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**Education, Economic Growth  
and Personal Income Inequality  
Across Countries**

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# Education, Economic Growth and Personal Income Inequality Across Countries\*

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## Abstract

This paper offers a supply-side explanation of the cross-country variation in long-run growth and inequality. In the model human capital is 'lumpy' and public education directly affects growth, the *number* of high-skilled people and wages. Growth and income equality are shown to depend in an important way on the composition of human capital and the productivity of the education sector. Contrary to some recent results the data show that when controlling for initial income or the educational mix of the labour force, higher (within-country) inequality (significantly) implies lower growth for a typical country in the period 1960-90. Furthermore, countries with a more productive education sector have lower inequality. Thus, institutions and policies which generate more high-skilled people or enhance the productivity of the education sector seem to affect long-run income equality and growth in a positive way.

KEYWORDS: Growth, Distribution, Education, Public Policy

JEL Classification: O4, I2, D31, H2

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# 1 Introduction

For a long time economists have been interested in the question of how income inequality and growth are associated. Recent results indicate that there does not seem to be a robust relationship between inequality and growth within countries over time.<sup>1</sup> However, based on compilations of inequality data from household surveys, it has been found that inequality varies substantially across countries. See, for example, Deininger and Squire (1996).

This paper argues that the cross-country variation in growth and inequality can be explained well by different education policies or institutions. These links are first analyzed in a theoretical model whose implications are then confronted with empirical evidence.

One issue for the theory part is that *human capital* and *education* explain long-run patterns of *growth* very well. See, for instance, Lucas (1988), Azariadis and Drazen (1990) Barro (1991), Mankiw, Romer and Weil (1992), Caballé and Santos (1993), Fernandez and Rogerson (1995), (1996), or Bénabou (1996a), (1996b).

Secondly, the paper considers the link between *distribution* and *growth* which has been analyzed in a vast number of contributions. Just to name a recent few suffice it to mention Bertola (1993), Alesina and Rodrik (1994), Persson and Tabellini (1994), Garcia-Peñalosa (1995) or Perotti (1996). The consensus emerging from these studies is that inequality negatively affects growth.

However, the consensus has recently been challenged by Deininger and Squire (1998) and Forbes (1998) who find a non-robust or even positive association between inequality and growth.

In this paper the *composition* of human capital matters in the growth process by assuming that human capital is 'lumpy' and can be

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<sup>1</sup>For instance, Li, Squire and Zou (1998) show for many countries that there is little variation in within country income dispersions over time. In contrast, Atkinson (1998) finds that for the G7 countries the income dispersions have changed significantly. For surveys on the relationship between growth and inequality see e.g. Bénabou (1996c), Bertola (1998) or Aghion and Howitt (1998), chpt. 9.

identified with 'degrees'. People are hired as high-skilled workers in the labour market only if they have obtained a degree. However, the underlying source of income inequality lies in the production process. High-skilled people carry human capital that enables them to perform all the tasks a low-skilled person can do and *more*. Effective labour depends on basic skills and high skills in production. By assumption basic skills and high skills are *imperfect substitutes* in production, but low and high-skilled people are *perfect substitutes* in basic skills. As a consequence high-skilled people may always perform the tasks of low-skilled people, but low-skilled people can never execute tasks that require a degree.

Thus, in a perfectly competitive labour market the high-skilled workers get a wage *premium* over and above what their low-skilled colleagues receive. The wage premium is shown to depend negatively on the percentage of high-skilled people, which captures an important and realistic aspect in the explanation of wage inequality. (See, for instance, Freeman (1977), Bound and Johnson (1992), Katz and Murphy (1992) or Autor, Krueger and Katz (1998).)

In the model the government finances education by raising a tax on the resources (wealth) of all individuals.<sup>2</sup> A simple relationship between government revenues and education is used by which the percentage of high-skilled people in the population is directly related to the tax rate. Ex ante all agents are identical in the model so that innate ability or initial wealth differences are not important in the set-up.<sup>3</sup> The model ignores problems arising from the time spent receiving education by assuming that education is provided as a public good and that all people spend the same time in school, but attend different courses leading to different degrees.<sup>4</sup>

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<sup>2</sup>Thus, even those who have not received education contribute to financing it. That is realistic in most public education systems and may be in the low-skilled people's interest. For instance, Rehme (1999) has recently presented a model in which the preferred policy of the low-skilled implies higher taxes and higher wages for the low-skilled, but also lower inequality and higher GDP growth than the preferred policy of the high-skilled.

<sup>3</sup>For instance, Mincer (1958) or Findlay and Kierzkowski (1983) have studied the effects of differences in wealth or ability on education and income inequality.

<sup>4</sup>Even in countries such as the United States a very significant fraction of educa-

In equilibrium growth is positively related to the percentage of high-skilled people in the labour force only up to a certain point, because the government takes resources away from the private sector in order to finance education, which reduces growth. On the other hand it generates more high-skilled people which exert a positive effect on production, growth and income equality. For high growth taxes and so the number of high-skilled people must not be too high. Furthermore, equality in the present value of personal, lifetime incomes as well as growth (for a given human capital composition) are shown to depend positively on the productivity of the education sector.

Summarizing, the theoretical model predicts for the long-run that (a) countries with relatively more high-skilled people have higher initial income and less gross income inequality, and (b) less inequality implies higher growth.

These predictions are then confronted with empirical evidence for the period 1960-90. The paper focuses on high quality data which reduces the sample size to twenty-one countries. That implies that each observation assumes great importance in any qualitative analysis. Simple correlations reveal that for the period considered and across countries inequality as measured by the (within-country, time-average) Gini coefficient covaries *positively* and the composition of human capital covaries *negatively* with the average growth rate of real GDP per capita. Both correlations are relatively weak, but they would suggest that in the long run and for the typical country an increase in inequality increases growth. However, the second correlation is at odds with what most people find in cross-country studies. There it is usually reported that human capital positively affects growth.

Clearly, no single variable alone can explain the cross-country variations. In fact, when controlling for initial income and the composition

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tion is carried out publicly. Furthermore, governments have fiscal and institutional instruments other than direct provision of education at their disposal which have a significant bearing on the working of private education systems. For a discussion of public vs. private education see, for instance, Glomm and Ravikumar (1992) or Fernandez and Rogerson (1998).

of the labour force, income inequality as measured by the Gini coefficient negatively affects growth in all of this paper's cross-country growth regressions. Furthermore, when controlling for initial income and inequality, an increase in the percentage of high-skilled people increases long-run growth across countries. These results are robust across samples or model specifications and would corroborate the main theoretical predictions.

That raises the question what forces determine the labour force mix in production. For instance, differences in the human capital composition may be caused by the *demand* side of an economy (e.g. skill-biased technological change) in that the firms' technologies require particular education mixes which are met by the education sector in equilibrium.<sup>5</sup>

This paper argues that they are *supply* driven in that the government determines the composition by its education policy. The data suggest that initially rich (United States) or fast growing (Korea) countries also have quite productive education technologies which generate more high-skilled people for given resources channelled into education than other countries. The productivity differences may be due to political decisions such as how the school system is organized (elitist or egalitarian), or how it is financed (fee structure), but also factors such as history, labour market conditions and other institutional arrangements.

Contrary to some recent results the paper's main insight is that the association between long-run growth and personal income inequality seems robust, is found to be negative across countries and appears to be well explained by national differences in public education policies or institutions.

The paper is organized as follows: Section 2 presents the theoretical model and derives testable predictions. Section 3 confronts the model with empirical evidence using high quality data. Section 4 provides concluding remarks.

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<sup>5</sup>The paper abstracts from the important phenomenon of skill-biased technological change and should, therefore, be viewed as complementary to recent models along the lines of, for instance, Acemoglu (1998), Huw (1999), or Caselli (1999).

## 2 The Model

Consider an economy that is populated by  $N$  (large) members of two representative dynasties of infinitely lived individuals. The two dynasties are *high-skilled* workers,  $L_h$ , and *low-skilled* workers,  $L_l$ , where  $L_h, L_l$  denote the total numbers of the respective agents in each dynasty. The difference between high and low-skilled labour is "lumpy", that is, *either* an individual has received education in the form of a degree and is then considered high-skilled *or* it has no degree and remains in the low-skilled labour pool.

By assumption the population is stationary so that  $L_h \equiv xN$  and  $L_l \equiv (1-x)N$  where  $x$  denotes the percentage of high-skilled people in population. Each worker supplies one unit of either high or low-skilled labour inelastically over time. All agents initially own an equal share of the total capital stock, which is held in the form of shares of many identical firms operating in a world of perfect competition. Thus, all agents receive wage and capital income and make investment decisions. Furthermore, aggregate output is produced according to

$$Y_t = A_t K_t^{1-\alpha} H^\alpha, \quad H^\alpha = [(L_h + L_l)^\alpha + L_h^\alpha], \quad 0 < \alpha < 1, \quad (1)$$

where  $K_t$  denotes the aggregate capital stock including disembodied technological knowledge,<sup>6</sup>  $H$  measures effective labour in production, and  $A_t$  is a productivity index at time  $t$ . The production function is a reduced form of the following relationship: By assumption *effective labour* depends on *basic skills* and *high skills* and that *basic skills and high skills are imperfect substitutes* in production. On the other hand it is assumed that *low and high-skilled people are perfect substitutes in basic skills*. Thus, high-skilled people may always perform the tasks of low-skilled people in the model, but low-skilled people can never execute tasks that require a degree. (See Appendix A.1.) Notice that each type of labour alone is *not*

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<sup>6</sup>Thus, technological knowledge is taken to be a sort of capital good which is used to produce final output in combination with other factors of production. For an up-to-date discussion of these kinds of endogenous growth models see, for instance, Aghion and Howitt (1998), chpt. 1.

an essential input in production.

The government runs a balanced budget, uses its tax revenues to finance public education and maintains a constant ratio of expenditure  $G_t$  to its tax base.<sup>7</sup> It taxes the agents' wealth holdings at a constant rate  $\tau$ . The capital stock (wealth) of the representative agent is  $k_t = \frac{K_t}{N}$  so that  $G_t = \tau k_t N = \tau K_t$  and  $\frac{G_t}{K_t} = \tau$  for all  $t$ . Thus, real resources are taken from the private sector and used to finance public education, which generates high-skilled agents.<sup>8</sup>

In general, public education is 'produced' using government resources and other factors such as high-skilled labour itself. That is captured by the following *reduced form* of the education technology

$$x = \tau^\epsilon \quad \text{where } 0 < \epsilon \leq 1, \quad (2)$$

$x_\tau = \epsilon \tau^{\epsilon-1} > 0$  and  $x_{\tau\tau} = \epsilon(\epsilon - 1)\tau^{\epsilon-2} \leq 0$ . Thus, if the government channels more resources into education, it will generate more high-skilled people,  $x_\tau > 0$ . However, doing this generally becomes more difficult at the margin,  $x_{\tau\tau} < 0$ , because more public resources provided to the education sector lead to a decreasing marginal product of those resources due to congestion or other effects.

The parameter  $\epsilon$  measures the productivity of the education sector.<sup>9</sup> If  $\epsilon < 1$ , the education sector is productive and a marginal increase in taxes increases education output substantially. Underlying that is the

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<sup>7</sup>It would be possible to investigate various tax bases in the model. Capital taxes are considered to keep the analysis simple and are supposed to capture a broad class of tax arrangements, the aim of which is to channel public resources into education. For a similar approach in a different context see Alesina and Rodrik (1994).

<sup>8</sup>In the model agents are endowed with the same *basic* ability and receive basic education which is produced and provided costlessly. Education is always meant to be higher education. *Ex ante* everybody is a candidate for receiving (higher) education and once chosen to be *in* the education process will complete the degree. The education process is taken to be sufficiently productive in converting no skills into high-skills.

<sup>9</sup>The reduced form directly relates the percentage of high-skilled people ( $x$ ) to the percentage of resources (wealth) going into the education sector ( $\tau$ ). Let  $pr$  denote the productivity of the education sector. Then  $pr = \frac{x}{\tau} = \tau^{\epsilon-1}$ , which is decreasing in  $\epsilon$  for given policy.

description of an education sector with spillovers from, for instance, high-skilled to new high-skilled people or where the capital equipment such as computers makes the education technology very productive. For a justification of the set-up see Appendix A.2.

**The Private Sector.** There are as many identical firms as individuals and the firms face perfect competition and maximize profits. By assumption the firms are subject to knowledge spillovers, which take the form  $A_t = \left(\frac{K_t}{N}\right)^\eta = k_t^\eta$  with  $\eta \geq \alpha$ . Thus, the *average* stock of capital, which includes disembodied technological knowledge, is the source of a positive externality.<sup>10</sup> Then simplify by setting  $\eta = \alpha$  which allows one to concentrate on steady state behaviour. For a justification see Romer (1986). As the firms cannot influence the externality, it does not enter their decision directly so that

$$\begin{aligned} r &= (1 - \alpha)k_t^\alpha K_t^{-\alpha} H^\alpha, \\ w_h &= \alpha k_t^\alpha K_t^{1-\alpha} [(L_h + L_l)^{\alpha-1} + L_h^{\alpha-1}], \\ w_l &= \alpha k_t^\alpha K_t^{1-\alpha} (L_h + L_l)^{\alpha-1}. \end{aligned} \tag{3}$$

The workers have logarithmic utility and own all the assets which are collateralized one-to-one by capital. A representative worker takes the paths of  $r, w_h, w_l, \tau$  as given and solves the problem

$$\max_{c_i} \int_0^\infty \ln c_i e^{-\rho t} dt \tag{4}$$

$$s.t. \quad \dot{k} = w_i + (r - \tau)k - c_i \quad i = l, h \tag{5}$$

$$k_0 = \text{given}, k_\infty = \text{free}.$$

Equation (5) is the worker's dynamic budget constraint. The worker's problem is a standard one and its solution involves the following

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<sup>10</sup>The results would not change if the externality depended on the *entire* capital stock instead.

growth rate of the average high or low-skilled worker's consumption

$$\gamma = \frac{\dot{c}_l}{c_l} = \frac{\dot{c}_h}{c_h} = (r - \tau) - \rho. \quad (6)$$

Thus, consumption of all workers grows at the same rate in the optimum and depends on the after-tax return on capital. As the agents own the initial capital stock equally and have identical utility functions, their investment decisions are the same. But then the wealth distribution will not change over time and all agents continue to own equal shares of the total capital stock over time.

**Market Equilibrium.** For the rest of the paper normalize by setting  $N = 1$  so that the factor rewards in (3) are given by

$$r = (1 - \alpha)(1 + x^\alpha), \quad w_h = \alpha k_t(1 + x^{\alpha-1}) \quad \text{and} \quad w_l = \alpha k_t. \quad (7)$$

The return on capital is constant over time and wages grow with the capital stock. As  $w_h = w_l(1 + x^{\alpha-1})$ , high-skilled labour receives a premium over what their low-skilled counterpart gets. That reflects the fact that the high-skilled may always perfectly substitute for low-skilled labour so that both types of labour receive the same wage  $w_l$  for routine tasks and that performing high-skilled tasks is remunerated by the additional amount  $w_l x^{\alpha-1}$ . The premium depends on the percentage of high-skilled labour in the population, grows over time at the rate  $\gamma$  and is decreasing in  $x$  for a given capital stock.

From the production function one immediately gets  $\gamma_y = \gamma_k$  so that per capita output and the capital-labour ratio grow at the same rate. With constant  $N$  total output also grows at the same rate as the aggregate capital stock. From (6) the consumption of the representative worker grows at  $\gamma$ . Each worker owns  $k_0 = \frac{K_0}{N}$  units of the initial capital stock. Equation (5) implies  $\dot{k} = w_i + (r - \tau)k - c_i$  so that  $\gamma_k = \frac{w_i - c_i}{k} - (r - \tau)$  for  $i = l, h$  where  $(r - \tau)$  is constant. In steady state,  $\gamma_k$  is constant

by definition. But  $\frac{w_i}{k}$  is constant as well, because from (7)

$$\frac{w_h}{k_t} = \frac{\alpha k_t (1 + x^{\alpha-1})}{k_t} = \alpha(1 + x^{\alpha-1}) \quad \text{and} \quad \frac{w_l}{k_t} = \alpha,$$

which implies  $\gamma_k = \gamma$ . Thus, the economy is characterized by *balanced growth* in *steady state* with  $\gamma_Y = \gamma_K = \gamma_y = \gamma_k = \gamma_{c_h} = \gamma_{c_l}$ .

Furthermore, from equation (5) and using  $\gamma_k k = \dot{k}$  and  $\gamma_k = \gamma_{c_h} = \gamma_{c_l}$  in steady state one obtains  $(r - \tau - \rho)k_t = w_i + (r - \tau)k_t - c_i$ . Thus,  $c_i = w_i + \rho k_t$  ( $i = h, l$ ) are the instantaneous consumption levels of a representative high or low-skilled worker in steady state. Notice that  $c_h > c_l$  for positive  $x$ . From (6), (7) and  $\tau = x^{\frac{1}{\epsilon}}$  one obtains  $\gamma = (1 - \alpha)(1 + x^\alpha) - x^{\frac{1}{\epsilon}} - \rho$  so that for given  $\tau$  an increase in  $x$  raises growth. It is also not difficult to verify that

$$\hat{x} = [\epsilon\alpha(1 - \alpha)]^{\frac{\epsilon}{1-\epsilon\alpha}}, \quad \text{and} \quad \hat{\tau} = [\epsilon\alpha(1 - \alpha)]^{\frac{1}{1-\epsilon\alpha}}$$

maximize growth, which is concave in  $x$  since for  $\epsilon \leq 1$  and any  $x$

$$\frac{d^2\gamma}{(dx)^2} = -\alpha(1 - \alpha)^2 x^{\alpha-2} - \frac{1}{\epsilon} \left( \frac{1}{\epsilon} - 1 \right) x^{\frac{1-2\epsilon}{\epsilon}} < 0.$$

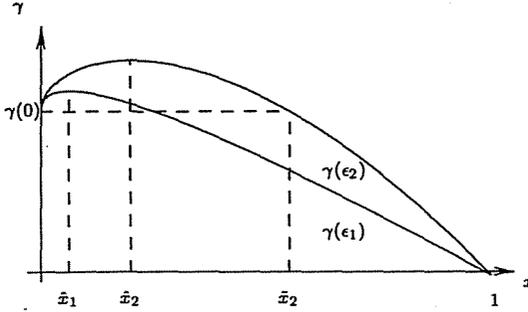
By the concavity of  $\gamma$  and given the above properties there exists  $\bar{x}$ , generating the same growth as  $\gamma(0)$ . Thus, in the model it is possible that an economy has high-skilled workers, but does not do better than another economy with no high-skilled people. The effect of a change in the productivity of the education sector for a given  $x \in (0, 1)$  is given by  $\frac{d\gamma}{d\epsilon} = \frac{\ln(x) x^{\frac{1}{\epsilon}}}{\epsilon^2} < 0$ . Hence, a reduction in  $\epsilon$ , that is, making the education technology more productive, raises growth.

**Lemma 1** *The growth rate  $\gamma$  satisfies the following properties:*

1.  $\gamma$  is concave in  $x$ .
2.  $\frac{d\gamma}{d\epsilon} < 0$  for  $x \in (0, 1)$ .
3. If  $x = \bar{x}$ , then  $\gamma(0) = \gamma(\bar{x})$ .

The properties can be read off from Figure 1 below.

Figure 1:  $\gamma$  as a function of  $x$  for different  $\epsilon$



**Income Inequality.** As growth is often related to measures of gross income inequality, the paper concentrates on the distribution of gross (of tax) income. In the model all income differences are due to differences in wage income. When one relates growth to income inequality one should look at an average of personal incomes over time. If the agents sold their income stream in a perfect capital market, they would discount their income stream by  $r - \tau$ , that is, by the after-tax market rate of return on assets. As their gross income at any point in time is  $y_{it} = w_{it} + \tau k_{it}$ , the present value of their lifetime incomes is

$$\int_0^{\infty} y_{it} e^{-(r-\tau)t} dt = \int_0^{\infty} y_{i0} e^{\tau t} e^{-(r-\tau)t} = \frac{y_{i0}}{\rho} \equiv y_i^d \quad \text{where } i = l, h.$$

Thus,  $y_i^d$  denotes the sum of an individual's gross incomes discounted by the after-tax market rate of return on assets.<sup>11</sup> Notice  $y_i^d = w_i^d + \tau k_0$  where

$$w_l^d = \frac{w_l}{\rho} = \frac{\alpha k_0}{\rho} \quad \text{and} \quad w_h^d = \frac{w_h}{\rho} = \frac{\alpha k_0(1 + x^{\alpha-1})}{\rho} \quad (8)$$

<sup>11</sup>Other income variables one may want to use are (gross) current income  $y_{it}$ , detrended initial incomes  $y_{i0}$ , or capital adjusted incomes  $\frac{y_{it}}{k_t}$ . All of these concepts suffer from the problem that they do not fully reflect the path incomes follow.

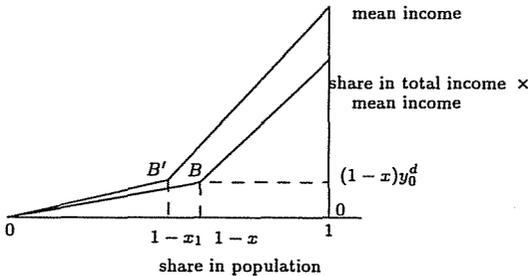
and that the mean of the discounted sum of incomes is

$$\mu^d = (1-x)w_i^d + xw_h^d + \tau k_0 = \frac{(1+x^\alpha)\alpha k_0}{\rho}. \quad (9)$$

implying  $\frac{dw_i^d}{dx} = 0$ ,  $\frac{dw_h^d}{dx} < 0$  and  $\frac{d\mu^d}{dx} > 0$  so that the mean of the PV of lifetime gross income is increasing in  $x$ . In order to compare any two cumulative income distributions of discounted lifetime income assume  $x_1 > x$ . Then the different values of  $x$  will give rise to two cumulative distribution functions,  $F(y_i^d(x_1))$  and  $G(y_i^d(x))$  with unequal means.

If  $F$  dominates  $G$  in the sense of *Second Order Stochastic Dominance* (SOSD), then  $F$  will be preferred to  $G$  by any increasing, concave social welfare function according to Atkinson (1970).<sup>12</sup> Second Order Stochastic Dominance is equivalent to *Generalized Lorenz Curve* (GLC) dominance. (For a proof see, for example, Lambert (1993), pp. 62-66.) A GLC is obtained by multiplying the values of the y-axis of an ordinary Lorenz Curve, which relates the share of the population (x-axis) to the share in total income (y-axis) which that population share receives, by mean income, i.e. (share of total income)  $\times$  (mean income).

Figure 2: Generalized Lorenz Curve



<sup>12</sup>Formally and for non-negative incomes, *Second Order Stochastic Dominance* requires  $\int_0^c F(w)dw \leq \int_0^c G(w)dw$ . Geometrically, a distribution  $F(w)$  dominates another distribution  $G(w)$  in the sense of SOSD if over every interval  $[0, c]$ , the area under  $F(w)$  is never greater (and sometimes smaller) than the corresponding area under  $G(w)$ .

A GLC *dominates* another one if the two curves do not cross and one is completely above the other one. In Figure 2 the income distribution with  $x_1 > x$  GLC-dominates the income distribution for  $x$ , because an increase in  $x$  raises  $\mu^d$  and shifts the kink at  $B$  to a point  $B'$  which is to the left and above GLC( $x$ ).

According to a theorem by Shorrocks (1983) every individualistic additively separable, symmetric, and inequality-averse social welfare function would prefer the GLC dominating income distribution. Hence, according to the GLC dominance criterion there exists a *unanimous* preference for the income distribution with the higher GLC. Even the high-skilled would prefer the distribution with a higher  $x$  under a veil of ignorance.<sup>13</sup>

Let  $I(x)$  be any inequality measure reflecting that a higher  $x$  leads to a GLC dominating income distribution. Then  $I(0) = I(1) = 0 < I(x)$  and  $\frac{dI}{dx} < 0$  for  $x \in (0, 1)$ . Thus, according to  $I(x)$  and for the PV of lifetime gross incomes there is no measured inequality if all agents get the same wage and they are all either equally high or low-skilled. When there is any skill heterogeneity, producing more skills reduces inequality. Furthermore, as  $x = \tau^\epsilon$ , a decrease in  $\epsilon$  for a given policy would lower  $I(x)$ .

**Proposition 1** *If there is heterogeneity in skills, an increase in the percentage of high-skilled people or an increase in the productivity of the education technology for given policy reduce inequality in the present value of lifetime (gross) incomes in the sense of Generalized Lorenz Curve Dominance.*

**Taking the Model to the Data.** In practice it is very difficult to calculate an agent's PV of lifetime gross income. Furthermore, it is usually difficult to find or to choose inequality measures satisfying certain

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<sup>13</sup>Exactly the same holds for the distribution of detrended (initial) incomes  $y_{i0}$  and capital adjusted incomes  $\frac{y_{it}}{k_t}$ . It also holds if one works with current incomes  $y_{it}$  and  $x \leq \hat{x}$ . In that case an increase in  $x$  causes the new GLC to be everywhere above the old GLC for  $t > 0$ , because the capital stock would be higher at each date and mean income would rise. However, if  $x > \hat{x}$  it does not necessarily hold.

desirable properties. One inequality measure that is frequently reported and employed in empirical research is the Gini coefficient, which measures the area between the Lorenz Curve and the 45° degree line as a fraction of the total area under the 45° degree line. A Gini coefficient of 0 (1) reports perfect equality (inequality).

In the model the Gini coefficient for the PV of lifetime gross income, but also for current and capital adjusted gross income is given by

$$G^g(x) = \frac{\alpha(1-x)x^\alpha}{1+x^\alpha} \quad (10)$$

and is not unambiguously decreasing in  $x$ , because for low (high)  $x$  an increase in human capital increases (decreases)  $G^g$ . See Appendix A.3. That raises three issues which merit comment for the subsequent empirical analysis.

First, the Gini coefficient in (10) is derived under the assumption of equal capital ownership and income. In reality, the capital income component of the distribution of total personal gross incomes affects (often reduces) measured inequality. However, the model's Gini coefficient captures that empirically the main source of inequality stems from wage inequality. (See Atkinson (1998), p. 19).

Second, households may consist of people with different educational backgrounds. But notice that when household surveys are based on observations of individual units, the Gini coefficient would not change its informational content if there was a rearrangement of persons into high or low-skilled groups.

Third, ambiguity in Gini coefficients reflects the well-known fact that Lorenz curves often intersect so that clear rankings of income distributions with equal or unequal means would not be possible by simple Lorenz curve comparisons. See e.g. Atkinson (1970) and, in particular, Fields (1987) who shows that the Gini coefficient usually generates a Kuznets curve *by construction*, when incomes are rising. However, changes in income (e.g. real GDP per capita) is what growth is all about. Thus, measurement issues such as the choice of inequality measures are

important and may not have received enough attention in the macroeconomics and growth literature.

For the model that raises an important point. Suppose the economies were identical except for their composition of human capital. Then countries with a higher  $x$  should have a higher mean and lower inequality in time-average incomes. That result (Proposition 1) was derived from the general notion of GLC Dominance. If the collection and quality of data force one to employ a simple measure like the Gini coefficient, one may find that countries with a higher  $x$  show up higher Gini coefficients, although over time gross income inequality in those countries may actually be lower than in other countries.

Expressing growth as a function of the Gini coefficient yields

$$\gamma(G^g, x) = (1 - \alpha) \left[ \frac{\alpha(1 - x)x^\alpha}{G^g} \right] - x^{\frac{1}{\epsilon}} - \rho. \quad (11)$$

For given  $x$  an increase in the Gini coefficient lowers growth. Furthermore, equation (1) implies  $\frac{dY}{dx} > 0$ , that is, output at *any* date is increasing in  $x$ . Thus, *initial* income is predicted to be higher for countries with a higher  $x$  as well.

In cross-country growth empirics variables such as  $Y_0$  or  $G^g$  are often included in the regressions. Equation (11) suggests that the model  $\gamma(G^g, x, \bar{y}_0; R)$  be investigated, where  $G^g$ ,  $x$ , and  $\bar{y}_0 \equiv \ln Y_0$  are taken to be the main explanatory variables and  $R$  denotes a vector of exogenous variables not included in the regression. Furthermore,

$$\frac{\partial G^g}{\partial x} \Big|_{x \text{ suff. high}} < 0, \quad \frac{\partial \gamma}{\partial G^g} < 0, \quad \text{and} \quad \frac{\partial Y_0}{\partial x} > 0. \quad (12)$$

are the predicted signs of the coefficients in regression analyses testing the model.<sup>14</sup>

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<sup>14</sup>Three alternative models would really require analysis, namely  $\gamma(G^g(x), x, \bar{y}_0; R)$ ,  $\gamma(G^g, x, \bar{y}_0(x); R)$ , or  $\gamma(G^g(x), x, \bar{y}_0(x); R)$  which would recognize the endogeneity of  $G^g$  and  $\bar{y}_0$ . Unfortunately, these models cannot be tested adequately here due to the small sample size of high quality data used in the paper.

### 3 Empirical Evidence

The basic implication of the theoretical model is that countries with relatively more high-skilled people have higher initial income and less gross income inequality over time. Less income inequality is in turn predicted to imply higher long-run growth. In order to test these implications the paper follows the common procedure of cross-country growth regressions by taking averages of data over time and running cross-country OLS regressions over these averaged data. For similar approaches see Barro (1991), Easterly and Rebelo (1993), Sala-i-Martin (1997) and many others.

All empirical studies linking education and income inequality with macroeconomic phenomena such as GDP growth are severely limited by the availability of high quality data. The present study is no exception. For instance, many authors use secondary school enrollment as a proxy for the measurement of human capital. Such a proxy suffers from the problem that school enrollment does not necessarily imply that students actually graduate or that graduates find jobs and become economically active.

The paper focuses on the composition of human capital which is measured by the percentage of the *labour force* from 25 to 64 years of age who have attained at least upper secondary education.<sup>15</sup> Data for that variable are provided by the OECD Education Database for 1996 and 34 countries. Thus, the variable may represent a better picture of the link between the human capital mix and production than school enrollment rates. Notice that it collapses the time series dimension into a single number by attaching weights to the human capital composition of different generations of all those who are economically active at a particular point in time.

Breaking the variable down by age cohorts reveals for the *population* as a whole that in almost all countries the percentage of the population that has attained at least upper secondary education has risen over time.

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<sup>15</sup>See Table A1.1, p. 34. Notice the binary nature of the variable.

(See Table A1.2a on p. 35.) For instance, in the United States 77 percent of the population aged 55-64 had attained at least upper secondary education whereas it is 87 percent for those aged 25-34. (For Germany the numbers are 71 percent for age group 55-64 and 86 percent for age group 25-34. More impressively, for fast growing Korea it is 25 percent for age group 55-64 and 88 percent for age group 25-34.) The implicit assumption here is that the variable for the *labour force* represents a long-run process which does not significantly change over time.

Comparable data on income distributions for large samples of countries are rare and often do not satisfy minimum quality requirements. However, Deininger and Squire (1996) have compiled a high quality and very valuable data set on inequality, covering many countries and periods. Their (minimum) standards of quality require that the data be based on (1) actual observation of individual units drawn from household surveys, (2) a representative sample covering all of the population, and (3) comprehensive coverage of different income sources as well as population groups. The reported Gini coefficients from their data set are used in this paper.

In an intertemporal framework one should measure inequality in lifetime incomes. That would require calculating some form of time-average of the incomes for households or individuals. Gini coefficients of such averages for large samples of countries do not exist. As an approximation one may take averages of Gini coefficients over time and interpret that average as the Gini coefficient of an average of income distributions at different dates. In this paper averages of Gini coefficients for each country are taken for the period 1960-90 and are meant to reflect long-run within-country inequality.

The income and recipient concept is gross income per household and, in contrast to Deininger/Squire or Forbes, it is strictly adhered to.<sup>16</sup>

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<sup>16</sup>The strict adherence to these concepts results in a small sample. Deininger and Squire (1998) and Forbes (1998) construct 'average' Gini coefficients by taking averages of Gini coefficients based on gross or net income or adjusted (add 6 percentage points) Gini coefficients based on expenditure, each for individual or household in-

The assumption that the average Gini coefficients represent steady states is only an approximation. For instance, for the United States there appears to be an upward trend in income inequality in the sample period, whereas for France income inequality seems to have fallen over time and for Germany no clear picture emerges. (See the Data Appendix, fn. 22.) Unfortunately, not enough data are available to uncover any robust time series behaviour of the reported Gini values for all countries in the sample. In 'defence' of viewing the average Gini coefficient as a steady state variable notice that countries with positive trends are usually showing up higher levels.

A related and important point is that most researchers restrict attention to initial positions. For instance, Alesina and Rodrik (1994) run their cross-country growth regressions on a measure of initial income inequality. Notice, however, that in contrast to classical growth theory (e.g. Solow (1956) or Kaldor (1957)), the income distribution determines growth at each point in time in endogenous growth models. Thus, growth is not predicted to depend just on the initial income distribution.

Working with inequality as an explanatory variable in the growth regressions assumes that the causality is from distribution to growth. That assumption is made throughout the paper and, thus, does not question the validity of endogenous growth frameworks. Hence, the hypothesis that GDP growth (a macroeconomic concept) may 'cause' changes in personal income inequality (a microeconomic concept) is rejected on a priori grounds in this paper. That may justify the use of time-average Gini coefficients in the subsequent analysis.

Furthermore, long-run growth rates were calculated for the period 1960-90 using the Penn World Table (Mark 5.6) from Summers and Heston (1991). All the other data are taken from Barro and Lee (1994). Together with the OECD and inequality data the sample comprises 21

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come recipients, for each country and year according to some quality criterion above. That procedure may yield a large sample, but a lot of important information is lost, making it very likely that their coefficients on inequality are biased upwards. On the importance of income and recipient concepts in the measurement of inequality see, for instance, Atkinson (1983), Lambert (1993), or Cowell (1995).

countries for which high quality data are available and which represent a significant fraction of world output.

**Results.** In the sample the typical country has a time-average Gini value of 36.7 with a standard deviation (SD) of 7.9, has approximately 61 percent of the labour force who have at least upper secondary education (SD 22) and grows at 3.1 percent (SD 1.4).<sup>17</sup> Thus, relatively there is not much variability in growth rates in the sample, but income inequality and the skill composition seem to differ widely across countries.

A standard deviation of 1.1 percentage points in growth rates may seem small, but it produces pronounced dynamic effects. If two economies started with the same initial income in 1960 and their growth rates differed by 1.1 percentage points, it would take the economy with the higher growth rate around 63 years (approx. 3 generations) to have twice the level of real GDP per capita of the other country. Thus, small differences in growth rates produce great differences in per capita income over time.<sup>18</sup>

For the sample period the intra-country variability in Gini values is low. For instance, they changed little in the United States and Germany (SD 1.42 and 0.76 percentage points, respectively) and changed most in France and Turkey (SD around 6 percentage points.) One should bear in mind that these small intra-country changes in Gini coefficients may reflect huge changes in welfare, that is, small variability in intra-country Gini coefficients may have drastic effects on some groups' income and

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<sup>17</sup>Summary statistics of the high quality data are presented in Table 3, p. 33.

<sup>18</sup>For example, in 1960 Germany and Korea had 67 percent, resp. 9 percent of the level of U.S. real GDP per capita. If real GDP in the United States continued to grow at 2 percent and, starting in 1960, Germany's and Korea's real GDP continued to grow at 2.6 percent and 6.7 percent it would take Germany 67 years and Korea 51 years to have the same level of real GDP per capita as the United States in the year 2027, resp. 2011. Thus, in 1990 it should take Germany another 37 years (approx. 2 generations) and Korea another 21 years (approx. 1 generation) to catch up with the United States. (These calculations are based on continuous growth, where the time unit is taken to be a year.) That highlights what differences in growth rates imply and justifies why any effects causing even only small cross-country differences in growth rates are worth analyzing.

overall welfare. However, the variability in inter-country, time-average Gini coefficients is even far greater.

Suppose the mean income in two economies were equal, then from the sample a one standard deviation difference would imply Gini values of 30 vs. 45, that is, a difference of 15 percentage points. That may entail huge welfare differences for the average income recipient in each country.

Table 1: Simple Correlations

	G60-90	SECL	AIHG	LY60	TERL	OECD	GEDU	PRIGHT	CVLIB
SECL	-0.366	1.000							
AIHG	0.146	-0.716	1.000						
LY60	-0.790	0.789	-0.640	1.000					
TERL	-0.117	0.644	-0.486	0.453	1.000				
OECD	-0.659	0.570	-0.632	0.832	0.307	1.000			
GEDU	-0.393	0.733	-0.507	0.639	0.493	0.459	1.000		
PRIGHT	0.729	-0.734	0.630	-0.948	-0.349	-0.844	-0.640	1.000	
CVLIB	0.766	-0.701	0.631	-0.940	-0.365	-0.803	-0.676	0.970	1.000
EDUPR	0.332	-0.970	0.727	-0.784	-0.648	-0.583	-0.640	0.734	0.676

Variable Definitions:

G60-90	average growth rate of real GDP per capita for the period 1960-90
SECL	Percentage of the labour force from 25 to 65 years of age who have attained at least upper secondary education. (Source: OECD)
TERL	Percentage of the labour force from 25 to 65 years of age who have attained tertiary education. (Source: OECD)
AIHG	Average Gini coefficient for gross income of households for the period 1960-1990. (Source: Deininger/Squire)
LY60	Natural logarithm of the level of real GDP per capita in 1960.
GEDU	Government expenditure on education as a fraction of GDP for the period 1960-85.
PRIGHT	Gastil's index of political rights (from 1 to 7; 1 = most freedom).
CVLIB	Gastil's index of civil liberties (from 1 to 7; 1 = most freedom).
OECD	Dummy for OECD countries.
EDUPR	Imputed productivity index of the education technology (from 0 to 1; 0 = most productive) for the period 1960-85.

The simple correlations in Table 1 suggest the following interpretations: An increase in the percentage of persons in the labour force with at least upper secondary or with tertiary education reduces growth across

countries. (This effect is relatively small.) Countries with higher initial income have lower growth (relatively strong effect) and those with higher income inequality have higher growth (relatively weak effect). Economies operating with a more high-skilled labour force have less income inequality and higher initial income. On average OECD countries have lower long-run growth, operate their economies with a relatively higher skilled labour force and have higher initial income, and lower income inequality. Interestingly and in relative terms, countries granting citizens more political or civil rights seem to have *lower* growth, but have higher initial income, spend more on education, have a more qualified labour force, and lower income inequality.<sup>19</sup>

Some of these direct effects are merely suggestive and - perhaps - not overly surprising. What is of interest in this context is that growth seems to covary *positively* with income inequality and *negatively* with the human capital composition and the education finance variable. The latter property is odd, as most studies find that human capital and more public resources for education affect long-run growth in a significantly positive way. (See e.g. Barro and Sala-i-Martin (1995), chpt. 12, Table 12.3.) Notice that the positive correlation between growth and inequality would seem to contradict the model's predictions.

However, simple correlations may present a misleading picture of any 'true', cross-country relationship between long-run growth and other economic variables. Furthermore, equation (11) only holds conditional on  $x$ . It is clear that a macro variable such as growth of GDP per capita is influenced by many different factors so that controlling for other factors is called for.

Columns (1) and (2) in Table 2 indicate that, when controlling for upper secondary education, income inequality and initial income, tertiary education and being a member country of the OECD does not significantly add to the explanation of long-run growth.

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<sup>19</sup>The OECD variable shares all the features of the variables PRIGHT and CVLIB when interpreting more political or civil rights as being a member country of the OECD.

Table 2: Cross-Country Growth Regressions for 1960-90

	(1)	(2)	(3)	(4)	(5)	(6)
Const.	21.722 (2.136) [0.000]	21.864 (2.060) [0.000]	22.155 (1.688) [0.000]	17.810 (1.786) [0.000]	21.246 (2.012) [0.000]	5.993 (2.430) [0.024]
SECL	0.020 (0.010) [0.051]	0.021 (0.008) [0.019]	0.022 (0.007) [0.007]	0.035 (0.009) [0.008]		- 0.028 (0.016) [0.100]
AIHG	- 0.066 (0.019) [0.003]	- 0.067 (0.018) [0.002]	- 0.065 (0.016) [0.008]		- 0.087 (0.017) [0.000]	- 0.034 (0.044) [0.450]
LY60	- 2.100 (0.316) [0.000]	- 2.107 (0.307) [0.000]	- 2.168 (0.194) [0.000]	- 2.030 (0.261) [0.000]	- 1.800 (0.184) [0.000]	
TERL	0.010 (0.022) [0.655]					
OECD	- 0.109 (0.462) [0.817]	- 0.118 (0.450) [0.796]				
R <sup>2</sup>	0.901	0.900	0.900	0.801	0.844	0.162
No. of obs.	21	21	21	21	21	21

The dependent variable is the average growth rate of real GDP per capita over the period 1960-90. The estimation method is OLS. Standard errors are shown in parentheses and *t*-probabilities are reported in square brackets.

Therefore, the paper's core variables are SECL, AIHG and LY60. In all regressions initial GDP has a negative impact on growth, which would corroborate the hypothesis of conditional convergence, that is, that initially poorer economies tend to have higher subsequent growth. According to the model initially poorer countries have less human capital, a prediction that is borne out by the data. (Recall the simple correlation between LY60 and SECL of around 79 percent.) Thus, LY60 depends positively on SECL. This endogeneity is ignored in the regressions, as more regressors required by more sophisticated estimation methods would make statistical results more fragile.

Models (3) to (5) test the key relationships of the theoretical model and show that controlling for initial income or income inequality an increase in the human capital of the labour force (significantly) raises a typical economy's rate of growth. Furthermore, controlling for initial in-

come or human capital, more gross income inequality reduces long-run growth. These models appear to explain growth rather well. However, relatively high  $R^2$ s may also indicate multicollinearity among the regressor variables. But as the model implies that to be the case, they may really reflect the explanatory power of the theoretical model.

Thus, the labour force composition has a level effect on initial income which in turn affects long-run growth. When controlling for that effect it has an impact on growth and it affects the personal income distribution. The results suggest that it reduces income inequality for a typical country and raises growth. Over the sample period economies that had initially higher income, had a more skilled labour force and lower income inequality.

Model (6) appears to be doing badly. The point estimate for the effect of human capital on growth is negative. On the other hand notice the large drop in  $R^2$ . As Model (6) captures the only variables contemplated in theory part, one might think that the theoretical model is flawed. However, there the relationship between the Gini coefficient and  $x$  is non-linear. Thus, one may only conclude that a linear approximation of the theoretical model by OLS does not perform well. Furthermore, the estimates are probably biased. If any 'true' model should include LY60 as an explanatory variable and if the 'true' effect of initial income on growth is negative as most studies assume and show, then the estimated coefficient SECL is biased downwards. Hence, due to an omitted variable bias the effect of SECL on growth may be significantly underestimated in Model (6).

Summarizing: When controlling for initial income countries with a more skilled labour force or lower inequality had higher long-run growth. In *all* regressions and when controlling for initial income or human capital, income inequality negatively affects long-run growth. Thus, countries with lower inequality than the typical one should be doing better in terms of growth.<sup>20</sup>

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<sup>20</sup>The results are robust to changes in the sample (e.g. when eliminating dubious, high quality data). These sensitivity checks are not reported here due to lack of space, but are available from the author. See the Data Appendix for further details.

In the paper the composition of human capital is supply driven. Cross-country differences in public education lead to different skill mixes, which influence an economy's growth and income inequality.

That raises the question why some economies have a more skilled labour force than others. One answer may be that they possess more productive education technologies. The variable EDUPR in Table 3 proxies how productive public resources have been in generating more high-skilled people over the sample period and attempts to pick up the productivity parameter  $\epsilon$  in the theoretical model.<sup>21</sup> The variable suggests that the United States and Germany, which have the highest percentage of people who have at least upper secondary education, also have the most productive education technologies. These two countries seem to generate more people with high skills for every unit of public resources channelled into education than all the other economies in the sample. These productivity differences may not be important for growth, but from Table 1 they seem to correlate highly with income inequality and initial income. All countries in the sample that have relatively unproductive education technologies also seem to be those that have high inequality. This suggests for a typical country that rather than the amount of resources going into education it is really the productivity of generating more high-skilled people that would help to reduce income inequality.

## 4 Concluding Remarks

The experience of high growth economies suggests that there is a link from education to income equality and growth. The paper provides a supply-driven explanation of how that link may operate across countries.

In the model the composition of human capital directly affects inequality and growth. Due to technology, and market imperfections or institutional restrictions, high-skilled workers contribute more to effective

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<sup>21</sup>Clearly, not all resources channelled into education are targeted at secondary education. But given the binary nature of SECL, and given data for GEDU, EDUPR may be a reasonable approximation to measure the (long-run) productivity of the education technologies.

labour in production than their unskilled counterpart. The high-skilled receive a wage premium which depends on how many of them are present in the economy. The government provides public education which produces human capital in the form of high-skilled people. It is shown that the productivity of the education sector positively affects growth and income equality. Furthermore, the model implies that countries with a more high-skilled labour force should exhibit lower inequality.

Using high quality data for the period 1960-90 it is found that, when controlling for initial income, long-run growth is higher for countries that (a) had a relatively more high-skilled labour force or (b) had lower income inequality as measured by the (time-average) Gini-coefficient. The data also suggest that countries with a more productive, public education technology exhibit lower income inequality.

Cross-country productivity differences in education may be due to many things such as history, labour market conditions, physical and human capital equipment used in schooling, laws, school financing (fees) etc. Furthermore, the differences may also reflect different demand conditions.

Untangling the precise demand-supply relationships between human capital, technology and institutions in the explanation of growth or inequality is interesting ongoing research and has been beyond the scope of this paper. These and other problems are left for future research.

# A Technical Appendix

## A.1 Technology

By assumption  $Y_t = A_t H_t^\alpha K_t^{1-\alpha}$ , where the index of effective labour  $H$  depends on labour requiring *basic skills* ( $B$ ) and labour requiring *high skills* ( $S$ ). Labour requiring basic skills is performed by high and low-skilled persons,  $B = B(L_l, L_h)$ , whereas high-skilled labour is only performed by high-skilled persons,  $S = S(L_h)$ . High and low-skilled people are perfect substitutes to each other when performing basic skill (routine) tasks, i.e.  $B(L_l, L_h) = L_l + L_h$ . Thus, high-skilled people also perform those routine tasks a low-skilled person may do. On the other hand, only high-skilled people can perform high-skilled tasks (labour) and for simplicity let  $S(L_h) = L_h$ . To capture the relationship between labour inputs assume  $H = [B^\rho + S^\rho]^{\frac{1}{\rho}} = [(L_h + L_l)^\rho + L_h^\rho]^{\frac{1}{\rho}}$ . For  $\rho < 1$  labour requiring basic skills ( $B$ ) and labour requiring high skills ( $S$ ) are imperfect (less than perfect) substitutes. For ease of calculations let  $\rho = \alpha < 1$  which yields equation (1).

## A.2 Discrete Time Justification for $x = \tau^\epsilon$

Equation (2) is compatible with many models that also use high-skilled labour as an input generating education. For instance, let  $h_t$  denote the *total* stock of human capital in the economy in a discrete time model. Assume that human capital evolves according to

$$h_{t+1} = f(G_t, K_t, h_t) h_t$$

where new human capital  $h_{t+1}$  is produced by non-increasing returns. Here human capital formation would depend on the level of the stock of knowledge  $h_t$ , government resources provided for education  $G_t$  and the tax base  $K_t$ . The function  $f(\cdot)$  governs the evolution of human capital. Assume that it is separable in the form  $f(g(G_t, K_t), h_t)$ . Let  $g = c \left( \frac{G_t}{K_t} \right) = c(\tau)$  and for simplicity

$$h_{t+1} = c(\tau) h_t^\beta, \quad \text{where } c \geq 0, c' > 0, c'' \leq 0, 0 < \beta < 1.$$

where  $\beta$  measures the productivity of the education sector and  $c(\tau)$  captures the efficiency or quality of education, depending on the government resources channelled into education. For similar expressions see, for example, eqns. (1), (2) in Glomm and Ravikumar (1992), eqn. (1) in Eckstein and Zilcha (1994), or eqn. (2) in Razin and Yuen (1996).

In the model human capital is carried discretely so  $h_t = x_t N$ . Normalize population by setting  $N = 1$ . Then total human capital at date  $t$  is given by  $x_t$ . In steady state  $\bar{x} = x_t = x_{t+1}$  and so

$$\bar{x} = c(\tau)^{\frac{1}{1-\beta}}.$$

Next suppose that the efficiency of the education sector is described by  $c(\tau) = \tau^\mu$  where  $0 < \mu < 1$ . For non-increasing returns to scale it is necessary that  $\mu + \beta \leq 1$ . Let  $\frac{\mu}{1-\beta} \equiv \epsilon$  then the more explicit set-up would be equivalent to (2) in steady state. As  $\bar{x}_\epsilon < 1$ , any increase  $\epsilon$  would mean that less human capital is generated in steady state. From non-increasing returns to scale it follows that  $\mu \leq 1 - \beta$  so that  $\epsilon \leq 1$ . Hence,  $\epsilon = 1$  would represent a relatively unproductive human capital formation process.

### A.3 The Gini Coefficient

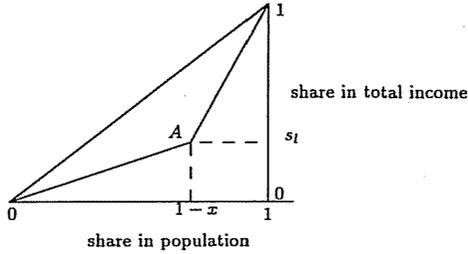
A Lorenz Curves (LC) relates population shares to income shares. In the model total gross income is  $\mu N$ . Furthermore,  $L_l = xN$ ,  $L_h = xN$  and mean income  $\mu$  is increasing in  $x$ . The share of total gross income going to the low-skilled is  $s_l \equiv \frac{w_l L_l + \tau k_l L_l}{\mu N}$  so that the Lorenz curve looks like Figure 3 below.

The LC has a kink at the point  $A$  at which  $(1-x)$  percent of the population receive  $s_l$  percent of total income. From this one may calculate the Gini coefficient as

$$G = 1 - 2 \left[ \frac{(1-x)s_l}{2} + x s_l + \frac{(1-s_l)x}{2} \right] = 1 - (s_l + x)$$

where the expression in square brackets represents the area under the LC. Recall that  $w_l = \alpha k_t$  and  $w_h = \alpha k_t(1+x^{\alpha-1})$  so that gross mean income is given by  $\mu = (1-x)w_l + xw_h + \tau k_t = (1+x^\alpha)k_t$ . Then  $s_l = \frac{\alpha(1-x)}{1+x^\alpha} + (1-\alpha)(1-x)$

Figure 3: Ordinary Lorenz Curve



so that

$$G^g = (1-x) - (1-\alpha)(1-x) - \frac{\alpha(1-x)}{1+x^\alpha} = \frac{\alpha(1-x)x^\alpha}{1+x^\alpha} \quad (\text{A1})$$

Then the effect of an increase in  $x$  on  $G^g$  depends on

$$\begin{aligned} \text{sgn}(G_x^g) &= [\alpha^2 x^{\alpha-1}(1-x) - \alpha x^\alpha] (1+x^\alpha) - \alpha^2 x^{\alpha-1} x^\alpha (1-x) \\ &= \alpha x^{\alpha-1} ([\alpha(1-x) - x] (1+x^\alpha) - \alpha x^\alpha (1-x)). \end{aligned}$$

For low  $x$  an increase in  $x$  raises  $G^g$ , whereas for higher values of  $x$  a higher  $x$  reduces it. Hence, the Gini coefficient does not produce unambiguous rankings of the (gross) income distribution.

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# B Data Appendix

## Data Sources

- Barro and Lee (1994): Data set available at:  
[www.nber.org/pub/barro.lee/ZIP/](http://www.nber.org/pub/barro.lee/ZIP/).
- Summers and Heston (1991): Penn World Table (Mark 5.6). Available at:  
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- OECD Education Database. Available at:  
[www.oecd.org//els/edu/EAG98/list.html](http://www.oecd.org//els/edu/EAG98/list.html).
- Deininger and Squire (1996). Data set available at:  
[www.worldbank.org/html/prdmg/grthweb/dddeisqu.html](http://www.worldbank.org/html/prdmg/grthweb/dddeisqu.html).

## Definition of variables<sup>22</sup>

G60-90	average growth rate of real GDP per capita for the period 1960-1990 in percentage points, where $G60-90 = \frac{\ln y_T - \ln y_0}{T}$ and $y_T$ denotes per capita GDP at final date $T$ . (Source: Penn World Tables, Mark 5.6.)
SECL	Percentage of the labour force from 25 to 64 years of age who have attained at least upper secondary education. (Source: OECD)
TERL	Percentage of the labour force from 25 to 64 years of age who have attained tertiary education. (Source: OECD)
AIHG	Average Gini coefficient for gross income of households for the period 1960-1990 (Source: Deininger/Squire)
LY60	Natural logarithm of the level of real GDP per capita in 1960. (Source: Penn World Tables, Mark 5.6; Variable: RGDP, i.e. real GDP per capita in 1985 international prices.)
GEDU	Government expenditure on education as a fraction of GDP for the period 1960-1985 in percentage points. (Source: Barro-Lee)
PRIGHT	Gastil's index of political rights (from 1 to 7; 1 = most freedom) for the period 1972-1989. (Source: Barro-Lee)
CVLIB	Gastil's index of civil liberties (from 1 to 7; 1 = most freedom) for the period 1972-1989. (Source: Barro-Lee)
OECD	Dummy for OECD countries.
EDUPR	Imputed productivity index of the education technology (from 0 to 1; 0 = most productive) for the period 1960-1985.

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<sup>22</sup> A detailed description of the data and how the paper's results were obtained is provided at: <http://www.tu-darmstadt.de/~rehme/gaac99/data.html>.

Table 3: Country Sample

	AIHG	G60-90	SECL	TERL	LY60	GEDU	PRIGHT	CVLIB	EDUPR
Belgium*	28.3	2.9	63.3	13.7	8.6	5.4	1.0	1.0	0.157
Italy*	28.7	3.3	45.8	11.5	8.4	3.8	1.2	1.6	0.238
Finland*	29.9	3.3	71.4	13.5	8.6	5.8	1.8	1.9	0.118
Norway*	30.8	3.3	85.0	17.2	8.6	6.3	1.0	1.0	0.059
Canada	31.2	2.9	81.6	19.6	8.9	6.8	1.0	1.0	0.076
Germany	31.4	2.6	86.3	15.4	8.8	4.0	1.0	1.6	0.046
Netherlands*	32.2	2.5	70.5	27.0	8.7	7.0	1.0	1.0	0.131
Sweden*	32.4	2.2	76.8	14.5	8.9	7.1	1.1	1.0	0.100
Denmark	32.5	2.4	71.2	17.2	8.8	6.3	1.0	1.0	0.123
United Kingdom*	33.6	2.2	81.3	14.7	8.8	5.2	1.0	1.0	0.070
New Zealand	34.4	1.2	65.5	12.9	9.0	4.7	1.0	1.0	0.138
Korea	34.5	6.7	62.3	20.9	6.8	3.7	4.4	5.2	0.144
Spain	34.6	3.7	38.3	16.9	8.0	1.9	2.4	2.9	0.242
United States	35.5	2.0	89.1	28.5	9.2	5.9	1.0	1.0	0.041
Australia	37.9	2.1	62.8	17.3	9.0	4.7	1.0	1.0	0.152
Ireland*	38.9	3.4	57.0	13.7	8.1	5.1	1.0	1.2	0.188
France	42.1	2.9	66.1	11.1	8.7	4.4	1.0	1.9	0.133
Thailand	45.5	4.4	14.2	6.5	6.8	3.0	3.9	3.8	0.557
Turkey	50.4	2.8	22.2	9.1	7.4	3.5	3.3	3.9	0.450
Malaysia	50.8	4.3	38.5	9.4	7.3	4.7	3.1	4.1	0.312
Brazil	56.1	2.7	28.3	11.0	7.5	2.8	3.4	3.4	0.353
Mean	36.7	3.1	60.8	15.3	8.3	4.9	1.8	2.0	0.182
Std. Dev.	7.9	1.1	21.8	5.5	0.7	1.4	1.2	1.3	0.135

EDUPR denotes the productivity of the education technology. It represents imputed values of  $\epsilon$  of equation (2) in the text and has been proxied by  $\frac{\ln(\text{SECL}/100)}{\ln(\text{GEDU}/100)}$ . The starred countries' data are based on 'cs' and the unstarred ones are based on 'accept' Gini coefficients from Deininger and Squire (1996).

Table A1.1

Distribution of the population and of the labour force 25 to 64 years of age by level of educational attainment (1996)

	Population					Labour force				
	Below upper secondary education	Upper secondary education	Non-university tertiary education	University-level education	Total	Below upper secondary education	Upper secondary education	Non-university tertiary education	University-level education	Total
Australia	43	32	10	15	100	37	35	11	17	100
Austria	29	63	2	6	100	23	68	2	7	100
Belgium	47	30	13	11	100	37	33	16	14	100
Canada	24	29	31	17	100	18	29	33	20	100
Czech Republic	16	74	x	10	100	12	76	x	12	100
Denmark	34	44	7	15	100	29	47	8	17	100
Finland	33	46	9	12	100	29	48	10	14	100
France	40	41	9	10	100	34	44	11	11	100
Germany	19	60	9	13	100	14	61	10	15	100
Greece	56	25	7	12	100	50	26	9	15	100
Hungary	37	50	x	13	100	24	59	x	17	100
Ireland	50	28	12	11	100	43	29	14	14	100
Italy	62	30	x	8	100	54	34	x	11	100
Korea	39	42	x	19	100	38	41	x	21	100
Luxembourg	71	18	x	11	100	63	21	x	16	100
Netherlands	37	40	x	23	100	29	43	x	27	100
New Zealand	40	35	14	11	100	35	38	15	13	100
Norway	18	55	11	16	100	15	56	12	17	100
Poland	26	61	3	10	100	21	64	4	12	100
Portugal	80	9	3	7	100	76	11	4	9	100
Spain	70	13	5	13	100	62	15	6	17	100
Sweden	26	47	14	13	100	23	48	15	14	100
Switzerland	20	58	12	10	100	17	58	14	10	100
Turkey	83	11	x	6	100	78	13	x	9	100
United Kingdom	24	55	9	13	100	19	57	10	15	100
United States	14	52	8	26	100	11	52	9	28	100
Country mean	40	40	10	13	100	34	43	11	15	100
WEI Participants										
Argentina	73	18	4	5	100	69	20	5	6	100
Brazil	75	16	x	9	100	72	17	x	11	100
India	92	3	1	5	100	m	m	m	m	m
Indonesia	81	15	2	2	100	m	m	m	m	m
Malaysia	67	26	x	7	100	62	29	x	9	100
Paraguay	67	19	3	11	100	64	21	3	13	100
Thailand	87	3	5	6	100	86	3	5	7	100
Uruguay	73	12	4	10	100	69	14	4	12	100

Poland: Year of reference 1995.

Turkey: Year of reference 1997.

Source: OECD Education Database. See Annex 3 for notes.

Table A1.2a

Percentage of the population that has attained a specific level of education, by age group (1996)

	At least upper secondary education					At least university-level education				
	Age 25-64	Age 25-34	Age 35-44	Age 45-54	Age 55-64	Age 25-64	Age 25-34	Age 35-44	Age 45-54	Age 55-64
Australia	57	62	60	54	46	15	16	18	14	8
Austria	71	82	75	67	53	6	7	7	5	4
Belgium	53	70	58	47	31	11	14	11	10	6
Canada	76	85	81	73	56	17	20	18	17	11
Czech Republic	84	92	87	84	71	10	11	12	10	8
Denmark	66	74	70	65	50	15	16	17	16	11
Finland	67	83	76	60	40	12	13	13	12	7
France	60	74	64	56	38	10	12	10	10	5
Germany	81	86	85	81	71	13	13	16	14	9
Greece	44	66	52	36	22	12	16	14	11	6
Hungary	63	80	75	62	28	13	14	15	15	9
Ireland	50	66	54	38	30	11	14	11	9	6
Italy	38	52	46	31	17	8	8	11	8	5
Korea	61	88	63	41	25	19	30	18	11	7
Luxembourg	29	32	33	28	20	11	11	14	12	6
Netherlands	63	72	66	57	47	23	25	25	21	16
New Zealand	60	65	64	56	49	11	14	13	10	6
Norway	82	91	87	78	62	16	19	17	14	8
Poland	74	88	82	68	47	10	10	10	12	8
Portugal	20	32	24	15	9	7	11	9	6	4
Spain	30	50	34	20	11	13	19	15	10	6
Sweden	74	87	80	70	53	13	11	15	16	10
Switzerland	80	87	82	78	71	10	11	10	9	6
Turkey	17	23	19	14	7	6	7	7	7	3
United Kingdom	76	87	81	71	60	13	15	15	12	8
United States	86	87	88	86	77	26	26	26	28	20
<b>Country mean</b>	<b>60</b>	<b>72</b>	<b>65</b>	<b>55</b>	<b>42</b>	<b>13</b>	<b>15</b>	<b>14</b>	<b>12</b>	<b>8</b>
<b>WEI Participants</b>										
Argentina	27	36	29	21	15	5	5	6	4	3
Brazil	25	31	27	19	11	9	9	11	9	4
India	8	11	9	6	3	5	6	5	3	2
Indonesia	19	28	17	13	7	2	3	2	1	1
Malaysia	33	48	32	18	8	m	m	m	m	m
Paraguay	33	43	31	26	19	11	13	11	9	6
Thailand	13	19	14	7	4	6	9	7	3	1
Uruguay	27	36	30	22	14	10	14	12	8	5

Poland: Year of reference 1995.

Turkey: Year of reference 1997

Source: OECD Education Database. See Annex 3 for notes.



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