	155	1,308	5,246	2,769	2,019
1934	19,200	243	3,080	3,866	210	1,486	5,471	2,569	2,275
1935	20,102	294	3,277	3,788	234	1,651	6,201	2,438	2,219
1936	20,840	334	3,487	3,655	308	1,782	6,730	2,425	2,119
1937	20,769	246	3,582	3,636	355	1,889	6,287	2,617	2,157
1938	22,470	314	3,755	3,684	367	2,497	6,802	2,598	2,453

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.11 The estimated general government final consumption expenditure on education in 1877–2000

EUR mil., at constant 2000 reference year prices (fp) (estimated backwards by type of schooling 1975–1877).

	Total education expenditure fp	Basic & secondary fp	Professional fp	Universities fp
1877	46.719	37.762	1.523	7.434
1878	47.683	38.276	1.558	7.849
1879	50.897	40.889	1.663	8.346
1880	53.824	45.058	1.860	6.906
1881	58.095	48.426	2.246	7.423
1882	59.640	49.623	2.411	7.606
1883	61.835	51.449	2.499	7.886
1884	70.830	58.934	2.863	9.033
1885	73.947	61.528	2.989	9.431
1886	84.014	69.791	3.526	10.697
1887	87.618	72.448	4.066	11.104
1888	87.399	71.977	4.459	10.962
1889	82.791	67.799	4.602	10.390
1890	87.201	71.202	5.155	10.844
1891	88.909	72.608	5.543	10.757
1892	92.088	75.205	5.999	10.883
1893	98.351	79.826	6.609	11.916
1894	102.208	83.503	7.262	11.442
1895	105.409	85.790	7.737	11.882
1896	110.567	89.763	8.446	12.357
1897	113.010	91.645	8.947	12.418
1898	119.118	98.089	9.380	11.649
1899	122.282	100.698	9.844	11.740
1900	137.412	113.124	11.097	13.191
1901	142.978	116.507	11.808	14.662
1902	164.620	136.059	12.441	16.119
1903	163.099	135.234	12.429	15.436
1904	173.207	144.066	13.232	15.909
1905	179.208	148.727	13.582	16.899
1906	182.108	149.391	14.259	18.459
1907	185.987	152.699	14.535	18.752
1908	219.428	183.050	15.471	20.907
1909	239.518	199.595	16.500	23.424
1910	241.000	199.907	17.294	23.799
1911	221.006	181.155	16.472	23.380
1912	207.139	169.395	17.101	20.644
1913	258.778	212.643	17.842	28.294
1914	236.272	192.438	17.541	26.293
1915	199.888	162.652	15.661	21.576
1916	162.169	132.322	12.586	17.261
1917	158.282	137.227	8.391	12.664
1918	175.950	154.284	8.256	13.410
1919	159.281	135.704	9.568	14.009
1920	169.134	146.283	9.664	13.187
1921	211.646	188.926	9.468	13.252
1922	254.857	228.713	11.868	14.276
1923	358.957	323.188	13.115	22.654
1924	390.116	349.521	13.804	26.791
1925	391.552	354.108	14.558	22.886
1926	405.784	365.359	15.952	24.473
1927	486.271	442.598	17.852	25.821
1928	495.294	450.600	18.376	26.319
1929	523.277	469.804	23.428	30.046
1930	578.232	514.071	25.493	38.668
1931	601.292	537.029	26.129	38.135
1932	532.474	468.799	26.589	37.086
1933	539.138	476.065	27.038	36.036
1934	552.226	487.111	27.941	37.173
1935	571.890	504.938	27.437	39.516
1936	597.530	528.946	28.703	39.880
1937	574.927	504.148	27.965	42.813
1938	606.227	525.322	29.268	51.637

	Total	Basic & secondary	Professional	Universities
1939	611.126	532.194	29.052	49.880
1940	473.183	405.827	25.586	41.770
1941	435.659	375.926	23.573	36.160
1942	405.854	348.072	27.268	30.514
1943	439.590	383.299	22.028	34.262
1944	488.210	410.261	24.307	53.642
1945	415.126	343.497	24.074	47.554
1946	452.043	390.224	25.379	36.439
1947	516.797	454.216	23.479	39.102
1948	685.538	614.102	31.743	39.693
1949	999.397	914.792	34.498	50.107
1950	906.534	820.380	35.327	50.827
1951	1076.689	979.741	41.379	55.569
1952	1078.034	975.565	43.663	58.806
1953	1270.625	1162.122	47.018	61.486
1954	1256.090	1140.153	48.739	67.198
1955	1300.377	1182.178	52.510	65.689
1956	1356.109	1231.470	54.780	69.860
1957	1376.178	1238.438	60.892	76.848
1958	1402.361	1257.374	64.541	80.446
1959	1516.128	1353.882	71.417	90.830
1960	1650.336	1466.600	76.992	106.743
1961	1767.970	1558.745	88.332	120.893
1962	1924.384	1677.980	105.103	141.300
1963	2081.240	1807.866	112.349	161.025
1964	2103.016	1813.344	119.366	170.306
1965	2166.694	1852.379	129.115	185.200
1966	2050.195	1721.545	126.756	201.894
1967	2749.440	2129.124	193.428	426.888
1968	2811.199	2171.318	201.079	438.803
1969	2997.234	2251.401	208.301	537.531
1970	3041.864	2218.919	232.419	590.526
1971	3102.693	2204.069	251.571	647.053
1972	3123.462	2189.497	255.898	678.068
1973	3301.217	2257.965	273.424	769.828
1974	3488.297	2427.526	265.843	794.929
1975	3496.000	2443.362	221.638	831.000
1976	3733.000	2640.639	233.361	859.000
1977	3876.000	2830.352	245.648	800.000
1978	4060.000	2989.106	264.894	806.000
1979	4173.000	3058.887	273.113	841.000
1980	4248.000	3106.303	277.697	864.000
1981	4381.000	3185.063	287.937	908.000
1982	4368.000	3106.982	292.018	969.000
1983	4459.000	3130.472	306.528	1022.000
1984	4474.000	3104.603	318.397	1051.000
1985	4602.000	3194.370	331.630	1076.000
1986	4734.000	3322.124	343.876	1068.000
1987	4922.000	3432.317	363.683	1126.000
1988	5050.000	3496.881	384.119	1169.000
1989	5179.000	3577.283	409.717	1192.000
1990	5287.000	3622.589	429.411	1235.000
1991	5317.000	3571.104	442.896	1303.000
1992	5155.000	3451.548	442.452	1261.000
1993	5014.000	3111.649	754.351	1148.000
1994	5084.000	3166.844	772.156	1145.000
1995	5350.000	3146.075	925.925	1278.000
1996	5327.000	3019.819	1069.181	1238.000
1997	5516.000	3064.616	1190.384	1261.000
1998	5673.000	3095.613	1224.387	1353.000
1999	5826.000	3122.922	1242.078	1461.000
2000	5873.000	3153.025	1240.975	1479.000

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.12 Number of students in Finland, 1880–2005

Sources: SYF 1880–2007, SVT X:96–99 (1970–76), SVT XA:104 (1981–86), SVT Koulutus Suomessa 1998:1 (1981–96), SVT Koulutus 2008, Oppilaitostilastot 2007 (1997– 2007), Kivinen (1988), Klemelä (1999), Mitchell (2005).

	Primary + lower Sec	Upper Secondary	Profes- sional	University	All pupils / students
1880	34,986	1,415	276	736	37,413
1881	35,488	1,512		811	
1882	39,749	1,551		805	
1883	43,257	1,643		1,477	
1884	45,276	1,624		1,527	
1885	46,378	1,622		1,662	
1886	50,644	1,656		1,799	
1887	52,912	1,688		1,820	
1888	55,015	1,685		1,745	
1889	58,036	1,664		1,816	
1890	63,473	1,727	3,011	1,863	70,074
1891	65,837	1,763		1,868	
1892	69,953	1,747		1,888	
1893	76,154	1,746		1,905	
1894	83,861	1,839		1,979	
1895	91,489	1,911		2,037	
1896	97,951	1,949		2,194	
1897	103,798	1,702		2,282	
1898	109,602	1,798		2,384	
1899	114,584	1,916		2,606	
1900	124,422	2,041	8,392	2,727	137,582
1901	130,275	2,225		2,795	
1902	130,054	2,446		2,880	
1903	138,485	2,615		2,908	
1904	140,826	2,774		3,034	
1905	148,226	3,144	9,375	2,285	163,030
1906	157,410	3,290		2,474	
1907	164,726	3,674		2,724	
1908	176,367	3,933		2,315	
1909	182,245	4,255		3,099	
1910	196,377	4,524	10,896	3,238	215,035
1911	203,289	4,511	11,600	3,468	222,868
1912	208,713	4,487	12,176	3,690	229,066
1913	214,893	4,407	12,348	3,849	235,497
1914	217,907	4,293	12,160	3,951	238,311
1915	221,041	4,259	12,590	4,067	241,957
1916	225,855	4,245	12,085	3,811	245,996
1917	237,600	4,246	11,990	3,323	257,159
1918	235,410	4,210	11,339	3,024	253,983
1919	273,352	4,529	13,283	3,460	294,624
1920	291,318	4,778	13,992	3,590	313,678
1921	339,433	5,473	14,747	3,753	363,406
1922	359,266	6,159	14,530	3,829	383,784
1923	359,980	6,834	15,076	4,087	385,977
1924	365,817	7,521	15,439	4,263	393,040
1925	366,674	8,225	16,726	4,530	396,155
1926	370,648	8,758	17,523	5,028	401,957
1927	380,248	9,289	17,725	5,493	412,755
1928	389,691	9,837	17,704	6,239	423,471
1929	402,946	10,344	17,064	6,824	437,178
1930	417,446	10,921	18,170	7,411	453,948
1931	427,125	10,914	18,540	7,829	464,408
1932	432,735	10,760	19,029	7,989	470,513
1933	438,433	10,689	17,993	8,539	475,654
1934	509,038	10,620	19,200	8,598	547,456
1935	516,475	10,663	20,102	8,656	555,896
1936	520,405	10,643	20,840	8,538	560,426
1937	533,381	10,904	20,769	8,585	573,639
1938	538,525	11,125	22,470	9,048	581,168
1939	468,716	11,053	18,839	8,200	506,808
1940	525,754	11,457	20,141	8,300	565,652
1941	473,411	11,363	12,782	6,300	503,856
1942	486,868	12,025	12,169	5,900	516,962
1943	503,784	13,055	15,738	6,800	539,377
1944	484,123	13,500	19,657	10,400	527,680
1945	505,563	14,007	24,162	13,774	557,506
1946	528,527	14,301	25,864	14,416	583,108
1947	536,227	14,566	26,652	14,565	592,010
1948	557,217	14,664	19,542	14,380	605,803
1949	561,171	14,905	20,794	13,836	610,706
1950	569,896	15,009	27,877	13,851	626,633
1951	579,857	15,871	28,459	14,208	638,395
1952	607,073	17,042	29,141	14,167	667,423
1953	637,057	18,445	31,302	14,433	701,237
1954	668,154	19,885	31,192	15,297	734,528
1955	703,369	21,746	34,573	16,181	775,869
1956	726,898	23,820	41,155	16,968	808,841
1957	757,687	26,525	45,322	18,023	847,557
1958	780,206	29,880	49,883	19,861	879,830
1959	800,259	33,128	53,050	21,755	908,192
1960	807,925	35,699	55,851	24,122	923,597
1961	803,543	39,628	60,796	27,134	931,101
1962	795,131	43,299	67,320	29,678	935,428
1963	786,794	46,845	73,558	32,955	940,152
1964	772,479	50,359	78,868	36,587	938,293
1965	757,582	54,204	84,178	41,205	937,169
1966	748,649	59,088	91,718	44,258	943,713
1967	741,552	64,658	98,558	50,521	955,289
1968	737,493	67,934	100,877	52,829	959,133
1969	734,622	72,287	104,870	55,907	967,686
1970	722,515	78,041	105,058	57,871	963,485
1971	716,786	83,578	106,845	59,643	966,852
1972	710,298	88,416	111,860	60,965	971,539
1973	708,410	91,150	113,624	65,517	978,701
1974	704,836	92,761	117,876	69,607	985,080
1975	698,576	92,736	123,404	75,442	990,158
1976	684,723	95,502	133,005	77,818	991,048
1977	666,622	99,775	134,230	80,006	980,633
1978	647,946	104,528	139,647	80,480	972,601
1979	626,529	108,487	141,545	81,379	957,940
1980	604,169	110,353	140,880	84,176	939,578
1981	590,118	111,946	142,342	86,026	930,432
1982	579,519	111,051	145,879	87,488	923,937
1983	573,887	111,984	146,101	88,242	920,214
1984	569,553	111,142	147,619	89,716	918,030
1985	569,452	108,187	149,390	92,230	919,259
1986	570,183	105,208	150,820	95,987	922,198
1987	572,919	102,154	151,741	99,246	926,060
1988	577,552	99,639	152,926	103,895	934,012
1989	587,213	99,259	156,188	108,125	950,785
1990	592,920	100,875	164,617	112,921	971,333
1991	595,997	109,322	180,173	115,358	1,000,850
1992	594,221	118,819	193,185	121,736	1,027,961
1993	590,306	125,595	199,525	124,370	1,039,796
1994	587,523	129,028	202,859	127,846	1,047,256
1995	588,162	130,600	203,134	133,359	1,055,255
1996	589,128	131,524	208,731	140,129	1,069,512
1997	592,375	135,074	215,914	142,962	1,086,325
1998	591,679	137,747	223,920	147,278	1,100,624
1999	591,272	139,799	239,548	152,466	1,123,085
2000	593,451	140,711	245,111	157,796	1,137,069
2001	595,727	140,060	248,017	162,939	1,146,743
2002	597,356	138,030	260,626	164,312	1,160,324
2003	597,414	134,425	266,084	169,846	1,167,769
2004	593,148	133,962	279,440	173,974	1,180,524
2005	586,381	130,420	285,111	176,061	1,177,973

DATA APPENDIX 3.13 School enrolment ratios in Finland, 1880–2005

Sources: Own calculations; SYF 1880–2007, SVT X:96–99 (1970–76), SVT XA:104 (1981–86), SVT Koulutus Suomessa 1998:1 (1981–96), SVT Koulutus 2008, Oppilaitostilastot 2007 (1997– 2007), Kivinen (1988), Klemelä (1999), Mitchell (2005), Statistics Finland, Population Statistics.

	Prim+lowSec per age 7-15	UpperSec per age 16-18	Prof per age 16-22	Uni per age 19-26	All students per age 7-26
1880	9.7%	1.2%	0.1%	0.3%	4.9%
1881	9.5%	1.3%		0.3%	
1882	10.3%	1.4%		0.3%	
1883	10.9%	1.6%		0.5%	
1884	10.9%	1.7%		0.5%	
1885	11.0%	1.6%		0.6%	
1886	11.7%	1.5%		0.6%	
1887	12.0%	1.3%		0.7%	
1888	12.3%	1.3%		0.6%	
1889	12.8%	1.2%		0.6%	
1890	13.8%	1.3%	1.1%	0.6%	7.9%
1891	14.1%	1.3%		0.6%	
1892	14.9%	1.3%		0.6%	
1893	16.3%	1.2%		0.6%	
1894	17.5%	1.3%		0.6%	
1895	18.8%	1.3%		0.6%	
1896	20.1%	1.3%		0.6%	
1897	20.9%	1.2%		0.7%	
1898	21.6%	1.2%		0.7%	
1899	22.3%	1.3%		0.7%	
1900	24.4%	1.3%	2.5%	0.8%	13.5%
1901	25.6%	1.4%		0.8%	
1902	25.4%	1.6%		0.8%	
1903	27.0%	1.7%		0.8%	
1904	27.2%	1.7%		0.8%	
1905	28.1%	2.0%	2.7%	0.6%	15.4%
1906	29.3%	2.1%		0.7%	
1907	30.3%	2.3%		0.7%	
1908	31.8%	2.4%		0.6%	
1909	32.2%	2.6%		0.8%	
1910	34.3%	2.8%	3.0%	0.8%	19.0%
1911	34.8%	2.7%	3.1%	0.9%	19.4%
1912	35.2%	2.6%	3.3%	0.9%	19.7%
1913	35.5%	2.5%	3.3%	1.0%	20.0%
1914	35.6%	2.4%	3.2%	1.0%	20.0%
1915	35.8%	2.3%	3.2%	1.0%	20.1%
1916	35.9%	2.3%	3.0%	0.9%	20.1%
1917	37.4%	2.3%	2.9%	0.8%	20.7%
1918	36.8%	2.2%	2.7%	0.7%	20.5%
1919	42.3%	2.4%	3.2%	0.8%	23.4%
1920	45.2%	2.5%	3.3%	0.8%	24.7%
1921	52.3%	2.8%	3.4%	0.8%	28.1%
1922	55.7%	3.0%	3.3%	0.8%	29.4%
1923	56.5%	3.3%	3.3%	0.9%	29.4%
1924	57.8%	3.5%	3.3%	0.9%	29.7%
1925	58.8%	3.8%	3.5%	0.9%	29.8%
1926	61.4%	4.0%	3.6%	1.0%	30.4%
1927	63.2%	4.3%	3.6%	1.1%	31.1%
1928	65.1%	4.5%	3.6%	1.2%	31.7%
1929	67.3%	4.9%	3.5%	1.3%	32.6%
1930	69.6%	5.2%	3.7%	1.4%	33.7%
1931	70.8%	5.4%	3.8%	1.4%	34.4%
1932	71.0%	5.5%	4.0%	1.5%	34.8%
1933	71.6%	5.6%	3.8%	1.6%	35.1%
1934	82.9%	5.5%	4.1%	1.6%	40.5%
1935	82.3%	5.8%	4.5%	1.6%	41.2%
1936	83.4%	5.6%	4.6%	1.6%	41.7%
1937	85.8%	5.6%	4.6%	1.6%	42.7%
1938	87.2%	5.3%	5.0%	1.8%	43.5%
1939	77.0%	5.3%	4.1%	1.6%	38.2%
1940	87.8%	5.5%	4.3%	1.7%	43.2%
1941	80.0%	5.5%	2.8%	1.3%	39.0%
1942	82.7%	5.9%	2.6%	1.2%	40.2%
1943	86.0%	6.5%	3.4%	1.4%	41.9%
1944	83.1%	6.7%	4.3%	2.1%	41.3%
1945	86.5%	7.0%	5.2%	2.8%	43.4%
1946	90.2%	7.0%	5.6%	2.8%	44.8%
1947	92.5%	7.3%	5.7%	2.8%	45.7%
1948	93.1%	7.5%	4.3%	2.8%	46.3%
1949	94.2%	8.0%	4.6%	2.7%	46.8%
1950	94.2%	8.2%	6.2%	2.7%	48.0%
1951	94.6%	8.7%	6.5%	2.8%	48.8%
1952	94.8%	9.1%	6.7%	2.8%	50.1%
1953	94.4%	9.7%	7.2%	2.9%	51.4%
1954	94.5%	10.2%	7.1%	3.1%	52.4%
1955	95.3%	10.7%	7.8%	3.3%	54.1%
1956	93.7%	12.1%	9.3%	3.5%	55.3%
1957	96.4%	12.6%	9.8%	3.7%	57.0%
1958	95.5%	15.1%	10.9%	4.0%	58.4%
1959	95.6%	15.9%	11.4%	4.5%	59.2%
1960	95.1%	17.8%	11.8%	4.7%	59.2%
1961	95.2%	17.0%	12.3%	5.3%	58.8%
1962	96.0%	16.5%	12.8%	5.8%	58.3%
1963	96.8%	16.2%	13.0%	6.3%	57.7%
1964	97.3%	16.9%	13.6%	6.7%	57.3%
1965	97.9%	18.5%	13.7%	7.2%	57.2%
1966	98.7%	20.7%	14.5%	7.4%	57.5%
1967	99.2%	23.6%	15.2%	7.9%	57.6%
1968	100.3%	25.4%	15.6%	8.2%	58.1%
1969	101.4%	28.0%	16.8%	8.4%	58.7%
1970	101.3%	30.7%	17.4%	8.6%	58.7%
1971	101.6%	33.3%	17.9%	8.5%	58.4%
1972	102.1%	35.2%	18.9%	8.7%	58.8%
1973	102.8%	36.7%	19.4%	9.4%	59.8%
1974	102.7%	38.5%	20.5%	10.1%	60.9%
1975	103.1%	39.5%	21.8%	11.1%	62.3%
1976	103.1%	41.3%	23.9%	11.8%	63.7%
1977	102.4%	42.9%	24.5%	12.4%	64.2%
1978	102.2%	45.2%	25.8%	12.7%	64.8%
1979	102.0%	47.0%	26.5%	13.1%	65.2%
1980	101.7%	48.0%	26.6%	13.7%	65.2%
1981	101.3%	49.2%	26.8%	14.0%	65.4%
1982	100.9%	49.5%	27.6%	14.3%	65.6%
1983	101.0%	50.6%	27.8%	14.5%	65.9%
1984	101.1%	51.2%	28.4%	14.9%	66.4%
1985	101.2%	51.9%	29.4%	15.3%	66.9%
1986	101.2%	53.0%	30.5%	16.1%	67.8%
1987	101.2%	54.0%	31.7%	16.8%	68.7%
1988	101.0%	54.5%	33.0%	17.9%	70.0%
1989	100.8%	56.4%	35.0%	19.0%	71.7%
1990	100.8%	56.9%	37.8%	20.4%	73.6%
1991	101.0%	59.3%	41.7%	21.4%	76.2%
1992	101.1%	61.1%	44.4%	23.3%	78.7%
1993	101.0%	63.3%	45.6%	24.3%	80.2%
1994	101.1%	65.2%	45.9%	25.3%	81.6%
1995	101.2%	66.7%	45.4%	26.6%	82.6%
1996	101.3%	67.7%	45.9%	27.9%	83.7%
1997	101.5%	69.5%	47.2%	28.4%	84.8%
1998	101.6%	69.8%	48.7%	29.0%	85.5%
1999	101.6%	69.5%	51.9%	29.8%	86.7%
2000	102.2%	69.5%	53.1%	30.3%	87.2%
2001	102.2%	70.3%	53.8%	31.0%	87.7%
2002	102.2%	71.4%	56.8%	31.1%	88.8%
2003	102.1%	71.4%	58.3%	32.1%	89.6%
2004	102.2%	70.9%	61.2%	32.9%	91.0%
2005	102.2%	68.1%	62.8%	33.4%	91.1%

NB: Because the pupils of the voluntary 10th grade and because of some pupils enrolling twice in the same grade, the school enrolment ratios in primary + lower secondary exceed 100% after l968. These could, of course, be rounded to 100%.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 3.14 GDP per capita and intangible human capital by schooling per capita in Finland in 1910–2000

NB: This is the data used in the cointegration analysis in Chapter 3. Variables in natural logarithms.

Sources: Own calculations; GDP per capita: Statistics Finland, Historical National Accounts (obtained from the database in Jan 2007), human capital per capita: see the discussion in Chapter 3.

	Log Gdp pc	Log H pc
1910	9.0079	7.5098
1911	9.0228	7.5605
1912	9.0651	7.6025
1913	9.1113	7.6463
1914	9.0553	7.6990
1915	8.9942	7.7485
1916	9.0029	7.7796
1917	8.8215	7.8295
1918	8.6853	7.8556
1919	8.8731	7.8993
1920	8.9757	7.9069
1921	8.9942	7.9187
1922	9.0826	7.9132
1923	9.1446	7.8975
1924	9.1624	7.8947
1925	9.2063	7.8984
1926	9.2344	7.9085
1927	9.3015	7.9336
1928	9.3582	7.9692
1929	9.3637	8.0082
1930	9.3431	8.0547
1931	9.3109	8.1131
1932	9.2989	8.1729
1933	9.3583	8.2356
1934	9.4582	8.2945
1935	9.4922	8.3333
1936	9.5514	8.3982
1937	9.5989	8.4534
1938	9.6408	8.5018
1939	9.5899	8.5400
1940	9.5370	8.5825
1941	9.5664	8.6154
1942	9.5693	8.6509
1943	9.6714	8.6702
1944	9.6709	8.6886
1945	9.6013	8.7044
1946	9.6638	8.7010
1947	9.6731	8.6974
1948	9.7360	8.6981
1949	9.7823	8.6975
1950	9.8096	8.6933
1951	9.8829	8.6967
1952	9.9029	8.7119
1953	9.8990	8.7276
1954	9.9712	8.7540
1955	10.0095	8.7837
1956	10.0285	8.8084
1957	10.0657	8.8479
1958	10.0636	8.8793
1959	10.1127	8.9204
1960	10.1930	8.9689
1961	10.2598	9.0189
1962	10.2822	9.0669
1963	10.3070	9.1235
1964	10.3544	9.1633
1965	10.4035	9.2038
1966	10.4221	9.2493
1967	10.4376	9.2904
1968	10.4574	9.3372
1969	10.5530	9.3827
1970	10.6286	9.4441
1971	10.6433	9.5127
1972	10.7109	9.5520
1973	10.7707	9.5916
1974	10.7948	9.6454
1975	10.8027	9.6888
1976	10.7996	9.7329
1977	10.8044	9.7735
1978	10.8265	9.8167
1979	10.8883	9.8558
1980	10.9350	9.9047
1981	10.9508	9.9510
1982	10.9760	9.9995
1983	10.9981	10.0389
1984	11.0243	10.0778
1985	11.0545	10.1142
1986	11.0753	10.1494
1987	11.1160	10.1836
1988	11.1576	10.2202
1989	11.2001	10.2567
1990	11.1919	10.2910
1991	11.1198	10.3165
1992	11.0759	10.3324
1993	11.0588	10.3497
1994	11.0933	10.3712
1995	11.1323	10.3980
1996	11.1666	10.4211
1997	11.2238	10.4535
1998	11.2697	10.4839
1999	11.3007	10.5149
2000	11.3474	10.5414

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

4. THE ROLE OF HUMAN AND PHYSICAL CAPITAL IN THE FINNISH ECONOMIC GROWTH

In this chapter the analysis of the Finnish growth experience is broadened to cover all the core variables in modern growth theories: physical (or fixed) capital, human capital and labour input. At first, theoretical background for the discussion on the role of reproducible capital, including both physical and human capital, in economic growth will be reviewed. Then the role of reproducible capital in the long-run growth process is examined by Vector Equilibrium Correction Models (VECM, also known as vector error correction models), using an estimate for intangible human capital by schooling which is formed in the National Accounts.

4.1 Theoretical Background

One of the major discussions regarding growth theories is whether the modern economic growth could be best modelled by neo-classical or endogenous growth models. One of the questions inside this discussion is the role of human and physical capital and whether diminishing returns or constant returns to scale with respect to reproducible capital would be prevailing in the production of GDP[229].

Along with the early rise of endogenous growth theories, Gregory Mankiw, David Romer and David N. Weil introduced an augmented neoclassical Solow-Swan model with exogenous technology in 1992.[230] By using enrolment in secondary schooling as a proxy for human capital, they conducted a cross-country study and reported strong empirical support for the diminishing returns to scale on reproducible capital and for the neo-classical growth model augmented by human capital. In this model, as in the original neoclassical Solow-Swan model, economic growth would finally cease without exogenous technical change, because of diminishing returns to the factors of production. In the long run investments in physical and human capital would only have a level effect on GDP, and the long-run steady state growth is determined by the exogenous technology.

[229] See, for instance, Jones, Charles I (2005). Growth and ideas, in Aghion, Philippe, Durlauf, Steven N. (Eds.) (2005) *Handbook of Economic Grwoth*, vol 1B, Elsevier B.V., Amsterdam, The Netherlands, Chapter 16, pp. 1064–1111.

[230] Mankiw, N. Gregory, Romer, David, Weil, David N. (1992). A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics*, Vol. 107, 2 (May), pp. 407–437.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Mankiw, Romer and Weil were employing a constant returns to scale Cobb-Douglas production function in the following form

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{\gamma} \tag{4.1.1}$$

where $\alpha + \beta + \gamma = 1$, i.e. there are constant returns to scale with respect to all of the inputs, and at the same time $\alpha + \beta < 1$, referring to diminishing returns to reproducible capital.[231] The empirical counterpart for Y_t is GDP, K_t refers to physical capital and H_t to human capital (secondary schooling in their analysis), L_t is labour input and A_t is the level of technology. With constant returns to scale prevailing on production the equation above can be given in intensive form $(Y_t / L_t) = (K_t / L_t)^{\alpha} (H_t / L_t)^{\beta} A_0 e^{gt}$, where technology is assumed to advance from the initial level, A_0, with a constant average rate of g along time (t). Log-linearising the intensive form will give

$$LN\,(Y_t / L)_t = \alpha\, LN\,(K_t / L_t) + \beta\, LN\,(H_t / L_t) + LN\, gt + LN\, A_0, \tag{4.1.2}$$

where $\alpha + \beta < 1$.

In accordance with the assumption of constant returns to scale in the production function in equation (4.1.1), $\alpha + \beta$ should be less than unity, referring to decreasing returns to scale on reproducible capital, *K* and *H*. In this case the production function satisfies properties for a neo-classical model. In case of $\alpha + \beta$ would equal unity, constant (instead of diminishing) returns to scale are prevailing on the reproducible capital supporting the endogenous growth theory models. Mankiw, Romer and Weil came to the conclusion that the production function consistent with their empirical results would have $\alpha = \beta = \gamma = 1/3$, and therefore clearly $\alpha + \beta < 1$.

In contrast, a branch of endogenous growth theories has suggested that there could be constant returns to scale with respect to broad reproducible capital, including both physical and human capital.[232] In these models, the growth would not have to come to an end without

[231] See Mankiw, N. Gregory, Romer, David, Weil, David N. (1992). A Contribution to the Empirics of Economic Growth. Human capital and labour input are separate inputs in this formulation.

[232] Theoretical literature often refers to $Y = AK$ type of models, in which K includes all the reproducible capital. See, for instance, Romer, Paul M. (1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy*, vol. 94, 1986: 5, pp. 1002–1037; Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

exogenously defined technology. Investments in and the accumulation of reproducible capital would be the main drivers of the growth in the long run as well.

This is the case in an alternative, endogenous growth model, which is reviewed next. Assume a Cobb-Douglas production function with constant returns to physical and human capital, K and H:

$$Y_t = AK_t^{\alpha} H_t^{1-\alpha} \quad = AK_t^{\alpha} (h_t L_t)^{1-\alpha} \quad = AK_t^{\alpha} (\frac{H_t}{L_t} L_t)^{1-\alpha}, \qquad (4.1.3)$$

where $0 \leq \alpha \leq 1$. Human capital is the number of workers, L, multiplied by the human capital of a typical worker, $h_t = H_t / L_t$. Therefore, it is not only the quantitative input of labour, but the quality adjusted labour input $L_t h_t$ that is important for output in this model. If the human capital of the typical worker increases steadily, the quality adjusted labour input (i.e., human capital or human input) here grows even if the number of workers stays constant.[233] The model exhibits long-run growth because of constant returns to reproducible capital, including both K and H, without exogenous technological progress.[234] With constant returns to scale, the model can again be rewritten in intensive form. This results in log-linear form as:

$$LN\,(Y_t / L)_t = \alpha\, LN\,(K_t / L_t) + \beta\, LN\,(H_t / L_t) + LN\ A, \qquad (4.1.4)$$

where $\alpha + \beta$ will equal unity.

At a first glance, the log-linearised, intensive forms of the production functions seem quite similar. However, the difference of the latter with the neo-classical one is important: there is no exogenous technical change (or MFP growth) needed in the long-run production function and $\alpha + \beta$ equals unity. This can be tested in empirics if there is a long-run equilibrium type of cointegration relation between the variables. In that case, the estimation of

Growth, *Journal of Political Economy*, vol. 99, 3, pp. 500–21; Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*. The MIT Press, Cambridge, Massachussetts,1999. Originally published by McGraw-Hill, Inc., 1995.

[233] Strictly speaking, theoretically the assumption is that the quantity of workers, L, and the quality of workers, h, are perfect substitutes in production in the sense that only the combination, Lh, is important for output. As a consequence, a fixed number of bodies, L, is not a source of diminishing returns in the model: a doubling of K and H, keeping L fixed, will lead to a double amount of Y.

[234] See, e.g. Romer, Paul M. (1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy;* Jones, Larry E, Manuelli, Rodolfo E. (1990). A Convex Model of Equilibrium Growth: Theory and Policy Implications. *Journal of Political Economy*, 98, 5 (October), pp. 1008–1038; Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, pp. 38–42, 144–146, 172–174.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

the parameters including statistical inference can be done straightforwardly for the level variables in 4.1.4 and in 4.1.2.

The focus of this chapter is on whether the reproducible factors would be more important for the long-run GDP and Labour Productivity growth than the unexplained residual, technical change or multifactor productivity, once human capital is assessed in the National Accounts frame instead of using the conventional proxy variables. The empirical analysis is done for *LN Y(t)/L(t), LN K(t)/L(t)* and *LN H(t)/L(t)* in accordance with equations 4.1.2 and 4.1.4, so that labour productivity is explained by physical and human capital by schooling in the labour input together with multifactor productivity or the Solow residual. For simplicity, from now on the variables will be denoted with small letters, i.e. $y_t = LN(Y_t / L_t), k_t = LN(K_t / L_t), h_t = LN(H_t / L_t)$.

In the following empirical analysis the first natural hypothesis is that *there is a long-run cointegration relation between the variables* referring to that there would be a long-run steady state relation between the variables. It can be tested whether we can find long-run cointegration relations between the variables at all. *The second hypothesis* is that *there is exactly one cointegration relation*. *An alternative hypothesis* is that there are actually *two cointegration relations*, one between y and k and h and the second between k and h. *The third hypothesis* is related to the coefficients, i.e. *whether alpha and beta in* 4.1.3 *will sum up exactly to one*, referring to constant returns to scale with respect to broad capital *(H + K*), or *will the sum of alpha and beta* be *less than one* in accordance with decreasing returns to broad capital. In the CVAR framework this can be tested with homogenous restriction on the parameters. Decreasing returns to broad capital would give support to the neo-classical family of models and to (4.1.1), whereas constant returns to broad capital would imply support to the family of endogenous growth models (4.1.3).

4.2 Exploring economic growth with physical capital, human capital and labour input

In the essence, economic growth is driven by labour productivity growth and therefore the empirical analysis of this section will also focus on explaining labour productivity growth. In the previous section it was shown that human capital has had a connection with GDP per capita growth in Finland. In the empirical analysis of this section the basic questions in connection with modern growth literature are: What role has human capital had in economic growth? Have there been constant or diminishing returns to scale with respect to broad capital in the production?

As noted in Section 3.3.2, economic variables are often non-stationary as the variables in this analysis. When wishing to study long-run growth the focus turns to the levels of economic variables. Cointegration analysis by vector equilibrium correction models will be used to explore the empirical results, since it is particularly suitable for the long-run analysis of the levels of non-stationary time series. The analysis from now on is carried out using the program CATS in RATS, version 2[235].

The VAR model with two lags in the unrestricted form in levels is given by[236]:

$$\mathbf{x_t} = \mathbf{\Pi_1 x_{t-1}} + \mathbf{\Pi_2 x_{t-2}} + \mathbf{\Phi D_t} + \boldsymbol{\varepsilon}_\mathbf{t}, \qquad \varepsilon_t \sim iid \;\; N_p\,(0, \Omega) \qquad (4.2.1)$$

The Cointegrated VAR model (CVAR) in the vector equilibrium correction form can be derived by subtracting $\mathbf{x_{t-1}}$ from both sides of 4.2.1, and can be expressed equivalently in terms of likelihood as $\mathbf{\Delta x_t} = \mathbf{\Pi x_{t-1}} + \mathbf{\Gamma \Delta x_{t-1}} + \mathbf{\Phi D_t} + \boldsymbol{\varepsilon}_\mathbf{t}$. The reduced form with the deterministic components estimated is expressed in 4.2.2:

$$\mathbf{\Delta x_t} = \mathbf{\Pi x_{t-1}} + \mathbf{\Gamma \Delta x_{t-1}} + \boldsymbol{\mu}_\mathbf{0} + \boldsymbol{\alpha\beta}_1^{'}\,\mathbf{t} + \mathbf{\Phi D_t} + \boldsymbol{\varepsilon}_\mathbf{t}\;, \qquad \varepsilon_t \sim iid \;\; N_p\,(0, \Omega) \qquad (4.2.2),$$

[235] Dennis, J.G., Hansen H., Johansen S. and Juselius K. (2005). *CATS in RATS, version 2*, Estima 2005.
[236] The VAR model with a lag length of two is reviewed since the lag length was inferred to be two by both Schwarz and Hannan-Quinn criteria in the following empirical analysis. The presentation of the Cointegrated VAR model is based on Juselius, Katarina (2006). *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*. Advanced Texts in Econometrics, Oxford University Press: Oxford.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

where $\mathbf{x_t}$ = (y_t, k_t, h_t)' in the empirical analysis following, with small letters in the variables referring to a variable divided by the number of hours worked and expressed in natural logarithms, $\mathbf{\Pi = -(I - \Pi_1 - \Pi_2)}$ and $\mathbf{\Gamma = -\Pi_2}$, $\boldsymbol{\mu_0}$ is a vector of constants, D_t a vector of dummies, *t* is a time trend restricted to cointegration relations. In the case of *I(1)*-analysis the rank of the coefficient matrix **Π** can be used to test the number of stationary cointegration relations (which is the rank, *r*, of **Π**) between the levels of the variables and the number of unit roots, i.e. common trends (with *p* variables, the number of common trends is $p - r$).

If there exists *r* cointegration relations, the matrix **Π** has a reduced rank, and **Π** can be expressed as ***α β'***, where ***α, β*** are $p \times r$.The transposed matrix ***β'*** includes the long-run cointegration coefficients and the matrix **α** adjustment coefficients for the variables under review. The constant, $\boldsymbol{\mu_0}$, appears unrestrictedly in the model generating a time trend in the Moving Average (MA) form. The time trend in the Autoregressive representation of the model above is restricted to the cointegration relations, thus denoted by $\boldsymbol{\alpha\beta_1'}\mathbf{t}$, implying a time trend in at least one of the cointegration relations.

It is worth noticing that the point estimates of the parameters are exactly the same in 4.2.1 and 4.2.2 because the parameter estimates of 4.2.1 can be simply calculated from 4.2.2 by $\mathbf{\Pi = -(I - \Pi_1 - \Pi_2)}$ and $\mathbf{\Gamma = -\Pi_2}$. The latter form is favoured in estimation since statistical significance on the parameters of the level variables can only be inferred by 4.2.2 in the case of cointegration.

Inverting the VAR model gives the Moving Average (MA) representation defining the pushing forces of the system or the common stochastic trends. The MA form, assuming no dummies for the moment, is given by:

$$\mathbf{x_t} = \mathbf{C}\sum_{\mathbf{i=1}}^{\mathbf{t}} \boldsymbol{\varepsilon}_\mathbf{i} + \mathbf{tC}\boldsymbol{\mu}_\mathbf{0} + \mathbf{C^*(L)}(\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\mu}_\mathbf{0} + \boldsymbol{\alpha\beta}_\mathbf{1}\mathbf{t}) + \widetilde{\mathbf{X}}_\mathbf{0} \quad . \tag{4.2.3}$$

where $\mathbf{C} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp' \boldsymbol{\Gamma} \boldsymbol{\beta}_\perp)^{-1} \boldsymbol{\alpha}_\perp'$ or $\mathbf{C} = \tilde{\boldsymbol{\beta}}_\perp \boldsymbol{\alpha}_\perp'$, $\widetilde{\mathbf{X}}_\mathbf{0}$ contains both the initial value, $\mathbf{x}_0$, of the process $\mathbf{x}_t$ and the initial value of the short-run dynamics $\mathbf{C}^*(L)\boldsymbol{\varepsilon}_0$. Equation (4.1.3) shows that the evolution of the level variables $\mathbf{x}_t$ can be described by stochastic trends $\mathbf{C}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_i$

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

(which can also be denoted as $\tilde{\boldsymbol{\beta}}_{\perp}\boldsymbol{\alpha}_{\perp}^{'}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_i$), linear time trend cumulated by the constant $\boldsymbol{\mu}_0 t$ (multiplied by $\mathbf{C}$) and stationary stochastic components $\mathbf{C}^*(L)\boldsymbol{\varepsilon}_t$, and initial values.[237]

For given $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ one can find the orthogonal complements, $\boldsymbol{\alpha}_{\perp}^{'}$ and $\boldsymbol{\beta}_{\perp}$ of dimension *p x (p – r)* and of full rank so that $rank(\boldsymbol{\alpha}'\boldsymbol{\alpha}_{\perp}) = p, rank(\boldsymbol{\beta}'\boldsymbol{\beta}_{\perp}) = p$. These orthogonal complements can be used to decompose the long-run impact matrix $\mathbf{C}$ in the MA form as shown above. When the time trend is restricted to the cointegration relations, it will appear in the Moving Average representation in the stationary part, and hence, is not affecting the non-stationary part. The time trend of the levels of the variables is induced by the unrestricted constant in the Autoregressive form of the model.

The decomposition of the $\mathbf{C}$ matrix is similar to the $\boldsymbol{\Pi}$ matrix: however, in the AR representation $\boldsymbol{\beta}$ determines the common long-run relations and $\boldsymbol{\alpha}$ the loadings, whereas in the moving average representation $\boldsymbol{\alpha}_{\perp}^{'}$ determines the common stochastic trends and $\tilde{\boldsymbol{\beta}}_{\perp}$ their loadings. The non-stationarity in the process $\mathbf{x_t}$ originates from the cumulative sum of the combinations $\boldsymbol{\alpha}_{\perp}^{'}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$. In the case of an *I(1)*-process the number of such combinations is *p – r*. The common driving trends are defined as the variables $\boldsymbol{\alpha}_{\perp}^{'}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$.[238]

It is worth noticing that the matrices $\boldsymbol{\alpha}_{\perp}$ and $\boldsymbol{\beta}_{\perp}$ can be directly calculated for given estimates of $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, (and $\boldsymbol{\Gamma} = -(\mathbf{I} - \boldsymbol{\Gamma}_1 - \boldsymbol{\Gamma}_2 - \ldots - \boldsymbol{\Gamma}_{\mathbf{k-1}})$, with lag length *k*, as shown by Johansen.[239] This means that the common stochastic trends and their weights can be found either based on unrestricted $\hat{\boldsymbol{\alpha}}, \hat{\boldsymbol{\beta}}$ or on restricted estimates $\hat{\boldsymbol{\alpha}}^{\mathbf{c}}, \hat{\boldsymbol{\beta}}^{\mathbf{c}}$. The CATS program used later for conducting the empirical analysis uses the latest estimates of $\boldsymbol{\alpha}, \boldsymbol{\beta}$ as a basis for the calculations in the moving average representation.

The notion of cointegration relations $\boldsymbol{\beta}'\mathbf{x_t}$, and the notion of common trends $\boldsymbol{\alpha}_{\perp}^{'}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$ are two sides of the same coin, as are the adjustment coefficients $\boldsymbol{\alpha}$ and the loading

[237] Juselius, Katarina (2006). *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*. Advanced Texts in Econometrics, Oxford University Press: Oxford, p. 256.
[238] Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 2nd. edn. Advanced Texts in Econometrics, Oxford University Press: Oxford; xJuselius, Katarina (2006). *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*.
[239] See Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 2nd edn., Chapter 4.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

coefficients $\tilde{\boldsymbol{\beta}}_{\perp}$. The cointegrated VAR model provides a general framework within which one can describe economic behaviour in terms of forces pulling towards equilibrium, generating stationary behaviour ($\boldsymbol{\beta}'\mathbf{x_t}$), and forces pushing away from equilibrium, generating non-stationary behaviour ($\boldsymbol{\alpha}_{\perp}^{'}\sum_{i=1}^{t}\boldsymbol{\varepsilon_i}$).

Let us first open the notation in the case of one cointegration relation in the Autoregressive representation for the first equation of the model:

Case 1: Analysis in the AR form of the model when *r = 1:*

(three variables y_t, k_t, h_t (p = 3), all variables ~ *I(1)*), one cointegration relation, the number of unit roots or common trends in the system, $p - r = 3 - 1 = 2$)[240]

$$\boldsymbol{\Pi}\mathbf{x_{t-1}} = \boldsymbol{\alpha}\boldsymbol{\beta}'\mathbf{x_{t-1}} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} (\beta_1 y_{t-1} + \beta_2 k_{t-1} + \beta_3 h_{t-1}).$$

It is often useful to normalise the cointegration relation by the coefficient of one of the variables. If we normalise on y_t, the equation for the first variable, Δy_t, can be given the usual equilibrium correction form

$$\Delta y_t = \alpha_1\beta_1(y_{t-1} + \frac{\beta_2}{\beta_1}k_{t-1} + \frac{\beta_3}{\beta_1}h_{t-1}) + \Gamma_{11}\Delta y_{t-1} + \Gamma_{12}\Delta k_{t-1} + \Gamma_{13}\Delta h_{t-1} + \varepsilon_{1t}, \qquad \text{or}$$

$$\Delta y_t = \overline{\alpha}_1(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{11}\Delta y_{t-1} + \Gamma_{12}\Delta k_{t-1} + \Gamma_{13}\Delta h_{t-1} + \varepsilon_{1t} \qquad ,$$

where the bars above the alphas and betas refer to the normalisation, in which the β parameters are divided by the beta-parameter of the normalised variable (and α:s multiplied by it).

[240] See Dennis, J.G., Hansen H., Johansen S. and Juselius K. (2005). *CATS in RATS*, *version 2*, Estima 2005.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The cointegration relation in the parenthesis above is stationary, which is why it is often interpreted as the long-run equilibrium for the levels $\mathbf{x_t} = (y_t \; k_t \; h_t)'$. If $\boldsymbol{\beta}'\mathbf{x_t} \neq 0$, it is interpreted as a long-run disequilibrium error and for fixed lags, the loading $\overline{\alpha}_1$ captures its effect on Δy_t. The growth of GDP per hours worked is explained above i) by the stationary cointegration or equilibrium correction relation of itself with physical capital per hours worked and human capital per hours worked, and ii) by the one lag differenced values of itself and the other two variables mentioned.

The whole CVAR model in the Vector Equilibrium Correction (VEC) form in the case of one cointegration relation is given in (4.2.4). In this three-equation system, the growth rates of Δy_t, Δk_t and Δh_t (differenced variables expressed in natural logarithms) are each explained at the same time by the stationary cointegration relation, with each having their own adjustment parameter, α_i, and by the growth rate with one lag of the growth rate of each variable:

$$\begin{cases} \Delta y_t = \overline{\alpha}_1(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{11}\Delta y_{t-1} + \Gamma_{12}\Delta k_{t-1} + \Gamma_{13}\Delta h_{t-1}) + \varepsilon_{1t} \\ \Delta k_t = \overline{\alpha}_2(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{21}\Delta y_{t-1} + \Gamma_{22}\Delta k_{t-1} + \Gamma_{23}\Delta h_{t-1}) + \varepsilon_{2t} \\ \Delta h_t = \overline{\alpha}_3(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{31}\Delta y_{t-1} + \Gamma_{32}\Delta k_{t-1} + \Gamma_{33}\Delta h_{t-1}) + \varepsilon_{3t} \end{cases} \tag{4.2.4}$$

As noted above with the number of variables equalling to 3 (p = 3), one cointegration relation (r = *1*), the number of common stochastic trends, $p - r$ = 3 – 1 = 2, refers to two common trends which are combinations of the cumulated residuals $\boldsymbol{\alpha}'_{\perp,1}\sum_{i=1}^{t}\boldsymbol{\varepsilon_i}$, $\boldsymbol{\alpha}'_{\perp,2}\sum_{i=1}^{t}\boldsymbol{\varepsilon_i}$ with loadings to the variables $\tilde{\boldsymbol{\beta}}'_{\perp,1}$ and $\tilde{\boldsymbol{\beta}}'_{\perp,2}$. Next, let us open the notations for all equations of the system with two cointegration relations.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Case 2: Analysis in the AR form of the model when *r = 2:*

(two cointegration relations, $p - r = 3 - 2 = 1$ unit root or common trend in the system):

$$\begin{pmatrix} \Delta y_t \\ \Delta k_t \\ \Delta h_t \end{pmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{33} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \end{bmatrix} \begin{pmatrix} y_{t-1} \\ k_{t-1} \\ h_{t-1} \end{pmatrix} + \begin{bmatrix} \Gamma_{11} & \Gamma_{12} & \Gamma_{13} \\ \Gamma_{21} & \Gamma_{22} & \Gamma_{23} \\ \Gamma_{31} & \Gamma_{32} & \Gamma_{33} \end{bmatrix} \begin{pmatrix} \Delta y_{t-1} \\ \Delta k_{t-1} \\ \Delta h_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix}.$$

By normalising the first cointegration relation on y_t and the second on k_t and opening up the matrix notation, we will get to a system of three equations.

$$\begin{cases} \Delta y_t = \overline{\alpha_{11}}(y_{t-1} + \overline{\beta_{12}}k_{t-1} + \overline{\beta_{13}}h_{t-1}) + \overline{\alpha_{12}}(\overline{\beta_{21}}y_{t-1} + \overline{\beta_{22}}k_{t-1} + h_{t-1}) + \Gamma_{11}\Delta y_{t-1} + \Gamma_{12}\Delta k_{t-1} + \Gamma_{13}\Delta h_{t-1} + \varepsilon_{1t} \\ \Delta k_t = \overline{\alpha_{21}}(y_{t-1} + \overline{\beta_{12}}k_{t-1} + \overline{\beta_{13}}h_{t-1}) + \overline{\alpha_{22}}(\overline{\beta_{21}}y_{t-1} + \overline{\beta_{22}}k_{t-1} + h_{t-1}) + \Gamma_{21}\Delta y_{t-1} + \Gamma_{22}\Delta k_{t-1} + \Gamma_{23}\Delta h_{t-1} + \varepsilon_{2t} \\ \Delta h_t = \overline{\alpha_{31}}(y_{t-1} + \overline{\beta_{12}}k_{t-1} + \overline{\beta_{13}}h_{t-1}) + \overline{\alpha_{32}}(\overline{\beta_{21}}y_{t-1} + \overline{\beta_{22}}k_{t-1} + h_{t-1}) + \Gamma_{31}\Delta y_{t-1} + \Gamma_{32}\Delta k_{t-1} + \Gamma_{33}\Delta h_{t-1} + \varepsilon_{3t} \end{cases} \quad (4.2.5)$$

In the system above each of the variables growth rates are explained by two cointegration relations and with growth rates of other variables. The first cointegration relation (in each equation in the first brackets) is the relation between y_t, k_t and h_t normalised on y_t, and the second cointegration relation is between the same variables normalised on h_t .

The number of common stochastic trends is here, $p - r = 3 - 2 = 1$, referring to one common trend which, again, is formed by the combinations of the cumulated residuals $\boldsymbol{\alpha}_{\perp}'\sum_{i=1}^{t}\boldsymbol{\varepsilon}_{\mathbf{i}}$ with loadings $\tilde{\boldsymbol{\beta}}_{\perp}$.

If the system is tested to have two cointegration relations (*r = 2*), there is more testing required to identify the system. With two (or more) cointegration vectors, the interpretation in terms of long-run equilibria is no longer straightforward. The problem is that any linear combination of the two cointegration relations in 4.2.5 will preserve the stationarity property. In other words, when the cointegration rank is higher than one there is an

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

identification problem: it is the space spanned by **β** and not **β** itself which is uniquely determined. CATS provides procedures for testing structural hypotheses on the cointegration space. These procedures allow the user to impose and test hypothesis by identifying restrictions on the cointegration vectors.[241]

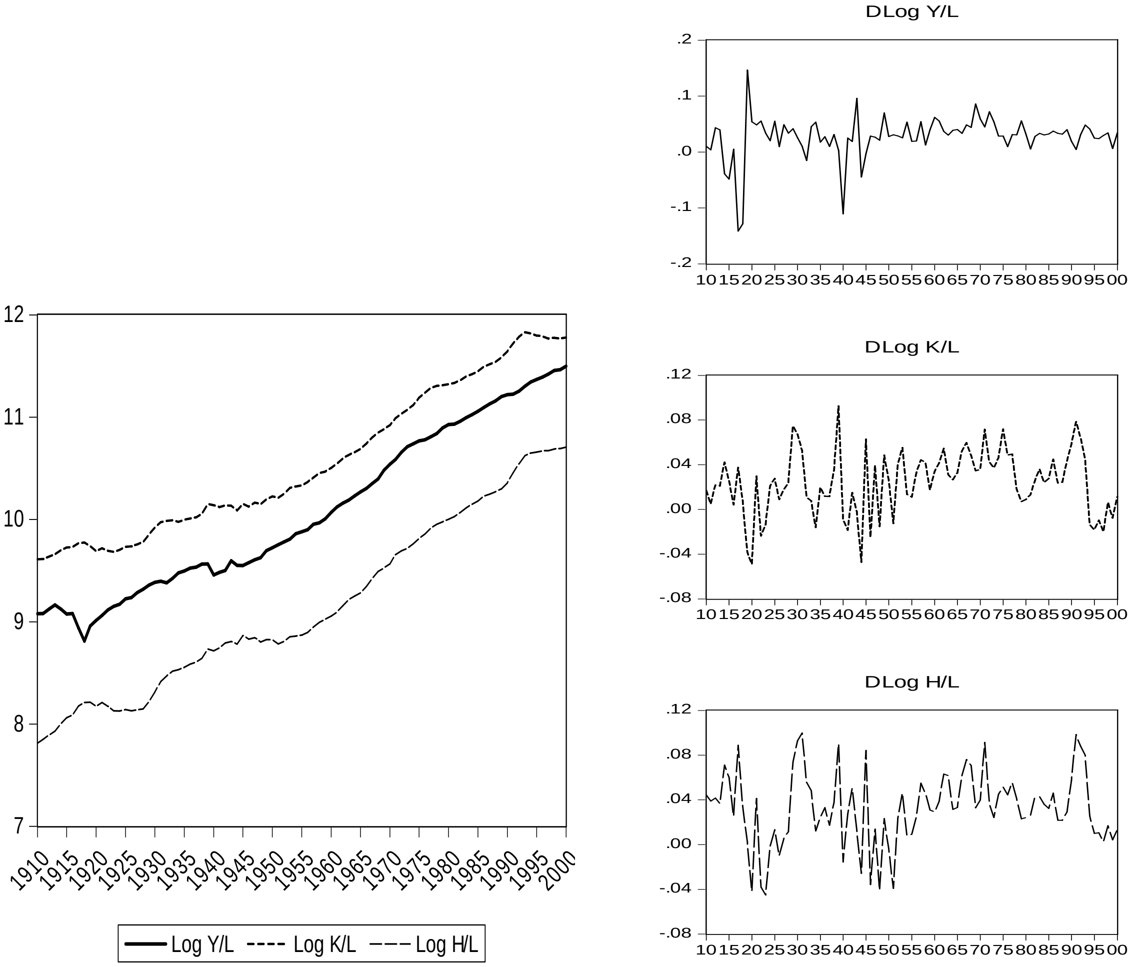
The normalising here is based on the hypothesis that the growth of GDP per hours worked could be explained by the cointegration relation on levels of itself and k_t and h_t and by the cointegration relation where human capital per hours worked is explained by y_t and k_t. The unique identification problem of the parameters in the cointegration relation is visible in 4.2.5, since all the variables exist in both cointegration relations. Therefore, in order to identify the interaction of the variables in the system explicitly, the relations of the variables in each cointegration equation are needed to be tested with restrictions on the parameters.

In the empirical analysis that follows, a time trend was originally included in both of the cointegration relations to start with the most unrestricted model. Figures 4.2.1 a) and b) demonstrate the evolution of the levels of the variables in natural logarithms and their growth rates along time. APPENDIX 4.1 gives the scatter plot graphs between the respective level variables demonstrating that the variables may be good candidates for cointegration. The analysis here is carried out for the years 1910–2000 for ensuring that the human capital stock variable has really reached its own fluctuation level. At the same time, for estimation purposes, the data should be as long as possible. The first phase of modelling is to determine the rank of PI. Before that, it is required that the residuals are non-autocorrelated white noise. For this, the non-normal large shocks to the variables are needed to be modelled by deterministic dummies.

[241] Dennis, J.G., Hansen H., Johansen S. and Juselius K. (2005). *CATS in RATS, version 2*, Estima 2005; Johansen, S. (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, 2nd edn.*; Juselius, K. (2006) *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figures 4.2.1 a) Physical capital per number of hours worked (Log K/L), GDP per number of hours worked (Log Y/L) and human capital per number of hours worked (Log H/L) in Finland in 1910–2000, in (natural logarithmic) form.
b) The LN growth rates of the same variables.



a) Levels (later vector $\mathbf{x}_t$) **b) Growth rates** ($\Delta\mathbf{x}_t$)

Sources: Physical capital: Jalava, Jukka and Matti Pohjola (2007): “The roles of electricity and ICT in growth and productivity: case Finland”, Pellervo Economic Research Institute Working Papers, N:o 94 (April 2007). K per hours worked: own calculations; Human capital stock by schooling (corrected for people deceased in wars and for migration) per hours worked and GDP per hours worked: own calculations; data from Hjerppe, Finland’s Historical National Accounts 1860–1994; statistics on financial accounts of the state, Statistical yearbooks 1879–1975, Statistics Finland; National Accounts publications: 1948–1965 and database of Finland 1975–; Statistics of the financial statements of municipalities and joint municipal authorities, *Suomen taloushistoria 3. Historiallinen tilasto*. (1983).

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

All the (level) variables are trending upwards and the inclusion of a time trend (possibly to be interpreted as technological progress, or the long-run average Solow residual – Multi Factor Productivity, MFP) in the cointegration relations seems to be feasible, which refers to a possibility that the series have both deterministic and stochastic trends. Looking at the first differences of the variables it becomes obvious that there are two periods containing probably outliers: the end of WWI around 1917–1919 (including the year of the Russian revolution and Finland gaining independence, 1917, the civil war year 1918 in Finland and the beginning of the recovery 1919) and the years of WWII 1939–1945 (in Finland the war ended mainly in 1944 and 1945 can be considered as the first year of recovery[242]).

There seems to be a structural break in the development of Finnish labour productivity in the WWII period. The level of labour productivity drops in the war period and continues from the lower level afterwards. First, in 1939 and 1940 there is a sudden decline associated with the Winter War between Finland and the Soviet Union. In 1943 there is blip upwards in the growth rate due to the military build-up in the second war period with the Soviet Union in WWII. This time Finland was in a military alliance with the Nazi Germany. One of the worst war years for Finland was the last war year, 1944, which can particularly be detected in the labour productivity growth and in the growth of k_t

After the war the growth rates of k_t and h_t accelerate from the 1950s to early 1970s with a blip around 1970–1971 followed by a decline in the growth rates. The blip and the sudden decline in the growth rate can be detected in the growth rate of y_t as well. This blip can probably be associated with the collapse of the Bretton Woods system in 1971 and the decline in the growth rates with the first oil crisis. One additional interesting aspect can be noticed from Figure 4.2.1b): the growth rates of k_t and h_t seem to be surprisingly similar when considering how differently the estimate for H has been cumulated taking into account the long graduation times from a person's all formal education (for instance, 20 years for a person graduating from the university).

In the end, after testing the residuals for several outlier combinations a level shift restricted to the cointegration relations was set to 1944, to separate the development before and after WWII in the long-run relations of the variables and to take into account the recovery from the war with a lot of physical and human capital destroyed. For the other outliers in the

[242] As a matter of fact, with respect to the terms of peace, Finns were to cast out the Germans from the North Finland which resulted in the war of Lapland from mid-September 1944 to the late April 1945. With all the difficulties included and damage to the property in Lapland, this had, however, not as big effect on the whole economy as the long lasting war. Economically it was more an aftermath. In 1945 the economy began already to recover. For instance, the resettlement of the Karelian people as well as the war reparation payments had begun already in the autumn 1944.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

WWII era, a transitory impulse dummy was used for 1939–1943, and a permanent impulse dummy was set to 1940, which, together with 1944, were perhaps the most destructive war years for Finland. A permanent impulse dummy was set for 1945, to describe the first recovery year.

To account for the turbulent end of the WWI period including the civil war in 1918, a permanent impulse dummy was located at 1917 and a transitory impulse dummy for the years 1918–1919. The blip in 1971 was modelled by a permanent impulse dummy. The role of the dummy and other deterministic variables in this analysis is discussed in APPENDIX 4.2 and the final specified VAR model with deterministic components is given in equations (A4.6.36) and (A4.6.37).

The dummies included are specified below:

- A level shift dummy for 1944: $Ds1944_t = 1$ for $t \geq 1944$, zero otherwise;
- A permanent impulse dummy for the year 1917: $D_{pt} = 1_{1917}$, zero otherwise; and for the years 1940: $D_{pt} = 1_{1940}$, zero otherwise; 1945: $D_{pt} = 1_{1945}$, zero otherwise and 1971: $D_{pt} = 1_{1971}$, zero otherwise.
- A transitory intervention dummy for the years 1918–1919: $D_t = -1_{1918}, 1_{1919}$, zero otherwise; for the war period 1939–1943: $D_t = -1_{1939}, 0_{1940}, 0_{1941}, 0_{1942}, 1_{1943}$, zero otherwise.

After the inclusion of these deterministic variables, the residuals of the baseline model in 4.2.2 were independently, identically and normally distributed white noise, as is assumed in the VAR model. The LM-tests with 1 to 2 lags of no multivariate residual autocorrelation could not be rejected with *p*-values 0.34 and 0.47. A little sign of minor ARCH effects of multivariate residuals was detected as LM-test *p*-value of no ARCH effects with one lag was 0.041, however, the hypothesis of no ARCH effects with two lags could not be rejected with a *p*-value of 0.09. Also, the rank test, which is used later to determine the number of cointegration relations, is robust to moderate ARCH effects.[243] This implies that the possible minor problems with ARCH will not impact on the analysis in any important way. The joint normality test of the residuals was accepted with a *p*-value of 0.33.

[243] See Rahbek A, Hansen E, Dennis J. G. (2002). ARCH Innovations and their impact on cointegration rank testing. *Working Paper No.22*, Centre for Analytical Finance, University of Copenhagen.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table 4.2.1 The unrestricted baseline VAR(2) model in the VECM form ,

t-ratios in brackets [ ]

	y_t	k_t	h_t	D_{s1944}	t
β'_1	3.6	–16.8	18.1	3.7	–0.31
β'_2	16.6	–16.8	6.0	1.6	–0.27
β'_3	–9.3	17.2	–1.6	–0.24	–0.15

	α_1	α_2	α_3
y_t	0.003 [0.14]	**–0.008** [–4.22]	–0.003 [–1.62]
k_t	**–0.0084** [–4.43]	0.0029 [1.54]	–0.005 [–2.69]
h_t	**–0.015** [– 6.92]	0.0030 [1.40]	0.0029 [1.37]

Table 4.2.2 Misspecification tests for the unrestricted VAR(2) ,

t-ratios in brackets [ ], dummies included

Multivariate tests						
Residual autocorrelation:	*p*-value		*p*-value			
$LM_1 : \chi^2(9)$	0.34	$LM_2 : \chi^2(9)$	0.47			
Normality:						
$LM : \chi^2(6)$	0.33					
ARCH:						
$LM_1 : \chi^2(36)$	0.041	$LM_2 : \chi^2(72)$	0.089			
				$\varepsilon_{\Delta y}$	$\varepsilon_{\Delta k}$	$\varepsilon_{\Delta h}$
Univariate residual std. errors and cross-correlations :				0.017	0.018	0.020
			$\varepsilon_{\Delta y}$	1		
			$\varepsilon_{\Delta k}$	0.052	1	
			$\varepsilon_{\Delta h}$	–0.099	0.880	1
Trace correlation	0.72					

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The unrestricted baseline VAR model was first estimated, and the results are shown in Table 4.2.1. It can be detected that there are statistically significantly adjusting parameters (with $|t| > 3.51$, which is the 5% critical value in the Dickey-Fuller distribution) in the two of the alpha-vectors implying two cointegration relations. The multivariate residuals of the model are assumed to be independently, identically and normally distributed with mean zero and a constant variance. The misspecification tests are shown in Table 4.2.2 and the assumptions mentioned cannot be rejected after including the deterministic dummies defined above. The cross correlation between the residuals of Δk_t and Δh_t is very high, 0.88, which is not a surprise looking at the growth rates of the variables.

Determining the cointegration rank (rank of PI)

As mentioned above, when the process is *I(1)*, the number of unit roots equals to *p – r*, which is the number of stochastic trends in the system There are four different ways to gather information for making inference on the rank of PI, *r*. First, as discussed above, the significance of the coefficients (in accordance with the DF-distribution) in the alpha vectors in the unrestricted VAR model can be used in inference of the rank. Secondly, a trace test (possibly with a small sample correction) with simulated critical values (adjusted for dummies, etc.) can be carried out in CATS.

With deterministic components (dummies) in the analysis, the trace test suggest the rank of PI to be two (*p*-value*=0.22). Rank equal to one, (*r* = 1), with a small sample corrected *p*-value* =0.0558 could be on the border of acceptance. The trace test without dummies was clearly rejecting r=1 and suggesting r=2, as well as the simulated *p*-values above without the small sample Bartlett correction.

Table 4.2.3 Trace test and characteristic roots

Trace refers to simulated asymptotic distribution with respect to deterministic components in the model
*small sample Bartlett corrected, refers to the model without deterministic components

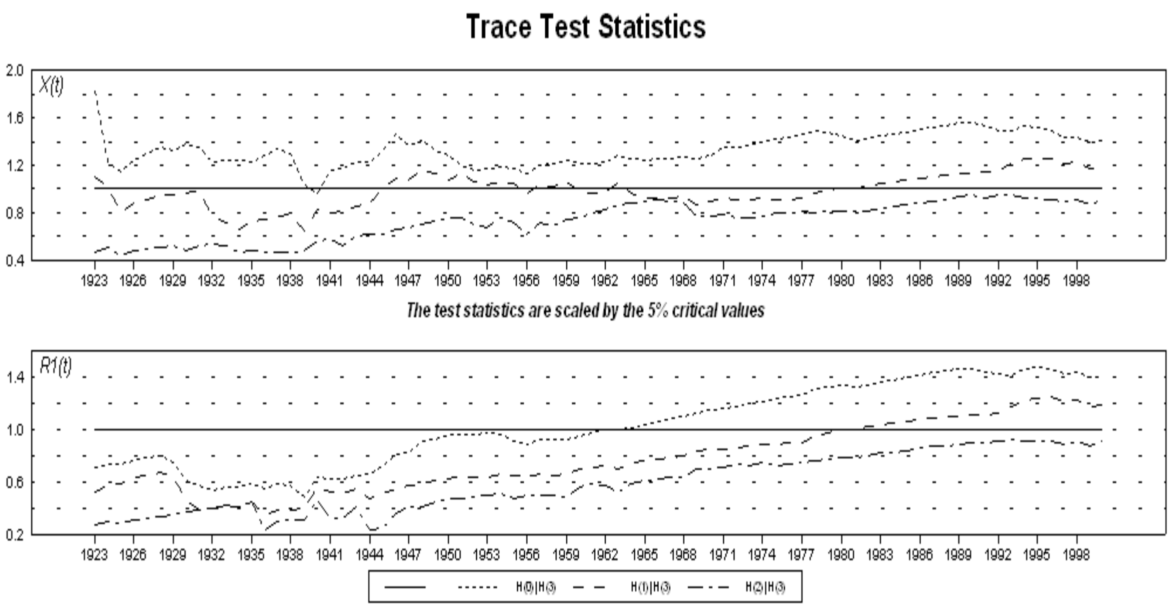
r	*p – r*	Trace *p*-value	Trace* *p*-value	Modulus of the 5 largest characteristic roots				
0	3	0.0000	0.0001	1	1	1	0.58	0.58
1	2	0.0327	*0.0558*	1	1	*0.76*	0.76	0.31
2	1	**0.1675**	**0.2231**	1	**0.81**	0.73	0.73	0.40

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

As a third step, the rank can be further detected by reducing the rank of **Π** in the model, and hence imposing an increasing number of unit roots ($p - r$) in the model. With the feasible rank the next largest root of the characteristic function after the unit roots should be clearly less than 1. This enables to suggest a choice for r as well.

With one stochastic trend (unit root) in the model, and therefore rank = *2*, the next largest root gets the value of 0.8, which can obviously be considered a non-unit root (the difficult area of testing a unit root is in the range of values between 0.95 – 1). With two stochastic trends, implying a rank equal to one, the next root will get a value of approximately the same size as in the previous case, 0.76. These observations support a choice of $r = 2$.

Figure 4.2.2 The recursively estimated trace test statistics



Fourthly and finally, recursive estimation for the trace test statistics was executed without the deterministic dummies in the model (see above especially the lower graph, the test with a model, from which the short-run effects have been concentrated out).[244] The graph of the test is implying $r = 2$, as the tests for $r = 1, 2$ surpass the critical value of the 95% quantile of the appropriate asymptotic distribution (this 5% critical value is scaled to one in the graph).

With all of the above analysis, it can be inferred that the cointegration rank of the model should most likely be determined to two, with some indication of $r = 1$ being on the

[244] The recursive tests were executed with CATS in RATS version 2.01. The dummies were exluded in the recursive tests since the 95% quantile is not appropriate when the co-integration relations contain shift dummies.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

borderline of acceptance. Therefore, the focus is on the analysis of two cointegration relations and the hypotheses on which of the variables form the two equilibrium correction relations will be first tested. After this the case of *r = 1* will be reviewed.

Analysis with two cointegration relations between y_t, k_t and h_t

The analysis with *r = 2* is based on the three-equation system, which is shown below, with the time trend and the level shift, both restricted to cointegration relations, included in each of the long-run relations to begin with. As was explained before, in the case of two cointegration relations, a lot of work may occur for identifying the model by testing hypothesis. This means setting and testing restrictions on the $\overline{\beta}$ -coefficients.

The three-equation model with rank equal to two is opened up again below. The first cointegration relation is normalised on y_t, the second one is chosen to be normalised on h_t at least to start with, referring to the possibility that either k_t or y_t and possibly the time trend and level shift could explain the long-run development of it. The short-run part of the equations, one differenced lag of all of the variables, is denoted briefly with $\mathbf{\Gamma\Delta X_{t\text{-}1}}$.

$$\begin{cases}\Delta y_t = \overline{\alpha_{11}}(y_{t-1} + \overline{\beta_{12}}k_{t-1} + \overline{\beta_{13}}h_{t-1} + D_s 44 + g_1 t) + \overline{\alpha_{12}}(\overline{\beta_{21}}y_{t-1} + \overline{\beta_{22}}k_{t-1} + h_{t-1} + D_s 44 + g_2 t) + \mathbf{\Gamma\Delta X_{t\text{-}1}} + \varepsilon_{1t} \\ \Delta k_t = \overline{\alpha_{21}}(y_{t-1} + \overline{\beta_{12}}k_{t-1} + \overline{\beta_{13}}h_{t-1} + D_s 44 + g_1 t) + \overline{\alpha_{22}}(\overline{\beta_{21}}y_{t-1} + \overline{\beta_{22}}k_{t-1} + h_{t-1} + D_s 44 + g_2 t) + \mathbf{\Gamma\Delta X_{t\text{-}1}} + \varepsilon_{2t} \\ \Delta h_t = \overline{\alpha_{31}}(y_{t-1} + \overline{\beta_{12}}k_{t-1} + \overline{\beta_{13}}h_{t-1} + D_s 44 + g_1 t) + \overline{\alpha_{32}}(\overline{\beta_{21}}y_{t-1} + \overline{\beta_{22}}k_{t-1} + h_{t-1} + D_s 44 + g_2 t) + \mathbf{\Gamma\Delta X_{t\text{-}1}} + \varepsilon_{3t}\end{cases}$$

Before proceeding to testing the hypothesis, the baseline VAR is estimated with rank two and the general model specific data properties can be tested. These model specific data properties refer to general tests whether some of the variables could be excluded from the model, whether there are stationary (or trend stationary when a time trend is included) variables in the analysis, whether some of the variables are the primarily purely adjusting pulling forces and some define the pushing forces. The two latter tests can be conducted by imposing restrictions on alpha matrix, i.e. whether some of the variables are always adjusting to the innovations of

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

all other variables and whether some do not adjust at all to the innovations in other variables but cannot be excluded from the cointegration relations.

According to these general tests, none of the variables could be excluded, none were stationary with the time trend and the level shift included and all of the variables proved to be adjusting at least to one variable in the model. Instead, as the results with the baseline VAR for *r = 2* below indicate, y_t is only adjusting to k_t and h_t in one relation, in which k_t and h_t are not adjusting at all. In the other cointegration relation k_t and h_t are the only variables adjusting. This suggests a test of a known alpha vector where y_t is the pulling force and only adjusting to the other variables to maintain the long-run cointegration equilibrium, whereas the other variables forming the pushing forces of the system. This test of a unit vector in alpha on y_t could not be rejected with a *p*-value 0.45.

Table 4.2.4 The unrestricted VECM with *r* = 2 ,
t-ratios in brackets [ ]

	y_t	k_t	h_t	D_{s1944}	t
$\boldsymbol{\beta}_1'$	0.196	–0.92	1	0.20	–0.0169
$\boldsymbol{\beta}_2'$	1	–1.01	0.36	0.09	–0.0161

	$\boldsymbol{\alpha}_1$	$\boldsymbol{\alpha}_2$
y_t	0.046 [0.14]	**–0.13** [–4.16]
k_t	**–0.15** [–4.27]	0.049 [1.48]
h_t	**–0.27** [– 6.85]	0.049 [1.38]

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table 4.2.5 The long-run structure with unit vector in alpha on y,
LR test of restricted model $\chi^2(1)$, p-value [0.45],
t-ratios in brackets [ ]

	y_t	k_t	h_t	D_{s1944}	t
$\boldsymbol{\beta}_1'$	1	–0.88	0.35	0.096	–0.0195
$\boldsymbol{\beta}_2'$	0.096	–0.86	1	0.20	–0.0155

	$\boldsymbol{\alpha}_1$	$\boldsymbol{\alpha}_2$
y_t	**–0.12** [–4.50]	0.00 [0.00]
k_t	0.00 [0.00]	**–0.15** [–4.29]
h_t	0.00 [0.00]	**–0.26** [– 6.84]

Table 4.2.6 The MA representation corresponding to a unit vector in alpha on y,
t-ratios in brackets [ ]

	ε_{yt}	ε_{kt}	ε_{ht}
$\sigma_{\varepsilon i}$	0.0241	0.0402	0.0323
Common trend (CT) weights			
$\boldsymbol{\alpha}_{\perp}'$	–0.00	1	–0.58
Loadings to CT			
$\tilde{\boldsymbol{\beta}}_{\perp}'$	2.36	3.94	3.17

The Log Run Impact matrix C

	ε_{yt}	ε_{kt}	ε_{ht}	$t \bullet \gamma_{0,i}$
y_t	0.00 [0.00]	**2.36** [2.92]	**–1.365** [–2.08]	0.0301
k_t	0.00 [0.00]	**3.94** [2.92]	**–2.28** [–2.08]	0.0260
h_t	0.00 [0.00]	**3.17** [2.92]	**–1.83** [–2.08]	0.0350

The MA representation with a unit vector in alpha is given in Table 4.2.6. It shows that, as expected here, the common stochastic trend is defined by the combination of the cumulated

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

residuals of k_t and h_t, and y_t has not had any long-run effects, only transitory effects, to the evolution of the levels of the variables in the system. The common stochastic trend is defined here as $\left[\sum_{i=1}^{t}\varepsilon_{ki} - 0.58\sum_{i=1}^{t}\varepsilon_{hi}\right]$ with positive loadings for each variable $\tilde{\boldsymbol{\beta}}_{\perp} = \begin{bmatrix}2.4 & 3.9 & 3.2\end{bmatrix}'$. The economy and each of the variables have grown when the sum of all the previous innovations in k_t has grown more than 0.58 times the sum of all the previous innovations in h_t.

The purpose of the following analysis is to identify the two cointegration relations in the system in such a way that they are distinct from each other, and the system can be equally, in terms of likelihood of the model, presented with a reduced number of parameters. The main *hypotheses* to be tested *in the case of two cointegration relations* are: *Is there a long-run relation between y_t, k_t and h_t* to be found referring to a Cobb-Douglas type production function in 4.1.6? If there is, *are the coefficients of k_t and h_t summing up to one or less than one* implying either constant or decreasing returns to scale of the broad reproducible capital? *Has there been a long-run relation between k_t and h_t and technological progress? How have k_t and h_t been interacting with each other in accordance with technological progress?*

In order to identify the system and test statistically the significance of the parameters, the parameters of the variables need to be restricted so that the two cointegration relations can be distinguished from each other.[245] Several combinations of restrictions on $\bar{\beta}$-coefficients were tested to identify the system. Statistical tests and graphical inspections to analyse the mean reverting properties of the cointegration relations were conducted. The analysis of the finally chosen identified cointegration relations and the identified final long-run structure will be presented next.

Starting with the first hypothesis, the stationarity of the long-run relation between y_t, k_t and h_t was tested by imposing a homogenous restriction so that the parameters of k_t and h_t would sum to a unity, when the relation is normalised on y_t. The level shift and the time trend were restricted to zero in this relation. The LR-test could obviously not reject this hypothesis with *p*-value of 0.395, indicating that the likelihood of the estimated model did in practice not change with the imposed restriction. Therefore, we will have to accept the hypothesis of the other long-run relation being the production function of the type in 4.1.6 with constant returns

[245] See Juselius, K. (2006) *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications.*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

to scale when human capital by formal education is assessed in the National Accounts frame. This implies non-decreasing returns to scale on broad reproducible capital, *H* + *K*.

After this, the hypothesis of the capitals and technological progress together with the imposed level shift in 1944 was imposed as a second cointegration relation in the model. With exactly these two cointegration relations, the model could not be rejected with a *p*-value of 0.35, see Table 4.2.7.

According to this model, given in Table 4.2.7, the long-run development of each of the variables has been endogenous: In the first – constant returns to scale production function – relation labour productivity, y_t, has been induced by a weighted sum of k_t and h_t. Physical capital in proportion to labour input has a weight of 0.53 and human capital of 0.47, referring to almost identical long-run average contributions to the labour productivity development. Labour productivity shows to have been adjusting to the shocks of the other variables with a *t*-ratio -3.1 (here the normal *t*-ratio value |1.98| with 5% risk level should be exceeded for statistical significance). At the same time, k_t and h_t have not been adjusting in the same relation to the innovations of labour productivity growth and to the innovations of the other type of capital in the labour input. Thus, it can be obviously referred to as the production function relation.

Table 4.2.7 The final identified long-run structure,
LR test of restricted model $\chi^2(2)$, p-value [0.35],
t-ratios in brackets [ ]

	y_t	k_t	h_t	D_{s1944}	t
β'_1	**1**	**–0.53** [–5.47]	**–0.47** [–4.93]	0	0
β'_2	0	**–0.74** [13.3]	**1**	**0.176** [5.81]	**–0.0155** [8.53]

	α_1	α_2
y_t	**–0.11** [–3.10]	–0.08 [–1.68]
k_t	0.05 [1.34]	**–0.12** [–2.53]
h_t	0.01 [0.30]	**–0.25** [– 4.94]

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

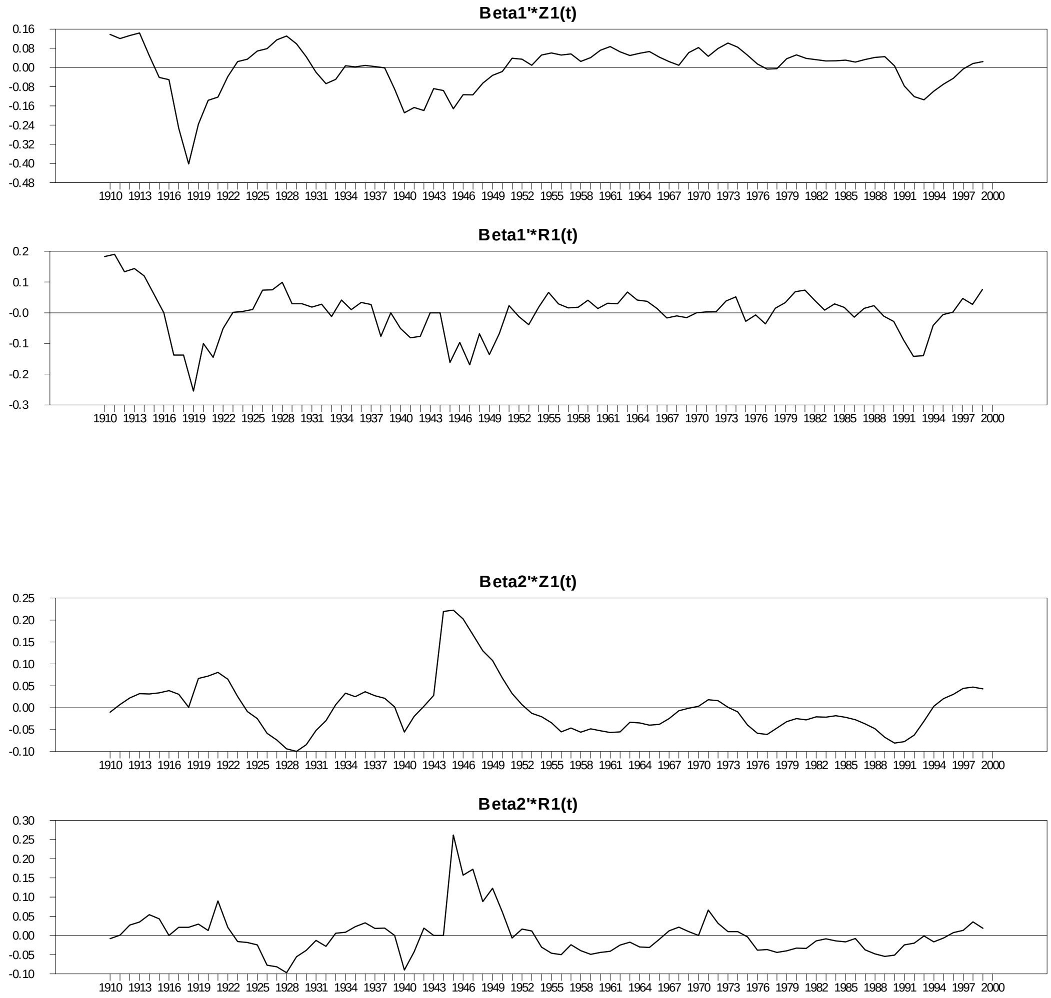
Instead, in the second relation k_t and h_t have been adjusting to each other, which is making the development of the variables in this empirical model endogenous. As one type of capital has grown, the other type of capital must have grown, in accordance with the time trend, to keep the relation $h_t = 0.74k_t + gt$ or $h_t - 0.74k_t - gt = 0$ stable. Since $(H_t / L_t) / (0.74K_t / L_t) = H_t / 0.74K_t$, in non-logarithmic form, the relation describes the evolution of capitals themselves. As both are adjusting in the relation, physical capital and human capital have grown with respect to each other along with technological change.

Human capital has grown faster, and in order for the relation to stay stable, the technological progress, the time trend is needed for enhancing the effects of physical capital. This is realistic since the technology embodied in the equipment and machinery has no doubt advanced in k_t, and with the same costs the capital goods produced later are of higher quality. The technological progress and the growth of K_t has created demand for human capital. At the same time, more human capital has induced a possibility to higher technology capital goods and promoted interest in investing in production equipment in Finland. Consequently, in the empirical model above, a positive increase in human capital has stimulated physical capital to grow and vice versa. After 1944 the whole relation between the capitals has shifted 18% in favour of human capital, $t \geq 1944: \; [h_t + 0.18 = 0.74k_t + gt]$. This is probably due to the destruction of physical capital in WWII and to the schooling expansion that has provided more possibilities to use higher and higher technology from the evolving world technology frontier. The latter has created an incentive to invest in continuously advancing physical capital. In addition, more physical capital was destroyed in 1939–1944 than human capital[246], and the shift in that time also reflects an exogenous shock in the relative relation of the capitals. The rate of the average growth of technological progress is estimated at 1.6% per year in the model.

[246] The productive stock of physical capital declined -0.3% in 1941–1944 in Finland despite the positive investments e.g. in the machinery of war at the same. The average growth of this stock has been 2.9% a year in 1910–2000. The productive stock of human capital by schooling continued growing during the war years because of graduates from primary and lower secondary schools. However, due to those deceased in war, the pace of growth was substantially lower, on average 2.0% per year e.g. in 1941–1950, compared with 3.8% per year on average in 1910–2000.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figures 4.2.3 The cointegration relations with *r =2*, CRS-production function as the first relation (Beta 1, upper graphs), capitals and technical change in the second relation (Beta 2, lower graphs)



The long-run equilibrium correction (or cointegration) relations $\mathbf{B_1}:[y_t - 0.53k_t - 0.47h_t = 0]$ and $\mathbf{B_2}:[h_t - 0.74k_t - 0.18D_{s1944} - 0.016t = 0]$ are sketched in Figure 4.2.3. The upper graph ($\mathbf{B_i^{'}Z_1(t)}$) in both figures refers to the $\boldsymbol{\beta}\mathbf{'X_t}$ relation in the model in (4.2.2) with the short-run effects of the lagged differences $\mathbf{\Gamma\Delta X_{t\text{-}1}}$ included in the model. The lower graphs ($\mathbf{B_i^{'}R_1(t)}$) refer to a model from which the short-run effects have been concentrated out. The $\mathbf{R_1}$ model is of more importance in identifying the long-run structure. However, the mean reverting properties should be present in both graphs, and the evolution of the relation should not differ significantly between the models. Both relations exhibit a mean reverting stationary behaviour, with similar evolution in both, $\mathbf{Z_1}$ and $\mathbf{R_1}$, models.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table 4.2.8 The MA representation corresponding to the identified long-run structure, *t*-ratios in brackets [ ]

	ε_{yt}	ε_{kt}	ε_{ht}
$\sigma_{\varepsilon i}$	0.0237	0.0270	0.0200
Common trend (CT) weights			
$\boldsymbol{\alpha}_{\perp}'$	0.38 [1.55]	**1**	**–0.58** [–5.98]
Loadings to CT			
$\tilde{\boldsymbol{\beta}}_{\perp}'$	**1.75** [2.54]	**2.00** [2.54]	**1.48** [2.54]

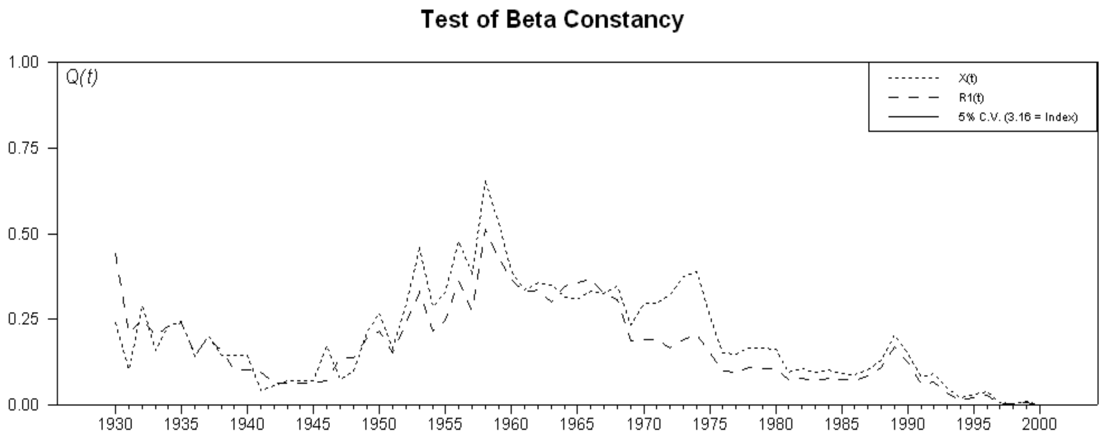
The Log Run Impact matrix C

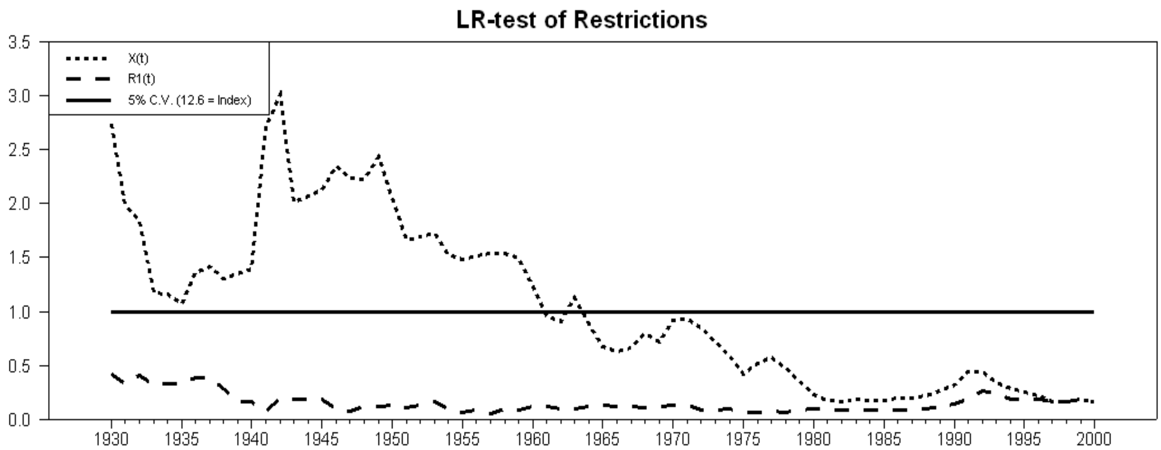
	ε_{yt}	ε_{kt}	ε_{ht}	$t \bullet \gamma_{0,i}$
y_t	**0.66** [3.19]	**1.75** [2.53]	**–1.01** [–2.08]	0.0312
k_t	**0.75** [3.19]	**2.00** [2.53]	**–1.15** [–2.08]	0.0272
h_t	**0.55** [3.19]	**1.48** [2.53]	**–1.47** [–2.08]	0.0356

The Moving Average representation of the identified model is given in Table 4.2.8. The main message of the MA form with regard to the common trend is the same as in the case of a unit vector in alpha on y_t: the common stochastic trend is defined by the combination of the cumulated shocks to k_t and h_t by $\left[\sum_{i=1}^{t}\varepsilon_{ki} - 0.58\sum_{i=1}^{t}\varepsilon_{hi}\right]$. The proportion in non-logarithmic form, K/L / H/L = K/H, and the innovations in K and H seems to be the source for the pushing force in the model. The alpha orthogonal coefficient for y_t is not statistically significant. All the variables have a positive loading with respect to the common trend, $\tilde{\boldsymbol{\beta}}_{\perp} = [1.75 \quad 2.0 \quad 1.48]'$.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figures 4.2.4 Recursively estimated tests for the constancy of the model long-run parameters and identifying restrictions





Finally, the constancy of the model β-parameters and the constancy of the restrictions imposed above on $\boldsymbol{\beta}$ in the long run were inspected with recursive tests. The parameters of the long-run relations have been stable over the estimation period and certainly below the critical value (scaled to 1) of rejecting the constancy, as can be seen in the upper graph in Figures 4.2.4. Similarly, it becomes obvious from the lower graph that the identifying restrictions on the cointegration relations would have been accepted in all of the recursively estimated sample periods along the time frame. The attention here should be paid to the lower line, referring to the stability of the long-run $\mathbf{R}_1$ model, from which the short-run effects have been concentrated out.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Above the Finnish labour productivity growth was modelled together with physical and human capital in the labour input in 1910–2000. Most likely the labour productivity growth can be best modelled with two long-run steady state relations. One is a production function in the intensive form of the type $(Y_t / L_t) = A(H_t / L_t)^{1-\alpha}(K_t / L_t)^{\alpha}$. The other is a relation between the capitals $H_t = T(t) \cdot 0.74K_t$, where both types of capital influence the evolution of the other and where the technological progress is attached to physical capital. The results can be seen supporting models with a production function expressed as $Y_t = AH_t^{1-\alpha}K_t^{\alpha}$ or as $Y_t = AK_{T,t}$, where $K_{T,t}$ includes both physical and human capital, however, taking into account that physical (or fixed) capital and human capital have been nourishing the development of each other, and that technological progress is embodied in fixed capital.

By joining both aspects to a single equation model, these results can also be interpreted giving support to a variety of fixed capital goods model, of the type $Y_t = A \cdot H_t^{1-\alpha}K_t^{\alpha} = A \cdot (H_t)^{1-a} \cdot \sum_{j=1}^{N}(k_{j,t})^{\alpha}$, where $k_{j,t}$ is one type of fixed capital good and N expresses the number of variety of capital goods used in that country, discussed in the Introduction of this dissertation as well. The model should be augmented, though, to express the simultaneous growth of human and physical capital with capitals being complements and affecting the evolution of each other. The fact that N has increased over time is reflected in the steady state equation of the capitals by the time trend $T(t)$ attached with the used aggregate K_t in the empirical analysis. Another way to interpret the time trend in connection with the aggregate K_t would be that the quality, and therefore the productivity, of a unit of physical capital at a later point of time has been higher. Therefore, the results would give support as well to the quality ladder models and to the idea of capital vintages. It is argued here that both the effects may have been working along time. The later vintages of the same type of capital goods, k_j, have been of better quality, resulting in part in technological progress. Simultaneously, the number of new varieties of fixed capital goods, N, has increased resulting obviously as well in technological progress. These effects are observed together in the time trend, $T(t)$, attached to fixed capital in the analysis with two cointegration relations. The fact that N (or $T(t)$), attached with fixed capital, has grown along time suggests technological transfer to Finland in the form of imported new varieties (or qualities) of K_t,

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

since Finland has obviously not have innovated and produced all the new varieties of fixed capital employed at home.

Analysis with one cointegration relation between y_t, k_t and h_t

The analysis of only one cointegration relation will be reviewed here first because the analysis of the cointegration rank gave some signs of $r = 1$ being on the borderline of acceptance. Secondly, we can use this analysis to ensure that the first relation above can be named a production function relation.

With one cointegration relation and the other variables normalised on GDP per number of hours worked (y_t), the vector equilibrium correction model gets the form of that in equation 4.2.2:

$$\begin{cases} \Delta y_t = \overline{\alpha}_1(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{11}\Delta y_{t-1} + \Gamma_{12}\Delta k_{t-1} + \Gamma_{13}\Delta h_{t-1}) + \varepsilon_{1t} \\ \Delta k_t = \overline{\alpha}_2(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{21}\Delta y_{t-1} + \Gamma_{22}\Delta k_{t-1} + \Gamma_{23}\Delta h_{t-1}) + \varepsilon_{2t} \\ \Delta h_t = \overline{\alpha}_3(y_{t-1} + \overline{\beta}_2 k_{t-1} + \overline{\beta}_3 h_{t-1}) \quad + \Gamma_{31}\Delta y_{t-1} + \Gamma_{32}\Delta k_{t-1} + \Gamma_{33}\Delta h_{t-1}) + \varepsilon_{3t} \end{cases}$$

In the analysis above it was shown that the level shift 1944 was not present in the first cointegration relation. Therefore, a permanent impulse dummy was set to 1944, to account for the level shift in the Moving Average form in the evolution of the levels of $\mathbf{x_t}$, (see also APPENDIX 4.2 for a thorough discussion of the deterministic components in the VAR model). This produces the same effect to the evolution of the level series as a level shift restricted to cointegration relation plus a difference of it unrestricted included in the model.

After the estimation of the baseline VAR, the parameters of k_t and h_t were restricted to sum up to the coefficient of y_t and for testing that the production function would be exactly of the type $y = k^{\alpha}h^{1-\alpha}$, the time trend was restricted to zero. The estimation results (below with *t*-values in parenthesis) of this model with restricting the parameters of k and h summing up to one in the cointegration relation argue that GDP per hours worked could be explained solely by physical and human capital per hours worked. The LR test on the restriction was accepted with a *p*-value of 0.24. Along with the homogenous restriction on the parameters,

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

the constant returns to scale hypothesis with respect to broad capital could not be rejected. Together with this, it was tested that the technical change could be left out of the production relation when human capital by formal education is included.

All the variables are statistically obviously significant in this long-run relation. Physical capital in the labour input gets a parameter value of -0.54 and human capital in the labour input only a slightly smaller value of -0.46, implying that with a simple production function approach they would explain each half of the long-run GDP per hours worked in Finland in 1910–2000. More importantly, technical change or the Solow residual could be excluded from the model, with LR-test *p*-value of 0.24 in the case of one cointegration relation. Here, with only one long-run stationary relation in the ECM model, all of the variables adjust statistically significantly to the long-run equilibrium between the variables: labour productivity adjusts with a pace of 6.7% each year to get back to the equilibrium of the disequilibrium caused by shocks, physical capital per hours worked by 11% and human capital per hours worked by 14% a year. What we could not hypothesise in this model is that the capitals may have adjusted to the development on each other and not on y_t.

Table 4.2.9 The identified long-run structure with *r* = 1

LR test of restricted model $\chi^2(2)$, p-value [0.24], *p*-value* [0.46]

t-ratios in brackets [ ]

	y_t	k_t	h_t	t
β'_1	**1**	**–0.538** [–5.86]	**–0.462** [–5.04]	0

	α_1
y_t	**–0.07** [–2.61]
k_t	**0.11** [4.15]
h_t	**0.14** [4.56]

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The MA form, in Table 4.2.10, shows that the two stochastic trends, with r = 1, are defined by the innovations of y_t and k_t and by y_t and h_t, stating that the growth in labour productivity growth itself has pushed the system to grow together with k_t and h_t.

Table 4.2.10 The MA representation corresponding to the identified long-run structure with *r* =1

t-ratios in brackets [ ]

	ε_{yt}	ε_{kt}	ε_{ht}
$\sigma_{\varepsilon i}$	0.0211	0.0297	0.0222
Common trends (CT) weights			
$\boldsymbol{\alpha}'_{\perp,1}$	**1.63** [2.09]	**1**	0.00 [0.00]
$\boldsymbol{\alpha}'_{\perp,2}$	**2.15** [2.26]	0.00 [0.00]	**1**
Loadings to CT:s			
$\tilde{\boldsymbol{\beta}}'_{\perp,1}$	*0.91* [1.78]	**2.50** [3.49]	*–0.95* [1.77]
$\tilde{\boldsymbol{\beta}}'_{\perp,2}$	–0.30 [–0.86]	**–1.60** [–3.22]	**1.20** [3.24]

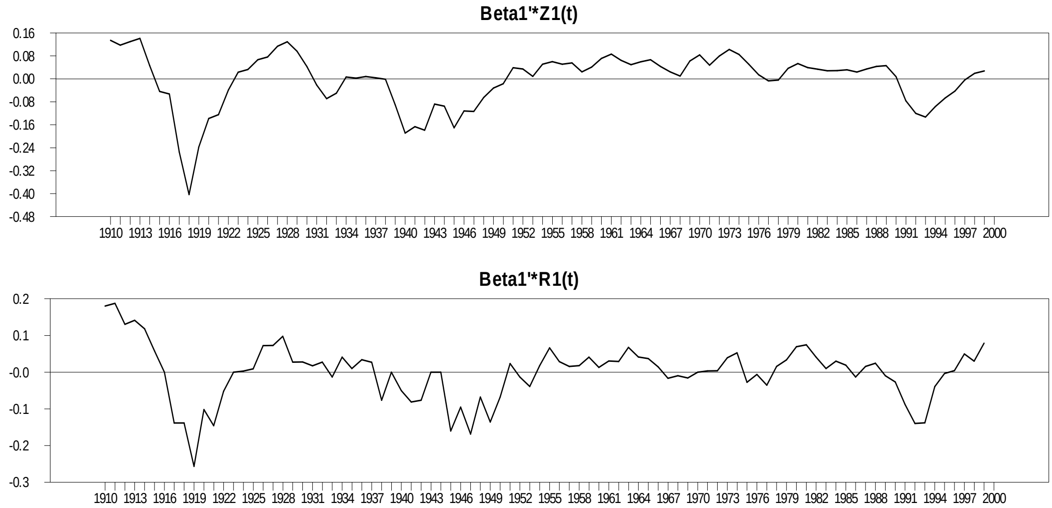
The Log Run Impact matrix C

	ε_{yt}	ε_{kt}	ε_{ht}	$t \bullet \gamma_{0,i}$
y_t	**0.83** [5.34]	*0.91* [1.78]	–0.30 [–0.85]	0.031
k_t	**0.65** [2.98]	**2.50** [3.49]	**–1.60** [–3.22]	0.027
h_t	**1.03** [6.31]	*–0.95* [–1.77]	**1.20** [3.24]	0.035

The cointegration relation is sketched in Figure 4.2.5 (the lower of them is estimated by reducing the short-run effects from the relation). The relation is obviously stationary and the biggest shocks to the system caused by the wars (1917–1919 and 1939–1945) and depressions (the early 1930s and early 1990s) are the causes for momentary disequilibria between the variables.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure 4.2.5 The cointegration relation with r =1 , only y_t, k_t and h_t in the model



What if human capital per hours worked would not exist as an empirical variable in the analysis? Could it be excluded from the model? How would the rate of the technical change (or Solow residual) change in the long run? These questions can be answered by imposing a hypothesis $\bar{\alpha}_1 = \bar{\beta}_3 = 0$. The results are shown in Table 4.2.11.

The LR-test comparing the Log-Likelihoods of the models does not support excluding human capital from the model. The growth of the estimated time trend (or the "Solow residual") interpreted as technological progress would be 2.4% a year when human capital per hours worked was excluded from the model. In addition, physical capital per hours worked does not seem to be alone statistically significant in the cointegration equation. If still this model was fitted to the data, k would not be adjusting statistically significantly (t-value -0.64) to the long-run equilibrium, which would imply it to be weakly exogenous in the model and therefore the determinant of long-run labour productivity growth. Without having human capital in the model, it would be possible to end up with a traditional neo-classical explanation of labour productivity growth, with a high Solow residual. The cointegration graph below is perhaps not exhibiting strong mean reverting properties throughout the sample and could not give strong support to stationary behaviour.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

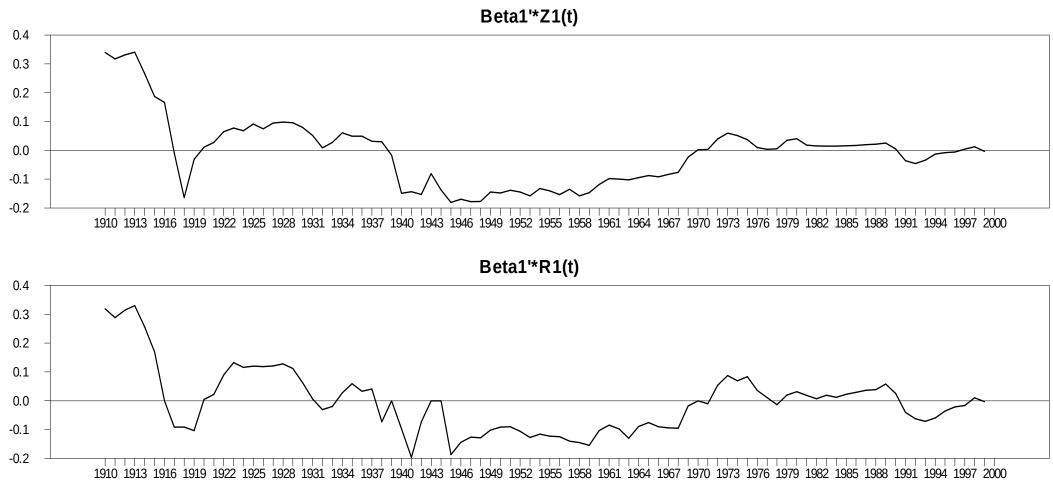
Table 4.2.11 The long-run structure without h in the model, r = 1

LR test of restricted model $\chi^2(2)$, p-value [0.0027], p-value* [0.0341]
t-ratios in brackets [ ]

	y_t	k_t	h_t	t
β_1'	**1**	**−0.263**	0	**−0.0243**
		[−5.86]		[−3.89]

	α_1
y_t	**−0.07**
	[−4.23]
k_t	−0.12
	[−0.65]
h_t	0
	[0.00]

Figure 4.2.6 The cointegration relation with *r =1* and only k and t in the model



To conclude the analysis with one cointegration relation between the variables, GDP per hours worked could be explained solely by physical and human capital per hours worked. This relation replicates a constant returns to scale production function in intensive form $Y/L = A(K/L)^{\alpha}(H/L)^{1-\alpha}$ referring to endogenous growth models of the type $Y = AK_{T,t}$, where $K_{T,t}$ is defined as broad reproducible capital including human capital. All the variables are endogenous in the model and adjust to the development of the other variables. This implies that the empirical evolution of the variables has been truly endogenous in the model.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The time trend or technical change could be left out of the production relation when human capital by formal education, assessed in the National Accounts, is included in the model. This is signalling for an endogenous technological progress induced by human and physical capital accumulation.

Without a human capital variable, constructed as in this study, the conclusion would be in favour of exogenous neo-classical growth. Therefore, the building of the human capital variable in the National Accounts frame, as GDP and physical capital, can change our insight into the growth process and may give support to endogenous growth theories.

4.3 Conclusions

The role of human and physical capital in the process of economic growth was explored by studying the long-run labour productivity (GDP per hours worked) growth together with physical capital in proportion to hours worked and human capital in proportion to hours worked in Finland in 1910–2000. The long-run analysis was conducted by cointegrated VAR methodology, since cointegration analysis allows for studying empirically the long-run, steady-state type relations between the variables. The number of cointegration relations between the variables mentioned was tested to be most likely two, however, some signals of acceptance were also given to only one cointegration relation.

The long-run labour productivity growth can quite probably be best modelled with two cointegration relations, in which one can be referred to as a production function with constant returns to scale on physical and human capital in labour input, and the other describes the relation between capitals in the labour input and time trend. In the first relation, only labour productivity growth proved to be adjusting for the shocks in physical capital and human capital by schooling per hours worked in the long run, and hence the long-run Granger causality is running from the capital in labour input to labour productivity. The second cointegration relation revealed that physical capital and human capital have been growing with respect to each other along with technological progress.

According to the results, technology can be seen embodied in physical (or fixed) capital. The time trend associated with the growth of physical capital refers to a vintage model of capital, where capital goods in a more recent vintage capital are more productive for a given cost. Physical capital and technological progress appear to have induced the growth of

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

human capital. Economic growth seems to have triggered off when a sum of cumulated innovations to physical capital has been bigger than the respective sum of cumulated innovations to human capital. However, physical capital has adjusted in return to the growth of human capital, and therefore, the development of the capitals has been nourishing each other.[247] Especially, with a vintage capital interpretation, human capital can be deemed to have enhanced both the growth of labour productivity and physical capital, by making the usage of new physical capital with new technology embodied possible. The results showed that the growing amount of human capital in the labour input has intensified labour productivity growth through both as an input with physical capital per labour input and in interaction with the technological progress and physical capital.

By joining the features of the two cointegration relations into a single equation, the results can be seen giving support to a variety of capital goods model with technology diffusion and human capital of the type $Y_t = A \cdot H_t^{1-\alpha} K_t^{\alpha} = A \cdot (H_t)^{1-a} \cdot \sum_{j=1}^{N} (k_{j,t})^{\alpha}$, where $k_{j,t}$ is one type of fixed capital good and N expresses the number of capital goods used in that country. The model should be augmented, though, to express the simultaneous growth of human and physical capital with capitals being complements and affecting the evolution of each other. The fact that N has increased over time is reflected in the steady state equation of the capitals by the time trend $T(t)$ attached with the used aggregate K_t in the empirical analysis.

Another way to interpret the time trend in connection with the aggregate K_t would be that the quality, and therefore the productivity of a unit of physical capital at a later point of time has been higher. Therefore, the results can give support as well to the quality ladder models and to the idea of physical capital vintages mentioned above. It is argued here that both effects may have been working along time. The later vintages of the same type of capital goods, k_j, have been of better quality, resulting in part in technological progress. Simultaneously, the number of new varieties of fixed capital goods, N, has increased resulting obviously as well in technological progress. These effects are observed together in the time trend, $T(t)$, attached to physical capital in the analysis with two cointegration relations. Since it is not possible that a follower country such as Finland could have produced all the new

[247] This is also in line with. unified growth theory: Galor Oded (2005). From Stagnation to Growth: Unified Growth Theory. In Aghion P., Steven N. Durlauf (Eds), *Handbook of Economic Growth*, vol 1A, Elsevier B.V., Amsterdam, The Netherlands, Chapter 4, pp. 171–293

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

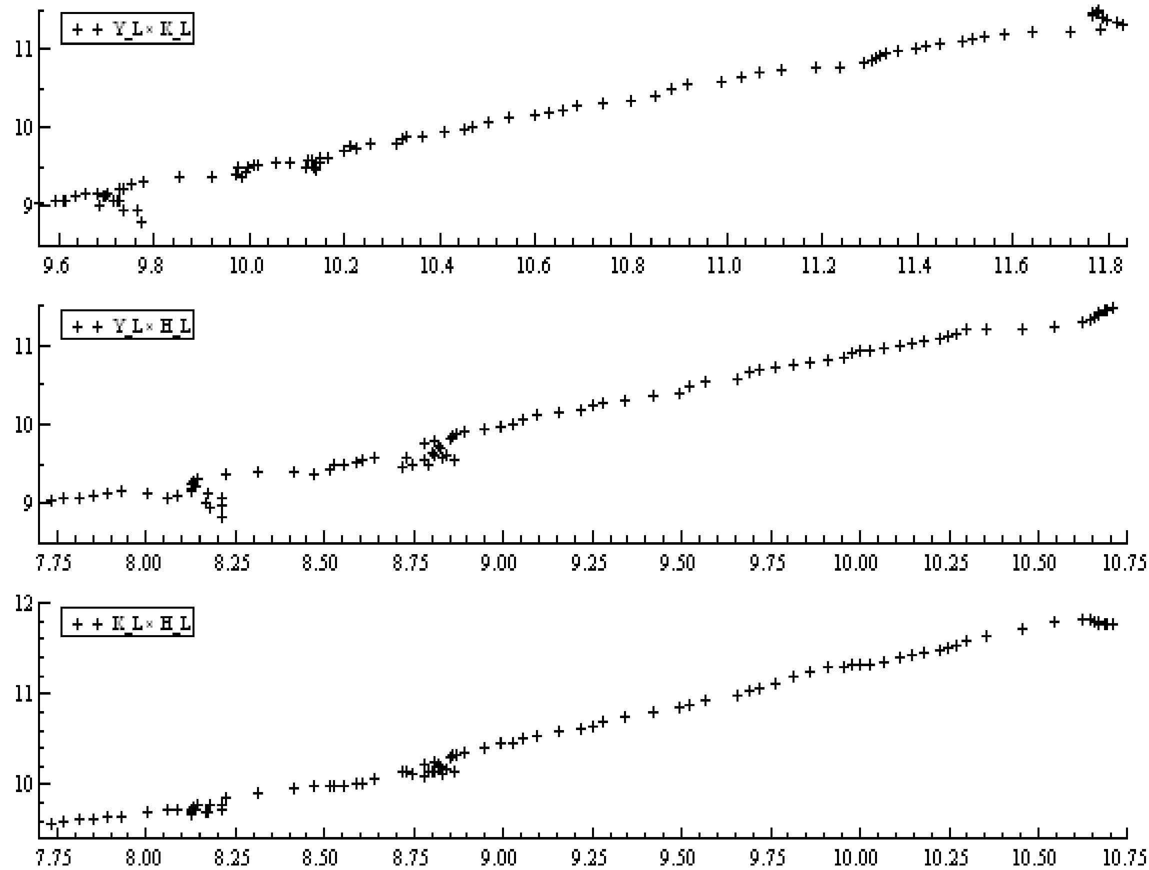
varieties, or the new better qualities of the same type of capital goods, the new technology capital goods have been implemented in Finland in by importing them, by learning from the foreign corporations using them in Finland or by the Finnish enterprises learning to use them first abroad in their foreign activities and then employing them in the home country.

The analysis with a single long-run relation suggested that labour productivity growth has been an endogenous process, where all the variables adjust to the shocks in each of the variables. This process can be described as endogenous constant returns to scale production relation in intensive form of the $y_t = Ah_t^{1-\alpha} k_t^{\alpha} = Ak_{T,t}$ type, with $k_{T,t}$ referring to both capitals, where labour productivity is explained by physical and human capital in the labour input. However, the fact that all variables adjusted, combined with the common trends analysis, implicate that physical and human capital per hours worked have been catalysed by the economic growth. With one cointegration relation it could not be hypothesised whether actually the capitals have been adjusting to each other and labour productivity only to capitals. Within a tested model without human capital as constructed in this study, and only physical capital in the labour input explaining labour productivity, the deterministic time trend, with an average pace of 2.4% a year could not be excluded. The pace of the deterministic time trend needed in the model, declined from 2.4% a year to 0 when human capital per hours worked was included in the case of a single cointegration relation. In the analysis of two cointegration relations, the average rate of a time trend in the capitals/technology relation was estimated at 1.55% per annum. Therefore, the inclusion of human capital by schooling, constructed in the National Accounts frame, reduced the rate of the time trend or technological progress needed in explaining the evolution of the labour productivity notably in all cases. In addition, in the case of two cointegration relations the time trend can be attached with physical capital in the second steady state relation between the capitals.

In accordance with the above results, Chapter 4 can be closed with the conclusion that the Finnish labour productivity growth has been induced in the 20th century by physical and human capital in proportion to labour input. Technological progress can be seen embodied in physical capital, the development of which has been enabled by human capital. In addition, the developments of physical capital and technology have created demand for human capital.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

APPENDIX 4.1 Scatter-plot graphs of Y/L–K/L, Y/L–H/L and K/L–H/L in 1910–2000



Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

APPENDIX 4.2 The cointegrated VAR-model[248]

Consider an unrestricted Vector Autoregressive (VAR) process with two lags (*k=2*)[249]:

$$\mathbf{x_t} = \mathbf{\Pi_1 x_{t-1}} + \mathbf{\Pi_2 x_{t-2}} + \boldsymbol{\varepsilon}_\mathbf{t}, \qquad \text{where } \boldsymbol{\varepsilon}_\mathbf{t} \sim i.i.d.\mathbf{N(0,\Omega)} \qquad \text{(A4.6.1)}$$

In (A4.6.1) $\mathbf{x_t}$ is a (*p x 1*) vector of the variables of the process (*p* is the number of the variables), $\mathbf{\Pi_1}$ and $\mathbf{\Pi_2}$ are (*p x p*) parameter matrices and $\boldsymbol{\varepsilon}_\mathbf{t}$ is a (*p x 1*) vector consisting of independently, identically normally distributed shocks to the variables in the system.

It is convenient to formulate the VAR as a polynomial in the lag operator L, where $L^i \mathbf{x_t} = \mathbf{x}_{\mathbf{t}-i}$:

$$\mathbf{x_t} - \mathbf{\Pi_1 x_{t-1}} - \mathbf{\Pi_2 x_{t-2}} = \boldsymbol{\varepsilon}_\mathbf{t}$$

$$(\mathbf{I} - \mathbf{\Pi}_1 L - \mathbf{\Pi}_2 L^2)\mathbf{x_t} = \boldsymbol{\varepsilon}_\mathbf{t}$$

$$\mathbf{\Pi}(L)\mathbf{x_t} = \boldsymbol{\varepsilon}_\mathbf{t} \qquad \text{(A4.6.2)}$$

The characteristic polynomial of the VAR process is $\mathbf{\Pi}(z) = \mathbf{I} - \mathbf{\Pi_1} z - \mathbf{\Pi_2} z^2$ and the roots of the characteristic polynomial, $|\mathbf{\Pi}(z)| = \mathbf{0}$, summarise important information about the dynamics and the stability of the process. Three possible cases can be distinguished:

---

[248] This appendix is based on Juselius, Katarina (2006). *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*. Advanced Texts in Econometrics, Oxford University Press: Oxford, and on Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 2nd edn. Advanced Texts in Econometrics, Oxford University Press: Oxford. Results from several chapters particularly in the book of Juselius are brought here together in order to facilitate the reading and understanding of the notation and analysis in Chapter 4 in this dissertation. The object is also to discuss the important role of the deterministic components in the CVAR, and open up how the deterministic components modelled in this study affect the evolution of the variables in the analysis.

[249] In the empirical analysis of this study the specified VAR models were tested to have two lags. In accordance with that, the stationary and non-stationary VAR model and their autoregressive and moving average representations, as well as the vector error correction model and the cointegrated VAR are introduced here in the essence with two lags.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

a) If the inverse of the roots z_i $(1/z_i)$ are all inside the unit circle, then $\{\mathbf{x_t}\}$ is stationary.

b) If the inverse of the roots z_i $(1/z_i)$ are inside or on the unit circle, then $\{\mathbf{x_t}\}$ is non-stationary.

c) If any of the inverse roots z_i $(1/z_i)$ are outside the unit circle, then $\{\mathbf{x_t}\}$ is explosive.

The roots of the process in the VAR-model with k lags ($VAR(k)$) can be conveniently calculated by reformulating the $VAR(k)$ model into the 'companion $AR(1)$ form' and then solving an eigenvalue problem. In that case the eigenvalue solution gives roots of the process directly as $\rho_{1,}\rho_{2,\ldots,}\rho_{pxk}$ instead of the inverse roots obtained by solving the characteristic polynomial.[250] In the case of *k=2* the $VAR(2)$ model can be written in the companion $AR(1)$ form:

$$\begin{bmatrix} \mathbf{x_t} \\ \mathbf{x_{t-1}} \end{bmatrix} = \begin{bmatrix} \mathbf{\Pi_1} & \mathbf{\Pi_2} \\ \mathbf{I} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{x_{t-1}} \\ \mathbf{x_{t-2}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_\mathbf{t} \\ \mathbf{0} \end{bmatrix}$$

or more compactly

$$\tilde{\mathbf{x}}_\mathbf{t} = \tilde{\mathbf{\Pi}}\tilde{\mathbf{x}}_\mathbf{t-1} + \tilde{\boldsymbol{\varepsilon}}_\mathbf{t}\,. \qquad \text{(A4.6.3)}$$

The roots of the matrix $\tilde{\mathbf{\Pi}}$ can be found by solving the eigenvalue problem:

$$\rho\mathbf{V} = \tilde{\mathbf{\Pi}}\mathbf{V} \qquad \text{(A4.6.4)}$$

where $\mathbf{V}$ is a *kp x 1* vector (*p* is the number of variables in VAR). With *k=2:*

$$\rho\begin{bmatrix} \mathbf{v_1} \\ \mathbf{v_2} \end{bmatrix} = \begin{bmatrix} \mathbf{\Pi_1} & \mathbf{\Pi_2} \\ \mathbf{I} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{v_1} \\ \mathbf{v_2} \end{bmatrix}$$

i.e. $$\begin{aligned} \rho\mathbf{v_1} &= \mathbf{\Pi_1 v_1} + \mathbf{\Pi_2 v_2} \\ \rho\mathbf{v_2} &= \mathbf{v_1}. \end{aligned}$$

[250] Juselius, Katarina (2006). *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*. Advanced Texts in Econometrics, Oxford University Press: Oxford, pp. 48–51.

The solution can be found by inserting $\mathbf{v_2} = \mathbf{v_1} / \rho$ from the second to the first one and then dividing both sides of the first equation by ρ to get

$$\mathbf{v_1} = \mathbf{\Pi_1}(\mathbf{v_1} / \rho) + \mathbf{\Pi_2}(\mathbf{v_1} / \rho^2).$$

Therefore, the eigenvalues of $\tilde{\mathbf{\Pi}}$ are the ρk roots of the second-order polynomial:

$$|\mathbf{I} - \mathbf{\Pi_1}\rho^{-1} - \mathbf{\Pi_2}\rho^{-2}| = \mathbf{0} \quad . \qquad \text{(A4.6.5a)}$$

It is worth noticing that *the roots of the companion matrix* $\tilde{\mathbf{\Pi}}$ *are the inverses of the roots of the characteristic polynomial*

$$|\mathbf{I} - \mathbf{\Pi_1}z - \mathbf{\Pi_2}z^2| = \mathbf{0}, \qquad \text{where } \rho_i = z_i^{-1}. \qquad \text{(A4.6.5b)}$$ [251]

The Moving Average representation of a stationary VAR

If the process is stationary (the roots of the companion matrix, ρ_i, and the inverse roots of the characteristic polynomial, z_i^{-1}, are all inside the unit circle), the Moving Average (MA) representation can be found directly by inverting the VAR model so that $\mathbf{x_t}$, t = 1, 2, 3, ..., T, is expressed as a function of past and present shocks ε_{t-j}, $j = 0,1,2,...$ and initial values $\mathbf{X^0}$:

$$\begin{aligned}
\mathbf{\Pi}(L)\mathbf{x_t} &= \boldsymbol{\varepsilon}_\mathbf{t} \\
\mathbf{x_t} &= \mathbf{\Pi}^{-1}(L)\boldsymbol{\varepsilon}_\mathbf{t} + \mathbf{X^0} \quad , t = 1,...,T \\
&= (|\mathbf{\Pi}(L)|^{-1}\ \mathbf{\Pi^a}(L))\boldsymbol{\varepsilon}_\mathbf{t} + \mathbf{X^0} \quad , t = 1,...,T \\
&= (\mathbf{I} + \mathbf{C_1}L + \mathbf{C_2}L^2 + \mathbf{C_3}L^3 + ...)\boldsymbol{\varepsilon}_\mathbf{t} + \mathbf{X^0}, \quad t = 1,...,T \qquad \text{(A4.6.6)}
\end{aligned}$$

[251] Ibid, p. 51.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

where $\mathbf{\Pi}^{-1}(L)$ is the inverse of the matrix $\mathbf{\Pi}(L)$, which in accordance with matrix algebra is achieved by the quotient of the adjunct matrix $\mathbf{\Pi}^{a}(L)$ and the determinant of the lag polynomial matrix, $|\mathbf{\Pi}(L)|$. The effect of the initial values of the process and its dynamics is summarised in $\mathbf{X}^{\mathbf{0}}$. A recursive formula for $\mathbf{C_j = f(\Pi_1,...,\Pi_k)}$ for the stationary VAR process is given in Johansen (1995).[252] It can be noted that if $|\mathbf{\Pi}(L)| = \mathbf{0}$, the inverse matrix $\mathbf{\Pi}^{-1}(L)$ would not be defined. This would be the case, for instance, if one of the roots would be a unit root, referring to a non-stationary process. Then the $\mathbf{C_j}$ matrices have to be derived under the assumption of reduced rank.

According to Juselius, the moving average representation is especially useful when examining the properties of the process. The autoregressive representation is useful for expressing hypotheses on economic behaviour.[253] The two representations are a mirror image of the same process.

Cointegrated non-stationary VAR integrated of order one

Next, the focus will be turned back to the AR-representation of the VAR model and the case of unit roots in the characteristic polynomial will be studied. Before proceeding further, the terms integration and cointegration will be defined:[254]

Definition 1: $\mathbf{x}_t$ is integrated of order d if $\mathbf{x}_t$ has the representation $(1-L)^d\mathbf{x}_t = \mathbf{C}(L)\boldsymbol{\varepsilon}_t$, where $\mathbf{C}(1) \neq \mathbf{0}$, and $\boldsymbol{\varepsilon}_t \sim i.i.d \;\; N(\mathbf{0},\mathbf{\Omega})$.

Definition 2: The *I(d)* process $\mathbf{x}_t$ is called cointegrated *CI(d,b)* with cointegrating vector $\boldsymbol{\beta} \neq \mathbf{0}$ if $\boldsymbol{\beta}'\mathbf{x}_t$ is *I(d – b), b* = 1,...,d and *d* = 1,...

Now, consider a non-stationary $VAR(2)$ model with a vector of constant terms ($\boldsymbol{\mu}$) in the AR-form

[252] Johansen, Søren (1995). Identifying restrictions of linear equations. With applications to simultaneous equations and cointegration. Journal of Econometrics, 69(1), pp. 111–132.
[253] Juselius, Katarina (2006). *The Cointegrated VAR model*, p. 48.
[254] Ibid, p. 79.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$$\mathbf{x_t} = \boldsymbol{\mu} + \boldsymbol{\Pi}_1\mathbf{x_{t-1}} + \boldsymbol{\Pi}_2\mathbf{x_{t-2}} + \boldsymbol{\varepsilon}_t \quad . \tag{A4.6.7}$$

Here, $\mathbf{x}_t$, and consequently $\mathbf{x}_{t-1}, \mathbf{x}_{t-2}$, all are assumed to be integrated of order 1 (often marked as $\mathbf{x}_t \sim I(1)$), meaning that 1 is one of the roots of the characteristic polynomial: $\boldsymbol{\Pi}(z=1) = (\mathbf{I} - \boldsymbol{\Pi}_1 - \boldsymbol{\Pi}_2)$ and $\det \boldsymbol{\Pi}(z=1) = |1 - \boldsymbol{\Pi}_1 - \boldsymbol{\Pi}_2| = 0$.

When fitting the model to data, the point estimators of the parameters in $\boldsymbol{\mu}, \boldsymbol{\Pi}_1, \boldsymbol{\Pi}_2$ can be calculated as well as the value of the likelihood function $L(\theta)$ in the maximum likelihood estimation. However, making inference on the statistical significance of the parameters is not feasible as the residuals for the variables of the model after fitting the data, $\boldsymbol{\varepsilon}_t$, would not necessarily be any more stationary, independent and normally distributed, which is assumed in the asymptotic test distributions for the parameters. The model needs to be transformed in order to ensure the inference on the parameters. Johansen has shown that this can be done without losing information.[255] By subtracting first $\mathbf{x_{t-1}}$ from both sides, then adding $(+\boldsymbol{\Pi}_2\mathbf{x_{t-1}} - \boldsymbol{\Pi}_2\mathbf{x_{t-1}})$ on the right hand side and rearranging a little bit, one will get:

$$\begin{aligned}
\mathbf{x_t} - \mathbf{x_{t-1}} &= \boldsymbol{\mu} + \boldsymbol{\Pi}_1\mathbf{x_{t-1}} - \mathbf{x_{t-1}} + \boldsymbol{\Pi}_2\mathbf{x_{t-2}} + \boldsymbol{\varepsilon}_t \\
\Delta\mathbf{x_t} &= \boldsymbol{\mu} + (\boldsymbol{\Pi}_1 - \mathbf{I})\mathbf{x_{t-1}} + \boldsymbol{\Pi}_2\mathbf{x_{t-2}} + (\boldsymbol{\Pi}_2\mathbf{x_{t-1}} - \boldsymbol{\Pi}_2\mathbf{x_{t-1}}) + \boldsymbol{\varepsilon}_t \\
\Delta\mathbf{x_t} &= \boldsymbol{\mu} + (\boldsymbol{\Pi}_2 + \boldsymbol{\Pi}_1 - \mathbf{I})\mathbf{x_{t-1}} + \boldsymbol{\Pi}_2\mathbf{x_{t-2}} - \boldsymbol{\Pi}_2\mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_t \\
\Delta\mathbf{x_t} &= \boldsymbol{\mu} + (\boldsymbol{\Pi}_2 + \boldsymbol{\Pi}_1 - \mathbf{I})\mathbf{x_{t-1}} + \boldsymbol{\Pi}_2(\mathbf{x_{t-2}} - \mathbf{x_{t-1}}) + \boldsymbol{\varepsilon}_t \\
\Delta\mathbf{x_t} &= \boldsymbol{\mu} + (\boldsymbol{\Pi}_2 + \boldsymbol{\Pi}_1 - \mathbf{I})\mathbf{x_{t-1}} - \boldsymbol{\Pi}_2(\mathbf{x_{t-1}} - \mathbf{x_{t-2}}) + \boldsymbol{\varepsilon}_t \\
\Delta\mathbf{x_t} &= \boldsymbol{\mu} + (\boldsymbol{\Pi}_2 + \boldsymbol{\Pi}_1 - \mathbf{I})\mathbf{x_{t-1}} + \boldsymbol{\Gamma}\Delta\mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_t \\
\Delta\mathbf{x_t} &= \boldsymbol{\mu} + \boldsymbol{\Pi}\mathbf{x_{t-1}} + \boldsymbol{\Gamma}\Delta\mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_t \quad ,
\end{aligned} \tag{A4.6.8}$$

where $\boldsymbol{\Pi} = (\boldsymbol{\Pi}_2 + \boldsymbol{\Pi}_1 - \mathbf{I})$ and $\boldsymbol{\Gamma} = -\boldsymbol{\Pi}_2$. It is worth noticing that $\boldsymbol{\Pi} = (\boldsymbol{\Pi}_2 + \boldsymbol{\Pi}_1 - \mathbf{I}) = -(\mathbf{I} - \boldsymbol{\Pi}_1 - \boldsymbol{\Pi}_2)$. Therefore $\boldsymbol{\Pi}$ in (A4.6.8) includes all the information of the characteristic function with a unit root in (A4.6.7), only with a negative sign, (in (A4.6.7)

[255] E.g. Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 2nd edn. Advanced Texts in Econometrics, Oxford University Press: Oxford.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$-\mathbf{\Pi}(z=1) = -(\mathbf{I} - \mathbf{\Pi}_1 - \mathbf{\Pi}_2)$). The equation in (A4.6.8) is called the Vector Equilibrium Correction (VEC) form of the VAR model or the *Vector Equilibrium Correction Model (VECM)*. It includes the same information on the parameter matrices as (A4.6.7), has the same parameters as (A4.6.7) ($\mathbf{\Pi} = (\mathbf{\Pi}_2 + \mathbf{\Pi}_1 - \mathbf{I})$ and $\mathbf{\Gamma} = -\mathbf{\Pi}_2$) and the same likelihood function $L(\theta)$ as (A4.6.7).

Let us have a closer look at the order of integration of the variable vectors in (A4.6.8):

$$\begin{array}{l} \Delta \mathbf{x_t} = \boldsymbol{\mu} + \mathbf{\Pi x_{t-1}} + \mathbf{\Gamma} \Delta \mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_\mathbf{t} \\ I(0) \qquad\qquad\qquad\quad I(0) \quad I(0) \end{array}$$

Since $\mathbf{x}_t \sim I(1), \Delta\mathbf{x}_t \sim I(0), \Delta\mathbf{x}_{t-1} \sim I(0)$, and $\boldsymbol{\varepsilon}_\mathbf{t} \sim I(0)$ (the last by definition in the theoretical model), the model, to be balanced and make sense, should have $\mathbf{\Pi x}_{t-1} \sim I(0)$. At the same time, it can be noticed that by definition, when $\mathbf{x}_t$ has unit roots, one is the root of the characteristic function, $\det \mathbf{\Pi}(1) = |1 - \mathbf{\Pi}_1 - \mathbf{\Pi}_2| = 0$ in (A4.6.7), and in the VECM form in (A4.6.8), $\det \mathbf{\Pi} = 0$.

This implies that in the VECM form in (A4.6.8) $\mathbf{\Pi}$ (*p x p*) is a singular matrix and has a reduced rank (*r* < *p*). It does not have *p* independent columns or rows (and therefore *p* non-zero eigenvalues). The presence of unit roots in VAR in (A4.6.7) leads to a reduced rank condition on the long-run parameter matrix for the lagged levels, $\mathbf{\Pi}$ in the VECM in (A4.6.8).

This means the *(p x p)* matrix $\mathbf{\Pi}$ can be presented as a product of two smaller matrices, $\mathbf{\Pi} = \boldsymbol{\alpha\beta}'$ with dimensions (*p x r)(r x p)*, where *r* is the rank of $\mathbf{\Pi}$.

$$\Delta \mathbf{x_t} = \boldsymbol{\mu} + \mathbf{\Pi x_{t-1}} + \mathbf{\Gamma} \Delta \mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_\mathbf{t}, \qquad \text{where} \quad \mathbf{\Pi} = \boldsymbol{\alpha}\,\boldsymbol{\beta}' \text{ and therefore}$$

$$\Delta \mathbf{x_t} = \boldsymbol{\mu} + \boldsymbol{\alpha\beta}'\mathbf{x_{t-1}} + \mathbf{\Gamma} \Delta \mathbf{x_{t-1}} + \boldsymbol{\varepsilon}_\mathbf{t} \tag{A4.6.9}$$

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Now, recall from the **definition 2**: ... $\mathbf{x}_t$ is called cointegrated *CI(d,b)* with cointegrating vector $\boldsymbol{\beta} \neq \mathbf{0}$ if $\boldsymbol{\beta}'\mathbf{x}_t$ is $I(d - b)$ b = 1,...,d and d = 1,.. .

Above we began from $\mathbf{x}_t \sim I(1)$, (therefore $\mathbf{x}_{t-1} \sim I(1)$), and ended up with $\boldsymbol{\alpha\beta}'\mathbf{x}_{t-1} \sim I(0)$. In the Johansen approach $\boldsymbol{\Pi}$ is divided into $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ so that $\boldsymbol{\beta}'\mathbf{x}_{t-1}$ can be defined as a cointegration vector – a certain linear combination of the variables of the vector process $\mathbf{x}_t$ that is integrated of lower order, in the case of $\mathbf{x}_t, \mathbf{x}_{t-1}, \sim I(1)$, $\boldsymbol{\beta}'\mathbf{x}_{t-1} \sim I(1-1) = I(0)$. The *(p x r)* matrix $\boldsymbol{\alpha}$ captures the loadings to the cointegration vector $\boldsymbol{\beta}'\mathbf{x}_{t-1}$ with a dimension *(r x p) (p x 1) = (r x 1)*. The loadings $\boldsymbol{\alpha}$ are often called adjustment coefficients for telling how the variables in the VAR model adjust to the cointegration relations.

Under the *I*(1) hypothesis, the *cointegrated VAR(k) model* (CVAR(*k*)) in the *VECM form* is given by

$$\boldsymbol{\Delta}\mathbf{x}_t = \boldsymbol{\alpha\beta}'\mathbf{x}_{t-1} + \boldsymbol{\Gamma}_1\boldsymbol{\Delta}\mathbf{x}_{t-1} + ... + \boldsymbol{\Gamma}_{k-1}\boldsymbol{\Delta}\mathbf{x}_{t-k-1} + \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t \quad , \qquad \text{(A4.6.10)}$$

where $\boldsymbol{\beta}'\mathbf{x}_{t-1}$ is an *(r x 1)* vector of stationary cointegration relations.[256] Under the *I*(1) hypothesis, $\mathbf{x}_t \sim I(1)$, all stochastic components are stationary in the model (A4.6.10) and the system is now logically consistent. When estimating the model with a real world data, the statistical significance of the parameters can be now tested in accordance with the available asymptotic test statistic distributions. The lag length k (referring to lags in the original VAR in levels in (A4.6.7)) can be tested with information criteria (such as Hannan-Quinn or Schwarz) and/or with the likelihood ratio test by comparing step by step the likelihood of the bigger model in lags to a reduced lag model.

When $\mathbf{x}_t \sim I(1)$, the reduced rank (r) of the $\boldsymbol{\Pi}$ matrix reveals the number of stationary cointegration relations of the levels of the variables ($\boldsymbol{\beta}'\mathbf{x}_{t-1}$ is *(r x 1)*. Furthermore, in the *I*(1) case, the number of common stochastic trends (see the MA representation) is $p - r$.

[256] See also Juselius, Katarina (2006). *The Cointegrated VAR model*, p. 80.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Moving Average representation of the non-stationary VAR integrated of order one

When the VAR model contains unit roots, the autoregressive lag polynomial is non-invertible. Consider the same VAR(2) model with a vector of constants ($\boldsymbol{\mu}$):

$$\boldsymbol{\Pi}(\mathbf{L})\mathbf{x_t} = (\mathbf{I} - \boldsymbol{\Pi}_1\mathbf{L} - \boldsymbol{\Pi}_2\mathbf{L}^2)\mathbf{x_t} = \boldsymbol{\mu} + \boldsymbol{\varepsilon_t} \qquad \text{(A4.6.11)}$$

When the characteristic polynomial contains a unit root (i.e. when setting $|\mathbf{I} - \boldsymbol{\Pi}_1\mathbf{z} - \boldsymbol{\Pi}_2\mathbf{z}^2| = \mathbf{0}$, one of the roots is one), the determinant $|\boldsymbol{\Pi}(\mathbf{1})| = \mathbf{0}$ and therefore $\boldsymbol{\Pi}(\mathbf{z})$ cannot be inverted for $z = 1$. The unit root component of the matrix lag polynomial of the VAR model is needed to be factored out. First the lag polynomial is moved to the right-hand side of the equation for $\mathbf{x_t}$:

$$\boldsymbol{\Pi}(\mathbf{L})\mathbf{x_t} = \boldsymbol{\mu} + \boldsymbol{\varepsilon_t}$$

$$\mathbf{x_t} = \boldsymbol{\Pi}^{-1}(L)(\boldsymbol{\mu} + \boldsymbol{\varepsilon_t}) \qquad \text{(A4.6.12)}$$

Now, the non-invertible unit root is cancelled out by multiplying both sides of (A4.6.12) with the difference operator $(1 - L)$ (this is feasible since $\boldsymbol{\Pi}^{-1}(L) = \boldsymbol{\Pi}^{\mathbf{a}}(L)/\det(\boldsymbol{\Pi}(L))$ and $\det(\boldsymbol{\Pi}(L))$ is a polynomial in z):

$$(1 - L)\mathbf{x_t} = (1 - L)\boldsymbol{\Pi}^{-1}(\mathbf{L})(\boldsymbol{\varepsilon_t} + \boldsymbol{\mu})$$

$$\mathbf{x_t} - \mathbf{x_{t-1}} = \mathbf{C}(L)(\boldsymbol{\varepsilon_t} + \boldsymbol{\mu})$$

$$\Delta\mathbf{x_t} = (\mathbf{C_0} + \mathbf{C}_1 L + \mathbf{C}_2 L^2 + \ldots)(\boldsymbol{\varepsilon_t} + \boldsymbol{\mu}) \qquad \text{(A4.6.13)}$$

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The lag polynomial $\mathbf{C}(L)$ is now stationary. The characteristic function $\mathbf{C}(z) = \mathbf{C_0} + \mathbf{C_1}z + \mathbf{C_2}z^2 + ...$ can be expanded by the Taylor rule and evaluated for z = 1. As in Juselius (2006), $\mathbf{C}(L)$ can be reformulated as:

$$\mathbf{C}(L) = \mathbf{C}(1) + \mathbf{C}^*(L)(1-L) \qquad \text{(A4.6.14)}$$

Inserting (A4.6.14) in (A4.6.13) gives:

$$(1-L)\mathbf{x_t} = \{\mathbf{C} + \mathbf{C}^*(L)(1-L)\}(\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\mu}), \qquad \text{where } \mathbf{C} = \mathbf{C}(1).$$

The equation above can be written as

$$\begin{aligned}\mathbf{x}_s &= \mathbf{x}_{s\text{-}1} + \mathbf{C}\boldsymbol{\varepsilon}_\mathbf{s} + \mathbf{C}\boldsymbol{\mu} + \mathbf{C}^*(L)(\boldsymbol{\varepsilon}_s - \boldsymbol{\varepsilon}_{s-1}) \\ &= \mathbf{x}_{s-1} + \mathbf{C}\boldsymbol{\varepsilon}_s + \mathbf{C}\boldsymbol{\mu} + \mathbf{Y}_s - \mathbf{Y}_{s-1}\end{aligned}$$

where $\mathbf{Y}_s = \mathbf{C}^*(L)\boldsymbol{\varepsilon}_s$ is a shorthand notation of the stationary part of the process. Summing for s = 1, 2, ..., t, will give:

$$\begin{aligned}\mathbf{x}_t &= \mathbf{C}\sum_{s=1}^{t}\boldsymbol{\varepsilon}_s + \mathbf{C}\boldsymbol{\mu}\mathbf{t} + \mathbf{C}^*(L)\boldsymbol{\varepsilon}_t + \mathbf{x}_0 - \mathbf{C}^*(L)\boldsymbol{\varepsilon}_0 \\ &= \mathbf{C}\sum_{s=1}^{t}\boldsymbol{\varepsilon}_s + \mathbf{C}\boldsymbol{\mu}\mathbf{t} + \mathbf{C}^*(L)\boldsymbol{\varepsilon}_t + \widetilde{\mathbf{X}}_\mathbf{0}\end{aligned} \qquad \text{(A4.6.15)}$$

where $\widetilde{\mathbf{X}}_\mathbf{0}$ contains both the initial value, $\mathbf{x}_0$, of the process $\mathbf{x}_t$ and the initial value of the short-run dynamics $\mathbf{C}^*(L)\boldsymbol{\varepsilon}_0$. Equation (A4.6.15) shows that $\mathbf{x}_t$ can be described by stochastic trends $\mathbf{C}\sum_{s=1}^{t}\boldsymbol{\varepsilon}_s$, linear time trend cumulated by the constant $\boldsymbol{\mu}t$ (multiplied by $\mathbf{C}$) and stationary stochastic components $\mathbf{C}^*(L)\boldsymbol{\varepsilon}_t$, and initial values.[257]

[257] Juselius, Katarina (2006). *The Cointegrated VAR model*, p. 85.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

From the AR to the MA representation

Above it was shown that the $\mathbf{C_i}$ matrices are functions of the $\mathbf{\Pi_i}$ matrices. The discussion from the autoregressive to the moving average representation here is related to the derivation of the Granger representation theorem of Chapter 4 in Johansen (1996), where the derivation can be found for the general VAR(k) model.[258] Juselius illustrates with VAR(1) model how one can find the $\mathbf{C}$ matrix when $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$ are known, as the inclusion of the short-run $\mathbf{\Gamma_i}$ effects complicates the derivation significantly.[259]

Consider the VAR(1) model:

$$\Delta\mathbf{x_t} = \boldsymbol{\alpha}\boldsymbol{\beta}'\mathbf{x_{t-1}} + \boldsymbol{\mu} + \boldsymbol{\varepsilon_t}, \qquad t = 1, ..., T, \qquad \text{(A4.6.16)}$$

with initial value $\mathbf{x_0}$. For given $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ the orthogonal complements, $\boldsymbol{\alpha}_\perp$ and $\boldsymbol{\beta}_\perp$ of full rank and of dimension *p x (p – r)* can be found so that $\boldsymbol{\beta}'\boldsymbol{\beta}_\perp = \mathbf{0}$ and rank $(\boldsymbol{\alpha}'\boldsymbol{\alpha}_\perp)$ = *p* and $(\boldsymbol{\beta}'\boldsymbol{\beta}_\perp)$ = *p*.

The following relationship between $\boldsymbol{\alpha}, \boldsymbol{\beta}$, $\boldsymbol{\alpha}_\perp$ and $\boldsymbol{\beta}_\perp$ will be used:

$$\boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}\boldsymbol{\beta}' = \mathbf{I} \quad . \qquad \text{(A4.6.17)}$$

Now, by making use of (A4.6.17) any vector $\mathbf{v}$ in R^p can be decomposed into a vector $\mathbf{v}_1 \in sp(\boldsymbol{\beta}_\perp)$ and a vector $\mathbf{v}_2 \in sp(\boldsymbol{\alpha})$, where $sp(\mathbf{z})$ is a shorthand notation for the space spanned by $\mathbf{z}$. Next Juselius (2006) applies the results to the *p*-dimensional vector $\mathbf{x_t}$:[260]

$$\begin{aligned}\mathbf{x_t} &= \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp'\mathbf{x_t} + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}\boldsymbol{\beta}'\mathbf{x_t} \\ &= \boldsymbol{\omega}_1\boldsymbol{\alpha}_\perp'\mathbf{x_t} + \boldsymbol{\omega}_2\boldsymbol{\beta}'\mathbf{x_t}\end{aligned} \qquad \text{(A4.6.18)}$$

[258] Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 2nd edn. Advanced Texts in Econometrics, Oxford University Press: Oxford, Chapter 4.
[259] Juselius, Katarina (2006). *The Cointegrated VAR model*, pp. 85–88.
[260] Ibid, p. 86.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The equations (A4.6.18) show that $\mathbf{x}_t$ can be expressed as a linear combination of the common trends, $\boldsymbol{\alpha}_{\perp}'\mathbf{x_t}$ and the cointegration relations $\boldsymbol{\beta}'\mathbf{x_t}$. The next step in Juselius' illustration is to express $\boldsymbol{\alpha}_{\perp}'\mathbf{x_t}$ and $\boldsymbol{\beta}'\mathbf{x_t}$ as a function of initial values and the errors $(\boldsymbol{\varepsilon}_\mathbf{t}, \boldsymbol{\varepsilon}_{\mathbf{t}-1}, \boldsymbol{\varepsilon}_{\mathbf{t}-2}, ...)$.

Pre-multiplying first equation (A4.6.16) with $\boldsymbol{\beta}'$ and then solving for $\boldsymbol{\beta}'\mathbf{x_t}$ gives:

$$\boldsymbol{\beta}'\mathbf{x_t} = (\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})\boldsymbol{\beta}'\mathbf{x}_{\mathbf{t}-1} + \boldsymbol{\beta}'\boldsymbol{\mu} + \boldsymbol{\beta}'\boldsymbol{\varepsilon}_\mathbf{t}$$

The eigenvalues of the matrix $(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})$ are inside the unit circle when the *r*-dimensional process $\boldsymbol{\beta}'\mathbf{x_t}$ is stationary, so that $(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^l \to \mathbf{0}$ as $l \to \infty$. Juselius (2006) argues that it is straightforward to represent $\boldsymbol{\beta}'\mathbf{x_t}$ as a function of $\boldsymbol{\varepsilon}_\mathbf{i}, i = 1,...,T$ and the constant $\boldsymbol{\mu}$:[261]

$$\boldsymbol{\beta}'\mathbf{x_t} = \sum_{i=0}^{\infty}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^i \ \boldsymbol{\beta}'(\boldsymbol{\varepsilon}_{\mathbf{t-i}} + \boldsymbol{\mu}) \qquad \text{(A4.6.19)}$$

Similarly, finding an expression for $\boldsymbol{\alpha}_{\perp}'\mathbf{x_t}$ as a function of the errors $(\boldsymbol{\varepsilon}_\mathbf{t}, \boldsymbol{\varepsilon}_{\mathbf{t}-1}, \boldsymbol{\varepsilon}_{\mathbf{t}-2}, ...)$ is begun by pre-multiplying (A4.6.16) with $\boldsymbol{\alpha}_{\perp}'$ to get:

$$\boldsymbol{\alpha}_{\perp}'\Delta\mathbf{x_t} = \boldsymbol{\alpha}_{\perp}'\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\alpha}_{\perp}' \perp \boldsymbol{\mu}$$

The expression $\boldsymbol{\alpha}_{\perp}'\mathbf{x_t}$ can be solved by noticing that the level $\mathbf{x_t}$ is the sum of the cumulated errors plus constant starting from the initial value:

$$\boldsymbol{\alpha}_{\perp}'\mathbf{x_t} = \sum_{i=1}^{t}\boldsymbol{\alpha}_{\perp}'(\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\mu}) + \boldsymbol{\alpha}_{\perp}'\mathbf{x_0}. \qquad \text{(A4.6.20)}$$

Inserting (A4.6.19) and (A4.6.20) into (A4.6.18) gives the following results:

[261] Ibid, p. 86.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$$\mathbf{x_t} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\ \ \boldsymbol{\alpha}_\perp'\sum_{i=1}^{t}(\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\mu}) + \boldsymbol{\alpha}_\perp'\mathbf{x_0}$$

$$+\ \ \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}\ \ \sum_{i=0}^{\infty}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^{i}\ \ \boldsymbol{\beta}'(\boldsymbol{\varepsilon}_\mathbf{t-i} + \boldsymbol{\mu})$$

$$= \mathbf{C}\sum\nolimits_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i} + \mathbf{C}\boldsymbol{\mu}t + \mathbf{C}\mathbf{x_0}\quad +\ \ \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}\ \ \sum\nolimits_{i=0}^{\infty}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^{i}\ \ \boldsymbol{\beta}'(\boldsymbol{\varepsilon}_\mathbf{t-i} + \boldsymbol{\mu})$$

$$= \mathbf{C}\sum\nolimits_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i} + \boldsymbol{\tau}_1 t + \boldsymbol{\tau}_\mathbf{0} + \mathbf{Y_t}$$

(A4.6.21)

where $\mathbf{C} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\ \ \boldsymbol{\alpha}_\perp'$, $\boldsymbol{\tau}_\mathbf{1} = \mathbf{C}\boldsymbol{\mu}$ measures the slope of a linear trend in $\mathbf{x_t}$, $\boldsymbol{\tau}_\mathbf{0} = \mathbf{C}\mathbf{x_0}$ depends on the initial values, and $\mathbf{Y_t}$ is a stationary process.

It is possible to derive the results for the more general case using the same principle as above by expressing the VAR(k) model in the companion form. As in Juselius (2006), here only the main result is reproduced showing how the $\mathbf{C}$ matrix is related to all the parameters of the VAR(k) model:[262]

$$\mathbf{C} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\Gamma}\,\boldsymbol{\beta}_\perp)^{-1}\ \ \boldsymbol{\alpha}_\perp'\quad , \tag{A4.6.22}$$

where $\boldsymbol{\Gamma} = -(\mathbf{I} - \boldsymbol{\Gamma}_\mathbf{1} - \boldsymbol{\Gamma}_\mathbf{2} - \ldots - \boldsymbol{\Gamma}_\mathbf{k-1})$, see Johansen (1996), Chapter 4.[263] Therefore, (A4.6.21) is a special case of (A4.6.22) with $\boldsymbol{\Gamma} = -\mathbf{I}$.

The result (A4.6.22) can be given a shorthand expression as:

$$\mathbf{C} = \tilde{\boldsymbol{\beta}}_\perp\boldsymbol{\alpha}_\perp'\qquad , \tag{A4.6.23}$$

where $\tilde{\boldsymbol{\beta}} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\Gamma}\ \boldsymbol{\beta}_\perp)^{-1}$. With (A4.6.23) it can be noticed that the decomposition of the $\mathbf{C}$ matrix is similar to the $\boldsymbol{\Pi}$ matrix: however, *in the AR representation* $\boldsymbol{\beta}$ *determines the common long-run relations and* $\boldsymbol{\alpha}$ *the loadings*, whereas *in the moving average*

---

[262] Ibid, p. 87.

[263] Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Chapter 4.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

representation $\boldsymbol{\alpha}_\perp'$ *determines the common stochastic trends and* $\tilde{\boldsymbol{\beta}}$ *their loadings*. The non-stationarity in the process $\mathbf{x_t}$ originates from the cumulative sum of the combinations $\boldsymbol{\alpha}_\perp'\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$ (in the $I(1)$-case $p-r$ combinations) leading to the following definition:

Definition 3: The common driving trends are the variables $\boldsymbol{\alpha}_\perp'\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$.

As noted above, it is useful to express the $\mathbf{C}$ matrix as a product of two matrices (as $\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$)

$$\mathbf{C} = \tilde{\boldsymbol{\beta}}_\perp\boldsymbol{\alpha}_\perp' \qquad \text{or} \qquad \mathbf{C} = \boldsymbol{\beta}_\perp\tilde{\boldsymbol{\alpha}}_\perp' \tag{A4.6.24}$$

where $\tilde{\boldsymbol{\beta}} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\Gamma}\ \boldsymbol{\beta}_\perp)^{-1}$ and $\tilde{\boldsymbol{\alpha}}_\perp' = (\boldsymbol{\alpha}_\perp'\boldsymbol{\Gamma}\ \boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp'$. It is worth noticing that *the matrices* $\boldsymbol{\alpha}_\perp$ *and* $\boldsymbol{\beta}_\perp$ *can be directly calculated for given estimates of* $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, *and* $\boldsymbol{\Gamma}$ *based on (*A4.*6.22)*. This means that the common stochastic trends and their weights can be found either based on unrestricted $\hat{\boldsymbol{\alpha}}, \hat{\boldsymbol{\beta}}$ or on restricted estimates $\hat{\boldsymbol{\alpha}}^\mathbf{c}, \hat{\boldsymbol{\beta}}^\mathbf{c}$. The CATS program uses the latest estimates of $\boldsymbol{\alpha}, \boldsymbol{\beta}$ as a basis for the calculations in the moving average representation.

To conclude, the notion of cointegrating relations $\boldsymbol{\beta}'\mathbf{x_t}$, and the notion of common trends $\boldsymbol{\alpha}_\perp'\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$ are two sides of the same coin, as are the adjustment coefficients $\boldsymbol{\alpha}$ and the loading coefficients $\tilde{\boldsymbol{\beta}}_\perp$. The cointegrated VAR model provides a general framework within which one can describe economic behaviour in terms of forces pulling towards equilibrium, generating stationary behaviour ($\boldsymbol{\beta}'\mathbf{x_t}$), and forces pushing away from equilibrium, generating non-stationary behaviour ($\boldsymbol{\alpha}_\perp'\sum_{i=1}^{t}\boldsymbol{\varepsilon}_\mathbf{i}$).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

A trend, a constant and dummies in the VAR

The deterministic components have an important, and sometimes complicated, role in the VAR analysis. First, the case of a trend restricted to the cointegration relations and a constant is discussed. Second, the role of dummy variables will be illustrated. Often, to ensure that the residuals are white noise, various types of dummy variables are needed in the analysis.

The VAR in the equilibrium-correction form includes both differenced and level variables, which allows us to investigate both the short-run and long-run effects in the data with one model. When two variables share the same stochastic trend, it is possible to find a linear combination (a cointegration relation) of the variables that cancels the trend. However, many economic variables exhibit a linear deterministic trend growth at the same time. In the case of linearly trending variables, Juselius (2006) guides to begin with a deterministic trend included in the VECM model. And if finding the trend insignificant, it can be removed. According to Juselius (2006), in most cases we need a combination of the two, deterministic trend and stochastic trend. A good reason to include a deterministic trend in cointegration relations, and to test it, is of course, a theory suggesting such a variable in the long-run development between the variables.

Juselius (2006) uses a simple VAR(1) model to illustrate the basic effects of a constant, $\boldsymbol{\mu}_{\mathbf{0}}$, and a trend $\boldsymbol{\mu}_1 t$ (all the short-run dynamic effects $\boldsymbol{\Gamma}_i$, $i = 1,....,k-1$, have been set to zero): [264]

$$\Delta\mathbf{x}_{\mathbf{t}} = \boldsymbol{\alpha\beta}'\mathbf{x}_{\mathbf{t-1}} + \boldsymbol{\mu}_{\mathbf{o}} + \boldsymbol{\mu}_1 t + \boldsymbol{\varepsilon}_{\mathbf{t}} \qquad \text{(A4.6.25)}$$

It is worth noticing that the VAR model describes *p* equations, $\Delta\mathbf{x}_{\mathbf{t}}$, and r relations, $\boldsymbol{\beta}'\mathbf{x}_{\mathbf{t}}$, in just one model. Therefore, the vector term of constants, $\boldsymbol{\mu}_{\mathbf{0}}$, (and similarly $\boldsymbol{\mu}_1$) can be considered as the sum of two vectors, one accounting for the mean value of the equations $\Delta\mathbf{x}_{\mathbf{t}}$ (describing the slope of a linear trend in $\mathbf{x}_{\mathbf{t}}$) and the other for the mean value of the relations, $\boldsymbol{\beta}'\mathbf{x}_{\mathbf{t}}$ (describing the intercept of a long-run relation):

[264] Juselius, Katarina (2006). *The Cointegrated VAR model*, pp. 95–102.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

$$\boldsymbol{\mu}_0 = \boldsymbol{\alpha\beta}_0 + \boldsymbol{\gamma}_0$$
$$\boldsymbol{\mu}_1 = \boldsymbol{\alpha\beta}_1 + \boldsymbol{\gamma}_1 \qquad \text{(A4.6.26)}$$

The equation (A4.6.25) can be written now

$$\Delta\mathbf{x}_t = \boldsymbol{\alpha\beta}'\mathbf{x}_{t-1} + \boldsymbol{\alpha\beta}_0 + \boldsymbol{\alpha\beta}_1 t + \boldsymbol{\gamma}_0 + \boldsymbol{\gamma}_1 t + \boldsymbol{\varepsilon}_t$$

$$\Delta\mathbf{x}_t = \boldsymbol{\alpha}\left[\boldsymbol{\beta}', \boldsymbol{\beta}_0, \boldsymbol{\beta}_1\right]\begin{bmatrix} \mathbf{x}_{t-1} \\ 1 \\ t \end{bmatrix} + \boldsymbol{\gamma}_0 + \boldsymbol{\gamma}_1 t + \boldsymbol{\varepsilon}_t$$

and reformulated as

$$\Delta\mathbf{x}_t = \boldsymbol{\alpha}\tilde{\boldsymbol{\beta}}'\tilde{\mathbf{x}}_{t-1} + \boldsymbol{\gamma}_0 + \boldsymbol{\gamma}_1 t + \boldsymbol{\varepsilon}_t \, , \qquad \text{(A4.6.27)}$$

where $\tilde{\boldsymbol{\beta}}' = \left[\boldsymbol{\beta}', \boldsymbol{\beta}_0, \boldsymbol{\beta}_1\right]$ and $\tilde{\mathbf{x}}_{t-1} = (\mathbf{x}_{t-1}, 1, t)'$.

Five different models arise from imposing different restrictions on the deterministic components in (A4.6.25):

Case 1: $\boldsymbol{\mu}_1, \boldsymbol{\mu}_0 = \mathbf{0}$. In this case the model would have no deterministic components, which means that in the data $E(\Delta\mathbf{x}_t) = \mathbf{0}$ and $E(\boldsymbol{\beta}'\mathbf{x}_t) = \mathbf{0}$, implying that the intercept of every cointegrating relation is zero. In practice, this is a hypothetical case, as an intercept is generally needed to account for the initial level of measurements, $\mathbf{X}_0$, as shown above.

Case 2: $\boldsymbol{\mu}_1 = \mathbf{0}, \boldsymbol{\gamma}_0 = \mathbf{0}$, but $\boldsymbol{\beta}_0 \neq \mathbf{0}$. The constant term is restricted to the cointegration relations in this case, implying that the equilibrium mean is different from zero. The data of the variables of the model do not exhibit linear trends, consistent with $E(\Delta\mathbf{x}_t) = \mathbf{0}$.

Case 3: $\boldsymbol{\mu}_1 = \mathbf{0}, i.e. (\boldsymbol{\beta}_1, \boldsymbol{\gamma}_1) = \mathbf{0}$, but the constant term $\boldsymbol{\mu}_0$ is unrestricted. There are no linear trends in the Equilibrium correction model in (A4.6.25) but linear trends in the variables $\mathbf{x}_t$. In this case there is no trend in the cointegration space. However, $E(\Delta\mathbf{x}_t) = \boldsymbol{\gamma}_0 \neq \mathbf{0}$ is

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

consistent with linear trends in the variables, but since $\boldsymbol{\beta}_1 = \mathbf{0}$, these trends cancel in the cointegration relations.

Case 4: $\boldsymbol{\gamma}_1 = \mathbf{0}$, but $(\boldsymbol{\gamma}_0, \boldsymbol{\beta}_0, \boldsymbol{\beta}_1) \neq \mathbf{0}$. This case restricts the trend only to appear in the cointegration relations, but the constant is unrestricted in the model. With $\boldsymbol{\gamma}_1 = \mathbf{0}$, a linear, but no quadratic trend is allowed in the variables $\mathbf{x_t}$. As above, $E(\Delta\mathbf{x_t}) = \boldsymbol{\gamma}_0 \neq \mathbf{0}$ implies to a linear trend in the variables. When, in addition, $\boldsymbol{\beta}_1 \neq \mathbf{0}$ the linear trends in the variables do not cancel out in the cointegration relation. Therefore, the model contains a trend in the cointegration relations.

Case 5: *No restrictions* on $\boldsymbol{\mu}_1, \boldsymbol{\mu}_0$. The trend and constant are unrestricted in the model. This model would be consistent with linear trends in the differenced variables $\Delta\mathbf{x_t}$ and hence quadratic trends in $\mathbf{x_t}$. When modelling economic variables in logarithmic form, this is in practice likely a theoretical case.

A correct specification is important for the estimates of the model and for their interpretation. Moreover, the asymptotic distribution of the rank test depends on the specification of the appearance of the constant and the trend above.

Next, the focus will be turned to deterministic dummy variables, to account for extraordinary large shocks in the data, resulting in a violation of the normality assumption of the residuals in the VAR analysis. These shocks in the data may be due to wars, political interventions, changes in institutional setting, etc.

With dummies the cointegrated VAR(2) model with a vector of constants is reformulated as:

$$\Delta \mathbf{x_t} = \boldsymbol{\alpha\beta}'\mathbf{x_{t-1}} + \boldsymbol{\Gamma}_1 \Delta \mathbf{x_{t-1}} + \boldsymbol{\Phi}_\mathbf{s}\mathbf{D_{s,t}} + \boldsymbol{\Phi}_\mathbf{p}\mathbf{D_{p,t}} + \boldsymbol{\Phi}_\mathbf{tr}\mathbf{D_{tr,t}} + \boldsymbol{\mu}_0 + \boldsymbol{\varepsilon}_\mathbf{t} \quad ,$$
$$\boldsymbol{\varepsilon}_\mathbf{t} \sim NI(\mathbf{0}, \boldsymbol{\Omega}) \qquad , \; t = 1, ..., T \quad , \tag{A4.6.28}$$

where $\mathbf{D_{s,t}}$ is a (d_1 x 1) vector of mean-shift dummy variables (...,0,0,0,1,1,1,...), $\mathbf{D_{p,t}}$ is a (d_2 x 1) vector of permanent impulse dummy variables (...,0,0,0,1,0,0,...) and $\mathbf{D_{tr,t}}$ is a (d_3 x 1) vector of transitory impulse dummy variables (...,0,0,0,1,–1,0,0,...), The role of dummy

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

variables (as all the deterministic components) is fairly complicated, as the VAR model contains both differences and levels of the variables.
Juselius (2006) partitions the dummy effects (as the effects of constant and time trend above) into an $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}_\perp$ component:[265]

$$\boldsymbol{\Phi}_\mathbf{s} = \boldsymbol{\alpha}\boldsymbol{\delta}_\mathbf{0} + \boldsymbol{\delta}_\mathbf{1}, \tag{A4.6.29}$$

$$\boldsymbol{\Phi}_\mathbf{p} = \boldsymbol{\alpha}\boldsymbol{\varphi}_\mathbf{0} + \boldsymbol{\varphi}_\mathbf{1}, \tag{A4.6.30}$$

$$\boldsymbol{\Phi}_\mathbf{tr} = \boldsymbol{\alpha}\boldsymbol{\psi}_\mathbf{0} + \boldsymbol{\psi}_\mathbf{1}\ . \tag{A4.6.31}$$

Under the simplifying assumption $\boldsymbol{\Gamma}_\mathbf{1} = \mathbf{0}$ in (A4.6.28), Juselius (2006) demonstrates that $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}_\perp$ components can be determined so that (A4.6.28) can be rewritten in the form:[266]

$$\Delta\mathbf{x}_\mathbf{t} = \boldsymbol{\alpha}\tilde{\boldsymbol{\beta}}'\tilde{\mathbf{x}}_\mathbf{t-1} + \boldsymbol{\delta}_\mathbf{1}\mathbf{D}_\mathbf{s,t} + \boldsymbol{\varphi}_\mathbf{1}\mathbf{D}_\mathbf{p,t} + \boldsymbol{\psi}_\mathbf{1}\mathbf{D}_\mathbf{tr,t} + \boldsymbol{\gamma}_\mathbf{0} + \boldsymbol{\varepsilon}_\mathbf{t}\ ,$$

where $\tilde{\boldsymbol{\beta}}' = \left[\boldsymbol{\beta}', \boldsymbol{\beta}_\mathbf{0}', \boldsymbol{\delta}_\mathbf{0}', \boldsymbol{\varphi}_\mathbf{0}', \boldsymbol{\psi}_\mathbf{0}'\right]$ and $\tilde{\mathbf{x}}_\mathbf{t-1} = (\mathbf{x}_\mathbf{t-1}, \mathbf{1}, \mathbf{D}_\mathbf{s,t}', \mathbf{D}_\mathbf{p,t}', \mathbf{D}_\mathbf{tr,t}')'$.

The dynamic effects of the dummies in (A4.6.28) on the data can be investigated by using the moving average representation of the model. The MA representation defines the variables $\mathbf{x}_\mathbf{t}$ as a function of $\boldsymbol{\varepsilon}_\mathbf{i}$, $i = 1, ..., T$, the dummy variables $\mathbf{D}_\mathbf{s,t}$, $\mathbf{D}_\mathbf{p,t}$, and $\mathbf{D}_\mathbf{tr,t}$ and the initial values, $\widetilde{\mathbf{X}}_\mathbf{0}$:

$$\begin{aligned}\mathbf{x}_\mathbf{t} = {} & \mathbf{C}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\boldsymbol{\varepsilon}_\mathbf{i} + \mathbf{C}\boldsymbol{\mu}_\mathbf{0}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}1 + \mathbf{C}\boldsymbol{\Phi}_\mathbf{s}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D}_\mathbf{s,i} + \mathbf{C}\boldsymbol{\Phi}_\mathbf{p}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D}_\mathbf{p,i} + \mathbf{C}\boldsymbol{\Phi}_\mathbf{tr}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D}_\mathbf{tr,i} \\ & + \mathbf{C}^*(L)(\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\mu}_\mathbf{0} + \boldsymbol{\Phi}_\mathbf{s}\mathbf{D}_\mathbf{s,t} + \boldsymbol{\Phi}_\mathbf{p}\mathbf{D}_\mathbf{p,t} + \boldsymbol{\Phi}_\mathbf{tr}\mathbf{D}_\mathbf{tr,t}) + \widetilde{\mathbf{X}}_\mathbf{0}\end{aligned} \tag{A4.6.32}$$

where, as before,

$$\mathbf{C} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\Gamma}\boldsymbol{\beta}_\perp)^{-1}\ \boldsymbol{\alpha}_\perp' \tag{A4.6.33}$$

[265] Juselius, Katarina (2006). *The Cointegrated VAR model*, p. 108.
[266] Ibid, pp. 106, 96.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

and $\mathbf{C^*}(L)$ is an infinite polynomial in the lag operator L referring to a stationary part of (A4.6.32). The summations in (A4.6.32) show the important effects on the variables $\mathbf{x_t}$:

- $\mathbf{C}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\boldsymbol{\varepsilon}_\mathbf{i}$ produces the common stochastic trends originating from the shocks $\boldsymbol{\varepsilon}_\mathbf{t}$,
- $\mathbf{C}\boldsymbol{\mu}_\mathbf{0}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}1$ yields a linear trend originating from the constant,
- $\mathbf{C}\boldsymbol{\Phi}_\mathbf{s}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D_{s,i}}$ generates a broken linear trend from the shift dummy,
- $\mathbf{C}\boldsymbol{\Phi}_\mathbf{p}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D_{p,i}}$ creates a shift in the level of the variables from the permanent impulse, and
- $\mathbf{C}\boldsymbol{\Phi}_\mathbf{tr}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D_{tr,i}}$ gives a blip in levels of the variables from the transitory dummy.

Because of $\mathbf{C} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\Gamma}\boldsymbol{\beta}_\perp)^{-1}\ \boldsymbol{\alpha}_\perp'$ the $\boldsymbol{\alpha}$ components will disappear in the summations in (A4.6.33), so that

$$\begin{aligned}\mathbf{C}\boldsymbol{\Phi}_\mathbf{s} &= \mathbf{C}\boldsymbol{\delta}_\mathbf{1},\\ \mathbf{C}\boldsymbol{\Phi}_\mathbf{p} &= \mathbf{C}\boldsymbol{\varphi}_\mathbf{1},\\ \mathbf{C}\boldsymbol{\Phi}_\mathbf{tr} &= \mathbf{C}\boldsymbol{\psi}_\mathbf{1}.\end{aligned} \tag{A4.6.34}$$

Only the $\boldsymbol{\beta}_\perp$ component of the dummy variable cumulates in the level variables, $\mathbf{x_t}$. With (A4.6.34), (A4.6.32) can be reformulated:

$$\begin{aligned}\mathbf{x_t} &= \mathbf{C}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\boldsymbol{\varepsilon}_\mathbf{i} + \mathbf{C}\boldsymbol{\gamma}_\mathbf{0}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}1 \quad + \mathbf{C}\delta_1\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D_{s,i}} + \mathbf{C}\boldsymbol{\varphi}_\mathbf{1}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D_{p,i}} + \mathbf{C}\boldsymbol{\psi}_\mathbf{1}\sum_{\mathbf{i=1}}^{\mathbf{t-1}}\mathbf{D_{tr,i}}\\ &\quad + \mathbf{C}^*(L)(\boldsymbol{\varepsilon}_\mathbf{t} + \boldsymbol{\mu}_\mathbf{0} + \boldsymbol{\Phi}_\mathbf{s}\mathbf{D_{s,t}} + \boldsymbol{\Phi}_\mathbf{p}\mathbf{D_{p,t}} + \boldsymbol{\Phi}_\mathbf{tr}\mathbf{D_{tr,t}}) + \widetilde{\mathbf{X}}_\mathbf{0}\end{aligned} \tag{A4.6.35}$$

Some important, typical dummy variable combinations in accordance with (A4.6.35) are:

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

- $\mathbf{\Phi_s = \alpha\delta_0 + \delta_1}$, $\mathbf{\delta_0 \neq 0}$, $\mathbf{\delta_1 = 0}$: A model with a mean shift in the cointegration relations, $\mathbf{\beta' x_t}$, refers to $\mathbf{\delta_1 = 0}$ in (A4.6.35) with no broken linear trend in the evolution of the levels of the variables. There is a mean shift in $\mathbf{\beta' x_t}$ as a result of mean shifts in the variables that do not cancel by cointegration.
- $\mathbf{\Phi_p = \alpha\varphi_0 + \varphi_1}$: First, it is worth noticing in the previous case that a mean shift in a variable $x_{j,t}$ implies a permanent blip in $\Delta x_{j,t}$ and hence $\mathbf{\delta_0 \neq 0}$ generally implies $\mathbf{\Phi_p \neq 0}$. Secondly, when $\mathbf{\Phi_s = 0}$ and $\mathbf{\Phi_p \neq 0}$ with $\mathbf{\varphi_1 \neq 0}$ there is a level shift in the levels of the variables that cancel in $\mathbf{\beta' x_t}$. In this case, $\mathbf{\varphi_0 \neq 0}$ describes a blip in the cointegration relations.
- $\mathbf{\Phi_{tr} = \alpha\psi_0 + \psi_1}$: A blip in the levels of the variables, $\mathbf{x_t}$, i.e. $\mathbf{\varphi_1 \neq 0}$, implies a transitory shock in $\mathbf{\Delta x_t}$ and therefore $\mathbf{\Phi_{tr} \neq 0}$. The blips in $\mathbf{x_t}$ which can be seen generated by transitory shocks in $\mathbf{\Delta x_t}$ do not cancel in $\mathbf{\beta' x_t}$.

Juselius (2006) adds an important feature with regard to the VAR model with dummies:[267] It should be noted that a large shock at time *t*, accounted for by the dummies $\mathbf{D_{p,t}}$ or $\mathbf{D_{tr,t}}$, will influence the variables with the same dynamics as an ordinary shock unless the dummy variable is entered in the model with lags. If the modelling requires a dummy with lags, it will be considered an ‘intervention’ shock, otherwise a big, ordinary shock.

The CVAR(2) model in this study with deterministic components

For the conclusion of the discussion, the deterministic components in the VAR(2) model in this study will be introduced.

$$\begin{aligned}\mathbf{\Delta x_t} = {} & \mathbf{\Gamma_1 \Delta x_{t-1}} + \mathbf{\alpha\beta' x_{t-1}} + \mathbf{\alpha\beta_0} + \mathbf{\alpha\beta_1} t + \mathbf{\alpha\delta_0 D_s} 44_t \\ & + \mathbf{\Phi_{p.1} D_p} 17_t + \mathbf{\Phi_{p.2} D_p} 40_t + \mathbf{\Phi_{p.3} D_p} 44_t + \mathbf{\Phi_{p.4} D_p} 45_t + \mathbf{\Phi_{p.5} D_p} 71_t \\ & + \mathbf{\Phi_{tr.1} D_{tr}} 1819_t + \mathbf{\Phi_{tr.2} D_{tr}} 3943_t \\ & + \mathbf{\gamma_0} + \mathbf{\varepsilon_t}\end{aligned}$$

[267] Juselius, Katarina (2006). *The Cointegrated VAR model*, p. 108.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

First, a trend restricted to the cointegration relations could not be rejected, and hence $\boldsymbol{\alpha\beta_1 t},\ (\boldsymbol{\gamma_1} = \mathbf{0})$ was included together with an unrestricted constant $\boldsymbol{\alpha\beta_0} \neq \mathbf{0},\ \boldsymbol{\gamma_0} \neq \mathbf{0}$. A level shift, $\mathbf{D_s}44_t (=1, \text{for } t \geq 1944, \text{otherwise zero})$, for the devastating final war year for Finland in WWII was modelled. The difference of it at time *t* (...,0,0,1,0,0,...) was added in (by CATS) as a permanent impulse dummy $\boldsymbol{\Phi}_{\mathbf{p}.3}\mathbf{D_p}44_t$. The final war year is considered an intervention shock, since for achieving white noise residuals, the VAR needed a dummy with one lag, $\boldsymbol{\Phi}_{\mathbf{p.4}}\mathbf{D_p}45_t$, to account for the extraordinary dynamics for the recovery from the shock.

In addition to those, a permanent impulse dummy for the year of the Russian revolution and of Finland gaining independence, $\boldsymbol{\Phi}_{\mathbf{p}.1}\mathbf{D_p}17_t\ (1, \text{for } t = 1917, \text{otherwise zero})$, for the second year of the Winter War, $\boldsymbol{\Phi}_{\mathbf{p}.2}\mathbf{D_p}40_t\ (1, \text{for } t = 1940, \text{otherwise zero})$, and for the break-up of the Bretton Woods system of currencies in 1971, $\boldsymbol{\Phi}_{\mathbf{p}.5}\mathbf{D_p}71_t\ (1, \text{for } t = 1971, \text{otherwise zero})$ were needed. The year of 1917 is also an intervention shock, since the unusual recovery dynamics required the inclusion of a transitory impulse dummy, $\boldsymbol{\Phi}_{\mathbf{tr.1}}\mathbf{D_{tr}}1819_t$ ($-1,\ \textit{for}\ \ t = 1918,\ \ \textit{and}\ \ 1,\ \textit{for}\ \ t = 1919,\ \ \text{otherwise zero})$. A transitory impulse dummy to take into account the wartime years in WWII not yet mentioned was used, $\boldsymbol{\Phi}_{\mathbf{tr}.2}\mathbf{D_{tr}}3943_t$ ($-1,\ \textit{for}\ \ t = 1939,\ \ \textit{and}\ \ 1,\ \textit{for}\ \ t = 1943,\ \ \text{otherwise zero})$.

By using the notation for augmented cointegration relations, the model can be written as well:

$$
\begin{aligned}
\boldsymbol{\Delta x_t} &= \boldsymbol{\Gamma_1 \Delta x_{t-1}} + \boldsymbol{\alpha}\left[\boldsymbol{\beta}', \boldsymbol{\beta_0}, \boldsymbol{\beta_1}, \boldsymbol{\delta_0}\right]\begin{bmatrix} \mathbf{x_{t-1}} \\ 1 \\ t \\ \mathbf{D_s}44 \end{bmatrix} \\
&+ \boldsymbol{\Phi}_{\mathbf{p}.1}\mathbf{D_p}17_t + \boldsymbol{\Phi}_{\mathbf{p}.2}\mathbf{D_p}40_t + \boldsymbol{\Phi}_{\mathbf{p}.3}\mathbf{D_p}44_t + \boldsymbol{\Phi}_{\mathbf{p}.4}\mathbf{D_p}45_t + \boldsymbol{\Phi}_{\mathbf{p}.5}\mathbf{D_p}71_t \\
&+ \boldsymbol{\Phi}_{\mathbf{tr.1}}\mathbf{D_{tr}}1819_t + \boldsymbol{\Phi}_{\mathbf{tr.2}}\mathbf{D_{tr}}3943_t \\
&+ \boldsymbol{\gamma_0} + \boldsymbol{\varepsilon_t}
\end{aligned}
$$

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

and reformulated as

$$
\begin{aligned}
\mathbf{\Delta x_t} = \mathbf{\Gamma_1 \Delta x_{t-1}} &+ \mathbf{\alpha \tilde{\beta}' \tilde{x}_{t-1}} \\
&+ \mathbf{\Phi_{p.1} D_p} 17_t + \mathbf{\Phi_{p.2} D_p} 40_t + \mathbf{\Phi_{p.3} D_p} 44_t + \mathbf{\Phi_{p.4} D_p} 45_t + \mathbf{\Phi_{p.5} D_p} 71_t \, , \\
&+ \mathbf{\Phi_{tr.1} D_{tr}} 1819_t + \mathbf{\Phi_{tr.2} D_{tr}} 3943_t \\
&+ \mathbf{\gamma_0} + \mathbf{\varepsilon_t} \, ,
\end{aligned}
$$

(A4.6.36)

where $\tilde{\boldsymbol{\beta}}' = [\boldsymbol{\beta}', \boldsymbol{\beta}_0, \boldsymbol{\beta}_1, \boldsymbol{\delta}_0]$ and $\tilde{\mathbf{x}}_{\mathbf{t-1}} = (\mathbf{x}_{\mathbf{t-1}}, 1, t, \mathbf{D}_{\mathbf{s}} 44)'$

Finally, we will look at the moving average representation of the VAR(2) model in this study.[268] Such a CVAR model can be expressed as:

$$
\mathbf{x_t} = \mathbf{C} \sum_{\mathbf{i=1}}^{\mathbf{t-1}} \boldsymbol{\varepsilon}_{\mathbf{i}} + \mathbf{C} \boldsymbol{\gamma}_{\mathbf{0}} \sum_{\mathbf{i=1}}^{\mathbf{t-1}} 1 \quad + \mathbf{C} \boldsymbol{\varphi}_{\mathbf{1}} \sum_{\mathbf{i=1}}^{\mathbf{t-1}} \mathbf{D}_{\mathbf{p,i}} + \mathbf{C} \boldsymbol{\psi}_{\mathbf{1}} \sum_{\mathbf{i=1}}^{\mathbf{t-1}} \mathbf{D}_{\mathbf{tr,i}}
$$

(A4.6.37)

$$
+ \ \mathbf{C}^* (L) (\boldsymbol{\varepsilon}_{\mathbf{t}} + \boldsymbol{\mu}_{\mathbf{0}} + \boldsymbol{\Phi}_{\mathbf{s}} \mathbf{D}_{\mathbf{s,t}} + \boldsymbol{\Phi}_{\mathbf{p}} \mathbf{D}_{\mathbf{p,t}} + \boldsymbol{\Phi}_{\mathbf{tr}} \mathbf{D}_{\mathbf{tr,t}}) + \breve{\mathbf{X}}_{\mathbf{0}}
$$

where $\mathbf{C} = \boldsymbol{\beta}_{\perp} (\boldsymbol{\alpha}_{\perp}' \boldsymbol{\Gamma} \boldsymbol{\beta}_{\perp})^{-1} \boldsymbol{\alpha}_{\perp}'$ or $\mathbf{C} = \tilde{\boldsymbol{\beta}}_{\perp} \boldsymbol{\alpha}_{\perp}'$, and $\breve{\mathbf{X}}_{\mathbf{0}}$ contains both the initial value, $\mathbf{x}_0$, of the process $\mathbf{x}_t$ and the initial value of the short-run dynamics $\mathbf{C}^*(L)\boldsymbol{\varepsilon}_0$.

- The common driving trend(s) is the combination of the cumulated residuals $\boldsymbol{\alpha}_{\perp}' \sum_{\mathbf{i=1}}^{\mathbf{t-1}} \boldsymbol{\varepsilon}_{\mathbf{i}}$ (in the expression $\mathbf{C} \sum_{\mathbf{i=1}}^{\mathbf{t-1}} \boldsymbol{\varepsilon}_{\mathbf{i}} = \tilde{\boldsymbol{\beta}}_{\perp} \boldsymbol{\alpha}_{\perp}' \sum_{\mathbf{i=1}}^{\mathbf{t-1}} \boldsymbol{\varepsilon}_{\mathbf{i}}$).
- The $\boldsymbol{\beta}_{\perp}$ component, $\boldsymbol{\gamma}_{\mathbf{0}}$ of the unrestricted constant, ($\boldsymbol{\mu}_{\mathbf{0}} = \boldsymbol{\alpha} \boldsymbol{\beta}_{\mathbf{0}} + \boldsymbol{\gamma}_{\mathbf{0}}$) shows up in the non-stationary part (the first row), whereas the $\boldsymbol{\alpha}$component of the unrestricted constant ($\boldsymbol{\alpha} \boldsymbol{\beta}_{\mathbf{0}}$) is marked in the stationary part (the second row) for simplicity with $\boldsymbol{\mu}_{\mathbf{0}}$. When summing up in the non-stationary part, $\boldsymbol{\gamma}_{\mathbf{0}}$ cumulates to a time trend in the levels of the variables, $\mathbf{C} \boldsymbol{\gamma}_{\mathbf{0}} t$.

[268] See also Juselius, Katarina (2006). *The Cointegrated VAR model*, p. 256.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

- The level shift dummy in 1944 is restricted to the stationary part, $\boldsymbol{\beta}'\mathbf{x}_t$. However, the difference (...,0,0,1,0,0,...) with the same *t*, is included in $\mathbf{C}\boldsymbol{\varphi}_1\sum_{i=1}^{t-1}\mathbf{D}_{p,i}$ producing with summation (or integration) a level shift in the variables $\mathbf{x}_t$, similarly to the other permanent impulse dummies (1917, 1940, 1945, 1971). The effects of these shocks never die out of the process.
- The transitory impulse dummies in 1918–1919 (the lag-dynamics of the year 1917), and in 1939–1943, generate transitory impulses to the stationary part (opening the period with -1, closing the period with 1). In the summation in the non-stationary part, their effects generate a permanent blip to the level variables $\mathbf{x}_t$.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

DATA APPENDIX 4.1 GDP, hours worked, fixed capital and intangible human capital by schooling in Finland in 1910–2000

NB: This is the data used in the cointegration analysis in Chapter 4. GDP, fixed capital (K) and intangible human capital by schooling (H) in EUR million (2000 year ref. price).

Sources: Own calculations; GDP, hours worked: Statistics Finland, Historical National Accounts (obtained from the database in Jan 2007), human capital (adjusted for wars and net-migration, see the discussion in Chapter 3, human capital is constructed in accordance with Historical National Accounts obtained in Jan 2007): fixed capital: Jalava, Jukka and Matti Pohjola (2007): The roles of electricity and ICT in growth and productivity: case Finland, *Pellervo Economic Research Institute Working Papers*, No. 94 (April 2007).

	GDP	Hours (ind. 1926=100)	K	H
1910	7165	81.88	12,207	2,023
1911	7363	83.82	12,557	2,154
1912	7773	84.73	12,973	2,270
1913	8195	85.87	13,427	2,386
1914	7834	85.37	13,925	2,547
1915	7435	85.04	14,233	2,695
1916	7543	85.85	14,428	2,791
1917	6332	83.02	14,488	2,950
1918	5492	81.85	14,394	3,008
1919	6633	85.37	14,450	3,144
1920	7419	90.49	14,585	3,196
1921	7667	89.08	14,792	3,279
1922	8466	93.06	15,090	3,297
1923	9094	96.66	15,462	3,274
1924	9336	97.25	15,888	3,288
1925	9861	97.21	16,326	3,331
1926	10243	100.00	16,945	3,392
1927	11038	102.62	17,697	3,500
1928	11791	105.99	18,716	3,657
1929	11936	102.90	19,579	3,824
1930	11785	99.04	20,158	4,038
1931	11501	95.67	20,526	4,311
1932	11449	96.72	20,981	4,607
1933	12221	98.68	21,572	4,933
1934	13601	104.12	22,397	5,269
1935	14182	106.67	23,403	5,530
1936	15143	110.83	24,607	5,939
1937	16001	115.96	26,048	6,323
1938	16833	118.23	27,506	6,693
1939	16117	112.92	28,817	6,994
1940	15271	119.49	30,234	7,287
1941	15777	120.38	29,898	7,546
1942	15827	118.50	29,878	7,810
1943	17641	120.01	30,201	8,008
1944	17653	125.58	30,147	8,167
1945	16651	118.77	30,364	8,404
1946	17979	124.62	31,076	8,508
1947	18394	124.17	32,211	8,596
1948	19852	131.23	33,526	8,721
1949	21058	129.80	34,814	8,830
1950	21869	131.10	36,108	8,886
1951	23736	138.00	37,533	8,994
1952	24521	138.51	39,238	9,248
1953	24701	136.03	40,727	9,510
1954	26860	140.23	42,554	9,877
1955	28226	144.58	44,358	10,279
1956	29078	146.05	46,312	10,637
1957	30450	144.88	48,023	11,149
1958	30616	143.86	49,712	11,591
1959	32427	146.41	51,478	12,165
1960	35402	150.24	54,648	12,851
1961	38100	152.98	58,008	13,604
1962	39236	151.84	60,808	14,384
1963	40511	152.11	62,842	15,324
1964	42648	154.03	65,358	16,016
1965	44910	155.80	68,306	16,748
1966	45976	154.25	71,269	17,645
1967	46973	150.13	73,628	18,533
1968	48055	146.98	75,641	19,473
1969	52665	147.80	78,757	20,235
1970	56599	149.74	82,675	21,335
1971	57781	146.18	86,707	22,823
1972	62190	146.43	90,617	23,710
1973	66363	148.05	95,094	24,560
1974	68372	148.24	99,731	25,725
1975	69160	145.73	105,354	26,622
1976	69089	144.17	109,418	27,533
1977	69669	140.94	112,389	28,448
1978	71377	140.02	113,660	29,442
1979	76141	141.27	115,487	30,396
1980	80060	143.82	118,627	31,698
1981	81740	146.07	122,082	33,049
1982	84350	146.56	125,697	34,588
1983	86709	145.69	129,528	35,893
1984	89506	145.86	132,850	37,258
1985	92568	146.04	136,734	38,530
1986	94701	143.91	140,927	39,760
1987	98770	145.17	145,554	40,984
1988	103457	147.29	151,323	42,495
1989	108439	148.35	159,114	44,069
1990	108073	145.04	164,962	45,641
1991	101170	135.19	166,323	46,945
1992	97315	126.08	165,403	47,804
1993	96106	118.65	162,797	48,729
1994	99888	118.35	160,198	49,867
1995	104234	120.49	160,149	51,276
1996	108187	122.10	160,726	52,517
1997	114884	125.89	162,444	54,291
1998	120581	127.70	165,847	56,004
1999	124654	131.20	169,099	57,790
2000	130859	133.02	173,420	59,371

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

5. CONVERGING INCOME LEVELS – CONVERGING CYCLES?

In Chapter 2 it was shown that Finland has caught up with Sweden and the EU15 on average income levels or GDP per capita mostly after WWII. This has happened because of achieving higher labour productivity growth in services and later in secondary production together with the lower starting levels of GDP per capita and labour productivity (LP). The production structure of Finland has turned similar to the structures in the EU15 and especially in Sweden. In this part of the study the focus is on the fluctuations of GDP growth and therefore on economic cycles. Figure 5.1 delineates the GDP series for Finland, Sweden and the EU15 in 1860–2008, of which the cyclical properties will be explored. The series are expressed at 1990 Geary-Khamis dollars and therefore they should reflect the relative purchasing power parities between the economic areas.

The empirical evidence discussed in the Introduction of this study indicated that the close economic interaction combined with similarities in the preferences and cultural background can result in strict convergence of the GDP per capita levels. In the Finnish case most of the imports have come from and exports have been sold in the markets of the EEC and EFTA countries in 1920–2000. Moreover, the joint EFTA and EEC areas have had the biggest shares in foreign direct investments, both inwards and outwards in 1965–2009, and the biggest single country investing in and receiving investments from Finland has been Sweden. At the same time, the average income levels of Finland have strictly converged to the ones in Sweden and in Western Europe, or the EU15 nowadays. The evidence leads to the direction of technology diffusion growth theories in which the role of human capital is especially emphasised.

Finally, in Chapter 4 the Finnish labour productivity was modelled together with physical and human capital in the labour input in 1910–2000. The results suggest two long-run steady state relations, a production function in the intensive form of the type $(Y_t / L_t) = A(H_t / L_t)^{1-\alpha}(K_t / L_t)^{\alpha}$ and a relation between the capitals $H_t = T(t) \cdot 0.74K_t$, where both types of capitals influence the evolution of the other and where the technological progress is linked to physical capital. These results imply a technology diffusion model of the type $Y_t = AH_t^{1-\alpha} \cdot N^{1-\alpha} \cdot (K_t)^{\alpha}$, where $K_t = Nk_{j,t}$ and $k_{j,t}$ is one type of a fixed capital good. N expresses the number of capital goods used in that country. The model should be augmented, though, to express the simultaneous growth of human capital and physical capital

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

and their effect on each other. The fact that *N* has increased over time is reflected in the steady state equation of the capitals by the time trend $T(t)$ attached with the used aggregate K_t in the empirical analysis. Another way to interpret the time trend in connection with the aggregate K_t would be that the quality of physical capital has increased along time. Therefore, the results would give support as well to the quality ladder models and to the idea of capital vintages. I would argue that probably both effects have been working along time. To simplify the analysis here, let us consider only the model with increasing capital good varieties along time.

Finland has not been able to produce all of the new capital goods implemented in her production along time. Instead, Finland has imported them or foreign enterprises have implemented them in their production in Finland, or Finnish corporations have adopted them in their foreign activities and have employed them in the production at home as well. As noted above, most of the new capital good varieties must have come from Western Europe and from Sweden because of the dominant foreign trade and FDIs with these economic areas. According to the definition of the FDI in the Balance of Payment Statistics, a foreign direct investment relation arises by foreign corporate acquisition or by purchasing enough shares for controlling (> 50%) or for having a stabile economic relation with (10% – 50%) the foreign corporation. In practice, this often means that the production of the original enterprise now takes place in both countries at separate establishments. The establishment in the foreign country may produce intermediate inputs for the parent company at home. Having this type of value added chain or producing the same products in both countries will make both establishments equally influenced by the fluctuations in the world demand for their final products, in the prices of raw materials and financing services. The business cycles of the two establishments would be literally alike. Obviously, this type of economic interaction in the two countries will render the countries more dependent on each other and should breed convergence or synchronicity in their economic cycles.

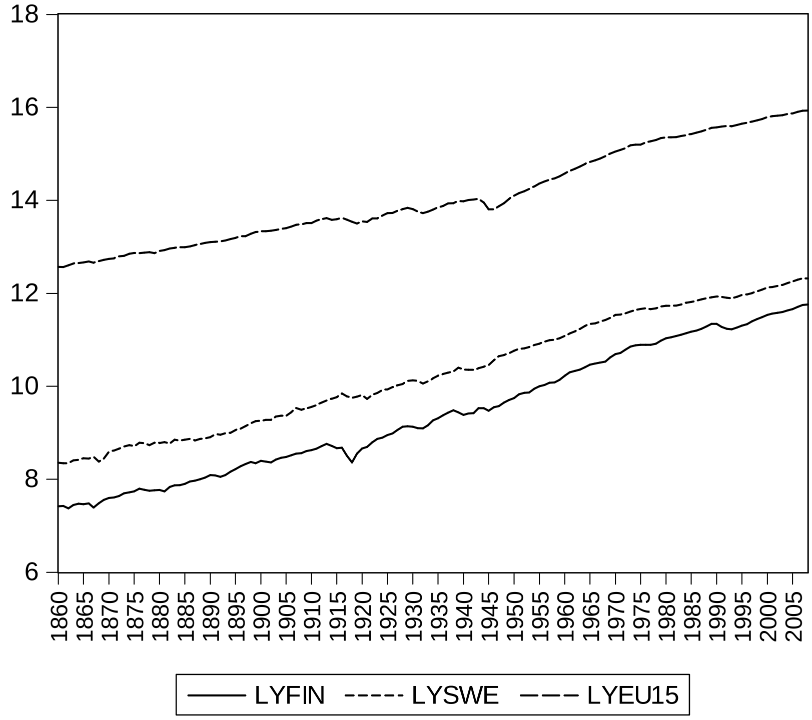
This will be explored first by delineating the cyclical fluctuations of the economic areas by combining an ARIMA-model-based unobserved component approach and filtering.[269] The similarities of the resulting economic cycles will be studied by cross correlations of the cycles along time. Secondly, a strict econometric testing approach will be used in order to test whether there have actually been common cycles between Finland and

[269] The model-based approach combined with filtering is based on Kaiser, Regina and Maravall, Agustin (2001). *Measuring Business Cycles in Economic Time Series.* Lecture Notes in Statistics 154, Springer-Verlag, New York.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Sweden as well as between Finland and the EU15 along the development after WWII.[270] Before the empirical analysis, the basic theoretical background for separating long-run variation and short-run cyclical variation from the observed time series will be discussed in 5.1.

Figure 5.1 GDP at 1990 Geary-Khamis dollars of Finland, Sweden and the EU15 in 1860–2008 in natural logarithms



Sources: Own calculations; data for Finland 1860–1950 from Hjerppe, Riitta, *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* Jyväskylä: Kopi-Jyvä Oy 1996; data for Sweden 1860–1950 from Krantz, Olle and Lennart Schön, *Swedish Historical National Accounts 1800–2000*, Lund, Almqvist & Wiksell International, 2007, LU – MADD URL: http://www.ehl.lu.se/database/LU-MADD/, (2009-09-09); data for Finland and Sweden 1950–2008 from *The Conference Board, Total Economy Database, June 2009, http://www.conference-board.org/economics*, (2009-09-09); data for the EU15 1860–1995 from Carreras, Albert and Xavier Tafunell, European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, pp. 63–87, 1996–2008 Eurostat database http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database, (2009-09-09).

[270] The testing of common cycles follows Mills, Terence C. (2003). *Modelling Trends and Cycles in Economic Time Series.* Palgrave Mcmillan, New York, pp 123–127.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

5.1 Unobserved trend and cycle components[271]

The first problem faced by researchers when aiming to study the cyclical fluctuation is how to separate the cyclical fluctuation from longer term trend in time series as in Figure 5.1. To describe this, let us denote GDP by Y_t. Now, to make the long-run GDP log-linear, let $y_t \equiv \log Y_t$. The aim is to divide the original time series to components

$$y_t = \mu_t + \varepsilon_t \tag{5.1.1}$$

where μ_t is a long-term trend, ε_t is a stationary cyclical component. What is meant by (weak) stationarity is that ε_t is assumed to fluctuate around a constant, time-invariant mean with finite variance (again variance not changing in time). As can be seen in 5.1.1, cyclical fluctuation is left to the series when the trend is subtracted from the original series $y_t - \mu_t = \varepsilon_t$. The components are unobserved in the original series, and hence need to be estimated. One of the guiding rules often in estimating them is a requirement that the components are independent of each other, i.e.

$$E(\mu_t, \varepsilon_s) = 0 \quad \text{for all } t, s \qquad (5.1.2).$$

The first problem to engage in is how to estimate the trend component. Two possible cases for economic time series are that the series are Trend Stationary (TS) or Difference Stationary (DS). First, let a time series be generated by a linear trend buried in stationary noise (u_t),

$$y_t = \alpha + \beta t + u_t, \qquad t = 0, 1, 2, 3, \ldots \tag{5.1.3}$$

This is referred to as the trend stationary (TS) process, in contrast to an Integrated of order one, *I(1)*, process

$$\Delta y_t = \beta + u_t, \tag{5.1.4}$$

[271] This section draws heavily on Mills, Terence C. (2003). *Modelling Trends and Cycles in Economic Time Series*. Palgrave Mcmillan, New York, pp. 13–15, 54–58.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

known as Difference Stationary (DS). Accumulating the changes Δy_t from an initial value y_0 yields

$$y_t = y_0 + \beta t + \sum_1^t u_i \tag{5.1.5}$$

which looks close to 5.1.3. However, there is a fundamental difference: the intercept here is no longer a fixed parameter but instead, now depends on the initial value, y_0, and the error is no longer stationary, for its variances and covariances depend on time.

This is an important distinction for the analysis of economic cycles (and trends). If y_t is trend stationary then all variation of the time series is attributable to the stationary part (to cycle and random components), and any shock must have only a temporary effect as the series always returns to a linear growth path. Instead, if the time series is difference stationary, its trend component must be a non-stationary stochastic process, meaning that all the shocks (now or in the previous history) affect the future path. Treating difference stationary y_t as a TS instead of a DS process is likely to lead to an overstatement of the magnitude and duration of the cyclical component and an understatement of the importance and persistence of the trend component.[272]

Another important distinction between the processes is the forecasting properties. For a TS process the forecast errors are bounded no matter how far into the future the series is forecast, because u_t has a finite variance. In addition, even when autocorrelation in u_t can be used for making short-term (cyclical) forecasts, the only relevant information about the future of y_t over the long horizon is in its trend, $\alpha + \beta t$, so that neither current nor past events will alter long-term expectations. Contrary to this, in the DS process the forecast error variance will increase without bound, since the error variance is an increasing function of time. Long-term forecasts will always be influenced by historical events through the accumulation of the shocks u_t. Therefore, it is essential to be able to distinguish correctly between a TS and DS process.[273]

[272] Mills, Terence C. (2003). *Modelling Trends and Cycles in Economic Time Series.* Palgrave Mcmillan, New York, p 55.
[273] Ibid, p 55.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

It turns out that it is very easy to mistake a DS process for a TS process that seems to provide a good fit to the data, with a high R^2, small residual variance and significant coefficients, but which generates spuriously long cycles in the detrended data.

The two processes can be distinguished by computing a unit root test, an Augmented Dickey-Fuller (ADF) test, by running the regression

$$\Delta y_t = \alpha + \delta y_{t-1} + \beta t + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + v_t \qquad (5.1.6)$$

where $\delta = \rho - 1$.[274] The test is then the usual *t*-ratio with the null $\delta = 0$ against the alternative $\delta < 0$. A number of lags of Δy_t are included for ensuring the residuals being white noise. If beta is zero, so that there is no 'drift' in 5.1.5, the time trend can be deleted from 5.1.6, but in this case the critical values of DF-distribution have to be used for statistical inference.

In accordance with the above, a unit root test of (5.1.6) was conducted for logarithmic GDPs at 1990 Geary-Khamis dollars of Finland, Sweden and the EU15 in 1860–2000 demonstrated in Figure 5.1. Each of them proved to be *I(1)*-processes, the test accepting the null hypothesis of a unit root with *p*-values 0.49, 0.40 and 0.79, respectively. Hence the series are difference stationary.

5.2 Converging business cycles between Finland, Sweden and the EU15?

Particularly, in the case of a difference stationary time series the separation of the long-term trend and the short-run variation is not an easy task. Different approaches have been suggested: a traditional approach is to use ad hoc filters which are concentrating on the long-run and short-run frequencies for the respective components. Perhaps the most commonly used such filter is the Hodrick-Prescott filter.[275] The problem addressed to this approach is

[274] Cf., e.g. Dickey D. and Fuller W. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, pp. 427–431; Harris R (1992) Testing for unit roots using the Augmented Dickey-Fuller test: Some issues relating to size, power and lag structure of the test. *Economics Letters*, 38, pp. 381–386.

[275] See Hodrick, R. J. and Prescott, E. C. (1997). Postwar US business cycles: an empirical investigation. *Journal of Money, Credit and Banking*, 29, pp. 1–16.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

that the properties of the original series at hand, i.e. the autocorrelation structure of series, is not studied at all. Applying an a priori filter to the time series will violate the autocorrelation structure of the series and not take it into account in the analysis. This becomes obvious when a filter is applied to a random white noise series. A filter of this type manages to extract a trend component and a cycle from such a series, even when there is no systematic variation in the original series. The result is that the filter de facto by itself produced such variation that was not included in the original series.

Another approach is to start from the autocorrelation structure of the individual series and decompose the time series into components in accordance with the structure. This is called the Unobserved Components Model approach.[276] A traditional class in this approach are Autoregressive Integrated Moving Average (ARIMA) Models which accurately begin with the autocorrelation structure of the time series. The Unobserved Components ARIMA Models (UC-ARIMA) use the frequency analysis together with the autocorrelation structure to decompose the time series into

$$y_t = TC_t + \varepsilon_t \tag{5.2.1}$$

where TC_t is called a trend cycle and ε_t is here identically independently and normally distributed white noise random variation, $\varepsilon_t \sim i.i.d\ N(0,\delta^2)$. Within this approach, the very long-run trend variation and the cycle are not easy to distinguish from one another and in practice, trend (T_t) and cycle (C_t) are often modelled together and called a trend cycle component (TC_t).

Regina Kaiser and Agustin Maravall have shown an analytical solution for the business cycle analysis by combining these two approaches, the Unobserved Components ARIMA Model (UC-ARIMA) approach and the frequency filter approach.[277] In brief, they have shown that the Hodrick-Prescott filter can be rewritten as a Wiener-Kolmogorov filter (typically used with ARIMA models) and therefore can be theoretically included and analysed together with Unobserved Components ARIMA models. They have come to a conclusion that the individual time series can be first modelled and decomposed to a trend cycle (TC_t) and to

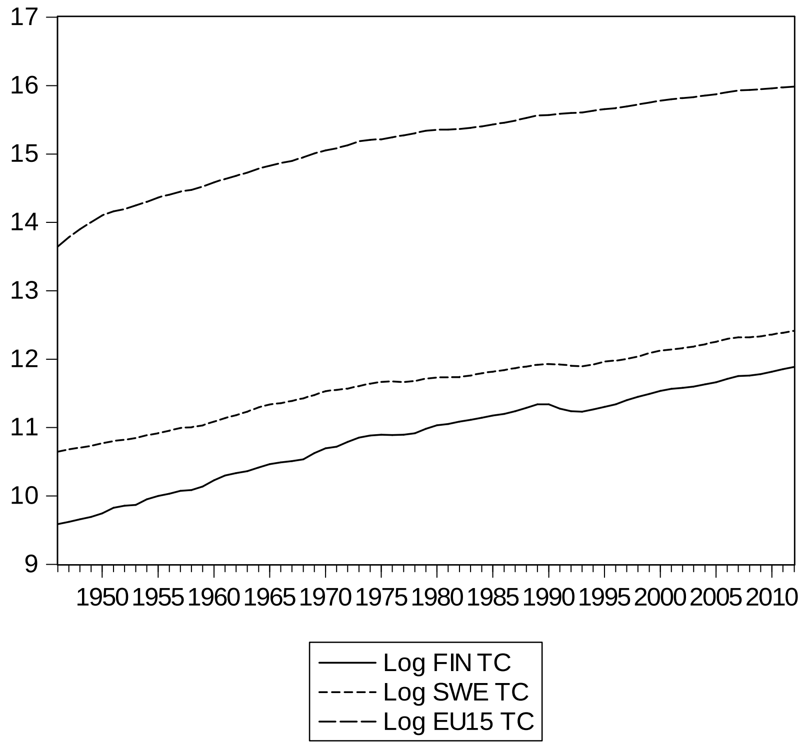
[276] See, e.g. Maravall, A. (1995): Unobserved Components in Economic Time Series. In Pesaran, H. and Wickens, M. (Eds.), *The Handbook of Applied Econometrics*, vol. 1, Oxford: Basil Blackwell.
[277] Kaiser, Regina & Agustin Maravall (2001), "*Measuring Business Cycles in Economic Time Series*" , Lecture Notes in Statistics 154, Springer-Verlag New York.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

random white noise ($\varepsilon_t \sim i.i.d\ N(0,\delta^2)$) by the UC-ARIMA approach with respecting the individual autocorrelation structure of the series. The obtained trend cycle component can be then decomposed further to a long-term trend and to a cycle by the Hodrick-Prescott filter.

The combined approach of Kaiser and Maravall is applied here next. A detailed Unobserved Components ARIMA model approach by Maravall, Time Series Regression with Missing observations and Outliers/Signal Extraxtion in Arima Time Series (TRAMO/SEATS), is used to decompose the original Finnish, Swedish and the EU15 real GDP series to trend-cycle and irregular variation components.[278] For taking care of the beginning and end point estimation problem of the cycles with the Hodrick-Prescott filter later, as Kaiser and Maravall have suggested, four observations were backcast and forecast with the individually specified ARIMA model for each of the series. Figure 5.2.1 gives the obtained trend-cycles in logarithms for the economic areas to be studied for 1950–2008 with the backcast and forecast observations.

Figure 5.2.1 Trend-cycle components of Finland, Sweden and the EU15 in 1950–2008 by TRAMO/SEATS (in natural logarithms, with two backcast and forecast observations).

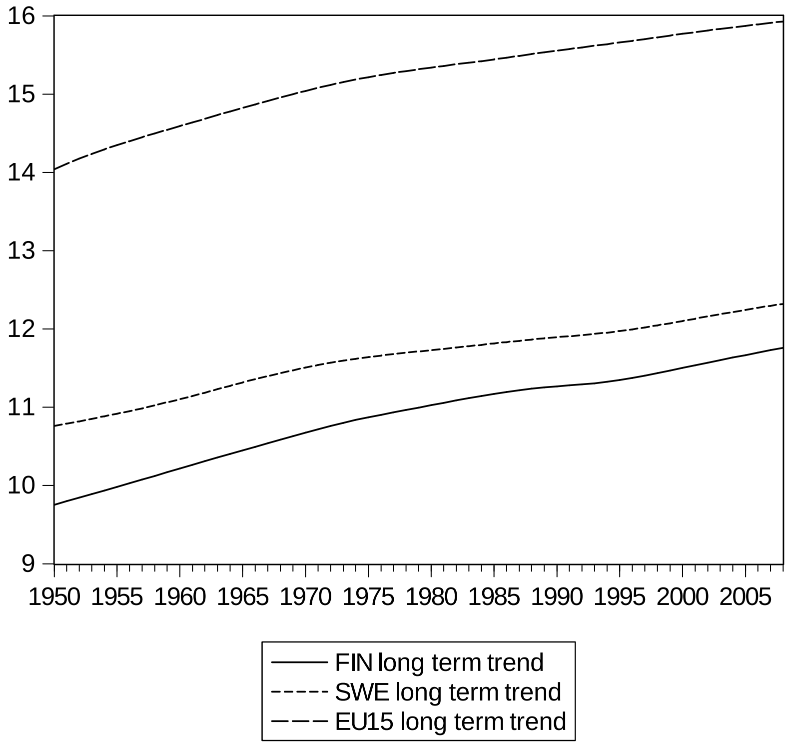


[278] See, e.g. Gomez, V., Maravall, A. (1996): Programs TRAMO and SEATS. Instructions for the User, (with some updates). *Working Paper 9628*, Servicio de Estudios, Banco de España.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The Hodrick-Prescott filter (with smoothing parameter $\lambda = 100$) was then applied to each of the series and the long-term trends and the estimated business cycles were obtained, the former displayed in Figure 5.2.2 and the latter in Figure 5.2.3. Each of the mentioned components should now reflect the systematic variation associated with the frequencies desired in the components. The trend-cycle component from the UC-ARIMA approach for each series is filtered out of the individual original series with respect to the autocorrelation structure of the series at hand in the long-term and cyclical fluctuation frequencies. The ARIMA model (and hence the autocorrelation structure) of the individual series is used to construct a Wiener-Kolmogorov filter to decompose the original series to trend-cycle (signal) and irregular (noise) components, the latter containing here a white noise error plus additive and transitory outliers. As the trend-cycle components for the economic areas at hand were derived like this, the Hodrick-Prescott filter is safe to use for separating the long-run stochastic trend and the cycle for each of the series.

Figure 5.2.2 Long-term trends of Finland, Sweden and the EU15 in 1950–2008.

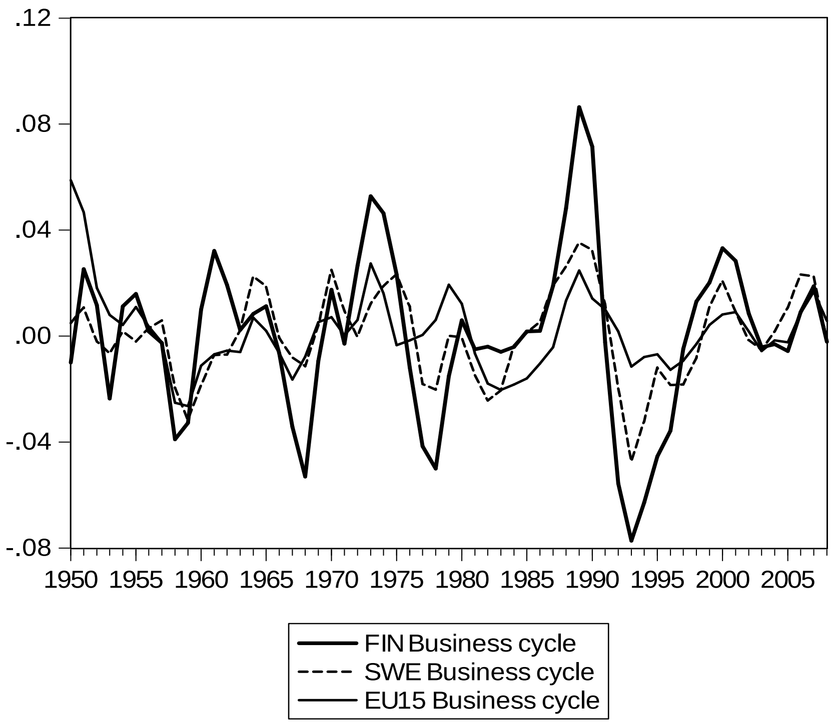


The estimated business cycles in Figure 5.2.3 are of primary interest here. The figure reveals that cyclical fluctuations around the long-term trend have been smallest for the biggest economic area, the EU15, with a standard deviation 0.015. The Swedish cyclical fluctuations

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

have been much closer to that of the EU15, the Swedish standard deviation of the cycle being 0.017 and the Finnish one 0.031. This means that due to high and low tides, the average deviations from long-run trend growth have been 1.5, 1.7 and 3.1 percentage points in the mentioned economic areas. The smaller economic areas have had a more specialised structure in their exports and the international fluctuations in their export markets can result to higher fluctuations in the whole GDP level. However, compared with Sweden, the larger cyclical variation in Finland is an interesting feature. It could reflect the fact that the exports in Finland in the first decades consisted more of raw materials, such as timber and pulp, which are sensitively reacting to the global price fluctuations. Nevertheless, later, at least since the 1980s, also in Finland the exports consisted more of final products, such as paper, not to forget the rise of the mobile telephone industry in the 1990s. Yet, the cyclic variation has remained the largest in Finland. Therefore, another reason could be that the state in Finland has not followed Keynesian stabilising economic policy to the same extent as in Sweden and in the Western Europe after WWII.

Figure 5.2.3 Business cycles of Finland, Sweden and the EU15 in 1950–2008 (in natural logarithms).



It is perhaps not very easy to draw conclusions of the similarity of the business cycles only from the graph, but the cycles do seem to have growing similarities towards the end of the

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

period. Focusing first on Finland (the thick solid line) and Sweden (the dashed line), it would seem that there are more unsynchronous peaks and troughs before 1976 than afterwards: for instance, after the mid-1950s Finland seems to peak first contrary to the mid-1960s with Sweden's leading peak with the reverse again in mid-1970s. Comparing Finland and the EU15 (the thin solid line) shows visible differences in the early 1950s and early 1960s with the EU15 not peaking and after the mid-1960s with the EU15 leading the trough. After the early 1970s the cycles seem to be more alike. However, the low tide has lasted longer on the bottom of the wave in the EU15 in the early 1980s. The boom in the late 1980s and the fall in the early 1990s have been obviously biggest in Finland.

More formally, the similarity of the business cycles can be examined by correlation along time. Table 5.2.1 delineates the correlation coefficients between the cycles of Finland, Sweden and the EU15 for the whole time period 1950–2008 and for mainly 15-year sub-periods. Obviously, there has been similarity in the cyclical fluctuations. The correlation between the Finnish and Swedish business cycles has been 0.77 for the whole period and between Finland and the EU15 0.44.

Table 5.2.1 Correlation of the business cycles between Finland, Sweden and the EU15 1950–2008

	Fi - Swe	Fi - EU15	Swe - EU15
	ρ	ρ	ρ
1950–2008	0.77	0.44	0.54
1950–1965	0.49	0.32	0.56
1965–1980	0.79	0.58	0.26
1980–1995	0.9	0.59	0.69
1993–2008	0.87	0.77	0.85
1996–2008	0.69	0.78	0.87

Detecting the correlation in the 15-year sub-periods, it becomes obvious that the correlation grows to the end of the whole period in both comparisons. In the comparison with Sweden, the two last 15-year periods, 1980–1995 and 1993–2008 are very high 0.9 and 0.87, but as

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

well with the EU15 in the last 15-year 0.77, while the correlations in the earlier sub-periods are lower. This must reflect the growing similarity of the production structure in Finland together with increasing foreign trade and foreign direct investments between the countries rendering the economic areas more dependent on each other. By exporting activities and daughter companies in Sweden, in the United Kingdom and in West Germany as well as Swedish, British and German products and increasing number of daughter companies in Finland, it can be argued that Finland must have got knowledge of the new production technologies from the evolving world technology frontier. Adopting this new technology has required more and more educated workers, which has been ensured in Finland, as shown in Chapter 4 of this study. Finally in 1996–2008, in the time period of Finland's membership to the EU, the correlation of Finland has been higher with the EU15 with the common currency since 1999, 0.78, than that with Sweden, 0.69. The last column demonstrates the correlation of the business cycles between Sweden and the EU15, showing that their business cycles have converged as well.

Since the correlation coefficient changes over time, all the 15-year-period correlations were calculated and they are shown in Figure 5.2.4. In addition, correlations in the last 14, 13 and 12-year periods in 1994–2008, 1995–2008 and 1996–2008 are shown in the same figure. In general, this inspection agrees with the findings above: the business cycles have converged towards the end of the whole period under review in both comparisons. Between Finland and Sweden, the correlation has been quite high since the early 1960s and has yet gradually grown until the EU membership of Finland in 1995. After the FINNEFTA agreement in 1961, by which Finland came to be an associate member of the European Free Trade Area, foreign trade and foreign direct investments rose between Finland and Sweden. As discussed in the Introduction of this dissertation, Sweden has been the biggest country in foreign direct investments inwards Finland after 1965 and already in the interwar period. In some industries Finland became a sub-contractor for Sweden. As an example, Volvo and Saab car components were produced in Finland. Swedish textile manufacturing companies also located their production in Finland in the late 1960s.[279]

[279] For many other examples see, e.g., Aunesluoma, Juhana and Fellman, Susanna (2006). Introduktion. In Aunesluoma, Juhana and Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet.* Svenska litteratursällskapet i Finland, Helsingfors. About Swedish textile manufacturing companies in Finland, see Rahikainen, Marjatta (2006). Svensk textil- och konfektionsindustris etableringar i Finland 1969–1973. En respit för både branschen och anställda kvinnor. In Aunesluoma, Juhana and Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet.* Svenska litteratursällskapet i Finland, Helsingfors, 355–382; About Finnish companies in Sweden, see Fellman, Susanna (2006). Utvidgad hemmamarknad eller språngbräda till Europa? Tidiga finska företagsetableringar i

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Between Finland and the EU15, in the 15-year periods 1951–66 to 1961–76 there has been a first convergence period in economic cycles. Finland had signed the agreement with the International Monetary Fund (IMF) in 1948, but it took a couple of years to stabilise the Finnish Markka with respect to other currencies in the system. The exchange rates were fixed and made official in 1951 starting the actual Bretton Woods time for Finland. As mentioned above, in 1961 Finland signed an associate member agreement with EFTA, the FINNEFTA agreement. The EFTA countries made a free trade agreement with the EEC in 1973, for Finland this was made in 1974.[280] The rise in the correlations of the cycles referring to the periods above can be associated with increased interaction by foreign trade in accordance with the opening the economy by the agreements. Again, as already noted in the Introduction of this dissertation, more than two thirds of the foreign direct investments inwards Finland have come from EFTA and EEC (later the EU15) areas since 1965, and also already in the interwar period.

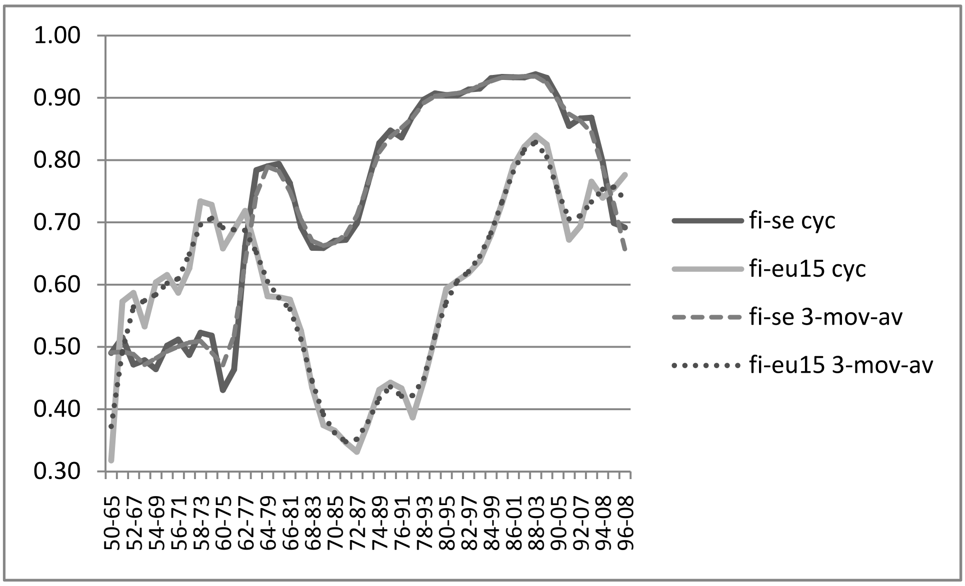
Instead, the fall in the correlations of the cycles between Finland and the EU15 is notable in the 15-year periods ending from 1962–77 up to the period 1972–87. These periods, with falling correlation, include in the centre of the periods the collapse of the Bretton Woods currency system in 1971 as well as the first and second OPEC oil crises. It is argued here that the crash of the currency co-operation affected the downfall of the cycle correlations. In addition, due to both oil crises Finland was especially gaining from the special position in foreign trade with the Soviet Union. As the oil price was rising and Finland was importing oil from the USSR, the value of the imports rose. According to the bilateral trade agreements with the Soviet Union, Finland could then export more to the Soviet Union. As a result, the foreign trade with the USSR reached its record shares in the foreign trade in Finland in the late 1970s and until the mid-1980s. After that, the shares started to decline due to imbalances in the two-way trade because of the excess exports of Finland over imports until the breakdown of the Soviet Union in 1991.

Sverige. In Aunesluoma, Juhana and Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet.* Svenska litteratursällskapet i Finland, Helsingfors, pp. 283–324.

[280] Finland became a full member of EFTA in 1986, however, in practice the free trade with the EEC countries had come into effect already in 1974.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Figure 5.2.4 Rolling window for correlation of the Business Cycles in 15-year time spans btw. Finland and Sweden and Finland and the EU15 in 1950–2008, and in the periods 1994–08, 1995–08, 1996–08



On the other hand, since the period 1973–88, after the free trade agreement between the EFTA and EEC areas, the correlation of the business cycles with the EU15 began to increase steadily. This coincides with the increased economic interaction: according to the FDI statistics, on average, even 88% of the annual inwards FDIs to Finland came from the EEC and EFTA areas in 1973–1990, and the share of EU15 and EFTA of the cumulated inward FDI stocks rose over 90% by late 1990s. Finland joined the EU and the second phase of the European Monetary Union with its convergence criteria for the economies involved in 1995. Gradually toward this membership time the correlation in the business cycles has grown to its highest values. The EMU's third phase started in 1999 as the euro began functioning as the account money in transactions, since 2002 the euro has been used in transactions in cash as well. Finland has been part of the euro area and Sweden not. The correlation between Finland and the EU15 cycles has exceeded that between Finland and Sweden in the last periods 1995–2008 and 1996–2008.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

5.3 Testing for common cycle[281] [282]

In this section, the dependence of the cyclical fluctuation of Finnish economic growth on Sweden's and the EU15's growth will be explored further by analysing whether the GDP growth rates have even shared a common cycle at least in some time period after WWII. This will be done by using stochastic time series modelling techniques, since, as discussed above, GDP level series mentioned are non-stationary *I(1)*-processes and thus difference stationary. To begin with, the theory of co-features in time series will be briefly discussed.

Co-features in time series

A framework for studying common features can be developed by considering two time series generated by the model

$$\begin{aligned} y_{1t} &= \lambda \omega_t + \varepsilon_{1t} \\ y_{2t} &= \omega_t + \varepsilon_{2t} \end{aligned} \qquad (5.3.1)$$

In 5.3.1 ω_t is a variable common to both y_{1t} and y_{2t} that has a particular statistical property that the components ε_{1t} and ε_{2t} do not share. This property, or feature, could be a trend, a seasonal pattern or serial correlation related to cyclical fluctuation, etc. Now, the interest here is on the possible case where y_{1t} and y_{2t} both have the feature but a linear combination of them, $z_t = y_{1t} + y_{2t}$, does not. In this case the feature is said to be common, and there is a non-zero linear combination of the time series in which the feature cancels out.

More generally, a feature that is present in each group of the time series, $y_{1t}, y_{2t}, ..., y_{nt}$, is said to be common to those series if there exists a non-zero linear combination of the series, $z_t = \sum_{i=1}^{n} \delta_i y_{it}$, that does not have the feature.[283]

[281] The theoretical presentation for testing common cycles is based on Mills, Terence C. (2003). *Modelling Trends and Cycles in Economic Time Series.* Palgrave Mcmillan, New York, pp 123–127.

[282] I would like to express my kindest gratitude to Dr. Carsten Burhop for guiding me to the direction of common cycle analysis.

A convenient regression approach is to generalise 5.3.1 to

$$\begin{aligned} y_{1t} &= \mathbf{x_t}\beta_1 + \mathbf{w_t}\lambda_1 + \varepsilon_{1t} \\ y_{2t} &= \mathbf{x_t}\beta_2 + \mathbf{w_t}\lambda_2 + \varepsilon_{2t} \end{aligned} \qquad (5.3.2)$$

Where $\mathbf{x_t}$ and $\mathbf{w_t}$ are k_x and k_w dimensional vectors of variables that influence both y_{1t} and y_{2t}. The latter vector contains the variables defining the potential common feature. For there to be such a common feature, it is required that there exists a δ such that $\lambda = 0$ in the model

$$y_{1t} = \delta y_{2t} + \mathbf{x_t}\beta + \mathbf{w_t}\lambda + \varepsilon_t \qquad (5.3.3)$$

According to Mills, a feasible way of testing this in practice is the case to estimate 5.3.3 under the null $\lambda = 0$ by two-stage least squares (2SLS) to take into account for including an ‘endogenous‘ variable, y_{2t}, as a regressor. This will produce the residuals $e_t = y_{1t} - \hat{\delta} y_{2t} - \mathbf{x_t}\hat{\beta},$, $t = 1, 2, ..., T$, where $\hat{\delta}$ *and* $\hat{\beta}$ are the 2SLS estimates. Then e_t are regressed on $\mathbf{x_t}$ and $\mathbf{w_t}$ and $T \cdot R^2$ from this regression can be computed. This is a Lagrange Multiplier (LM) test, distributed as χ^2 with k_w– 1 degrees of freedom (k_w is the dimension of the vector w_t in (5.3.3)) under the null $\lambda = 0$. Large values of the test statistics will lead to a rejection of the null of a common feature.[284]

[283] Mills, Terence C. (2003). *Modelling Trends and Cycles in Economic Time Series.* Palgrave Mcmillan, New York, 2003, p. 124.
[284] Ibid, p. 124.

Has the increased synchronicity led to a common cycle between Finland and Sweden and between Finland and the EU15 along time after WWII?

Initially, the fit of different ARMA models were tested with the differenced log GDPs of Finland, Sweden and the EU15. It turned out that all of our series could be modelled with AR-models, Finland with *t–1* and *t–2* lags, Sweden with *t–1* lag and the EU15 with lag *t–1*. In each case the residual of the fitted AR-model showed to be indistinguishable from white noise. The modulus of the inverse roots in the lag polynomial of each series was < 1, referring to a stationary process with a cyclical autocorrelation structure.[285]

First, two-stage least squares regression was carried out with the logarithmic growth rates of Finland and Sweden with *t–1* and *t–2* lags as instruments for both variables. To begin with, it was detected that Sweden's growth rate explains Finland's growth rate, and therefore $\delta \neq 0$ .The residual of the first stage was saved and in the second stage, the residual was then regressed on the lagged instruments on both variables. If the explaining power for the second stage regression is zero, there is no autocorrelation structure left in the first stage residual, and the growth rates of Sweden explained all the cyclical autocorrelation variation in the growth rate of Finland. Whether this is the case can be tested with LM-test on the second stage residual by $T \cdot R^2$ which is a Khi-squared distributed test with degrees of freedom k_{w-1}, in this case 2. The null hypothesis in this test is that the second stage residual is white noise, and hence the null for a common cycle cannot be rejected.[286]

Table 5.3.1 shows the results. It proved out that there has not been a common cycle between Sweden and Finland in the whole period after WWII, in 1950–2008. This did not change when moving ahead to 1960–2008. In Chapter 2 it was shown that Finland began to catch up Sweden only from 1965 onwards. In 1961 Finland became an associate member of the European Free Trade Area (EFTA), which continued the gradual opening of the Finnish economy and strengthened the economic integration to Western Europe. It is quite intriguing

[285] A growth rate series exhibiting cyclical behaviour is often referred to as having in the autoregressive form an AR(2) structure. However, above the growth rates of SWE and the EU15 are said to be modelled with AR(1) model. Mills (2003, Example 6.1, pp. 127, 156–157, Example 3.3, p. 52) argues in a similar case that the AR(1) structure can be inverted and rewritten in the Moving Average (MA) form with infinite lags. In this form the first two lags explain most of the variation of the growth rate series and can be seen expressing a cyclical behaviour in the growth rate series. In the testing procedure for the common cycle hypothesis, Mills was using two lags as instruments in the case of the U.S. and Canada for both countries, even when the growth rate of the U.S. could be modelled with one autoregressive lag.

[286] With reference to equation 5.3.3, in the testing procedure here $\mathbf{x_t} = \mathbf{1}$ and $\mathbf{w_t}$ includes the lagged *t–1* and *t–2* variables of y_{1t} and y_{2t} .

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

that for the sub-period 1965–2008, the common cycle hypothesis could not be rejected for the first time. This result is corroborated as the common cycle hypothesis was accepted for 1970–2008 as well.

Table 5.3.1 Common cycle test results for Finland and Sweden

	1st stage	Test on 2sls residual	Critical values / inference
	$\delta \neq 0$	$T \cdot R^2$	10%: 4.605 , 5%: 5.991
1950–2008	y	7.28	Reject
1960–2008	y	8.19	Reject
1965–2008	y	5.02	cannot reject
1970–2008	y	4.95	cannot reject

Data Sources: LN growth rates of GDP at 1990 Geary-Khamis dollars, data for Finland and Sweden: *The Conference Board, Total Economy Database, June 2009,* http://www.conference-board.org/economics (2009-09-09); data for the EU15: 1950–1995 Carreras, Albert and Xavier Tafunell, European Union economic growth experience 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, 63–87, 1996–2008 Eurostat database http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (2009-09-09).

The same testing procedure was done between the logarithmic growth rates of Finland and the EU15 with results presented in Table 5.3.2. Not surprisingly, thinking of the quite different structure of the economy in Finland compared with most Western European countries after WWII, the hypothesis of the common cycle was rejected for 1950–2008. The cyclical fluctuations proved not to be common in 1960–2008 and in 1970–2008. Finland became an associate member of the European Free Trade Area (EFTA) in 1961 and the EFTA area signed a free trade agreement with the EEC along with the EFTA area in 1973–74, both of which opened up the Finnish economy to a new level. According to these results, there has been a common cycle between Finland and the EU15 economic area already from 1973, which is not likely a coincidence with the EFTA–EEC free trade agreement.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Table 5.3.2 Common cycle test results for Finland and the EU15

	1st stage	Test on 2sls residual	Critical values / inference
	$\delta \neq 0$	$T \cdot R^2$	10%: 4.605 , 5%: 5.991
1950–2008	y	11.4	Reject
1960–2008	y	12.07	Reject
1970–2008	y	8.04	Reject
1973–2008	y	2.72	cannot reject

Data Sources: LN growth rates of GDP at 1990 Geary-Khamis dollars, data for Finland and Sweden: *The Conference Board, Total Economy Database, June 2009,* http://www.conference-board.org/economics (2009-09-09); data for the EU15: 1950–1995 Carreras, Albert and Xavier Tafunell, European Union economic growth experience 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday,* Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, 63-87, 1996–2008 Eurostat database http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (2009-09-09).

5.4 Conclusions

In the basic framework of this study, it was argued that for permanent growth of labour productivity in a latecomer country, continuous adoption of new production technologies is needed from the evolving world technology frontier. This requires openness and close interaction via foreign trade with the leading countries. The increasing foreign trade and foreign direct investments will render the countries involved more dependent on each other. This type of convergence along with convergence in economic structures should breed convergence in economic cycles. The basic question in Chapter 5 was whether there has been convergence in economic cycles along with the convergence in income levels and production structures after WWII.

This was explored first by delineating the cyclical fluctuations of the economic areas by combining an ARIMA-model-based unobserved component approach and filtering. By extracting the business cycles for Finland, Sweden and the EU15 with this combined approach, the similarities of the resulting economic cycles could be studied by cross correlations of the cycles. The results showed that the correlations between business cycles in the mentioned economic areas have grown along time in 1950–2008. Between Finland and Sweden the correlation has been quite high since the early 1960s, soon after the FINNEFTA

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

agreement in 1961, and the correlation with the EU15 had also grown. However, the Finnish business cycle correlations declined with both Sweden and the EU15, in the detected 15-year time periods covering the early 1970s up to the mid-1980s. The decline coincides with the collapse of the Bretton Woods currency system, in 1971, and the increased foreign trade of Finland with the Soviet Union from the early 1970s until the mid-1980s partly as a result of the two oil crises. After the free trade agreement between the EFTA and EEC areas, since the 15-year period 1973–88, the correlations in both comparisons began to increase steadily, referring to increased interaction by foreign trade and direct investments. The correlations grew gradually until the EU membership of Finland in 1995. Finland joined the EU (as did Sweden) and the second phase of the European Monetary Union with its convergence criteria for the economies involved in 1995. The common currency came into use in 1999 as an account money (also used in foreign trade), Finland being part of the euro area and Sweden not. The correlation between Finland and the EU15 cycles has exceeded that between Finland and Sweden in the last studied periods 1995–2008 and 1996–2008.

Secondly, to confirm the results for cycle convergence, a strict econometric testing approach was applied in order to see whether there have actually been common cycles between Finland and Sweden as well as between Finland and the EU15 along the development after WWII. The hypothesis of a common cycle in both comparisons was rejected for the whole period 1950–2008 and for 1960–2008. It turned out that in the periods 1965–2008 and 1970–2008 the common cycle hypothesis between Finland and Sweden could not be rejected. Between Finland and the EU15 this hypothesis could neither be rejected in 1973–2008. It is worth noticing that this timing coincides with the agreement for free trade between EFTA and the EEC in 1973–1974 and later with the EU membership from 1995 onwards.

According to all the analysis above, it seems that the growing interaction – at least in the forms of foreign trade, foreign direct investments and monetary co-operation – between the economic areas has rendered the cyclical fluctuation of the countries more dependent on each other. The cyclical fluctuations on the economic growth of Finland have converged to those of Sweden and the EU15 along with the converging average income levels after WWII.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

6. SUMMARY AND CONCLUSIONS

The advance of Finland's economic performance has been dramatic in the 20th century, not only in absolute terms of GDP per capita as in most locations on earth, but also relative to the leading countries: Beginning one hundred years ago with a gross domestic product per capita less than half of that of the United Kingdom or the United States, nowadays Finland's standard of living is ranked among the top fifteen to twenty-five countries in the world. In the same time frame, Finland has converged with the average income levels of her leading neighbours, Sweden and the EU15. The question behind this study has been: How did this happen in the geographically large but low population country with relatively scarce natural resources? Both for historical reasons, and also when thinking of today's poor countries, it would be important to understand the transformation processes experienced by the worldwide few absolute convergence countries.

In the Introduction of this thesis, the use of the concept convergence was defined in the empirical work of this study with regard to the original scientific strict meaning in mathematics, referring here to the difference of the logarithmic per capita GDPs of the countries (or economic areas) approaching zero in some point of time. This strict convergence was observed between Finland, Western Europe and Sweden in the 20th century up to the turn of the millennium. Correspondingly, Robert Barro and Xavier Sala-i-Martin have demonstrated convergence, in this strict sense, in 1870–1990 in groups of capitalistic countries with close interaction and sharing similar institutional and cultural characteristics, Canada, Australia and the USA as a one group, the United Kingdom, France, Germany and Italy as another group, and the Nordic countries (without data for Iceland) as a third example.[287] It was argued that since the strict convergence in GDP per capita of some groups of countries is observed, this phenomenon should be explored. It could also give feedback to the vast number of theoretical considerations on economic growth.

As part of the Introduction, the economic interaction of Finland with foreign countries in the 20th century after WWI was studied by using data on shares of foreign trade and foreign direct investments (FDI) by country. The analysis on foreign trade showed that, on average, 71% of the imported products have come to Finland from Europe without the Soviet Union in 1920–2000, and, respectively, on average, 73% of the exported products from

[287] Barro, Robert J. and Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*, pp. 332–335.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Finland found their markets in Europe without the Soviet Union. The most important partners in foreign trade in the 20th century have been Germany, Sweden and the United Kingdom, with their 38% average share of imports and 44% average share of exports. When adding to the group France, the Netherlands, Denmark, Italy, Norway and Belgium, the average share of imports climbed up to 56% of imports and to 65% of exports. The Soviet Union was an important trading partner for Finland especially from the early 1970s up to the early 1980s, in accordance with the bilateral trade agreement in the times of the two OPEC oil crises. The vast market there gave an opportunity for Finnish exports. Finland was also obviously gaining from the Soviet oil imports in the times of the oil crises. However, from the point of view on how a follower country could get in touch with new technologies from the advancing world technology frontier, the long-run interaction with Western Europe and Sweden has probably been crucial, particularly when their combined shares constantly exceeded the smaller shares of the Americas.

Foreign direct investments (FDI) inwards to Finland and outwards from Finland have formed another important channel for economic interaction. According to the data on FDIs, Sweden has been noticeably dominating the shares in the FDIs in both directions. According to the study of Riitta Hjerppe, most, 80%, of the foreign owned companies in Finland in the interwar period were Swedish, German, Norwegian, British and Danish companies.[288] The Swedish companies formed alone a share of 35% of the foreign companies. The official statistics on the FDIs are available from 1965 onwards, showing that the average annual share of the EFTA and EEC countries in the inward FDIs to Finland in 1965–1994 was 81.6%, and the average annual share of Sweden alone 37.5%, and the share of the U.S., 12.4%. In the economically integrating Europe, the next biggest investors to Finland have been the United Kingdom, the BENELUX countries (the Netherlands and Belgium), Denmark, Switzerland and Germany. The more or less same biggest candidates for technology diffusion to Finland are manifested in both imports and in FDIs, however, in the average annual shares for inward FDIs Sweden steps forth together with the UK and the BENELUX countries and Switzerland. Foreign investments into the service industries in Finland have been at least as big as in manufacturing since the interwar period.

The more solid presence of Finns in the foreign markets was illustrated by outward FDIs in 1965–1990. Again, most of the outward FDIs, approximately two thirds, were located in the EFTA and EEC areas. The countries with the biggest shares in Europe are the familiar

[288] Hjerppe, Riitta (2004). Monikansallisten yritysten tulo Suomeen ennen toista maailmansotaa. *Kansantaloudellinen aikakauskirja*, 3/2004, pp. 216–238.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

ones, Sweden with her share increasing in the positioning of the Finnish FDIs particularly after 1980s, the UK, the Netherlands, Belgium and Denmark. France and Switzerland are among the countries with the biggest share in Europe of outward FDIs from Finland, as they are in export shares as well. North America has been somewhat more favoured in the share of the investments from Finland than in the investments the other way around. The average annual share of Canada was 15.3% and that of the U.S., 7.8% in 1965–1990.

Finally, the available statistics on the accumulated stocks of FDIs, with holdings revalued every year with respect to the market values, were inspected for 1994–2009. The annual average share of the joint EU15 and EFTA areas in the inward FDI stocks was 90%, and the share was increasing towards 2009. The dominance of Sweden was even clearer, with a share of 50% of the total stock. The overall picture was quite similar in the stocks of outward FDIs, with the joint EU15 and EFTA areas having had an average annual share of 75%, and Sweden the biggest average share of single countries, 25%. In the foreign direct investments, the economic interaction with the US relative to others seems to have declined more or less in both directions since the EU membership of Finland in 1995.

On the basis of the economic interaction with the foreign countries, it is not an accident that Finland has converged to the average income levels of Western Europe and Sweden in the strict sense. This may have resulted from the similar cultural background, institutional settings, high interaction in foreign trade and in foreign direct investments (FDI) and finally from the economic and financial integration of Europe. The evidence implies to technological diffusion as an important source for economic convergence. Similar institutional set-ups and cultural characteristics can make the understanding and implementation of technologies from abroad easier.

The basic framework of the later analysis in this study was defined as follows: Firstly, the structural change is seen driven by new possibilities (technology) to produce products (old and new). Secondly, this production with new technology will drive labour productivity and GDP per capita up on the national level. Thirdly, to use new production technologies requires human capital (education, also resulting in the ability for constant learning and skills accumulation). To find out empirically the impacts of investing in and accumulation of human capital by schooling on GDP, investments in human capital were investigated in the same National Accounts framework as GDP. Fourthly, for permanent growth of labour productivity, continuous adoption of new production technologies from the evolving world technology frontier is needed. This requires openness and close interaction via foreign trade with the leading countries. The increasing foreign trade and foreign direct

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

investments will render the countries involved more dependent on each other. This type of convergence should breed convergence (or co-dependence) in economic cycles.

In accordance with the basic framework, the research was conducted in the following chapters: The first two items of the framework were analysed in Chapter 2, where structural change and labour productivity growth were explored as sources of Finland's convergence. In Chapter 3 the object was to explore whether the considerable input in education has been one of the sources for Finland's fast GDP per capita growth and speeding up the growth in the 20th century. Chapter 4 investigates the role of both physical and human capital in the Finnish economic growth. In Chapter 5 the possible deepening of cycle co-dependence among the mentioned economic areas was studied.

According to the results in Chapter 2, the Finnish catch-up has mostly taken place after WWII, although the interwar period can be seen as a take-off period. During the whole period reviewed, it seems that there was more room to expand to new fields of economic activities in the Finnish economy. Thus, in compliance with the classical view, beginning from a low production level, Finland gained from the latecomer position and from faster structural change. However, it was not only the late rapid industrialisation that helped Finland to catch up. When comparing with Sweden, the labour productivity growth contribution from services was essential for Finland's GDP per capita catch-up in 1965–80 since Sweden gained slightly more from secondary production labour productivity even in that period. It is worth noticing that in this time period the services, and especially trade, received, on average, 60% of the inward FDIs in Finland. In the last examined period here, in 1980–2003, Finland finally exceeded Sweden's labour productivity growth contributions in secondary production, and the most important effect for faster Finnish GDP per capita growth came from secondary production at that time. The importance of services, as already emphasised by Stephen Broadberry for the US and Germany with respect to the UK, in catch-up is a new result for Finland and worth considering also when analysing the catching up or lagging behind of other countries. The take-off in the interwar period agrees with Hjerppe's study on the higher than previously thought international economic interaction of Finland at that time. The convergence development was interrupted, as Finland did not catch up Sweden in 1945–1965, despite the Finnish potential to higher growth rates with respect to advantages in relative backwardness. This can be at least partly associated with the inward oriented protectionist atmosphere in the times when Finland had to build up the peacetime relationship with the

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Soviet Union.[289] Most of the Finnish convergence with Sweden occurred after 1965. At the same time, the Finnish economy opened up and integrated to Western European markets.[290]

The aim of Chapter 3 of this study was to explore whether the considerable input in education has had a connection to the dramatically changed economic performance in Finland in the 20th century. To reach this goal, education expenditures in 1877–2000 were estimated and the stock of intangible human capital by formal education in the 20th century was formed for Finland inside the systematic National Accounts frame. The long graduation times in education were taken into account and for this the number of students in primary, lower secondary, upper secondary, professional/vocational and university education were gathered in 1880–2005. At last, human capital stock by formal education was adjusted for people deceased in wars and for net migration. The advantage of this approach is that investments are valued in monetary terms as GDP and physical capital and they have a logical connection to GDP and to other variables in the National Accounts. It is worth noting as well that the empirical counterparts of the core variables in the growth theories (GDP and physical capital) come from the National Accounts. However, this means changes to the National Accounts, since human capital is not included inside the asset boundary in the international System of National Accounts.

The inclusion of investments in human capital by schooling changed the National Accounts of Finland. Using the annual final consumption expenditures in education as investments revealed that the investments in intangible human capital by schooling have contributed between 1% and 5% to GDP at current prices in Finland in peacetime, in 1877–2000. For comparison, the relation of investments in physical capital to GDP has varied at current prices between 10% and 33%. According to these calculations, Finland has invested more in total, and the new investment ratio (including investments in physical capital and in human capital by schooling) of GDP at current prices has ranged between 11% and 37%. Investments in physical capital have grown, on average, by 3.3% a year and investments in education at a higher 3.9% rate a year, on average, in 1877 to 2000. However, investments in physical capital formed 90% in the early years and in the late years still around 80% of the total investments and therefore the level of annual investments in physical capital has been substantially higher in the modified system. Eventually, the changes to the National Accounts – when concentrating on actual monetary flows paid for education – were fairly modest.

[289] Cf., Paavonen, Tapani (1998). *Suomalaisen protektionismin viimeinen vaihe*.
[290] Cf., Paavonen, Tapani (2008). *Vapaakauppaintegraation kausi. Suomen suhde Länsi-Euroopan integraatioon FINN-EFTAsta EC-vapaakauppaan*; Seppinen, Jukka (2001). *Mahdottomasta mahdollinen. Suomen tie Euroopan unioniin.*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The possible long-run relation of human capital by schooling and economic growth was explored in Chapter 3 by cointegration analysis. The hypothesis on a cointegration relation between GDP per capita and human capital per capita was statistically highly significantly detected in 1910–2000, 1920–2000 and 1946–2000. According to the results, the importance of human capital by schooling in the economic development of Finland has noticeably increased after WWII. The effects of human capital interacting together with physical capital remained unknown in the analysis based on the two variables alone.

In Chapter 4, the role of human capital by schooling together with physical capital in the process of economic growth was studied by incorporating GDP, physical capital and number of hours worked in the Cointegrated VAR analysis for the years 1910–2000. The long-run labour productivity growth with physical and human capital per number of hours worked was studied by the Vector Equilibrium Correction Model representation. With variables expressed in proportion to hours worked, the number of cointegration relations was tested to be most likely two, with some indication on one cointegration relation being on the borderline of acceptance. In accordance with this, the long-run labour productivity growth with physical and human capital per number of hours worked was studied first with two and then with one cointegration relation.

The long-run labour productivity growth in Finland can probably be best modelled with two cointegration relations, in which one can be referred to as a production function with constant returns to scale on physical and human capital in labour input, and the other describes the relation between capitals in the labour input and time trend. In the first relation, only labour productivity growth proved to be adjusting for the innovations in the physical and human capital per hours worked. The second cointegration relation revealed that human capital and physical capital with a time trend associated with it have been growing with respect to each other. After 1944, the whole relation between the capitals has shifted by 18% in favour of human capital, illustrating a structural break and a new balance between physical capital and human capital after WWII.

According to the results, technology can be seen embodied in physical capital. The time trend associated with the growth of physical capital refers to a consideration of capital vintages and to increasing varieties of fixed capital goods. The capital goods of more recent vintages have been more productive for a given cost. Another way to look at this is that the increase in the varieties of fixed capital goods in Finland is reflected in the time trend attached with fixed capital. Fixed (or physical) capital together with technological progress embodied

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

in it and human capital appear to have nourished the evolution of each other.[291] Economic growth seems to have triggered off when the cumulated innovations in physical capital have been bigger than the cumulated innovations in human capital. Both with a vintage capital interpretation and with a variety of capital goods interpretation, human capital can be deemed to have enhanced the growth of labour productivity both via physical capital and technological progress, by making the usage of new physical capital with new technology embodied possible. The results showed that the growing amount of human capital in the labour input has intensified labour productivity growth through both as an input with physical capital per labour input and in interaction with the technological progress and physical capital in Finland in the 20th century.

The aspects of the results can be summarised in a combined variety of capital goods model with technology diffusion and human capital of the type $Y_t = A \cdot H_t^{1-\alpha} K_t^{\alpha} = A \cdot (H_t)^{1-a} \cdot \sum_{j=1}^{N} (k_{j,t})^{\alpha}$, where $k_{j,t}$ is one type of fixed capital good and N expresses the number of capital goods used in that country. The model should be augmented, though, to express the simultaneous growth of human and physical capital with capitals being complements and affecting the evolution of each other. The fact that N has increased over time is reflected in this study in the cointegration relation of the capitals by the time trend $T(t)$ attached with the used aggregate K_t in the empirical analysis. Since it is not possible that a follower country such as Finland could have produced all of the new varieties, or the better new qualities of the same type of capital goods, the new technology capital goods have been implemented in Finland by importing them, with foreign corporations using them in Finland or by Finnish enterprises learning to use them first abroad in their foreign activities and then employing them at home. Human capital by schooling has been essential for Finland, in being able to implement continuously new technologies from the advancing world technology frontier, and later also in the research and development activities in the most advanced industries in inventing new capital good varieties. As shown in the Introduction, the vast majority of technology transfers must have come to Finland from Sweden and from Western Europe in the 20th century, which has resulted in the strict convergence on GDP per capita with the mentioned economic areas.

[291] Cf. unified growth theory: Galor Oded (2005). From Stagnation to Growth: Unified Growth Theory. In Aghion P., Steven N. Durlauf (Eds), *Handbook of Economic Growth*, vol 1A, Chapter 4, 171–293.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

The analysis with a single long-run relation suggested that labour productivity growth has been an endogenous process, where all the variables adjust to the shocks in each of the variables. This process can be described as endogenous constant returns to scale production relation of the $y_t = Ak_t$ type in intensive form, with k_t referring to both capitals, where labour productivity is explained by physical and human capital in the labour input. However, the fact that all variables adjusted, combined with the common trends analysis, implicate that physical and human capital per hours worked have been in turn catalysed by economic growth, also in the long run. Without human capital, as constructed in this study in the model, and only physical capital in the labour input explaining labour productivity, the deterministic time trend with an average pace of 2.4% a year could not be excluded from the model. The pace of the deterministic time trend needed in the model declined from 2.4% a year to 0 when human capital per hours worked was included in the case of a single cointegration relation. In the analysis of two cointegration relations, the average rate of a time trend in the capitals/technology relation was estimated to 1.55% per annum. Therefore, the inclusion of intangible human capital by education constructed in the National Accounts frame made it possible to reduce the "Solow residual" notably in all of the cases. The obvious conclusion from all what is said above is that the substantial input in education has contributed to the long-run economic growth of Finland. Intangible human capital by schooling has been one of the most important factors for the modern economic growth in Finland.

The basic question in Chapter 5 was whether convergence in economic cycles has occurred along with the convergence in income levels after WWII between Finland and Sweden as well as between Finland and the EU15. Extracting cyclical fluctuation from the time series has proven to be difficult. Particularly, in the case of difference stationary time series the separation of the long-term trend and the short-run variation is not an easy task. In this study, the growing similarity of business cycles was investigated first by delineating the cyclical fluctuations of the economic areas by combining an unobserved component ARIMA-model-based approach (UC-ARIMA) and filtering, therefore following an analytical solution provided by Regina Kaiser and Agustin Maravall in the early 2000s. By extracting the business cycles for Finland, Sweden and the EU15 with this combined approach, the similarities and dissimilarities of the resulting economic cycles were studied by correlations of the cycles along time. The results do show that the correlations between the business cycles in the mentioned economic areas have grown towards the end of the period 1950–2008.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Secondly, to confirm the results for cycle convergence, a strict econometric testing approach was applied in order to see whether there would be cycle co-dependence and common cycles to be detected between Finland and Sweden as well as between Finland and the EU15 along the development after WWII. The hypothesis of a common cycle in both comparisons was rejected for the whole period 1950–2008 and for 1960–2008. Instead, in the periods 1965–2008 and 1970–2008 the common cycle hypothesis between Finland and Sweden could not be rejected. It seems as well that between Finland and the EU15 this hypothesis cannot either be rejected in 1973–2008, right after when the EFTA area (including Finland) had made a free trade agreement with the EEC. According to these results, openness and close interaction via foreign trade between the economic areas have rendered the cyclical fluctuation of the countries more dependent on each other. This corresponds with the suggested combined model of technology diffusion and capital good varieties with human capital. As noted above, most of the new capital good varieties must have come from Western Europe and Sweden because of the dominant foreign trade and FDIs with these economic areas. Foreign companies have owned establishments in Finland and vice versa. The establishment in the foreign country often produces intermediate inputs for the parent company in the home country forming a value added chain with it, or the same final goods. In these circumstances, the establishments in both countries have been equally influenced by the fluctuations in the world demand for their final products, in the prices of raw materials and financing services. The business cycles of the two establishments in this set-up should become literally alike. This has bred convergence in the economic cycles on the macro level.

In addition to what was said above, the common history with Sweden for a long time and therefore the same cultural and religious heritage with Sweden, common labour markets after 1950s, and building up similar Nordic capitalism have obviously been in the background of the Finnish catch-up with Sweden as well. The long common history with Sweden has tied Finland at the same time to the Western European culture. Together with high interaction after the independence, it is not difficult to see similarities in property rights, in propensity to save, and in labour market regulations in Finland. Also, these observations correspond with theory, as accumulated fixed capital with the same level of technology included in it, similarly accumulated human capital, similarity in propensity to save and in hours worked per person refer to strict GDP per capita convergence, when the institutional set-up of the economic areas are alike. The cultural similarities have helped in implementing new technology. Finally, high economic interaction in foreign trade and FDIs in the 20th century, and the increased economic and financial integration in Europe have enabled technology diffusion, resulting in

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

convergence of the Finnish income levels and business cycles with respect to those of Sweden and the EU15.

The main objectives of the whole study were to bring new results on the process, timing and locating of Finland's convergence with Sweden and the EU15 on GDP per capita, to find out the role of human capital by schooling, also together with physical capital, in the Finnish economic development, and to discover whether the business cycles have converged along with the development between the mentioned economic areas and Finland. In accordance with the results summarised above, the goals of this research can be seen to have been reached.

Considering research in the future, the importance of services (together with manufacturing industries) is worth considering also when analysing the catching up or lagging behind of other countries. Their impact on the Finnish catch-up growth should be studied on a more detailed industrial class level. Measuring human capital by formal education in the context of National Accounts is applicable in other countries. This could open up an avenue for future research in order to study empirically the role of human capital in economic growth in a broader set of countries. The suggested combined aspects of capital good varieties, technological diffusion and human capital could be examined with respect to other country clubs of strict convergence. Together these topics could form a substantial research agenda.

The previous empirical growth and convergence studies in the Finnish and Nordic economic history have, with few exceptions, mainly relied on the fruits of the neo-classical theory. This study suggests a paradigm shift from the neo-classical growth and convergence explanation to a technology diffusion model with human capital, in which technological progress is embodied in the new varieties (qualities) of fixed capital.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

MAIN DATA SOURCES

Introduction:

GDP per capita for a group of today's OECD countries in 1890–2000:
- Maddison, Angus (2010). *Historical Statistics of the World Economy*: 1–2008 AD, updated 02-2010. http://www.ggdc.net/MADDISON/oriindex.htm (2010-12-16).

GDP per worker for the countries in the world in 1960–2007:
- Heston, Alan, Summers, Robert and Aten, Bettina, *Penn World Table* Version 6.3 (PWT 6.3), Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, August 2009. http://pwt.econ.upenn.edu/php_site/pwt_index.php (2010-12-08).

GDP per capita for the EU15:
- Carreras, Albert and Tafunell, Xavier, European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, pp. 63–87; 1996–2000 *Eurostat database* http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (2009-09-09).

Finnish imports and exports by country and region in 1920–2000:
- Database of Riitta Hjerppe (received from her).

Statistics on Foreign Direct Investments in 1965–2009:
- Balance of Payments Statistics, Bank of Finland.

Data on foreign companies in Finland in the interwar period:
- Hjerppe, Riitta (2004). Monikansallisten yritysten tulo Suomeen ennen toista maailmansotaa. *Kansantaloudellinen aikakauskirja*, 3/2004, pp. 216–238.
- Hjerppe, Riitta (2006). Svenska företag i Finland under mellankrigstiden. In Aunesluoma, Juhana, Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet*. Svenska litteratursällskapet i Finland, Helsingfors, 2006, 325–354.

Chapter 2:

European Union (the EU15), Historical National Accounts data: Carreras, Albert and Xavier Tafunell, European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, pp. 63–87.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Finland's Historical National Accounts, database: Hjerppe, Riitta, *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* Jyväskylä: Kopi-Jyvä Oy 1996; Updated by Statistics Finland (obtained Jan 2006).

Groningen Growth and Development Centre, *60-Industry Database*, October 2005, http://www.ggdc.net.

Maddison, Angus (2001). *The World Economy: a Millennial Perspective.* Paris: OECD, Development Centre, 2001.

Statistics Finland, National Accounts, Population Statistics, Education and Research. *Statistical Yearbook of Finland 2005*, Helsinki.

Sweden's Historical National Accounts, databases: Krantz, Olle, *Swedish Historical National Accounts 1800–1998: Aggregated Output Series*. Manuscript 2000; Edvinsson, Rodney (2005). Growth, *Accumulation, Crisis: With New Macroeconomic Data for Sweden 1800–2000*. Stockholm: Almqvist & Wiksell International 2005; Statistics Sweden.

Chapter 3:

Havén Heikki (Ed.) (1998), *Koulutus Suomessa* (Education in Finland), Suomen Virallinen Tilasto (SVT) (Official Statistics of Finland) 1998:1.

Hjerppe, Riitta (1989). *The Finnish Economy 1860–1985: Growth and Structural Change. Studies on Finland's Economic Growth XIII.* Helsinki: Bank of Finland Publications, Government Printing Office 1989.

Carter, Susan B., Scott, Sigmund G., Haines, Michael R., Olmstead, Alan L., Sutch, Richard, Wright, Gavin (Eds.) (2006). *The Historical Statistics of the United States*. New York: Cambridge University Press, 2006.

Godo, Yoshihisa, Hayami, Yujiro (1999). Accumulation of Education in Modern Economic Growth; Comparison of Japan with the United States, *ADBI Working Paper No. 4*, Tokyo: Asian Development Bank Institute.

Jorgenson, Dale W., Fraumeni, Barbara M. (1992b). *Investment in Education and U.S. Economic Growth*, Scandinavian Journal of Economics, 94. Supplement, pp. 51–70.

Kendrick, John W. (1976). *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York

Kivinen, Osmo (1988). *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini Suomessa 1800- ja 1900-luvuilla.* (The systematisation of education: basic education and the state school doctrine in Finland in the 19th and 20th centuries, in Finnish, with English Summary), Turun yliopisto, Annales Universitatis Turkuensis, 68, Turku.

Klemelä, Kirsi (1999). *Ammattikunnista ammatillisiin oppilaitoksiin: ammatillisen koulutuksen muotoutuminen Suomessa 1800-luvun alusta 1990-luvulle*, Turun yliopisto, Koulutussosiologisen tutkimuskeskuksen raportti 48, Turku.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Statistics Finland; National Accounts publications: 1948–1964 Finland's National Accounts 1948–64, Tilastollisia tiedonantoja 43. Statistics Finland; National Accounts 1964–77, KT 1978:7; National Accounts data available for the years 1964–1975 also in *Suomen taloushistoria 3. Historiallinen tilasto*. (1983) (in Finnish: Finland's economic history 3, Historical Statistics) (Ed.) Kaarina Vattula. Tammi, Helsinki 1983.

Statistics Finland (2006). Database of National Accounts, 1975–2000, (data obtained in Jan 2006).

Statistics Finland; Population Statistics, population by cohorts 1877–1939, 1940–2008. Population Statistics, Statistics Finland, 1880–2005, (cf. DATA APPENDIX 3.13) http://www.stat.fi/til/vrm.html (2011-04-15). Statistics on population by cohorts received from Senior Statistician Markus Rapo, Statistics Finland.

Vattula, Kaarina (Ed.) (1983). *Suomen taloushistoria 3. Historiallinen tilasto*. (Finland's economic history 3, Historical Statistics, in Finnish) Tammi, Helsinki 1983.

Data for education expenditures in Finland: see the discussion in Chapter 3 and the sources in DATA APPENDICES 3.1 – 3.10.

In addition, Statistical Yearbooks of Finland (SYF):
Total costs of primary schools in school statistics: SYF 1921: XIII, 182, 183; SYF 1930: XIII, 178, 179; SYF 1935: 171, 173; SYF 1938, XIII, 179, 181; SYF 1940, XIV, 179, 181; SYF 1942: XIV, 183, 185; SYF 1944–45: XIX, 193, 195; SYF 1948: XIX, 294, 296; SYF 1950: XIX, 287, 289, *NOTE: In years 1909, 1915, 1920, 1925 only upper primary school costs in the countryside included*
Total costs of secondary schools in school statistics: SYF 1920: XIV, 179; SYF 1930: XIII, 185; SYF 1935: XIII, 183; SYF 1938: XIII, 189; SYF 1950: XIX, 301; SYF 1953: XXII, 313 *NOTE: total costs of secondary schools in 1939 are that of the year 1938*.

Statistics Finland, Statistical Yearbooks of Finland (various years). Statistics on final accounts and financial statements of the state, education expenditures of central government 1877–1975 (see exact sources in DATA APPENDICES 3.4–3.8) in Statistical yearbooks of Finland 1879–.

Statistics Finland. Statistics of the financial statements of municipalities and joint municipal authorities, 1975–2000, database from 1993 onwards (data received from the database in 2006).

Statistics on professional education, state subsidies, number of students, number of teachers, in each branch of professional/vocational education in 1885–1938, Sources: SYF 1926 XIII: 185; SYF 1935 XIII: 189; SYF 1944–45 XIV: 213 (cf. exactly in DATA APPENDICES 3.8–3.10).

Data for the number of students in Finland: see also sources in DATA APPENDIX 3.12:
Statistical Yearbooks of Finland (SYF), SYF 1880–2007, Official Statistics of Finland (SVT) X:96–99 (1970–76), Official Statistics of Finland (SVT) XA:104 (1981–86), Official Statistics of Finland (SVT) Koulutus Suomessa 1998:1 (1981–96), Official Statistics of Finland (SVT) Koulutus 2008, Oppilaitostilastot 2007 (SVT) (1997–2007), Kivinen, Osmo (1988). *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini*

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Suomessa 1800- ja 1900-luvuilla. Turun yliopisto, Turku; Klemelä, Kirsi (1999). Ammattikunnista ammatillisiin oppilaitoksiin: ammatillisen koulutuksen muotoutuminen Suomessa 1800-luvun alusta 1990-luvulle, Turun yliopisto, Turku.

Statistics on educational institutions in Finland (the number of schools or universities, the number of students, the number of teachers (and lecturers plus professors, expenditures); Statistics Finland Library Archives:

- 1900– Secondary schools (old secondary schools beginning in the 5th grade – the end of high school); Statistical Yearbooks of Finland1900–
- 1884– Professional/vocational schools; Statistical Yearbooks of Finland 1884 – (divided by type of schooling not summed up to national level)
- 1880– Universities and other tertiary education institutions; Statistical Yearbooks of Finland1880–; Statistics on Universities and other tertiary education institutions 1917– (source: Official Statistics of Finland; SVTXXXVIII 8–9, Statistics on Universities, 1979, includes data 1917 – 1979, similar statistics available also from the Ministry of Education for the latest years).

<u>Chapter 4:</u>

In addition to those mentioned for Chapter 3:

Jalava, Jukka and Matti Pohjola (2007): The roles of electricity and ICT in growth and productivity: case Finland, *Pellervo Economic Research Institute Working Papers*, No. 94 (April 2007): Physical (or fixed) capital for Finland in 1900–2000.

<u>Chapter 5:</u> GDP at 1990 Geary-Khamis dollars for Finland, Sweden and the EU15 in 1860–2008

The EU15's Historical National Accounts, database: Carreras, Albert, Xavier Tafunell, European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, 63–87; data for the years 1996–2008 Eurostat database http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database, (2009-09-09).

Finland's Historical National Accounts, database: Hjerppe, Riitta, *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables.* Jyväskylä: Kopi-Jyvä Oy 1996; Statistics Finland; data for the years 1950–2008 from The Conference Board, Total Economy Database, June 2009, http://www.conference-board.org/economics, (2009-09-09).

Sweden's Historical National Accounts, database: Krantz, Olle and Lennart Schön, Swedish Historical National Accounts 1800–2000, Lund, Almqvist&Wiksell International, 2007, LU – MADD URL: http://www.ehl.lu.se/database/LU-MADD/, (2009-09-09);
data for the years 1950–2008 from The Conference Board, Total Economy Database, June 2009, http://www.conference-board.org/economics, (2009-09-09).

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

BIBLIOGRAPHY

Abramovitz, Moses (1986). Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, vol. XLVI, 1986: 2, 385–406.

Abramowitz, Moses (1993). The Search for the Sourses of Growth: Areas of Ignorance, Old and New. *Journal of Economic History*, Volume 53, Number 2, June 1993, 217–243.

Abramovitz, M., David, P.A. (1996). Technological Change and the Rise of Intangible Investments: The U.S. Economy's Growth-path in the Twentieth Century. *Employment and Growth in the Knowledge-based Economy*. OECD, Paris, 35–50.

Andersson, L-F., Krantz, O. (2006). Tillväxt och konvergens. En jämförelse an den ekonomiska utvecklingen i Finland och Sverige under 1800– och 1900–talen. In Aunesluoma, Juhana, Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet*. Svenska litteratursällskapet i Finland, Helsingfors, 2006.

Antikainen, Ari, Rinne, Risto, Koski, Leena (2006). *Kasvatussosiologia*. WSOY Oppimateriaalit Oy, Helsinki, 71.

Arrow, Kenneth (1962). The Economic Implications of Learning by Doing, *Review of Economic Studies*, vol. 29, 1962: June, 155–73.

Asplund, R.E. (1993). Essays on Human Capital and Earnings in Finland, *The Research Institute of the Finnish Economy, Series A18*.

Asplund, Rita (1998). Private vs. Public Sector Returns to Human Capital in Finland, *Journal of Human Resource Costing & Accounting*, Vol. 3 Iss: 1, 11–33

Asplund, Rita (2001). 'Education and Earnings in Europe: Finland', in: C. Harmon, I. Walker, and N. Westergaard-Nielsen (Eds.) *Education and earnings in Europe: A cross country analysis of the returns to education*, Cheltenham/Northampton, 2001, 68–83.

Asplund, Rita, Maliranta, Mika (2006). Productivity growth: The Role of Human Capital and Technology. In Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura, 263–283.

Aulin-Ahmavaara, Pirkko (1987). *A Dynamic Input-Output Model with Non-Homogenous Labour for Evaluation of Technical Change*. Finnish Academy of Science and Letters. Helsinki.

Aulin-Ahmavaara, Pirkko (1990). Dynamic Input-Output and Time. *Economic Systems Research*, 2, 239–34.

Aulin-Ahmavaara, Pirkko (1991). Production Prices of Human Capital and Human Time. *Economic Systems Research*, 3, 345–65.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Aulin-Ahmavaara, Pirkko (1997). Measuring the productivity of nations. In Simonovits, A. and Steenge A. E. (Eds.) *Prices, Growth and Cycles: Essays in Honour of András Bródy*, London, Macmillan.

Aulin-Ahmavaara, Pirkko (2002). *Human Capital as a Produced Asset.* Session Paper Number 1, Session 6A, 27th General Conference of the International Association for Research in Income and Wealth, Stockholm, Sweden August 18–24, 2002.

Aulin-Ahmavaara, Pirkko (2003). Inhimillinen pääoma ja kansantalouden tilinpito, *Tuottavuuskatsaus 2002*, Helsinki: Tilastokeskus, 2003.

Aulin-Ahmavaara, Pirkko (2004). Moving Human Capital Inside the Production Boundary. *The Review of Income and Wealth*, series 50, number 2, 213–228.

Aunesluoma, Juhana, Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet*. Svenska litteratursällskapet i Finland, Helsingfors, 2006.

Bairam, Erkin (1990). Verdoorn's Original Model and the Verdoorn Law Controversy: Some New Empirical Evidence Using the Australian Manufacturing Data, *Australian Economic Papers*, vol. 29, 1990, 107–112.

Baldwin, John, Gellatly, Guy, Tanguay, Marc (2007). *The Cost of Capital Input: Calculation Methods*, revised version of a paper presented at the Capital Measurement Workshop, Ottawa, 22 May 2006.

Barro, Robert J. (1991). Economic Growth in a Cross Section of Countries, *Quarterly Journal of Economics*, vol. 106, 1991:2, 407–33.

Barro, Robert J., Sala-i-Martin, Xavier (1997). Technological Diffusion, Convergence, and Growth, *Journal of Economic Growth*, vol. 2, 1997:1, 1–27.

Barro, Robert J., Sala-i-Martin, Xavier (1999, 1995). *Economic Growth*. The MIT Press, Cambridge, Massachussetts,1999. Originally published by McGraw-Hill, Inc., 1995.

Barro, Robert J. (1999b). Notes on growth accounting. *Journal of Economic Growth* 4, 119–137.

Benhabib, Jess, Spiegel, Mark M. (2005). Human Capital and Technology Diffusion. in Aghion, Philippe, Durlauf, Steven N. (Eds.) (2005) *Handbook of Economic Grwoth*, vol 1A, Elsevier B.V., Amsterdam, The Netherlands, Chapter 13, 936–966.

Bils, M., Klenow, P. (2000). "Does Schooling Cause Growth or the Other Way Around?" *American Economic Review*, 90 (December): 1160–83.

Bosworth, Barry P., Collins, Susan M. (2003). The Empirics of Growth: An Update. *Brookings Papers on Economic Activity*, 2:2003, 113–179.

Broadberry, S.N., Crafts, N.F.R. (1992). 'Britain's productivity gap in the 1930s: Some neglected factors', *Journal of Economic History*, 1992, Vol. 52 (3), 531–558.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Broadberry, Stephen N. (1998). How did the United States and Germany Overtake Britain? A Sectoral Analysis of Comparative Productivity Levels, 1870–1990, *Journal of Economic History*, vol. 58, 1998: 2, 375–407.

Carter, Susan B., Scott, Sigmund G., Haines, Michael R., Olmstead, Alan L., Sutch, Richard, Wright, Gavin (Eds.) (2006). *The Historical Statistics of the United States*. New York: Cambridge University Press, 2006.

Cass, David (1965). Optimum Growth in an Aggregative Model of Capital Accumulation, *Review of Economic Studies*, vol. 32, 1965: July, 233–40.

Clark, Colin (1940). *The Conditions of Economic Progress*. MacMillan & Co. London 1940, 395–439.

Carreras, Albert, Tafunell, Xavier (2004). European Union economic growth experience, 1830–2000, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers 2004, 63–87.

Chanda, Areendam, Putterman, Louis (2004). The Quest for Development. What role does history play? *World Economics*, vol. 5, 2004:2, 1–31.

Chaudhuri, Kausik, Maitra, Pushkar (2008). School Attainment, Completion, and Economic Development: A Cross-Country Analysis. *Review of Development Economics*, 12(1), 90–105.

Crafts, Nicholas F.R. (1995). Exogenous or Endogenous Growth? The Industrial Revolution Reconsidered. *Journal of Economic History*, Vol. 55, December 1995, Number 4, 745–772.

Crafts, Nicholas (2002). *Britain's Relative Economic Performance 1870–1999*. London: The Institute of Economic Affairs 2002.

Crafts, Nicholas F.R. (2004). Fifty Years of Economic Growth in Western Europe. No Longer Catching up But Falling behind? *World Economics*, 5 (2), 131–145.

Crafts, Nicholas (2004b). Quantifying the contribution of technological change to economic growth in different eras: a review of the evidence. In *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers, 205–226.

de la Fuente, Angel, Doménech, Rafael (2002). Human capital in growth regressions: how much difference does data quality make? An update and further results. *UFAE and IAE Working Papers 537.02*, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC).

de la Fuente, Angel (2011). "Human capital and productivity," *UFAE and IAE Working Papers 860.11*, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC).

De Long, Bradford, J. (1988). Productivity Growth, Convergence, and Welfare: Comment, *American Economic Review*, vol. 78, 5, 1138–1154.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Denison, E.F. (1962). *The Sources of Economic Growth in the United States and the Alternatives Before Us*, New York: Committee of Economic Development.

Denison, E.F. (1979). *Accounting for Slower Economic Growth. The United States in the 1970s*. The Brookings Institution, Washington, D.C.

Dennis, J.G., Hansen H., Johansen S. and Juselius K. (2005). *CATS in RATS, version 2*, Estima 2005.

Dickey, D., Fuller, W. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, 427–431, 1979.

Edvinsson, Rodney (2005). *Growth, Accumulation, Crisis: With New Macroeconomic Data for Sweden* 1800–2000. Stockholm: Almqvist & Wiksell International 2005

Eichengreen, B. (1996). Institutions and Economic Growth: Europe after World War II. In Crafts, N. and Toniolo, G. (Eds.) *Economic Growth in Europe since 1945*. Cambridge University Press, Cambridge.

Eisner, Robert (1988). Extended Accounts for National Income and Product. *Journal of Economic Literature*, Vol. 26, 4, Dec., 1611–1684.

Eisner, Robert (1989). *The Total Incomes System of Accounts*, Chicago and London, Chicago University Press.

Engle, R., Granger, C. (1987). Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, 55, 251–276.

Ethier, Wilfred J. (1982). National and International Returns to Scale in the Modern Theory of International Trade. *American Economic Review*, 72, 3 (June), 389–405.

Fellman, Susanna (2006). Utvidgad hemmamarknad eller språngbräda till Europa? Tidiga finska företagsetableringar i Sverige. In Aunesluoma, Juhana and Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet.* Svenska litteratursällskapet i Finland, Helsingfors, 283–324.

Fellman, Susanna (2008). Growth and investment. In Fellman, S., Iversen, M. J., Sjögren, H. and Thue, L. (Eds.) (2008). *Creating Nordic capitalism. The business history of a competitive periphery*. Palgrave Macmillan.

Fellman, Susanna, Sjögren, Hans (2008). Conclusion. In Fellman, S., Iversen, M. J., Sjögren, H. and Thue, L. (Eds.) (2008). *Creating Nordic capitalism. The business history of a competitive periphery*. Palgrave Macmillan.

Galor, Oded (2005). From Stagnation to Growth: Unified Growth Theory. In Aghion P., Steven N. Durlauf (Eds), *Handbook of Economic Growth*, vol 1A, Elsevier B.V., Amsterdam, The Netherlands, Chapter 4, 171–293.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Gerschenkron, Alexander (1952). Economic Backwardness in Historical Perspective. In *The Progress of Underdeveloped Areas*, Ed. B. F. Hoselitz. University of Chicago Press.

Gerschenkron, Alexander (1962). *Economic Backwardness in Historical Perspective: A Book of Essays.* Cambridge: Harvard University Press.

Glaeser, Edward L., La Porta, Rafael, Lopez-de-Silanes, Florencio, Schleifer, Andrei (2004). Do Institutions Cause Growth, *Journal of Economic Growth*, vol. 9, 2004:3, 271–303.

Gomez, V., Maravall, A. (1996). Programs TRAMO and SEATS. Instructions for the User, (with some updates). *Working Paper 9628*, Servicio de Estudios, Banco de España.

Graham, J.W., Webb, R.H. (1979). Stock and Depreciation of Human Capital: New Evidence from a Present-Value Perspective. *The Review of Income and Wealth*, Series 25, June, 209–224.

Grossman, Gene M., Helpman, Elhanan (1991). *Innovation and Growth in the Global Economy*, Cambridge MA, MIT Press, Chs. 11–12.

Grytten, O.H. (2004). Economic Growth and Purchasing Power Parities in the Nordic Countries 1830–1910. In *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden. Amsterdam: Aksant Academic Publishers.

Hall, Robert E., Jones, Charles I. (1998). Why Do Some Countries Produce So Much More Output Per Worker Than Others? *The Quarterly Journal of Economics*, Vol. 114, No. 1, (Feb., 1999), 83–116.

Hamalainen, Ulla, Uusitalo, Roope (2008). Signalling or Human Capital: Evidence from the Finnish Polytechnic School Reform. *Scandinavian Journal of Economics*, Vol. 110, Issue 4, pp. 755-775.

Harris, R. (1992). Testing for unit roots using the Augmented Dickey-Fuller test: Some issues relating to size, power and lag structure of the test. *Economics Letters*, 38, 381–386.

Hartwell, Ronald .M. (1973). The Service Revolution: The Growth of Services in Modern Economy, in *The Fontana Economic History of Europe 3: The Industrial Revolution, Ed. Carlo M. Cipolla*. Glasgow: Fontana/Collins 1973, 358–396.

Heikkinen, Sakari, van Zanden, Jan Luiten (2004). *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Amsterdam: Aksant Academic Publishers.

Herbertsson, T.T. (2003). 'Accounting for Human Capital Externalities with an Application to the Nordic Countries', *European Economic Review*, 2003, Vol. 47 (3), 553–567.

Hjerppe, Riitta (1989). *The Finnish Economy 1860–1985: Growth and Structural Change. Studies on Finland's Economic Growth XIII.* Helsinki: Bank of Finland Publications, Government Printing Office 1989.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Hjerppe, Riitta (1990). *Kasvun vuosisata*. Valtion painatuskeskus, Helsinki.

Hjerppe, Riitta (1996). *Finland's Historical National Accounts 1860–1994: Calculation Methods and Statistical Tables*. University of Jyväskylä, Department of History, Suomen historian julkaisuja 24. Jyväskylä 1996.

Hjerppe, Riitta (2001). The Convergence of Labour Productivity. In *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940*, Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters 2001.

Hjerppe, Riitta (2004). Monikansallisten yritysten tulo Suomeen ennen toista maailmansotaa. *Kansantaloudellinen aikakauskirja*, 3/2004, 216–238.

Hjerppe, Riitta (2006). Svenska företag i Finland under mellankrigstiden. In Aunesluoma, Juhana, Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet*. Svenska litteratursällskapet i Finland, Helsingfors, 2006, 325–354.

Hjerppe, Riitta, Jalava, Jukka (2006). Economic Growth and Structural Change: A Century and a Half of Catching-up, in *The Road to Prosperity: An Economic History of Finland*, Ed. Jari Ojala, Jari Eloranta and Jukka Jalava. Helsinki: Suomalaisen Kirjallisuuden Seura 2006.

Hodrick, R.J., Prescott, E.C. (1997). Postwar US business cycles: an empirical investigation. *Journal of Money, Credit and Banking*, 29, 1–16.

Hulten, Charles R., Wykoff, Frank C. (1996). ”Issues in the Measurement of Economic Depreciation: Introductory Remarks”. *Economic Inquiry*, 34, 10–23.

Islam, N. (1995). Growth Empirics: A Panel Data Approach. *Quarterly Journal of Economics*, 110, No. 4, 1127–70.

Jalava, J., Pohjola, M. (2002). Economic Growth in the New Economy, Evidence from Advanced Economies. *Information Economics and Policy*, 14, 189–210.

Jalava, Jukka (2004). Electrifying and digitalising the Finnish manufacturing industry: Historical notes on diffusion and productivity, in *Explorations in Economic Growth. A Festschrift for Riitta Hjerppe on her 60th Birthday*, Ed. Sakari Heikkinen and Jan Luiten van Zanden, Amsterdam: Aksant Academic Publishers 2004, 227–244.

Jalava, Jukka (2006). Production, Primary, Secondary, and Tertiary: Finnish Growth and Structural Change, 1860–2004, *Pellervo Economic Research Institute, Working Papers* No. 80, 2006: January.

Jalava, Jukka (2006b). Catching up with the Technology Frontier: Finnish Manufacturing Productivity, 1975–2003, *Scandinavian Economic History Review*, vol. 54, 2006: 1, 47–63.

Jalava, Jukka (2007). *Essays on Finnish Economic Growth and Productivity, 1860–2005.* Tutkimuksia 248, Tilastokeskus, Helsinki.

Johansen, Søren (1995). Identifying restrictions of linear equations. With applications to simultaneous equations and cointegration. *Journal of Econometrics*, 69(1), 111–132.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Johansen, Søren (1996). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, 2. edn. Advanced Texts in Econometrics, Oxford University Press: Oxford.

Jones, Larry E, Manuelli, Rodolfo E. (1990). A Convex Model of Equilibrium Growth: Theory and Policy Implications. *Journal of Political Economy*, 98, 5 (October), 1008–1038.

Jones, Charles I. (2002). *Introduction to Economic Growth.* 2nd edition , W. W. Norton & Company, New York.

Jones, Charles I (2005). Growth and ideas. In Aghion, Philippe, Durlauf, Steven N. (Eds.) (2005) *Handbook of Economic Growth*, vol 1B, Elsevier B.V., Amsterdam, The Netherlands, Chapter 16, 1064–1111.

Jonung, Lars, Kiander, Jaakko, Vartia, Pentti (Eds.) (2009). *The Great Financial Crisis in Finland and Sweden*, Edward Elgar Publishing Ltd., Cheltenham, UK.

Jorgenson, D.W, Griliches, Z. (1967). The Explanation of Productivity Change. *Review of Economic Studies*, July 1967.

Jorgenson, Dale W., Fraumeni, Barbara M. (1989). The Accumulation of Human and Nonhuman Capital, 1948–84. In R. E. Lipsey and H. S. Tice (Eds.) *The Measurement of Saving, Investment and Wealth*, Studies in Income and Wealth, Vol. 52, Chicago, IL, University of Chicago Press. Reprinted in D.W. Jorgenson (1995). *Productivity, Volume 1: Postwar U.S. Economic Growth*, Cambridge, MA and London, England, The MIT Press.

Jorgenson, Dale W., Fraumeni, Barbara M. (1992a). The Output of Education Sector. *Output Measurement in the Service Sector*, in Z. Griliches,(Ed.) Studies in Income and Wealth, Vol. 55, Chicago, IL, University of Chicago Press. Reprinted in D.W. Jorgenson (1995). *Productivity, Volume 1: Postwar U.S. Economic Growth*, Cambridge, MA and London, England, The MIT Press.

Jorgenson, Dale W., Fraumeni, Barbara M. (1992b). Investment in Education and U.S. Economic Growth, *Scandinavian Journal of Economics*, 94. Supplement, 51–70.

Josephson, C. (2005). Growth and Business Cycles. Swedish Manufacturing Industry 1952–2001. *Lund Studies in Economic History* 37.

Juselius, Katarina (2006). *The Cointegrated VAR model: Econometric Methodology and Macroeconomic Applications*. Advanced Texts in Econometrics, Oxford University Press: Oxford.

Kaldor, Nicholas (1967). *Strategic Factors in Economic Development*. New York: New York State School of Industrial and Labor Relations, Cornell University 1967.

Kaldor, Nicholas (1978). *Further Essays on Economic Theory.* London: Gerald Duckworth & Co. Ltd. 1978.

Kaiser, Regina, Maravall, Agustin (2001). *Measuring Business Cycles in Economic Time Series*. Lecture Notes in Statistics 154, Springer-Verlag, New York.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Kaukiainen, Yrjö (2006). Foreign trade and Transport. In Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura, 127–163.

Kendrick, John W. (1976). *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York.

Kivinen, Osmo (1988). *Koulutuksen järjestelmäkehitys. Peruskoulutus ja valtiollinen kouludoktriini Suomessa 1800- ja 1900-luvuilla.* (The systematisation of education: basic education and the state school doctrine in Finland in the 19th and 20th centuries, in Finnish, with English Summary), Turun yliopisto, Annales Universitatis Turkuensis, 68, Turku.

Klemelä, Kirsi (1999). *Ammattikunnista ammatillisiin oppilaitoksiin: ammatillisen koulutuksen muotoutuminen Suomessa 1800-luvun alusta 1990-luvulle*, Turun yliopisto, Koulutussosiologisen tutkimuskeskuksen raportti 48, Turku.

Knack, Stephen, Keefer, Philip (1997). Does Social Capital Have an Economic Payoff? A Cross-Country Investigation, *Quarterly Journal of Economics*, vol. 112, 1997:4, 1251–88.

Kokkinen, Arto, Jalava, Jukka, Hjerppe, Riitta, Hannikainen, Matti (2007). Catching up in Europe: Finland's Convergence with Sweden and the EU15, *Scandinavian Economic History Review*, 55:2, 153–171.

Koopmans, Tjalling C. (1965). On the Concept of Optimal Economic Growth. *Pontificae Academiae Scientiarum Scripta Varia*, vol. 28, 225–300.

Koopmans, Tjalling C. (1965b). On the Concept of Optimal Economic Growth. in *The Econometric Approach to Development Planning*. Amsterdam: North Holland, 1965.

Krantz, Olle (2001). Industrialisation in Three Nordic Countries: A Long-Term Quantitative View. In *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940,* Ed. Hans Kryger Larsen. Helsinki: The Finnish Society of Sciences and Letters 2001, 23–65.

Krantz, Olle (2002). Svensk ekonomi under 1900–talet: en omväxlande historia. In Andersson-Skog, L.and Krantz, O., *Omvandlingens sekel. Perspektiv på ekonomi och samhälle i 1900-talet Sverige*. Studentlitteratur, Lund.

Kuznets, Simon (1946). *National Income: A Summary of Findings*, New York: National Bureau of Economic Research.

Kuznets, Simon (1961). *Six Lectures on Economic Growth*. Frank Cass & Company, London, 1961.

Kryger Larsen, Hans, Ed. (2001). *Convergence? Industrialisation of Denmark, Finland and Sweden 1870–1940*, Helsinki: The Finnish Society of Sciences and Letters 2001.

Lau, L. J., Jamison, D.T., Louat, F.F. (1991). Education and Productivity in Developing Countries: An Aggregate Production Function Approach. *Policy Research Working Paper # 612*, World Bank.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Levine, R., Renelt, D. (1992). A Sensitivity Analysis of Cross-Country Growth Regressions. *American Economic Review*. 82, 942–63.

Lindert, Peter. H. (2004). *Growing Public.Social Spending and Economic Growth Since the Eighteenth Century. The Story*. Vol 1. Cambridge University Press.

Lindert, Peter. H. (2004b). *Growing Public.Social Spending and Economic Growth Since the Eighteenth Century. Further Evidence*. Vol 2. Cambridge University Press.

Lindmark, Magnus, Vikström, Peter (2003). Growth and Structural Change in Sweden and Finland: a Story of Convergence, *Scandinavian Economic History Review*, vol. 51, 1, 46–74.

Ljungberg, Jonas, Nilsson, Anders (2009). Human capital and economic growth: Sweden 1870–2000. *Cliometrica*, 3, 71–95.

Ljungberg, Jonas, Smits Jan-Pieter (Eds.) (2005). *Technology and Human Capital in Historical Perspective*. Palmgrave.

Lucas, Robert E. Jr. (1988). On the Mechanics of Economic Development, *Journal of Monetary Economics*, vol. 22, 1 (July), 3–42.

Maddison, Angus (1987). Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment, *Journal of Economic Literature*, Vol. XXV, (June 1987), 649–698.

Maddison, A. (2001). *The World Economy: a Millennial Perspective*, OECD, Development Centre, Paris.

Maddison, Angus (2003). *The World Economy: Historical Statistics*. Paris: Development Centre of the Organisation for Economic Cooperation and Development.

Mamgain, Vaishali (1999). Are the Kaldor-Verdoorn Laws Applicable in the Newly Industrializing Countries? *Review of Development Economics*, vol. 3, 1999: 3, 295–309.

Mankiw, N. Gregory, Romer, David, Weil, David N. (1992). A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics*, Vol. 107, 2 (May), 407–437.

Maravall, A. (1995). Unobserved Components in Economic Time Series. In Pesaran, H. and Wickens, M. (Eds.), *The Handbook of Applied Econometrics*, vol. 1, Oxford: Basil Blackwell.

Meinander, Henrik (2006). *Suomen historia. Linjat, rakenteet, käännekohdat*. WS Bookwell Oy, Porvoo.

Mills, Terence C. (2003). *Modelling Trends and Cycles in Economic Time Series.* Palgrave Mcmillan, New York, 123–127.

Mitchell, B.R. (2007). *International Historical Statistics, Europe 1750-2005*. sixth edition, MacMillan Publishers Ltd.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Mitch, David (2003). Human Capital. In Mokyr, Joel (Ed.) *The Oxford Encyclopedia of Economic History*, Volume 3, p. 1–7, Oxford University Press, 2003.

Mokyr, J. (1990). *The Lever of Riches: Technological Creativity and Economic Progress*. New York, Oxford: Oxford University Press.

Mokyr, J. (2005). Long-term Economic Growth and the History of Technology. In Aghion, P., Durlauf, S.N. (Eds.) (2005) *Handbook of Economic Grwoth*, vol 1B, Elsevier B.V., Amsterdam, The Netherlands.

Mokyr, J. (2006). Preface: Succesful Small Open Economies and the Importance of Good Institutions. In Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura, 8–13.

Nelson, Richard R., Phelps, Edmund S. (1966). Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review*, 56, 2 (May), 69–75.

Newey, W. K., West, K. D. (1987). A Simple, Positive Semi-definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix, *Econometrica*, vol. 55, 1987: 3, 703–708.

Niitamo, Olavi (1958). Tuottavuuden kehitys Suomen teollisuudessa vuosina 1925–1952. *Kansantaloudellisia tutkimuksia*, XX, Kansantaloudellinen yhdistys, Helsinki.

Nilsson, Nils (1975). ‘Industriell produktivitet och manskligt kapital’ (Industrial Productivity and Human Capital. With English summary), *Ekonomiska Samfundets Tidskrift*, 1975, Vol. 28 (3), 185–95.

Ojala, Jari, Eloranta, Jari, Jalava Jukka (Eds.) (2006). *The Road to Prosperity. An Economic History of Finland*. Suomalaisen Kirjallisuuden Seura.

O’Rourke, Kevin H. and Williamson Jeffrey G. (1999). *Globalisation and History. The Evolution of Nineteenth-Century Atlantic Economy*. MIT Press, London.

OECD (2003). *Education at a glance* 2003. ISBN: 9264102353 , OECD, Paris.

OECD (2007). PISA study 2006, ISBN: 9789264040007, www.pisa.oecd.org/ (2011-03-30).

OECD (2009). *Measuring Capital: OECD Manual 2009*, ISBN 978-92-64-02563-9, OECD.

Paavonen, Tapani (1998). *Suomalaisen protektionismin viimeinen vaihe*. Suomen Historiallinen Seura. Historiallisia Tutkimuksia 198, Helsinki.

Paavonen, Tapani (2008). *Vapaakauppaintegraation kausi. Suomen suhde Länsi-Euroopan integraatioon FINN-EFTAsta EC-vapaakauppaan.* Suomalaisen Kirjallisuuden Seura. Historiallisia Tutkimuksia 235, Helsinki.

Pekkala, Sari, Intonen, Nina, Järviö, Maija-Liisa (2005). Education Expenditure in Finland in the Twentieth Century and in the Future, *Discussion Papers* 365, Government Institute for Economic Research, Helsinki 2005.

Kokkinen, Arto (2011), On Finland’s Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Pekkarinen, Jukka, Vartiainen, Juhana (1993). *Suomen talouspolitiikan pitkä linja*. WSOY, Juva 1993.

Pekkarinen, Tuomas, Uusitalo, Roope, Kerr, Sari (2009). School tracking and intergenerational income mobility: Evidence from the Finnish comprehensive school reform. *Journal of Public Economics*, vol. 93(7-8), August, 965-973.

Pihkala, Erkki (1977). Valtion tulojen ja menojen rakenne 1800-luvun jälkipuoliskolla. *Helsingin kauppakorkeakoulun julkaisuja*, B-23.

Pihkala, Erkki (2008). *Yhdentyvä Eurooppa. Euroopan unionin taloushistoria*. [Verkkojulkaisu.] Helsinki: Suomalaisen Kirjallisuuden Seura, 2008, http://kirjat.finlit.fi/verkkokirjat/yhdentyva_eurooppa (2011-02-25).

Postner, Harry H. (1989). *Estimation of Human Capital Stocks and Flows: Is There a "Short-Cut" Procedure?* Session Paper, Session 8B, Twenty-first General Conference of the International Association for Research in Income and Wealth, Lahnstein, West Germany, 20-26 August 1989.

Prados de la Escosura, Leandro (2005). Gerschenkron Revisited. European Patterns of Development in Historical Perspective. *Universidad Carlos III de Madrid, Working Paper 05-79 (10), Economic History and Institutions Series 10,* December 2005.

Prados de la Escosura, Leandro, Rosés, Joan R. (2010). Human capital and economic growth in Spain, 1850–2000. *Explorations in Economic History,* 47, 520–532.

Pritchett, Lant (1997). Divergence, Big Time, *Journal of Economic Perspective*, vol. 11, 3, 3–17.

Putnam, Robert D., Leonardi, Robert, Nanetti, Raffaella Y. (1993). *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton, N.J.: Princeton University Press 1993.

Pyo, Hak. K., Sooil Jin, (2000). A Comparative Profile of Human Capital: US, Japan and Korea. In I. Hwang and K. Odaka (Eds), *The Long-Term Economic Statistics of Korea 1910–1990,* Institute of Economic Research. Hitotshubashi University, 2000, 289–311.

Rahbek A, Hansen E, Dennis J. G. (2002). ARCH Innovations and their impact on cointegration rank testing. *Working Paper No.22,* Centre for Analytical Finance, University of Copenhagen.

Rahikainen, Marjatta (2006). Svensk textil- och konfektionsindustris etableringar i Finland 1969–1973. En respit för både branschen och anställda kvinnor. In Aunesluoma, Juhana and Fellman, Susanna (Eds.) (2006). *Från olika till jämlika. Finlands och Sveriges ekonomier på 1900-talet.* Svenska litteratursällskapet i Finland, Helsingfors, 355–382.

Ramsey, Frank (1928). A Mathematical Theory of Saving, *Economic Journal*, vol. 38, December, 543–559.

Rebelo, Sergio (1991). Long-Run Policy Analysis and Long-Run Growth, *Journal of Political Economy*, vol. 99, 3, 500–21.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Relander, T. (1969). *Oppilaitoskoulutuspääoma Suomen tehdasteollisuudessa vuosina 1950 ja 1960*. Taloudellinen tutkimuskeskus. Helsinki.

Romer, Paul M. (1986). Increasing Returns and Long-Run Growth, *Journal of Political Economy*, vol. 94, 1986: 5, 1002–1037.

Romer, Paul M. (1987) Growth Based on Increasing Returns Due to Specialization, *American Economic Review*, vol. 77, 2, 56–62.

Romer, Paul M. (1990). Endogenous Technological Change, *Journal of Political Economy*, vol. 98, 5, part II, S71–S102.

Sandberg, L.G. (1982). Ignorance, Poverty and Economic Backwardness in the Early Stage of European Industrialization. Variations on Alexander Gerschenkron's Grand Theme. *The Journal of European Economic History*, 11:3, 675-697.

Schultz, Theodore W. (1961). Investment In Human Capital. *The American Review of Economics*, Vol. LI, March 1961, Number one, 1–17.

Self, Sharmistha, Grabowski, Richard (2003). Education and long-run development in Japan. *Journal of Asian Economics*, 14 (2003), 565–580.

Seppinen, Jukka (2001). *Mahdottomasta mahdollinen.* Suomen tie Euroopan unioniin. Gummerus Kirjapaino Oy, Jyväskylä 2001.

Sevon, Guje (1988). 'Det manskliga kapitalet' (Human Capital. With English summary), *Ekonomiska Samfundets Tidskrift*, 1988, Vol. 41 (1), 49–54.

Sharma, Devindra, Ram, Rati (1974). 'Suggestions for treatment of human capital in national accounts – with illustrations from Indian data', *Review of Income and Wealth*, Vol. 20 (4), 501–515.

Sheshinski, Eytan (1967). Optimal Accumulation with Learning by Doing, ed. Karl Shell, *Essays on the Theory of Optimal Economic Growth.* Cambridge, MA: MIT Press 1967, 31–52.

SNA93, (1993). The Inter-Secretariat Working Group on National Accounts, *System of National Accounts*, Commission of the European Communities-Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington D.C.

SNA2008 (2009). The Inter-Secretariat Working Group on National Accounts. *System of National Accounts 2008*, Commission of the European Communities-Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington D.C.

Solow, Robert M. (1956). A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, vol. 70, 1956:1, 65–94.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887

Solow, Robert M., (1957). Technical Change and the Aggregate Production Function, *Review of Economics and Statistics,* vol. 39, 1957: 3, 312–320.

Statistics Finland, (2005). National Accounts, Population Statistics, Education and Research. *Statistical Yearbook of Finland* 2005, Helsinki.

Stoneman, P. (1979). Kaldor's law and British economic growth: 1800–1970, *Applied Economics*, vol. 11, 1979: 3, 309–319.

Svanlund, Jonatan (2010). *Svensk och finsk upphinnartillväxt*. Dissertation, Umeå Studies in Economic History No. 38.

Swan, Trevor (1956). Economic Growth and Capital Accumulation, *Economic Record*, vol. 32, November, 334–361.

Temin, P. (2002). The Golden Age of European Growth Reconsidered. *European Review of Economic History*, Vol. 6, No 1: 3–22.

Temple, Jonathan (1998). Equipment Investment and the Solow Model, *Oxford Economic Papers*, vol. L, 1998, 39–62.

Temple, Jonathan, Johnson, Paul A. (1998b). Social Capability and Economic Growth, *Quarterly Journal of Economics*, vol. 113, 1998:3, 965–90.

Tiainen, P. (1994). *Taloudellisen kasvun tekijät Suomessa. Työvoiman, pääoman ja kokonaistuottavuuden osuus vuosina 1900–90*. Helsinki.

Truong, Công N., Tran-Nam, Binh (2007). Endogenous Growth and Publicly Funded Knowledge Accumulation. *Review of Development Economics*, 11(2), 421–435.

Uusitalo, Roope (1999). Essays in Economics of Education, *Research Reports,* 79:1999, Department of Economics, University of Helsinki.

Uzava, Hirofumi (1965). Optimal Technical Change in an Aggregative Model of Economic Growth, *International Economic Review*, vol. 6, 1965: January, 18–31.

Van Leeuwen, Bas (2007), *Human Capital and Economic Growth in India, Indonesia, and Japan. A quantitative analysis, 1890–2000*, ISBN: 978 90 8891 003 6. Doctoral dissertation, Utrecht University: Utrecht. http://www.basvanleeuwen.net/Papers.htm (2011-03-30).

Vartiainen, Juhana (2010). The Nordic Development and Growth Models. The Riddle is Still There but We May be a Little Bit Wiser. United Nations University, *UNU-WIDER, Working Paper No. 2010/116*.

Wells, Heather, Thirlwall, Anthony P. (2003). Testing Kaldor's Growth Laws across the Countries of Africa, *African Development Review*, vol. 15, 2003: 2–3, 89–105.

Kokkinen, Arto (2011), On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century
European University Institute DOI: 10.2870/35887