Department of Economics

North-South Trade and Growth: The Role of Product Quality

Teodora Borota

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

Florence, December 2009

EUROPEAN UNIVERSITY INSTITUTE
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DOI: 10.2870/13739

I dedicate this thesis to my parents.

 DOI: 10.2870/13739

I wish to express my deepest gratitude to my mentor, Professor Omar Licandro, for his teaching and inspiration. This thesis would not have been possible without his continuous guidance and support throughout my PhD studies.

Furthermore, I would like to thank my second advisor, Professor Giancarlo Corsetti, for numerous discussions, his invaluable comments and help. I am particularly indebted to Professor Timothy J. Kehoe for his enormous support and advisement. Also, I wish to thank Professor Bojan Jovanovic for his comments and the time devoted to our consultations.

I am also grateful for the support of the people with whom I have had the opportunity to discuss my work and share the ideas. I wish to thank Giammario Impullitti, Stephan Fahr, Michael Wycherley and Cristiana Benedetti Fasil, my friend and coauthor.

I wish to thank the Italian Ministry of Foreign Affairs and the European University Institute for the financial support during the four years of my studies.

Finally, I wish to thank my family and closest friends for their inestimable support and encouragement.

To all these, I am very grateful.

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Part I

Introduction

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Since the first seminal papers on the North-South economic interaction and growth, based on the notions of innovation, technology transfers and product cycles, the impact of globalization and the developing regions' opening to trade has attracted wide attention in economics literature. From the initial interest in explaining the role of technology and its transfer from the developed, industrialized North to the less developed South in shaping the world trade patterns, the focus has shifted to the mechanisms that define the feedback effect of trade on the incentives to develop and imitate the technologies. The protection of Intellectual Property Rights (IPR) within a globalized, trading world has been in the center of the ongoing debate as it directly affects the incentives for innovation in the North and the imitation in the South.

The traditional trade models, which rely on a comparative advantage based on regions' technology or endowments, or the new trade theory, designed to explain trade between the countries at a similar level of development, fail to replicate recent evidence on world trade patterns and prices. This evidence reveals North-South specialization across products of the same industries and product groups but different quality, rather than across different industries. Furthermore, countries at a higher level of technological development have higher export prices, which shows that more advanced technology does not necessarily imply higher cost efficiency. Therefore, in order to analyze the endogenous growth mechanisms and implications of the IPR protection policy in a North-South trade set-up, this thesis develops a fully-endogenous theoretical framework based on the notion of quality vintages, which results in the North-South production and trade specialization in different quality segments of the market. The model is used to investigate the growth effects of the South opening to trade and the welfare effects of different IPR policy instruments. Finally, the last chapter abstracts from endogenous growth mechanisms and focuses on the role of quality and cost efficiency in replicating the trade data.

In detail, the first chapter introduces a model of North-South trade with endogenous growth through innovation and imitation that is used to re-examine the impact of trade and

 DOI: 10.2870/13739

IPR protection on both the innovation in the North and the quality lag of the South. It is found that opening to trade increases the growth rate and welfare of both regions, but results in a larger lag in the quality level of the South. Stronger IPR protection decreases the world growth rate and increases the quality lag of the South, while the welfare is reduced. However, as opposed to the autarky case with the full catch-up of the South under no protection, the quality lag of the South is positive even with no IPR protection as a result of the revealed comparative advantage in lower quality goods production and trade. This contradicts the common predictions of Southern take-over of the whole industries due to bad IPR enforcement.

The second chapter of the thesis analyzes the welfare effects of international IPR protection in the North-South trade model with endogenous R&D in the two regions, as presented in chapter one. Two questions are addressed, the welfare and growth implications of perfectly enforceable patents of finite length compared to a world with no IPR protection, and the effects of the alternative IPR policy measures when patents are poorly enforced. The welfare optimizing patent length, from the perspective of the North, is positive and larger than the natural distance of the South, but it necessarily reduces the welfare of the South and growth in both regions. Compared to the social optimum, welfare and growth in both regions are lower, as the optimal North-South specialization pattern over quality is distorted. When patents are not enforced, in the sense that they prevent copying but allow the North to impose barriers on the imports of copies, the results show negative welfare and growth effects of increased protectionism. Substituting the lack of patent protection with other policy measures (information protection or an increase in the patent length) does not result in a welfare or growth improvement that would restore the levels that prevail in a world with either no IPR protection or perfectly enforced patents.

The final, third chapter proposes a trade model with exogenous technological lag of the South behind the North, but it introduces heterogeneous firms in two dimensions, quality and cost efficiency, which allows matching the evidence on world trade intensities and the prices of traded goods in relation to income per capita. Taking prices as a proxy for quality recent empirical literature identifies a positive relation between income per capita and both export and import prices, suggesting that rich countries trade goods of relatively higher quality. Instead of relying on the specific demand side mechanisms such as non-homothetic preferences, the chapter focuses on the North-South differences in technology. It employs a four country North-South trade model with two dimensions of firm heterogeneity. Differences in the firms' product qualities and cost efficiencies result in a price distribution generating different consumption bundles and the observed export and import prices across rich and poor countries. Furthermore, the resulting total expenditure allocation across quality shows that the North (South) spends a larger share of its income on high (low) quality even with the same homothetic preferences across the regions.

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Part II

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Chapter 1

Innovation and Imitation in a Model of North-South Trade

1.1 Introduction

The issues of trade and economic growth have been popular debate topics in the literature for more than two decades. Given the rapid increase in trade activity between the developed North and less developed South, particular attention has been given to the impact of South opening to trade on growth and welfare of the two regions.At the same time, concerns have been raised over the common practice of the South to copy Northern innovations and win the market shares due to substantially lower production costs. Numerous papers have already dealt with this issue, but recent evidence on the dimensions and market segments in which the North-South competition occurs calls for a different approach. This paper applies the notion of vertical innovation, incorporating the idea of quality vintages. In that framework, a different modeling of the IPR regime and the target of imitative effort of the South is introduced in order to revisit the implications of the South opening to trade. Finally, the effect of different levels of the IPR protection is analyzed in order to assess whether this Northern fear of losing economic dominance is indeed reasonable even with the low levels of

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IPR protection in the South.

This paper considers a model of North-South trade and endogenous growth which attempts to be in accordance with the empirical evidence on the current world trade patterns. Namely, the existing literature on North-South trade usually assumes that the trade pattern is determined either through endowment-driven specialization in different industries, or through technology-driven horizontal specialization in differentiated goods of the same value within the same industry. In the case of vertical intra-industry differentiation of goods, industries are modeled as monopolies so that imitation results in a product cycle with the whole industry being shifted between regions. Thus, the implied trade pattern is again of the inter-industry type. However, recent empirical evidence suggests that the North-South direct competition for dominance over entire industries might be exaggerated. Not neglecting the importance of the inter-industry specialization of countries, and thus, the importance of one-way-trade flows in the world, Fontagne et al. (2008) presents strong evidence of the North-South vertical specialization within industries. The North includes USA, Japan and EU25 as developed countries, while the South is a group of emerging countries, such as China, Russia, Brazil, India and others. When traded goods are distinguished according to the unit quality level, specialization in different quality ranges is revealed. It is argued that export bundles of these two regions are very similar at the industry level (low importance of inter-industry specialization), somewhat less similar at the product level (some evidence on horizontal intra-industry specialization), while the export structure is completely different at the quality level. South exports are of low quality, while North exports are of high quality. This supports intra-industry vertical specialization and the two-way trade in qualities within products.[1] In terms of market shares, there is strong evidence of down-market (low quality) share shifts in favor of the South, while in the up-market segment the North has the advantage. At the same time, within the South, only China is making slight gains in up-market share. Thus, there might be some basis for the Northern fear of competition from

[1] See also Schott (2004) for evidence on the unit value of US imports conditional on exporter's income per capita, which supports the specialization across quality in relation to income per capita.

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the growing South. However, this fear should not be exaggerated nor based on the common accusations that the large South, led by China, will soon become the manufacturing factory of the world and overtake this and other industries from the North. The reasoning should be based on the degree of the technological development of the South and its incentive and ability to advance in overtaking the up-market shares, regardless of the industry. Undoubtedly, IPR violation helps the South in doing so, but it seems that the North has been able to resist the competitive pressure through specialization in high qualities. Following the empirical findings, the aim of this paper is twofold. On one hand, its purpose is to develop a theoretical framework which replicates the new specialization pattern, and on the other, to use it for the analysis of endogenous technological progress, the impact of IPR protection policy and welfare implications.

This paper develops an endogenous R&D model of two regions and analyzes two scenarios based on the degree of trade openness. The North conducts innovating R&D which results in the creation of new varieties, each of a higher quality than the preceding one. The South is involved in the imitation of Northern products but at a certain lag. In the autarky scenario, there is no trade between the regions, but the South is still able to imitate Northern products at a lag. There are no patents, but the North can limit the leak of information concerning blueprints and thus affect the associated difficulty of imitation. In the second scenario, both regions are open to trade and the difficulty of imitation is still affected by the protection of information. This paper analyzes the determinants of the innovation effort in the North and the distance (on the quality-product scale) between the highest quality goods produced in the North and those produced in the South in a steady-state equilibrium within the two set-ups. The question of the incentives and the mechanisms for closing the gap is implicitly addressed as well.

The foundation for this study comes from two related groups of studies - a large body of literature on trade and growth (particularly in the North-South framework), and the literature on product cycles dealing with the issues of innovation and imitation. Vernon

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(1966) was first to raise the question of the North-South shift of production location in different stages of a product life cycle. A contemporary version of product cycle is presented by Antras (2005). What is common to both papers is that technological transfer comes only as a result of optimizing behavior of Northern firms.

Following the initial steps of Krugman (1979), Grossman and Helpman (1991a,b) are the most influential articles in which the production shifts occur due to imitation in an endogenous growth set-up. In both articles, the North is endowed with a comparative advantage, high enough to ensure that innovation takes place in the North and production transfers to the South due to endogenous imitation whose intensity determines the time of the transfer. They combine the notions of the quality ladder (a) or the variety expansion (b) with product cycles to develop a theoretical framework for analyzing the simultaneous behavior of innovation and imitation rates. The results show an increase in innovation and imitation rates coinciding with the two regions opening to trade. Although this paper uses on the same framework in many aspects, one of the main differences is the imitational R&D mechanism and the resulting target of imitation. The South does not necessarily aim at imitating the state-of-the-art products, but reproduces the less advanced goods up to the quality level determined in the stationary equilibrium. In other words, the endogenous level of R&D effort in the South determines how far, in terms of quality level, the imitation can reach, and not only how quickly and not at what scale it can replicate the most advanced industries of the North. In this way, the focus is shifted from the differences in growth rates to the differences in quality attainment of the two regions. With opening to trade, the innovation effort in the North increases, which results in the higher growth rates of both regions, but does not imply faster imitation by the South. This is due to the fact that innovative R&D not only creates new higher quality varieties, but also determines the incremental increase in quality for each new variety. Thus, higher innovation implies higher quality jumps which decreases relative R&D productivity in the South and requires stronger copying effort (higher cost) for any given lag behind the North. This opens a new dimension along which the regions' comparative advantage over quality is determined and allows for the international IPR policy

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analysis in a set-up that can predict the observed North-South trade patterns.

Helpman (1993) analyzes the welfare effects of the IPR protection in a framework that considers endogenous innovation but only exogenous imitation, and thus, does not capture the endogenous response of the imitation effort in the South to the changes in the innovational R&D in the North. More recent work in this field that relies on Grossman and Helpman's framework but considers endogenous imitation is presented in Parello (2008), Sener (2006), Stryszowski (2006). However, these papers do not consider the endogenous quality level attained by the South, only the endogenous rate of imitation of the Northern industries as aggregate measures. Horowitz and Lai (1996) analyze the IPR policy in autarky, but similarly to the idea here, they consider a technological lag in the sense that imitators cannot copy the most advanced products but copy only up to a certain level of quality, depending on the productivity of imitation. However, this lag is a result of the legally binding patents of a certain length and not a consequence of the imitators' optimization given the imitation technology. The IPR policy instrument introduced in this paper is in a form of intensive protection (information secrecy vs. extensive protection in the form of patents) and is given by a parameter that directly affects the imitational R&D productivity in the South. However, this instrument of IPR protection is not the only factor of influence on the R&D productivity in the South relative to that in the North. Increased IPR protection does make imitation more difficult, but the R&D technology in the South is also a function of the quality distance behind the North. The further behind the most advanced Southern variety is, the less difficult it is to imitate and the productivity of R&D is higher. In those terms, following Gancia and Zilibotti (2005), R&D technology in the South is modeled as a function of the relative quality index (South quality relative to that in the North), and thus as a function of the distance. In this way, this paper assumes also natural impediments of technological transfer besides the imposed IPR protection.

The framework in which this paper deals with the issues of the North-South trade mostly resembles Segerstrom and Dinopoulos (2006), whose structure of presentation is followed

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closely. They study a quality ladder model with a fixed number of industries, each producing only state-of-the-art goods. Once the good has been imitated, production moves to the South, yet returns to the North when that specific industry innovates again. In this paper, the number of varieties increases, but the notion of vintages is used to enrich the variety-expanding set-up with the improvements in quality. In this way, different qualities are not perfect substitutes, which allows for the production and consumption of the whole range of qualities, not only state-of-the-art goods. Furthermore, Segerstrom and Dinopoulos (2004) analyzes the effect of globalization through an increase in the size of the South, but does not study the effect of moving from autarky to trade, which is of interest here. Also, the growth rate of the two regions is semi-endogenous and is a function of the population growth rate, while here the equilibrium growth rate is a result of the interaction of the innovation and imitation mechanisms and is also affected by the IPR policy.

The rest of the paper is organized as follows: section 2 presents the two scenarios (autarky, free trade and restricted trade) and solves for the steady-state equilibrium analytically, section 3 analyzes the effect of a stronger IPR protection numerically, section 4 concludes and suggests steps for future research.

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1.2 Autarky

1.2.1 The Model

The model considers two regions, the North and the South, which differ in the abilities to conduct R&D and in the wages (w) their workers earn, with Northern wage higher than that in the South ($w_N(t) > w_S(t)$). As presented in the figure below, there is a continuum of goods in the world market indexed by $z(t) \in [-\infty, n_N(t)]$. Each good is characterized by a higher quality than the preceding one. Innovation is conducted by the North and each successful innovation results in a new variety with increased quality compared to the previous one. The North produces the whole range of existing varieties, $[-\infty, n_N(t)]$, where $n_N(t)$.grows through innovation. Workers in the South conduct imitative R&D and the highest quality variety copied by the South is $n_S(t)$, being inside the range of varieties produced in the North. The distance between the highest quality varieties produced in the North and the South is of measure d, i.e. $d(t) = n_N(t) - n_S(t)$.

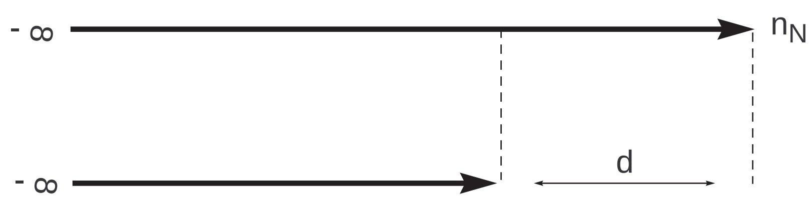

Figure 1.1: Autarky

Thus, the production in the two regions overlaps up to the variety $n_N(t) - d$, while varieties $[n_N(t) - d, n_N(t)]$ have not been copied and are produced only by the North. As there is no trade, the consumption bundles of the two regions are different and consist only of the varieties produced domestically.

Consumers

The population in both regions is fixed and it is of measure L_N and L_S in the North and the South, respectively. Each individual supplies one unit of labor inelastically and earns the wage (w). The wage is the same in both sectors of the economy, the manufacturing and R&D, w_N in the North and w_S in the South. Labor is not mobile between the regions.

Consumers in both regions have the same preferences and they maximize lifetime utility of the following form

$$U = \int_0^{\infty} e^{-\rho t} \ln u(t) dt, \tag{1.1}$$

with $\rho > 0$ as the discount factor and $u(t)$ the instantaneous utility given by

$$u(t) = \left\{ \int_{-\infty}^{n(t)} [(e^{\gamma})^{z\frac{(1-\alpha)}{a}} x(z,t)]^{\alpha} dz \right\}^{\frac{1}{\alpha}} = \left\{ \int_{-\infty}^{n(t)} e^{\gamma z(1-\alpha)} x(z,t)^{\alpha} dz \right\}^{\frac{1}{\alpha}}. \tag{1.2}$$

Utility at time t is a quality-augmented CES consumption index with $x(z,t)$ as the consumption of variety z of quality index $e^{\gamma z(1-\alpha)}$. Variable γ measures the size of quality improvement of each successive variety and is equal for both North and South. The parameter α measures the substitution between varieties, with $\frac{1}{1-\alpha}$ as the elasticity of substitution. With $0 < \alpha < 1$, consumers prefer goods of higher quality (higher z).

Given prices, consumers maximize the instantaneous utility subject to their individual expenditure on all goods ($C(t)$). This is a problem of static optimization across varieties

$$\max \left\{ \int_{-\infty}^{n(t)} e^{\gamma z(1-\alpha)} x(z,t)^{\alpha} dz \right\}^{\frac{1}{\alpha}} \quad \text{subject to} \quad C(t) = \int_{-\infty}^{n(t)} p(z,t)x(z,t)dz \tag{1.3}$$

which gives the optimal demand for each variety

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$$x(z,t) = \frac{(p(z,t)/e^{\gamma z(1-\alpha)})^{\frac{1}{\alpha-1}}}{\int_{-\infty}^{n(t)} (p(z,t)^{\alpha}/e^{\gamma z(1-\alpha)})^{\frac{1}{\alpha-1}} dz} C(t) = p(z,t)^{\frac{1}{\alpha-1}} e^{\gamma z} \frac{C(t)}{P(t)^{\frac{\alpha}{\alpha-1}}}. \quad (1.4)$$

The demand function takes the familiar form, where the share of each variety in the total consumption is given by the share of its quality-price ratio in the index of price-quality ratios of all varieties consumed (P).

With equal price of all varieties in a region (to be proved later), the demand function in the North and the South, respectively, can be simplified to

$$x_N(z,t) = \frac{1}{p_N(t)} \gamma e^{\gamma(z-n_N(t))} C_N(t) \quad (1.5)$$

$$x_S(z,t) = \frac{1}{p_S(t)} \gamma e^{\gamma(z-n_N(t)+d)} C_S(t). \quad (1.6)$$

Dynamic optimization of the lifetime utility given (2), (3) and the budget constraint

$$\dot{A}(t) = w(t) - C(t) + r(t)A(t), \quad (1.7)$$

where $A(t)$ represents individual assets and $r(t)$ the market interest rate at time t, results in the Euler condition

$$\frac{\dot{C}(t)}{C(t)} = r(t) - \rho. \quad (1.8)$$

Expenditure grows only when the market interest rate exceeds subjective discount factor. This paper will analyze a steady-state equilibrium in which wages (w_N and w_S) and expenditures (C_N and C_S) do not change over time, and thus, market interest rate is constant and equal to the subjective discount factor.

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Production

The North conducts costly innovative R&D, where the cost depends on the amount of labor employed in the research and the productivity of the R&D technology. When a new variety is invented, the producer that buys the blue-print becomes a monopolist. This is due to the fact that under Bertrand competition, no other Northern firm will have an incentive to copy a variety at any time. Its entry into the market and the competition with the first successful innovator would drive profits down to zero and would not allow for covering the R&D costs of imitation. For that reason, there is no need for any instrument of the IPR protection domestically. Each good requires one unit of labor for production, so the firm faces a marginal cost equal to wage w_N. The monopolist determines the product price by maximizing profits subject to the consumers demand

$$\max p(z,t)x(z,t) - wx(z,t) \quad \text{subject to (1.5)} \tag{1.9}$$

yielding the optimal monopoly price

$$p_N(z,t) = p_N = \frac{1}{\alpha} w_N, \tag{1.10}$$

which is constant and equal across varieties. This implies that the consumers' demand across varieties increases with the quality level, but the demand for each variety decreases over time due to invention of the higher quality varieties.

The South is involved in the imitative R&D and incurs costs depending on the R&D labor and the productivity of copying, which will also determine the highest quality level copied. When a variety is copied successfully, the imitator becomes a monopolistic producer using one unit of labor per good, so the marginal cost equals wage w_S. The firm charges the monopoly price which is needed to compensate for the cost of the blue-print

$$p_S(z,t) = p_S = \frac{1}{\alpha} w_S. \tag{1.11}$$

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As in the North, under Bertrand competition, no other Southern firm will have an incentive to copy an already copied product since its entry drives profits down to zero and does not allow for covering the R&D costs of copying a copy.

Both regions firms earn profits only at the local markets, and the profits are given by

$$\Pi_N(z,t) = p_N x_N(z,t)L_N - w_N x_N(z,t)L_N = (1-\alpha)\gamma e^{\gamma(z-n_N(t))} C_N L_N \quad (1.12)$$

$$\Pi_S(z,t) = p_S x_S(z,t)L_S - w_S x_S(z,t)L_S = (1-\alpha)\gamma e^{\gamma(z-n_N+d)} C_S L_S. \quad (1.13)$$

At any time t, the innovator's and the imitator's profits increase in total expenditure ($C_N L_N$, $C_S L_S$) and quality jump (γ), but they decrease over time as the quality level of the particular variety decreases relative to the highest quality produced.

R&D Processes

The North employs labor of measure $R_N(t)$ in research which, if successful, results in the invention of a new good of higher quality. The innovation is characterized by a difficulty parameter $\beta > 0$, with $\frac{1}{\beta}$ as the productivity of innovation. The R&D technology is modeled as

$$\hat{\gamma}_N(t) = \frac{R_N(t)}{\beta}. \quad (1.14)$$

$\hat{\gamma}_N(t)$, as the effective research labor, represents the growth rate of the quality index in the North

$$e^{\gamma(t)(1-\alpha)z^N(t)} = e^{\gamma(t)(1-\alpha)z_o^N} e^{\hat{\gamma}_N(t)t}. \quad (1.15)$$

The specification above implies that $\gamma(t)(1-\alpha)z^N(t) = \gamma(t)(1-\alpha)z_o^N + \hat{\gamma}_N(t)t$, and taking derivative with respect to time, one obtains $\dot{\gamma}(1-\alpha)z^N(t) + \gamma(t)(1-\alpha)\dot{z}^N = \dot{\gamma}(1-$

$\alpha)z_o^N + \frac{d\hat{\gamma}_N(t)}{dt}t + \hat{\gamma}_N(t)$. From the left-hand side, the technological progress comes in two forms, the invention of new goods and the increase in quality, which we might call extensive and intensive margins of change, respectively. Diverging from the common practice found in the growth literature, where the size of each quality jump is taken as constant and exogenous when analyzing the endogenous innovation rate, the assumption here is exactly the opposite. The invention frequency is exogenous and new products arrive along with time, i.e. $\dot{z}^N = 1$. However, the size of quality improvement with each new product is left free to be determined endogenously. In this way, the ranges of varieties can also be regarded as the measure of time, so that d in fact represents the lag of South in time. The analysis in this paper focuses on the balanced growth path (BGP) with a constant growth rate of the quality index ($\frac{d\hat{\gamma}_N(t)}{dt} = 0$) and the constant size of endogenous quality jumps ($\dot{\gamma} = 0$), so that the last expression, with $\dot{z}^N = 1$, collapses to

$$\gamma(1-\alpha)\dot{z}^N = \gamma(1-\alpha) = \hat{\gamma}^N$$

Imitation is conducted by the Southern R&D labor of measure $R_S(t)$, with the difficulty parameter $\theta(d) > 0$, which is proportional to β, but depends on the North-South distance. Namely, it can be argued that as the South attempts to imitate more intensively and decrease the quality gap relative to the North, the copying process increases in difficulty, and thus, θ is assumed to be a decreasing function of d. This factor of proportionality to β is given by the ratio of the highest quality in the South and the one in the North.[2] An additional parameter, η, with $\eta \geq 1$, represents the degree of the IPR protection by the North and directly affects the difficulty (productivity) of copying.[3] Therefore, the productivity of copying ($\frac{1}{\theta}$) is decreasing in η and increasing in d. With the free flow of information ($\eta = 1$) and no distance in quality ($d = 0$), θ becomes equal to β.

[2]See Acemoglu et al.(2006) and Stryszowski (2006) for similar modeling of imitational R&D productivity.

[3]Mansfield et al. (1981) finds that patents rarely hinder imitation but make it more expensive. This closely corresponds to the idea of making imitation more difficult, and thus more labor demanding and more costly, which would be the interpretation of η.

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$$\theta(d) = \eta\beta \frac{e^{\gamma(n_N - d)(1-\alpha)}}{e^{\gamma n_N (1-\alpha)}} = \eta\beta e^{-\gamma d(1-\alpha)}. \tag{1.16}$$

The effective Southern research labor, $\hat{\gamma}_S(t)$, gives the growth rate of the quality index in the South

$$\frac{R_S(t)}{\theta(d)} = \hat{\gamma}_S(t) \tag{1.17}$$

$$e^{\gamma(t)(1-\alpha)z^S(t)} = e^{\gamma(t)(1-\alpha)z_o^S} e^{\hat{\gamma}_S(t)t}. \tag{1.18}$$

As for the North, $\dot{\gamma} = 0$ and $\frac{d\hat{\gamma}_S(t)}{dt} = 0$ at the BGP, so that $\gamma(1-\alpha)\dot{z}^S = \hat{\gamma}^S$. The main trade-off in this paper is expressed in the relation between the intensive margin of innovation, given by γ, and the imitation distance coming from the South, given by d, in a steady-state equilibrium. To analyze this relation, this paper focuses on a steady-state equilibrium in which the quality distance $d = n_N - n_S$ between the North and the South is constant. This implies that for each new variety invented, one more variety is copied. In other words, $\dot{z}$ is the same in both regions, so it equals 1 in the South as well. Finally, this implies that $\hat{\gamma} = \gamma(1-\alpha)$ which is equal in both regions.

R&D Optimization

The expected benefit of a successful R&D effort, the value of a new variety, is represented by expected discounted profits from innovating or copying in the North and the South, respectively. Having assumed that $\frac{dz}{dt} = \dot{z} = 1$, it is convenient in computational sense to discount the profit flows over the index z, since, under given assumptions, it is equivalent to discounting over time.

With wages, prices and expenditures constant over time, profits change due to the growth in the price index. Therefore, the values of a new variety (V_N) and a copy (V_S) are given by

DOI: 10.2870/13739

$$V_N = (1-\alpha)\gamma e^{\gamma n_N} C_N L_N \int_{n_N}^{\infty} e^{-\gamma z} e^{-r(z-n_N)} dz = (1-\alpha)\frac{\gamma}{\gamma+r} C_N L_N \tag{1.19}$$

$$V_S = (1-\alpha)\gamma e^{\gamma(n_N-d)} C_S L_S \int_{n_N-d}^{\infty} e^{-\gamma z} e^{-r(z-n_N+d)} dz = (1-\alpha)\frac{\gamma}{\gamma+r} C_S L_S \tag{1.20}$$

The value of introducing a new variety is increasing in the total consumer expenditure and size of the quality jump, while it is decreasing in the elasticity of substitution between varieties.

The entry into the R&D races is free and all participants have access to the same R&D technology, so the benefits of winning a race will equal the costs of R&D in a steady-state equilibrium.

Given the specification of the R&D technology, research labor required for each innovation in the North is given by

$$R_N = \beta\gamma(1-\alpha), \tag{1.21}$$

and with w_N as the cost of each unit of the research labor, the optimal R&D condition (arbitrage condition) in the North is given by

$$V_N = w_N \beta\gamma(1-\alpha) \tag{1.22}$$

Combining this condition with the expression for the value of a new variety, V_N, it yields

$$\frac{1}{\gamma+r} C_N L_N = w_N \beta. \tag{1.23}$$

Similar derivation applies also to the South. Research labor needed for one new copy is given by

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$$R_S = \theta(d)\gamma(1-\alpha), \tag{1.24}$$

which, with the wage w_S, yields the arbitrage condition in the South

$$\frac{1}{\gamma + r} C_S L_S = w_S \theta(d). \tag{1.25}$$

Labor Markets

Full employment of labor requires that in both regions at any time t all workers are employed in either R&D sector or manufacturing. Under the assumption of $dz = dt$, at each point in time, the total R&D labor in either region is actually equal to the labor requirement for the development of one new product or a copy given by (1.21) for the North and (1.24) for the South. Therefore, the full employment labor market conditions for the two regions are given by

$$L_N = R_N + \int_{-\infty}^{n_N} D_N L_N dz = \beta\gamma(1-\alpha) + \frac{C_N L_N}{p_N} \tag{1.26}$$

$$L_S = R_S + \int_{-\infty}^{n_N - d} D_S L_S dz = \theta(d)\gamma(1-\alpha) + \frac{C_S L_S}{p_S} \tag{1.27}$$

1.2.2 Steady-State Equilibrium Analysis

Combining the full labor employment conditions, (1.26) and (1.27), with the R&D optimization conditions given by (1.23) and (1.25) for the North and the South, respectively, two steady-state equilibrium conditions are obtained,

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$$L_N = \beta\gamma(1-\alpha) + \frac{w_N\beta}{p_N}(\gamma + r) = \beta(\gamma + r\alpha) \tag{1.28}$$

$$L_S = \theta(d)\gamma(1-\alpha) + \frac{w_S\theta(d)}{p_S}(\gamma + r) = \theta(d)(\gamma + r\alpha). \tag{1.29}$$

The Northern condition determines the endogenous size of the quality jump (γ) as

$$\gamma = \frac{L_N}{\beta} - r\alpha. \tag{1.30}$$

The quality jump depends positively on the productivity of the R&D labor, $\frac{1}{\beta}$, while a higher interest rate and a larger α (higher elasticity of substitution) decrease γ due to their negative impact on the value of the innovation.[4] In the autarky scenario, the quality lag of the South has no impact on the quality jump which is solely determined by the conditions of the North. This results in the vertical Northern condition in the (γ, d) space in the autarky steady state equilibrium diagram (Figure 1.2).

The Southern equilibrium condition determines the quality lag (d) as a function of γ,

$$d = \frac{1}{1-\alpha}\ln\left(\frac{L_N}{L_S}\eta\right)\frac{1}{\gamma} \tag{1.31}$$

Higher γ implies smaller quality distance between the North and the South, as it increases the value of imitation and R&D labor productivity in the South, which together counteracts the increase in the R&D labor cost. In autarky, γ comes as "manna from North" whose increase results in a higher productivity in the South, reallocation of labor towards the R&D sector and a faster catch-up. Therefore, the Southern equilibrium condition is downward

[4]The model exhibits scale effect, which might not be of concern in a model with no population growth. Moreover, in the free trade scenario, the scale effect appears only in a relative form, where the quality lag depends on the ratio of the regions' sizes. In this model, scale effect could be corrected for by assuming that the number of industries is proportional to the population size.

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sloping in Figure 1.2. The elasticity of substitution and the degree of information protection both increase the distance as they decrease the value of copying and the productivity of imitative R&D labor.

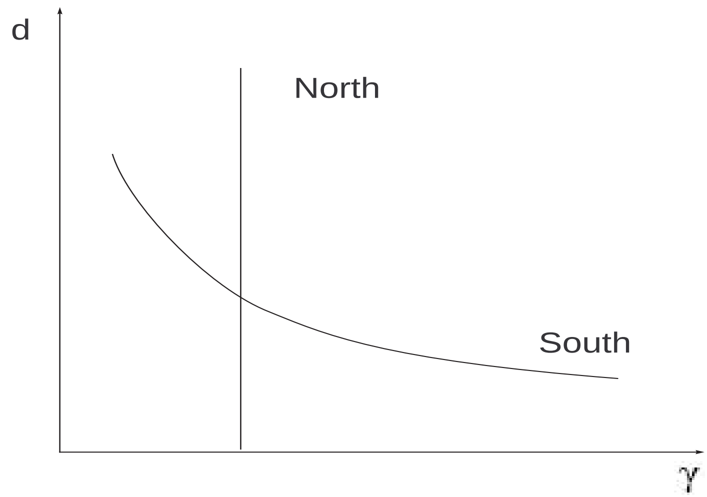

Figure 1.2: Steady state equilibrium in autarky

As by the construction of the model, the quality lag of the South cannot be negative, the assumption $L_N \geq L_S$ is imposed. This restriction might seem too strong if the labor sizes are expressed in absolute terms of the population sizes. However, as the model does not include measures of the human capital and assumes equal productivity in the manufacturing sector in the North and in the South, the labor sizes might be regarded in terms of the effective labor size. In that sense, the assumption implies that the total effective labor in the North is at least as large as the total effective labor in the South. This paper focuses on the analysis of the effects of opening to trade, and not the analysis of the autarky itself, and therefore the human capital measure has been left out in order to keep the analysis simple and focus on the differences in the R&D productivities.

Consumers in both regions maximize their lifetime utility subject to their budget constraint given by the expression for the change in assets they possess, A, i.e. $\dot{A} = w - C + rA$. Under the assumption of financial autarky, the growth rate of assets, given by $\frac{\dot{A}}{A} = \frac{w-C}{A} + r$, is constant in a steady-state equilibrium with constant w, C and r. It follows that A is constant which implies $C - w = rA$, and in aggregate form

$C_N L_N = w_N L_N + r\bar{A}_N$ in the North, and

$C_S L_S = w_S L_S + r\bar{A}_S$ in the South. $\bar{A}_N$ represents total Northern assets, which are equal to the sum of the values of all existing firms in the North at time t, while $\bar{A}_S$ stands for the total assets in the South, equal to the sum of the values of all copies at a given time t. Therefore, $\bar{A} = \int_0^\infty V(a)da$, where $V(a)$ stands for the value of a periods old firm at time t. This yields the expenditure conditions

$$C_N L_N = (1-\alpha) r w_N \beta + w_N L_N \quad (1.32)$$

$$C_S L_S = (1-\alpha) r w_S \theta(d) + w_S L_S \quad (1.33)$$

Utility in both regions is equal to $\frac{C}{P}$, and with constant consumer expenditure, the utility growth is given by the negative of the growth of the quality-price index

$$\frac{\dot{u}}{u} = \frac{1-\alpha}{\alpha}\frac{de^{\gamma n}}{dt}\frac{1}{e^{\gamma n}} = \frac{1-\alpha}{\alpha}\gamma = (1-\alpha)(\frac{L_N}{\alpha\beta} - r). \quad (1.34)$$

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1.3 Trade

1.3.1 The Model

The paper now considers two regions, the North and the South, which are open to trade. The South still produces varieties up to the one at d distance from the highest quality variety in the North. Since $w_N > w_S$, the South can produce these varieties at a lower cost and due to free trade, it is no longer optimal for the North to continue their production. However, the range of varieties that have not been copied by the South, $[n_N(t) - d, n_N(t)]$, are produced and traded exclusively by the North. As presented in the figure below, there is a continuum of goods in the world market indexed by $z(t) \in [-\infty, n_N(t)]$, but there is no overlapping in the production as in the autarky case; the South specializes in the production and trade of low quality varieties, while the North specializes in the high quality ones. The IPR protection policy is still represented by the degree of information protection which affects the difficulty of copying.

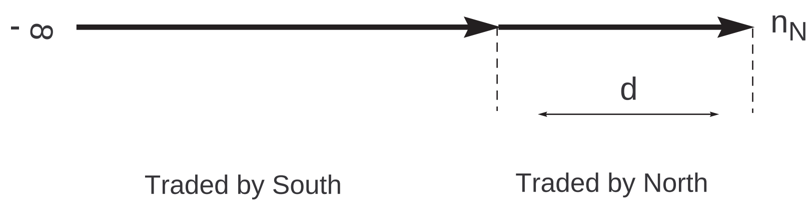

Figure 1.3: Trade

The composition of the consumption bundles is the same in both regions, as Southern consumers have access to the whole range of varieties due to trade. Since all world consumers are buying a particular variety at the same price (markup over the marginal cost in the region of production), the quality-price index is the same in both regions.

$$P_N = P_S = \left\{ \frac{1}{\gamma} e^{\gamma n_N} \left[p_N^{\frac{\alpha}{\alpha-1}} (1 - e^{-\gamma d}) + p_S^{\frac{\alpha}{\alpha-1}} e^{-\gamma d} \right] \right\}^{\frac{\alpha-1}{\alpha}} \tag{1.35}$$

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As in the autarky, the North (the South) conducts innovative (imitative) R&D and after a new variety is invented, each unit of good requires one unit of labor for production. The monopolist, innovator or imitator, determines the product price by maximizing profits subject to the consumers demand which again, yields the optimal monopoly price.

$$p_i(z,t) = p_i = \frac{1}{\alpha} w_i. \qquad i = N, S \tag{1.36}$$

However, the revenue now comes from both domestic and foreign market, and for the North it comes from sales of the $[n_N(t) - d, n_N(t)]$ range of varieties, while the South sells varieties in the range $[-\infty, n_N(t) - d]$. The value of a new variety or a new copy is determined as the discounted stream of profits from the domestic and the foreign market over the period of firm's operation. However, the life of a variety in the North is now not infinite but terminates at the time it is successfully copied by the South, i.e. d periods after the invention. Therefore, the time span over which the profits are discounted is different in the North and the South, and the values of innovation and imitation are given by

$$V_N = \frac{1-\alpha}{\alpha} w_N p_N^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \frac{CL}{\tilde{P}} (1 - e^{-(\gamma+r)d}) \tag{1.37}$$

$$V_S = \frac{1-\alpha}{\alpha} w_S p_S^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \frac{CL}{\tilde{P}} e^{-\gamma d}, \tag{1.38}$$

where $\tilde{P} = P^{\frac{\alpha}{\alpha-1}} e^{-\gamma n_N}$ and $CL = C_N L_N + C_S L_S$. Both values are functions of the total world demand, however, they are also functions of different life length of a new variety, compared to the autarky. In the North, this comes as the explicit cut of the variety life from below, represented by the $(1 - e^{-(\gamma+r)d})$ term, as the North loses the production of low quality varieties. In the South, this life span change does not come in the form of the finite life of a variety, but rather as an implicit cut of its life from above, as the highest quality in the South is no longer the highest one consumers allocate their expenditure to. In that sense, $e^{-\gamma d}$ term represents the loss in quality position relative to the highest in the market, and

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thus the loss in the variety's demand share relative to the total consumers demand. The R&D technology is defined in the same way as in the autarky scenario, and the arbitrage conditions for the North and the South, obtained by equalizing the benefits and costs of R&D, are given by

$$\frac{1}{\alpha} p_N^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \frac{CL}{\tilde{P}} (1 - e^{-(\gamma+r)d}) = \beta\gamma \tag{1.39}$$

$$\frac{1}{\alpha} p_S^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \frac{CL}{\tilde{P}} e^{-\gamma d} = \theta(d)\gamma \tag{1.40}$$

1.3.2 Steady-State Equilibrium Analysis

The full employment labor market conditions for the two regions are given by

$$L_N = \beta\gamma(1-\alpha) + p_N^{\frac{1}{\alpha-1}} \frac{1}{\gamma} \frac{CL}{\tilde{P}} (1 - e^{-\gamma d})] \tag{1.41}$$

$$L_S = \theta(d)\gamma(1-\alpha) + p_S^{\frac{1}{\alpha-1}} \frac{1}{\gamma} \frac{CL}{\tilde{P}} e^{-\gamma d}, \tag{1.42}$$

which, when combined with the arbitrage conditions in the North and the South, (1.38) and (1.39), yield the first two steady-state equilibrium conditions, endogenous in γ and d

$$L_N = \beta\gamma(1-\alpha) + \alpha\beta(\gamma + r)\frac{1 - e^{-\gamma d}}{1 - e^{-(\gamma+r)d}} \tag{1.43}$$

$$L_S = \theta(d)(\gamma + \alpha r) \tag{1.44}$$

In the free trade scenario, the size of the quality jump is not determined exclusively by the North, but also depends on the conditions of the South, so that γ and d are jointly determined by the two equations above.

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The third endogenous variable in the model is the relative wage ω, defined as $\frac{w_N}{w_S}$. Dividing the Northern arbitrage condition by that of the South yields the following condition

$$\omega^{\frac{1}{1-\alpha}} = \frac{\frac{1}{\beta}(1 - e^{-(\gamma+r)d})}{\frac{1}{\theta(d)}e^{-\gamma d}}. \tag{1.45}$$

The relative wage is proportional to the ratio of R&D productivities, corrected by the terms referring to the varieties lifetime. Thus, the relative wage in fact comes from the ratio of factual productivities in creating the value of new businesses in the two regions. When simplified, the relative wage condition determines ω as

$$\omega = \left[(1 - e^{-(\gamma+r)d})e^{\gamma d\alpha}\eta\right]^{1-\alpha}. \tag{1.46}$$

Both γ and d have a positive impact on the relative wage, and so does the degree of information protection which decreases the productivity of copying. For the model to be one of the North-South trade, it is necessary for monopolistic price in the South to be lower than the competitive price in the North. Therefore, the equilibrium ω has to be at least $\frac{1}{\alpha}$.[5] From the condition above, it follows that the equilibrium distance in the trading world has to be positive. Moreover, the size of the quality jump is positive in order to satisfy the wage condition for any value of η and the equilibrium condition (1.43).

Proposition 1.1. *The size of the quality jump, γ, increases with opening to trade.*

Proof. With $\gamma, \eta > 0$, the term $\frac{1-e^{-\gamma d}}{1-e^{-(\gamma+r)d}}$ is necessarily smaller than 1. For the equilibrium condition (1.43) to be satisfied, γ in the free trade scenario has to be larger than γ in the autarky that satisfies the condition (1.28), which completes the proof. ■

[5]With a wide range of parameters used in the numerical exercise, ω proves to be larger than 1 α. Even when this is not the case, relative wage never becomes lower than one. That calls for the limit pricing with the maximum price in the South being equal to the marginal cost in the North, without any loss in generality of the results.

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The mechanism behind this effect comes from the fact that varieties now live only d periods in the North. This translates in the loss of the value of innovation represented by $1 - e^{-(\gamma+r)d}$, which implies that the innovators need larger quality jump to ensure higher demand and their survival in the market. At the same time, the cut in the life of varieties corresponds to the loss in the production of the whole range of low quality varieties in the aggregate, those that are now produced exclusively by the South. Thus, the total demand for Northern production and therefore manufacturing labor depends only on $1 - e^{-\gamma d}$ share of expenditures. The excess manufacturing labor is being reallocated to the R&D sector, which in turn raises γ, the demand for new varieties and for production labor. The process continues until the full employment is restored, but as a result of more resources devoted to R&D, γ is necessarily higher, compared to autarky.

The life of any variety introduced and produced in the South is still infinite, so the Southern equilibrium condition is of the unchanged form, however, γ and d in equilibrium will be different. The effect of the increased size of the quality jump on the North-South distance in quality will now depend on the parameters of the model and will be analyzed in the numerical exercise. d in free trade is given by

$$d = \frac{1}{1-\alpha}\ln\left(\frac{\eta\beta(\gamma+\alpha r)}{L_S}\right)\frac{1}{\gamma} \tag{1.47}$$

Proposition 1.2. *Quality lag of the South, d, increases with opening to trade.*

Proof. In the special case with no IPR protection ($\eta = 1$) and equal size of population ($L_N = L_S$), the proof is straightforward. The distance of the South in the autarky given by equation (1.31) is equal to zero. In the trade scenario, with an increase in γ, the term $\beta(\gamma + \alpha r)$ is larger than L_N and thus, $\ln(\frac{\eta\beta(\gamma+\alpha r)}{L_S}) > 0$. Therefore, $d > 0$ in the trade equilibrium. For $\eta > 1$ and $L_N > L_S$, see Appendix B. for proof. ■

Intuitively, opening to trade reveals the specialization pattern which comes about as a result of the comparative advantage in the innovation/imitation and production of different

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ranges of varieties in the North and in the South, high and low quality ranges respectively. The loss of the low quality varieties allows the North to reallocate labor to comparatively more productive R&D sector as it gets freed from the manufacturing of the low quality varieties. The South concentrates on the production of the low quality range for the world market.

Free trade steady state equilibrium is presented in Figure 1.4, in (γ, d) space. In comparison with the autarky scenario both the North and the South conditions are changed. The Northern condition is now downward sloping, implying a negative relation between γ and d. Namely, with the larger lag of the South, on one hand, the North faces lower competitive pressure from the South due to increased life of varieties, and thus a lower incentive for R&D, and on the other hand it has to produce a larger range of varieties. Both effects work in favor of reallocating labor to manufacturing which results in the lower quality jump. Compared to the autarky scenario, the Southern steady state condition is perhaps more striking. In the free trade case, the conditions are upward sloping. An increase in the size of the quality jump now results in an increase of the quality lag, as the rising value of imitation and R&D labor productivity no longer counteract the increase in the R&D labor cost. This is the result of a drop on the quality ladder of the highest quality good in the South relative to the highest in the market, which was not the case in the autarky.

The role of η as the measure of the IPR protection will be analyzed in the numerical exercise, but it should be noted that by affecting productivity of copying and thus the quality distance of the South, η has an effect on γ in the free trade, and therefore on the common growth rate in both regions, still given by

$$\frac{\dot{u}}{u} = \frac{1-\alpha}{\alpha}\gamma. \tag{1.48}$$

Trade is balanced and the increase in the size of the market caused by the opening to trade has no direct effect on the endogenous variables of the model. What plays the central

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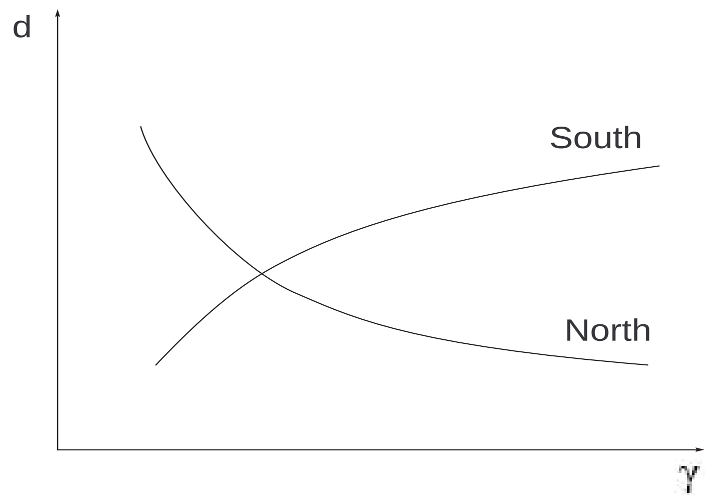

Figure 1.4: Steady state equilibrium with trade

role is the competition effect which brings along the specialization in different ranges of varieties, and thus the static and dynamic benefits of trade.

Proposition 1.3. *Welfare in both regions, the North and the South, increases with their opening to trade, while it is decreasing with the tightening of the IPR protection (increase in* η*).*

Proof. See Appendix C. ■

1.4 The IPR protection

This section investigates the impact of increasing information protection (η) on the size of the quality jump (γ) and thus the growth rate of the economy, on the North-South distance in quality (d), relative wage (ω) and the relative utility (welfare). The effect of η on other variables of interest, mainly concerning the R&D sector and the value of innovation/imitation, are reported as well, while the details of the parametrization and the calibration of the model are given in the Appendix. In all exercises, the degree of information protection (IPR protection) varies from 1 which stands for a completely free flow of information regarding the blue-prints, to 1.4, a 40% tighter information flow.

Figure 1.5 presents the results in the autarky scenario. Higher protection of information by the North and thus, higher difficulty of copying in the South, has no effect on the growth rate, but increases the quality lag of the South. With the free flow of information, the North-South quality gap is closed as the South completely converges to Northern frontier through copying.

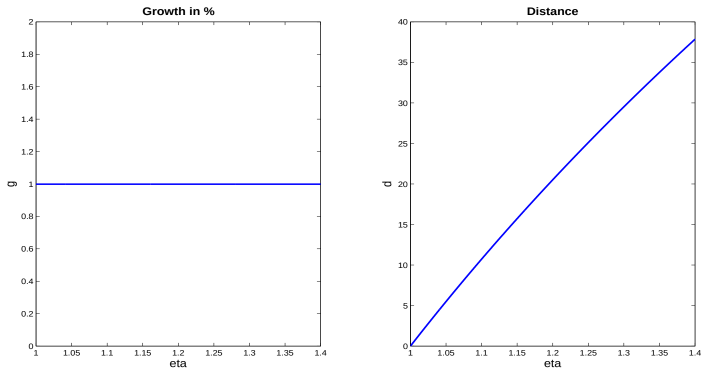

Figure 1.5: Autarky: The effect of increase in IPR protection

When the two regions are open to trade (Figure 1.6), γ and d are determined simultaneously by the equilibrium conditions from the North and the South. For any level of η, the

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size of the quality jumps and also the quality lag of the South are both higher compared to the autarky results for the reasons discussed in the previous section. In the free trade scenario, the effect of η on the distance also translates into the change in the size of the quality jump. With the higher information protection, γ and the welfare in both regions decrease, while the relative wage increases.

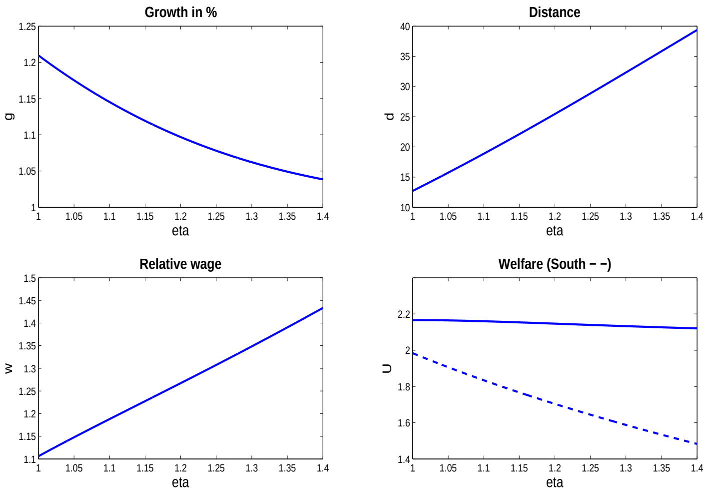

Figure 1.6: Trade: The effect of increase in IPR protection

The effect of η on the quality lag is positive as in the autarky case, though the distance is not zero even in the case of free information sharing. It might be concluded that trade necessarily brings incentives for the specialization of both regions, no matter how weak the IPR protection policy is. This results contradicts the common fear of the developed North that the South might overtake all manufacturing industry from the North due to violation of the IPR.

In most R&D driven growth models, higher protection of monopoly rights would bring about an incentive to increase R&D effort, which is not the case here (Figure 1.7). Raising η raises the value of innovation in the North. However, due to the increase in the wage it also raises the cost of R&D more than proportionally and puts a downward pressure on the

R&D labor demand. Together with the growing lag of the South and thus higher demand for the manufacturing labor in the North, this results in a lower R&D effort and a decrease in γ, until the arbitrage condition is satisfied.

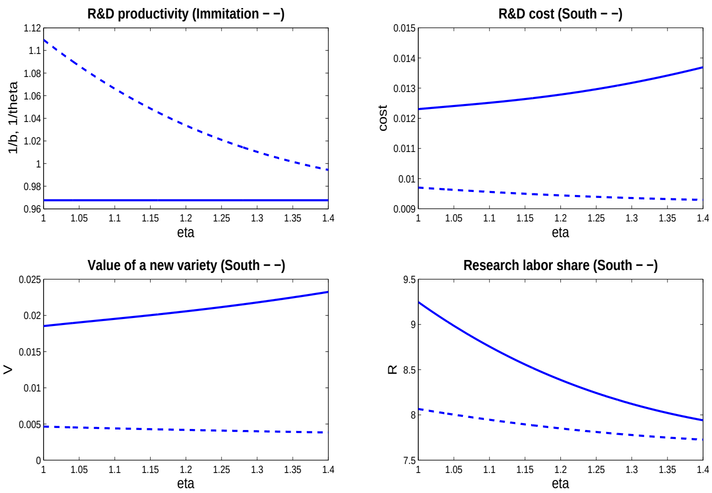

Figure 1.7: Trade: The effect of increase in IPR protection on R&D variables

Intuitively, stronger IPR protection is not enhancing growth but relieving the monopolists from the competitive pressure. In the South, an increase in η lowers the productivity of copying, and with the lower quality jump also results in a lower value of imitation, which cannot be compensated for by the decrease in the R&D cost. This brings about a decrease in the Southern research labor and a higher d. Besides the dynamic loss in growth, the static loss in both Northern and Southern welfare comes as a result of the lower quality jump and the increase in the price index (higher relative wage and higher d).

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1.5 Conclusion

The topic of this paper has been the impact of trade and the IPR protection on the intensive margin of innovation (size of quality jumps) and the extensive margin of imitation (distance in quality, i.e. quality lag of the South) in a steady-state equilibrium. The motivation behind the proposed theoretical framework stems from the recent empirical evidence on the North-South trade patterns which reveals the regions' specialization in different qualities of the same product within industries, and much less in different products or different industries. By considering a model of North-South trade with the endogenous R&D processes in both regions, innovation in the North and imitation in the South, the paper attempts to derive the resulting growth and welfare effects of opening to trade and changes in the IPR in order to provide possible answers to some questions brought by globalization. Two alternative scenarios are considered: the autarky case as a benchmark and the free trade case employing information protection ("intensive" IPR policy tool).

Based on the analytical and numerical analysis, it is found that opening to trade increases the growth rate of both regions while it also results in a larger lag in the quality level in the South, implying the appearance of specialization in the South. Also, the quality lag of the South is always positive in the trading world, contradicting the predictions of the Southern catch-up due to intellectual theft.

Stronger IPR protection is not enhancing growth but relieving the monopolists from the competitive pressure. Besides the dynamic loss in growth, the static loss in both Northern and Souther welfare comes as a result of the lower quality jump and the increase in the price index (higher relative wage and higher d).

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1.6 Appendix A: Calibration

Two parameters in this model can be determined empirically (r, α), while the rest of the parameters,(β, L_N, L_S, η), remain to be calibrated.

The interest rate is set equal to subjective discount factor and taken to be 0.04 (4 percent).

Most empirical studies show evidence on monopolistic mark-ups in the range of 10-40%, with the lowest ones being in the manufacturing industry. Since the model of interest in this paper mostly refers to such industries (with stronger monopolistic competition, less regulation and a larger number of producers), α is set closer to the lower bound at 0.89 which implies 12% mark-up and the elasticity of substitution between varieties of 8.

As there is no human capital in the model and due to presence of scale effects in the relative terms, equal size of the North and the South in the benchmark case is assumed, in order to abstract from the relative size effects. Nevertheless, the most important findings of the model prove to be robust to the changes in the relative size of the two regions. There are three calibration targets:

1) 1.5-2% growth of the economy

2) Northern relative wage of 2.2 (World Bank, International Comparison Program database, online edition, 2009) which in turn gives benchmark IPR protection, η of 2.25. However, since this paper examines the impact of IPR protection (η) ranging from free information flow ($\eta = 1$) to stronger levels of protection ($\eta > 1$), the resulting relative wage with low protection will be lower. Had the model included the measure of human capital, that parameter could have been calibrated to match the size of the relative wage independent of η. In that sense, η now includes more information than IPR protection. It measures the overall productivity of the labor in the two regions, stemming from the level of the human capital and the institutional quality in the two regions.

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3) 2% share of resources devoted to R&D relative to GDP in the North (average for OECD countries; National Science Foundation, US, http://www.nsf.gov/statistics)

The resulting parameter values are 1.0335 difficulty of innovation, β (0.97 productivity of innovation) and 0.1203 size of the population, L.

1.7 Appendix B

Proof of Proposition 2. with $\eta > 1$ and $L_N > L_S$

The quality distance in the autarky and the trade scenario are given by the condition

$$d = \frac{1}{1-\alpha}\ln(\frac{\eta\beta(\gamma+\alpha r)}{L_S})\frac{1}{\gamma}$$

In autarky, $\eta\beta(\gamma+\alpha r) = L_N$ while in the trade equilibrium this term will increase due to increase in γ. However, γ enters the condition in the $\frac{1}{\gamma}$ term, and the direction of the change in d with opening to trade depends on the derivative $\frac{dd}{d\gamma}$.

$$\begin{aligned}\frac{dd}{d\gamma} &= \frac{1}{1-\alpha}\frac{1}{\gamma}\Big(-\frac{1}{\gamma}\ln\frac{L_S}{\eta\beta(\gamma+r)} + \frac{1}{\gamma+\alpha r}\Big) \\ &= \frac{1}{\gamma+\alpha r} - (1-\alpha)d.\end{aligned}$$

For initial d not too large, such that it satisfies $d < \frac{1}{(1-\alpha)(\gamma+\alpha r)}$, the quality distance of the South increases with opening to trade. This also provides proof for the upward sloping Southern equilibrium condition in (γ, d) space.

1.8 Appendix C

Proof of Proposition 3.

Welfare in the North in the autarky and the trade scenario, respectively, is given by

$$U_N^A = [L_N - (1-\alpha)\beta\gamma]\left[\frac{e^{\gamma n}}{\gamma}\right]^{\frac{1-\alpha}{\alpha}}$$

in the autarky, and

$$U_N^T = [L_N - (1-\alpha)\beta\gamma]\left[\frac{e^{\gamma n}}{\gamma}\right]^{\frac{1-\alpha}{\alpha}}[\omega^{\frac{\alpha}{1-\alpha}}e^{-\gamma d} + 1 - e^{-\gamma d}]^{\frac{1-\alpha}{\alpha}}$$

in the trade scenario. The last term in the trade expression is larger than one, while the second term represents the average quality index in the North which increases with opening to trade due to an increase in γ, provided that the number of varieties, n, is large enough to satisfy $n\gamma > 1$. The first term in the welfare expression is the manufacturing labor which decreases with opening to trade. Therefore, the direction of change in the welfare is determined by the prevailing effect, an increase in average quality or decrease in manufacturing labor and thus lower production. If $n\gamma > 1$, the numerical solution shows that the positive effect dominates and the welfare increases with opening to trade.

Welfare in the South in the autarky and the trade scenario, respectively, is given by

$$U_S^A = \alpha\theta(d)(\gamma + r)\left[\frac{e^{\gamma(n-d)}}{\gamma}\right]^{\frac{1-\alpha}{\alpha}}$$

in the autarky, and

$$U_S^T = \alpha\theta(d)(\gamma + r)\left[\frac{e^{\gamma(n-d)}}{\gamma}\right]^{\frac{1-\alpha}{\alpha}}\left[1 + \omega^{\frac{\alpha}{\alpha-1}}(e^{\gamma d} - 1)\right]^{\frac{1-\alpha}{\alpha}}$$

in the trade scenario. The analysis is similar to that of the effect of opening to trade on the welfare in the North. The last term in the trade expression is larger than one, while the second term, the average quality index, increases if $n\gamma > 1$. The first term is the manufacturing

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labor which decreases with opening to trade. Assuming $n\gamma > 1$, the numerical solution shows that the welfare in the South increases with opening to trade.

The effect of increased IPR protection on welfare in the North and the South in the autarky equilibrium is different. While there is no change in the Northern welfare with an increase in η, the welfare in the South decreases

$$\frac{dU_S^A}{d\eta} = -\frac{1}{\alpha} e^{-\ln \eta \frac{1+\alpha}{\alpha}} \alpha\beta(\gamma + r) \left[\frac{e^{\gamma n}}{\gamma}\right]^{\frac{1-\alpha}{\alpha}} < 0$$

In the trade scenario, numerical solution shows a decrease in both the Northern and the Southern welfares with stronger IPR protection.

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Chapter 2

Welfare Effects of IPR Policy in a North-South Trade Model

2.1 Introduction

Given the rapid increase in trade activity between the innovating North and the imitating South, the issues of the Intellectual Property Rights (IPR) protection at the international level have become a common topic in the economics literature and policy agendas. It is often argued that the South enters the race by the means of unfair competition, through imitation and intellectual theft and thus hurts the incentives for innovation in the North. From the perspective of the South, there are fears that tightening of the IPR protection policy may impose significant impediment to development in the South. This paper analyzes the welfare effects of the international IPR protection in a model of North-South trade and endogenous growth which is in accordance with the empirical evidence on current world trade patterns.

The new trade data reveals an international trade specialization of the North and the South in varieties of different quality level (high and low, respectively) within the same product groups and the same industries. Therefore, the standard conception of North-South head-on competition in the same market segments has been loosing empirical grounds. The benchmark framework considers an endogenous R&D model of the two regions where the

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North conducts innovating R&D, which results in the creation of new varieties, each of a higher quality than the preceding one. The South is involved in the imitation of Northern products but at a certain lag. With opening to trade, the two regions specialize in the production and export in different quality segments of the market, the North specializing in high quality and the South in the low one.

There are two questions to consider. The first question concerns the welfare and growth implications of the perfectly enforceable patents of finite length, implying no copying of protected varieties, neither for domestic consumption nor for the export to the North. The equilibrium results in the optimal patent length scenario are compared to those in the free information flow scenario in which there are no other impediments to imitation by the South but its own productivity in the R&D sector. As for the second question, having in mind the practical difficulty in implementing and enforcing patent rights internationally, the main assumption is the lack of patent enforceability. Although the North cannot prevent the South from imitating, it can ensure that Southern copies of protected varieties are not placed in the Northern markets.[1] In that scenario, trade occurs only in goods which are produced exclusively by one region; goods whose patents have expired are traded by the South, while the North produces and trades high quality goods that are too advanced to be imitated. The middle range varieties are not traded. In such a set-up, the paper analyzes the effects of alternative IPR policy measures on the welfare and growth prospects of the two regions. In particular, it should be determined whether an intensive form of protection (knowledge flow restriction or secrecy) or the extension of the patent length can serve as a substitute for the poor IPR enforcement in the South.

Besides the old debate on the importance of the IPR protection for promoting R&D in a closed economy, a large body of literature has dealt with the issue of international harmonization of the IPR protection, especially after this topic was included in the official

[1]Under most patent laws, the imitators in the South are not allowed to export copies to the Northern market, which along with the poor protection of IPR implies the interpretation of the patent as a certain form of trade barrier.

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WTO discussion agenda.[2] Depending on a model set-up, the results related to the effects of the IPR protection have been mixed.[3] Nevertheless, it is important to note that, apart from the R&D incentive effects of the IPR protection within a country, there is an additional, comparative advantage dimension of the analysis within a trading world, particularly when the countries with different levels of technological development are involved. Thus, any study of the IPR issues within such framework should take into account the benefits of specialization even if it requires a faster North-South technological transfer than what would otherwise occur under perfect protection.

In general, most studies on North-South trade, growth and IPR introduce only a certain policy parameter measuring the level of protection in terms of how hard (legally or technically) it is to copy a product successfully, but once that occurs, a copy competes freely with the original in the market, and normally wins the battle due to lower costs. This IPR instrument corresponds to the notion of information protection here. However, in a framework that assumes differentiation of goods based on quality that is tied to the timing of the invention, protection in the form of patent (time) has a fundamentally different effect. Those two IPR instruments can not be regarded as the same: the first one affects the difficulty of copying directly, the other affects the timing of copying or the export ban lifting. Thus, patents and secrecy deserve separate consideration, as the individual producers' profits, and the resulting aggregate labor allocation and the investment in R&D are affected in different ways, through different mechanisms.

Dinopoulos et al. (2008a) considers a North-South growth and trade model where the IPR protection is introduced as the finite-length, perfectly enforced global patents which are awarded to Northern firms that discover new higher-quality products. They show that an increase in the global patent length worsens the wage gap between the North and the South, increases the rate of imitation and has an ambiguous effect on growth. However, if the number

[2]The WTOs Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), was negotiated in the 1986-94 Uruguay Round and it imposed the intellectual property rules into the multilateral trading system.

[3]See, e.g. Scotchmer (2003), Saint-Paul (2007), Lai and Qiu (2003), McCalman (2001).

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of protected industries is high, then an increase in the patent length reduces the innovation and growth rates. Dinopoulos et al. (2008b) analyzes the IPR policy harmonization based on a stronger Southern protection and finds that a move towards better harmonization accelerates the global rates of innovation and growth, reduces the North-South wage gap, and has an ambiguous effect on the rate of technology transfer. When there is a common patent policy regime, then a stronger global IPR protection increases the rates of innovation, growth and international technology transfer, and has no impact on the North-South wage gap. The novelty in this paper is that it models the imitational R&D in the South in a way that the R&D productivity decreases as the South attempts to copy products from the higher position on the quality scale. It is found that the natural distance of the South in the equilibrium is positive even with no IPR protection. However, the welfare optimizing patent length, from the perspective of the North, is positive and larger than the natural distance of the South, but it necessarily reduces the welfare of the South and growth in both regions. The result stems from the fact that patents do not enforce incentives for R&D. On the contrary, they only protect the monopoly rents, increase the wage gap and the cost of R&D in both regions, and thus reduce the innovation in the North, and imitation and welfare in the South. Higher Northern welfare comes only as a result of a higher wage. Compared to the social optimum, welfare and growth in both regions are reduced, as the patent distorts the optimal specialization pattern of the two regions over quality.

As far as the second part of the paper is concerned, Lai and Qiu (2004) investigate the interaction of the IPR and trade protections and their impact on Northern and Southern welfare. They find a rationale for a higher Northern tariff when protection is weak in the South. While the IPR protection comes through finite patents and the trade protection through tariffs, in this paper the instruments are somewhat opposite. The IPR protection is based on secrecy and the trade barrier is an IPR policy instrument - finite patents. Namely, when patents are not enforced to prevent copying, they might allow the North to prevent import of protected varieties and therefore serve as a trade barrier. Although the analogy might seem obvious, the results are significantly different. In this paper, increased protectionism in any

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form results in a lower welfare in the South, while increasing information protection up to a certain point might increase the welfare in the North. This positive effect does not occur when the trade barrier is increased. Furthermore, growth effects are always negative, and neither global nor individual region's welfare can attain the levels of the no-IPR protection world.

The rest of the paper is organized as follows: section 2 presents the model of enforceable patents and compares the results with the no-patent scenario, section 3 assumes non-enforced patents and analyzes the effect of the two IPR instruments in a numerical exercise, while section 4 concludes.

2.2 No IPR protection vs. perfectly enforced patents

2.2.1 The Model

The benchmark model for the analysis of the enforceable patent impact on welfare and growth is presented in the free trade scenario section of Chapter 1. The model considers two regions, the North and the South, which have different R&D capabilities and wages, with $w_N(t) > w_S(t)$. There is a continuum of goods in the world market indexed by $z(t) \in [-\infty, n_N(t)]$, where higher index $z(t)$ also implies that the good is of higher quality. Innovation is conducted by the North and each successful innovation results in growth of $z(t)$, i.e. a new good of higher quality than the one previously invented is introduced in the market. Workers in the South conduct imitative R&D and the highest quality variety copied by the South is $n_S(t)$. The distance between the highest qualities produced in the North and the South is of measure d, i.e. $d(t) = n_N(t) - n_S(t)$. Both regions are open to trade. Since $w_N > w_S$, the South can produce varieties up to variety $n_N(t) - d$ at a lower cost and due to free trade it is no longer optimal for the North to continue their production. However, the range of varieties that have not been copied by the South, $[n_N(t) - d, n_N(t)]$, are produced and traded exclusively by the North.

Consumers in both regions have the same preferences and they maximize lifetime utility of the following form

$$U = \int_0^{\infty} e^{-\rho t} \ln u(t) dt, \tag{2.1}$$

with $\rho > 0$ as the subjective discount factor, and $u(t)$ the instantaneous utility given by

$$u(t) = \left\{ \int_{-\infty}^{n(t)} [(e^{\gamma})^{z\frac{(1-\alpha)}{\alpha}} x(z,t)]^{\alpha} dz \right\}^{\frac{1}{\alpha}} = \left\{ \int_{-\infty}^{n(t)} e^{\gamma z(1-\alpha)} x(z,t)^{\alpha} dz \right\}^{\frac{1}{\alpha}}. \tag{2.2}$$

Utility at time t is a quality-augmented CES consumption index where $x(z,t)$ is the consumption of variety z of quality index $e^{\gamma z(1-\alpha)}$. Variable γ, equal for both North and

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South, determines the size of quality improvement of each successive variety. Parameter α measures the substitution between varieties, with $\frac{1}{1-\alpha}$ as the elasticity of substitution.

With trade, the composition of the consumption bundle is the same in both regions as all varieties are placed in both markets. With no variable trade cost, the price of any variety is the same in the North and South and thus, the quality-price index is the same in both regions.

$$P_N = P_S = \left\{ \frac{1}{\gamma} e^{\gamma n_N} \left[p_N^{\frac{\alpha}{\alpha-1}} (1 - e^{-\gamma d}) + p_S^{\frac{\alpha}{\alpha-1}} e^{-\gamma d} \right] \right\}^{\frac{\alpha-1}{\alpha}}. \tag{2.3}$$

In both regions one unit of labor produces one unit of output and the market structure is monopolistic competition. The monopolist (innovator or imitator) determines the product price by maximizing profits subject to the consumers demand which yields the optimal monopoly price,

$$p_i(z,t) = p_i = \frac{1}{\alpha} w_i, \qquad i = N, S. \tag{2.4}$$

The revenue of each firm comes from both domestic and foreign market. Firms in the North produce $[n_N(t) - d, n_N(t)]$ range of varieties, while firms in the South produce varieties in the range $[-\infty, n_N(t) - d]$. The value of a new variety or a new copy is determined as the discounted stream of profits over the period of a firm's operation. The life of a variety in the North is not infinite but terminates at the time it is successfully copied by the South, i.e. d periods after the invention[4].

The North and the South employ labor R_N and R_S, respectively, in the R&D sector with the productivity $1/\beta$ in the North and $1/\theta(d)$ in the South. The effective R&D labor (R_N/β and $R\ \theta(d)$) gives the growth rate of the quality index in each region. In a stationary equilibrium with constant measure of quality jumps, γ, and constant growth of the quality index, this growth rate is given by $\gamma(1-\alpha)$ and is equal in both regions. The arbitrage

[4]The invention frequency is exogenous and new products arrive along with time, i.e. $\dot{z} = 1$, but the size of quality improvement with each new product is determined endogenously. Therefore, the ranges of varieties is also the measure of time, so that d represents the lag of South in time.

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conditions for the North and the South equalize the benefits and costs of R&D and are given by

$$\frac{1}{\alpha}p_N^{\frac{1}{\alpha-1}}\frac{1}{r+\gamma}\frac{CL}{\tilde{P}}(1-e^{-(\gamma+r)d})=\beta\gamma \tag{2.5}$$

$$\frac{1}{\alpha}p_S^{\frac{1}{\alpha-1}}\frac{1}{r+\gamma}\frac{CL}{\tilde{P}}e^{-\gamma d}=\theta(d)\gamma. \tag{2.6}$$

The full employment labor market conditions for the two regions are combined with the arbitrage conditions (2.5) and (2.6) to the first two steady-state equilibrium conditions, both endogenous in γ and d,

$$L_N = \beta\gamma(1-\alpha)+\alpha\beta(\gamma+r)\frac{1-e^{-\gamma d}}{1-e^{-(\gamma+r)d}} \tag{2.7}$$

$$L_S = \theta(d)(\gamma+\alpha r) \tag{2.8}$$

The third equilibrium condition determines the relative wage given as the ratio of effective productivities of the R&D sectors in the two regions. The distance between the highest qualities produced in the North and the South, d, in the no-patent scenario is given by

$$d=\frac{1}{1-\alpha}\ln\left(\frac{\eta\beta(\gamma+\alpha r)}{L_S}\right)\frac{1}{\gamma}. \tag{2.9}$$

With higher elasticity of substitution between varieties, higher interest rate and a less open flow of information (η higher than 1), the equilibrium d will be higher.

As a benchmark, η is set equal to 1, so that, under no restrictions in the form of patents, there is no international IPR protection. After solving for the equilibrium of this scenario, a patent of finite length T is introduced. The patents do not serve as the domestic IPR protection since copying of the products in the same region is not optimal, but rather represent a form of international protection. It is assumed that patents impose perfect protection: there is no imitation by the South up to the variety of index $n_N(t)-T$. In that sense, T acts as exogenously imposed d for the South, so that the highest quality attainment of the

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South is not an endogenous outcome in the equilibrium, but a constraint imposed by the North which optimizes its welfare. Finally, this section considers a social planner who maximizes the global welfare and determines the optimal distance of the South, i.e. the optimal patent length. The equilibrium welfare and growth in both regions in the three scenarios are compared.

2.2.2 Numerical exercise

The dotted lines in Figure 2.1 represent the no-patent equilibrium values of growth rate and welfares in the North and the South, respectively, with the resulting equilibrium quality distance of the South at 14.5 years. The full lines represent the equilibrium values under patents of length T, which is found to be optimal for the North at the value of 19.5 years. The assumption of a perfectly free information flow ($\eta = 1$) is kept in order not to interfere the effects of the patents with the effects of the alternative IPR protection instrument.

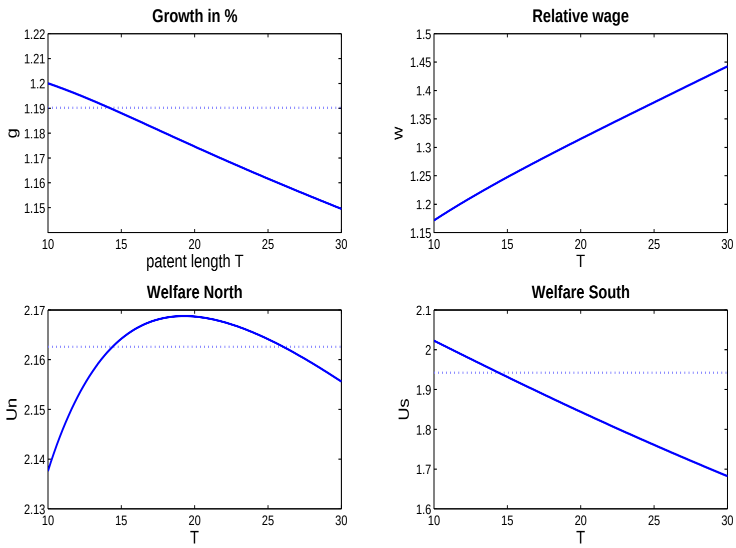

Figure 2.1: No IPR protection vs. perfectly enforced patents

As shown in Figure 1, there are both growth and welfare effects of introducing fully enforced patents, compared to the no IPR protection scenario. As the optimal patent length for the North is higher than the endogenous distance of the South, the life of any variety in the North is now longer, which results in an increase in the demand for manufacturing labor in that region. On the other hand, as the relative wage rises, the products from the North become relatively more expensive for the consumers, putting a downward pressure on the demand for Northern products. However, the first effect is larger, and thus the decrease in research labor results in a fall in γ and the growth rate (1.14% decrease) until the equalibrium in the labor market is restored. Figure 1 shows substantial welfare changes as opposed to the no protection scenario, but of different signs for the North and the South. Since the rise in the relative wage is more than proportional to the rise in the price index, Northern welfare increases (0.27% increase), while the welfare in the South is reduced (4.54% decrease) due to the negative effect of the increase in the price index (lower quality and higher prices, common to both regions). More importantly, the total world welfare is reduced by 2%.

The positive effect of increasing the patent length on Northern welfare is not present when the IPR protection is tightened through an increase in the information protection. In that case, stronger protection raises the overall difficulty of copying directly and increases the lag of the South faster. The increase in the relative wage is not high enough to compensate for the faster increase in the price index, which comes due to a slower transfer of production to the low-cost South.

It might be reasonable to assume that when strong IPR protection in the form of patents is imposed, not only that copying is prohibited for T range of varieties, but the productivity of copying is reduced for any particular distance from the quality frontier point. In other words, besides direct impediments for imitational R&D, patents might also impose an indirect impediment for the transfer of general knowledge and degrade the process of the imitator's knowledge accumulation. This corresponds to an increase in η that comes along with the introduction of patents. In this case, the effect on growth is negative and so is the effect on both Northern and Southern welfares, as opposed to the world with unrestricted knowledge diffusion. With a 10% higher η, optimal patent length increases to 25 years. The relative wage increase is not big enough to counteract the rise in the price index for the North and

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the welfare is reduced. In the South, welfare losses come as a result of a higher price index. Global welfare now drops by 5.34%.

2.2.3 Social optimum

This section introduces a social planner who maximizes global welfare and decides on the optimal patent length, T^{sp}, and labor allocation between the manufacturing and the R&D sector. The social planner associates a certain weight to each region's utility, with $(1-\delta)$ and δ, $\delta \in [0,1]$, as the weights on consumers' utility in the North and the South, respectively. The constraints social planner faces are given by: (1) total labor resources, (2) production technology, (3) the law of motion for the quality index in the North and the South, i.e. the R&D sector technology, and (4) the trade balance which is now expressed in terms of quantities, and the shadow values of input factors and traded output between the two regions.[5] The social planner's problem is given as

$$
\begin{aligned}
\max U^{sp} &= \int_0^\infty e^{-\rho t} \ln u(t) dt \qquad \text{subject to} \qquad (2.10)\\
u(t) &= (1-\delta)u^N(t) + \delta u^S(t)\\
R_N &+ L_N^p \leq L_N\\
R_S &+ L_S^p \leq L_S\\
x(z) &= l(z)\\
\dot{q}^N &= \frac{R^N}{\beta} q^N\\
\dot{q}^S &= \frac{R^S}{\theta(d)} q^S\\
X^{Sexp} &= \bar{\omega} X^{Nexp},
\end{aligned}
$$

where L^p represents manufacturing labor, q the quality index, $\bar{\omega}$ the rate et which goods are exchanged in the international market, and X^{exp} the quantity exported. The social planner takes into account that the efficient allocation would imply symmetry of $\frac{x(z)}{e^{\gamma z}}$ ratios across

[5]See Grossman and Helpman (1992), Chapter 6.

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the goods produced in the same region, and thus the instantaneous utility, $u(t)$, can be expressed as a function of total labor employed in manufacturing (for domestic consumption and export) and the quality index, q.

Figure 2.2 presents the optimal labor allocation between the manufacturing and the R&D sector in the North, and the optimal patent length, T^{sp}. The first panel gives the solutions of a planner who is concerned only with the welfare of the North, the middle panel assumes equal weights on the welfare in the North and the South, while in the third panel the planner associates full weight to the consumers in the South. The circled areas present the combination of R&D labor share and patent length that result in the highest global welfare, given the weights on each region's utility.

Compared to the results of a decentralized equilibrium, the panels show an increase in the research labor share in the North, resulting in a higher growth rate (11.1% with $\delta = 0$), and a shorter optimal patent lenght for all values of δ. Global welfare exhibits a substantial increase compared to the decentralized outcome. With δ increasing from 0 to 1 (from full weight on u^N to full weight on u^S), the optimal patent length increases from 2.5 to 4.2 years, while the welfare is the highest when the weights on the two region's utilities are the same (49% increase compared to decentralized equilibrium results).

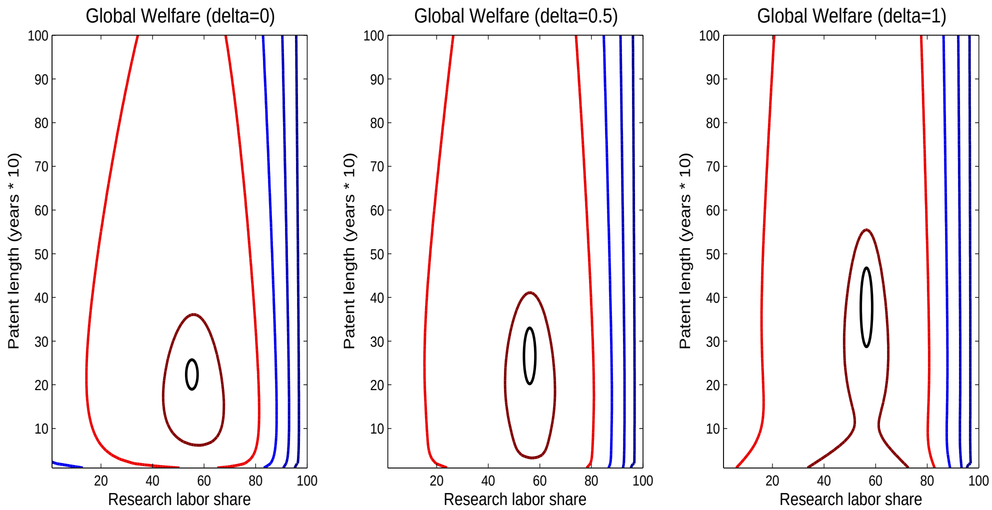

Figure 2.2: Social planner's solution

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From a social point of view, there is no rationale for promoting longer patents as a way of promoting innovation in the North and welfare in both regions. As the social planner's optimal patent length is smaller even than the natural distance of the imitating South with no IPR protection, it comes as straightforward to call for optimal government policy which would restore static and dynamic efficiency using instruments other than the IPR protection.

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2.3 Non-perfect enforcement (restricted trade)

2.3.1 The Model

In the restricted trade scenario patents of a finite length are introduced, but are no longer assumed to be enforced. Patents cannot prevent the South from imitating, but allow the North to ban the copies of the protected originals from its market. Since the South produces these varieties at a lower cost, it has no incentive to import them from the North, so that there is an interval of nontraded varieties, those that are protected in the North and already copied by the South. Thus, the trade occurs only in the ranges in which the regions are sole producers; the North imports low quality varieties, $[-\infty, n_N(t) - T]$, while the South imports the high quality range, $[n_N(t) - d, n_N(t)]$.

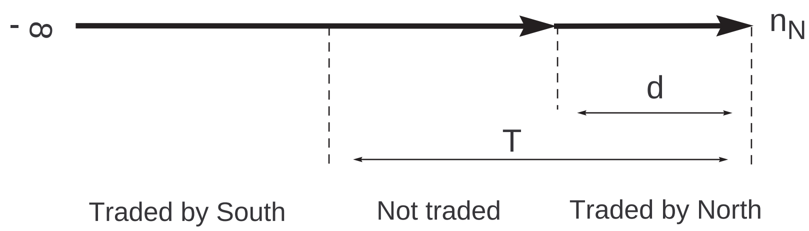

Figure 2.3: Restricted trade

The bundles consumed by the North and the South are of the same composition. However, the prices of varieties in the non-traded range are now different in the two markets. Therefore, the price-quality indices in the North and the South are different, and given by

$$P_N = \left\{ \frac{1}{\gamma} e^{\gamma n_N} \left[p_N^{\frac{\alpha}{\alpha-1}} (1 - e^{-\gamma T}) + p_S^{\frac{\alpha}{\alpha-1}} e^{-\gamma T} \right] \right\}^{\frac{\alpha-1}{\alpha}} \tag{2.11}$$

$$P_S = \left\{ \frac{1}{\gamma} e^{\gamma n_N} \left[p_N^{\frac{\alpha}{\alpha-1}} (1 - e^{-\gamma d}) + p_S^{\frac{\alpha}{\alpha-1}} e^{-\gamma d} \right] \right\}^{\frac{\alpha-1}{\alpha}} .$$

The value of a new variety or copy is determined as a discounted stream of profits over the periods of firms' operation. The production of a variety in the North does not cease with its successful imitation but only after the patent expires. Once it has been copied, the variety is no longer shipped to the South which produces it on its own, but it is still placed in the Northern market. Therefore, both Northern and Southern producers do not earn export profits over the whole period of operation, which is taken into account when discounting. The values of innovation and imitation are given by

$$\begin{aligned} V_N &= \frac{1-\alpha}{\alpha} w_N p_N^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \left[\frac{C_N L_N}{\tilde{P}_N} (1 - e^{-(r+\gamma)T}) + \frac{C_S L_S}{\tilde{P}_S} (1 - e^{-(r+\gamma)d}) \right] \qquad (2.12) \\ V_S &= \frac{1-\alpha}{\alpha} w_S p_S^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \left[\frac{C_N L_N}{\tilde{P}_N} e^{-r(T-d)} e^{-\gamma T} + \frac{C_S L_S}{\tilde{P}_S} e^{-\gamma d} \right], \end{aligned}$$

with $\tilde{P}_i = P_i^{\frac{\alpha}{\alpha-1}} e^{-\gamma n_N}$, for $i = N, S$. Equating the value of a new variety (copy) with the cost of innovation (imitation) yields the arbitrage conditions in the North and the South respectively

$$\begin{aligned} \frac{1}{\alpha} p_N^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} \left[\frac{C_N L_N}{\tilde{P}_N} (1 - e^{-(r+\gamma)T}) + \frac{C_S L_S}{\tilde{P}_S} (1 - e^{-(r+\gamma)d}) \right] &= \beta\gamma \qquad (2.13) \\ \frac{1}{\alpha} p_S^{\frac{1}{\alpha-1}} \frac{1}{r+\gamma} [\frac{C_N L_N}{\tilde{P}_N} e^{-r(T-d)} e^{-\gamma T} + \frac{C_S L_S}{\tilde{P}_S} e^{-\gamma d}] &= \theta(d)\gamma \end{aligned}$$

Full labor employment requires that all workers are allocated either to manufacturing or R&D sectors which translates into the following conditions

$$\begin{aligned} L_N &= \beta\gamma(1-\alpha) + p_N^{\frac{1}{\alpha-1}} \frac{1}{\gamma} \left[\frac{C_N L_N}{\tilde{P}_N} (1 - e^{-\gamma T}) + \frac{C_S L_S}{\tilde{P}_S} (1 - e^{-\gamma d}) \right] \qquad (2.14) \\ L_S &= \theta(d)\gamma(1-\alpha) + p_S^{\frac{1}{\alpha-1}} \frac{1}{\gamma} \left[\frac{C_N L_N}{\tilde{P}_N} e^{-\gamma T} + \frac{C_S L_S}{\tilde{P}_S} e^{-\gamma d} \right] \end{aligned}$$

Assumed financial autarky implies that in every period export revenues of the two regions are the same, thus the trade balance condition has to be satisfied. This condition holds also in the free trade scenario, but due to no non-traded varieties, price-quality index is the same in both regions and the demand for any product is a share of the total world expenditure

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divided by the common index. Here, price indices differ and the trade balance condition is used to facilitate solving the model. The condition is given as

$$\frac{C_N L_N}{P_N^{\frac{\alpha}{\alpha-1}}} = \frac{C_S L_S}{P_S^{\frac{\alpha}{\alpha-1}}} \omega^{\frac{\alpha}{\alpha-1}} e^{\gamma T}(1-e^{-\gamma d}) \tag{2.16}$$

Combining the arbitrage conditions, 2.13, with the labor market conditions, (2.14), and using the trade balance, two out of three steady-state equilibrium equations are derived. The third equation comes from the arbitrage conditions combined with the trade balance, which completes the equilibrium system of the three equations endogenous in γ, d and ω.

$$L_N = \beta\gamma(1-\alpha) + \beta\alpha(r+\gamma)\frac{(1-e^{-\gamma T}) + \omega^{\frac{\alpha}{1-\alpha}} e^{-\gamma T}}{(1-e^{-(r+\gamma)T}) + \omega^{\frac{\alpha}{1-\alpha}} e^{-\gamma T}\frac{(1-e^{-(r+\gamma)d})}{(1-e^{-\gamma d})}} \tag{2.17}$$

$$L_S = \theta(d)\gamma(1-\alpha) + \theta(d)\alpha(r+\gamma)\frac{e^{-\gamma T} + \omega^{\frac{\alpha}{1-\alpha}}\frac{e^{-\gamma(T+d)}}{(1-e^{-\gamma d})}}{e^{-(r+\gamma)T}e^{rd} + \omega^{\frac{\alpha}{1-\alpha}}\frac{e^{-\gamma(T+d)}}{(1-e^{-\gamma d})}} \tag{2.18}$$

$$\omega^{\frac{1}{1-\alpha}} = \frac{(1-e^{-(r+\gamma)T}) + \omega^{\frac{\alpha}{1-\alpha}} e^{-\gamma T}\frac{(1-e^{-(r+\gamma)d})}{(1-e^{-\gamma d})}}{e^{-(r+\gamma)(T-d)} + \omega^{\frac{\alpha}{1-\alpha}}\frac{e^{-\gamma T}}{(1-e^{-\gamma d})}}\eta e^{\gamma d\alpha} \tag{2.19}$$

As in the free trade scenario, equilibrium conditions in the restricted trade case can be compared to those in the autarky (Chapter 1). The manufacturing labor is necessarily lower than in the autarky, which implies reallocation of workers towards R&D and an increase in the size of quality jumps. However, the magnitude of this change is now affected also by the patent length T and the equilibrium relative wage, which makes the analytical analysis complicated enough to call for a numerical solution.

2.3.2 Numerical exercise

Figures 2.4 and 2.5 present the results of a numerical solution in the restricted trade scenario, and the effects of different IPR policy measures introduced by the North (an increase

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of η and an increase of patent length T, respectively).[6] Compared to the optimal enforced patent case, the size of quality jumps is smaller for any level of protection, while the distance and the relative wage are reduced. That contributes to a higher welfare in the South, but a lower one in the North. The social planner's welfare levels are still the highest. However, in a decentralized economy, if the South is copying, the North will find it optimal to impose patents. In turn, if there is a possibility of not enforcing the patent and keeping the trade partners, the South will find this strategy to be the optimal one.

More interestingly, the two channels of the IPR policy measures (information protection or patent length) have different welfare effects. The important issue is whether a change in any of the two IPR instruments decided by the North could compensate for the poor enforceability of the patents and restore the equilibrium welfare and growth rate under the enforced patent (dotted lines in figures 2.4 and 2.5). For a given $T = 19.5$, which corresponds to the optimal enforceable patent length for the North, an increase in η results in a rise of the quality lag of the South (Figure 2.4).[7]

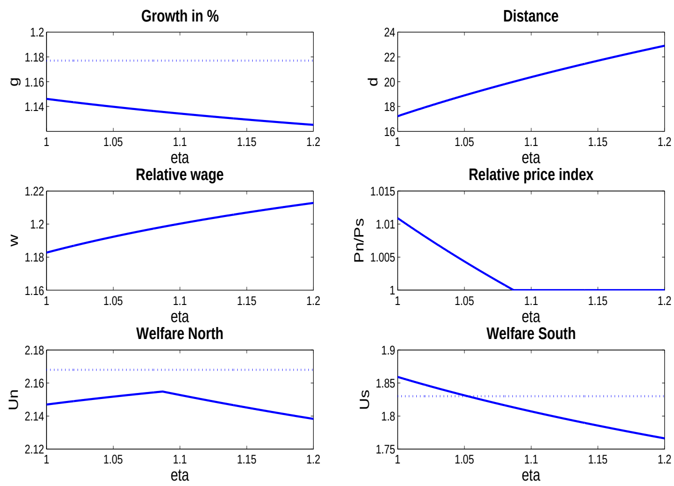

Figure 2.4: Non-enforced patents: effects of the information protection

[6]The calibration procedure is the same as that used in the previous chapter. See Appendix of Chapter 1 for details.

[7]$T = 19.5$ is also very close to the general US patent length of 20 years.

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For a change in η up to a certain level, the increase in the distance of the South does not affect the composition of the domestic and imported bundles of the North, i.e. the goods are still obtained from the same producer. With a rise in the relative wage, Northern goods are more expensive, resulting in an increase in the price index. However, the rise in the relative wage more than compensates for this increase in the price index and the Northern welfare rises. On the other hand, the South not only pays higher prices for Northern goods as the relative wage rises, but pays high price on more goods that are now too difficult to copy. Therefore, the Southern welfare necessarily decreases. At the same time, the relative price index falls. For an increase in η larger than 8%, the distance of the South becomes larger than the patent length, and the North has to continue with the production of some of the goods that are no longer protected but are also not copied by the South. This hurts the price index in the North as it can no longer import some of the cheap varieties from the South. At that point, the rise in the relative wage does not cover for the rise in the price index and the Northern welfare starts decreasing. It is important to note that even though the initial increase in the intensive IPR protection has a positive effect on the welfare in the North, it is not possible to reach the welfare levels of the optimal (fully enforced) patent scenario by substituting the lack of patent enforceability with the information flow restriction. Moreover, the effect on the welfare in the South is negative for any change in η.

The same conclusion holds for the change in the other policy instrument, patent length. In fact, increasing the patent length in order to compensate for bad enforcement is welfare reducing for both regions, for any change in T (Figure 2.5).

For a given η, an increase in the patent length brings about an increase in the relative price index, which is an effect opposite from the one of the previously analyzed IPR policy tool. Rise in the quality distance is pushing up the price index in the South due to an increase in the relative wage. Southern welfare decreases, but longer T, on the other hand, implies that now the North imports fewer varieties as more copies are banned, and thus pays higher prices for more low quality varieties (the composition effect). It turns out that the

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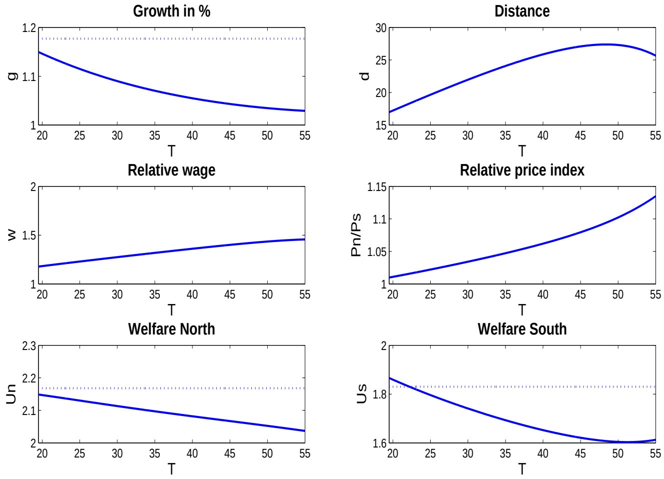

Figure 2.5: Non-enforced patents: effects of the patent length increase

latter effect always dominates the wage effect and the welfare in the North decreases, as well. Moreover, it is not only that the price index composition effect is much stronger, but the rise in the relative wage is not as strong as in the previous scenario. Namely, longer patent increases d, but does not hurt the productivity of the R&D labor in the South, and therefore does not affect the relative wage to a large extent. On the other hand, an increase in η has a direct negative effect on the R&D productivity in the South which results in a stronger relative wage rise.

At lower patent lengths, the increase in the relative wage is still strong enough to secure a rising relative utility, but compared to the effect of η, the rise in the relative utility is now slower. For an even larger patent length, d starts falling and the relative wage (expenditure) increase is not sufficient to reverse the strong effect the rising relative prices have on the utility. As a result, the relative welfare falls. In other words, by increasing the patent length, the North does not only hurt the welfare of both regions, but may do so to a larger extent in the case of its own consumers.

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2.4 Conclusion

This paper considered an endogenous R&D model of the two regions where the North conducts innovating R&D, which results in the creation of new varieties, each of a higher quality than the preceding one. The South is involved in the imitation of Northern products but at a certain lag. With opening to trade, the two regions specialize in the production and export in different quality segments of the market, the North in high quality and the South in the low one, which supports the empirical findings on current world trade patterns.

The model was used to address two questions, the welfare and growth implications of perfectly enforced patents of finite length compared to the no-IPR protection scenario, and the effects of alternative IPR policy measures when patents are poorly enforced.

The imitational R&D productivity in the South decreases as the South attempts to copy products from the higher position on the quality scale, and thus, it is found that the natural distance of the South in the equilibrium will be positive even with no IPR protection. The welfare optimizing patent length, from the perspective of the North, is positive and larger than the natural distance of the South, but it necessarily reduces the welfare of the South and growth in both regions. This is due to the fact that patents do not enforce incentives for R&D, but only protect the monopoly rents, increase the wage gap and the cost of R&D in both regions. This in turn reduces both the innovation and the imitation, and the welfare of the South. An increase in the welfare of the North comes only as a result of a higher wage. Compared to the social optimum, welfare and growth in both regions are reduced, as the optimal specialization pattern of the two regions over quality becomes distorted.

The goal of the second part of the analysis was to determine whether an intensive form of protection (the knowledge flow restriction, secrecy) or the extension of the patent length can serve as a substitute in the case when patents are not enforced in the South. The results show that increased protectionism in any form results in lower welfare in the South, while increasing information protection might increase welfare in the North up to a certain point. However, growth effects are always negative, and neither global nor individual region's welfare can attain the welfare levels of the no-IPR protection world.

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Chapter 3

World Trade Patterns and Prices: The Role of Productivity and Quality Heterogeneity

Joint work with Cristiana Benedetti Fasil

3.1 Introduction

World trade patterns and their relation to the technological development and income per capita levels of the trading partners have been studied extensively in the theoretical and empirical literature. Employing either the traditional trade models or the new trade theory incorporating the notion of heterogeneous firms, the studies have focused on the determinants of the direction and intensity of trade flows and the empirical validity of such models. We wish to analyze import and export prices, and trade patterns within and across the regions of the North and the South (developed, relatively richer countries and developing countries, respectively). We provide a theoretical framework for this analysis in the form of a four country North-South trade model with heterogeneous firms in two dimensions, product

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quality and labor efficiency, and focus on intra-industry trade, particularly the manufacturing sector.

To the extent that the unit values of traded goods can represent quality, data on export and import prices might as well serve as evidence of countries' trade specialization and demand schedules over quality. Fieler (2007) finds that export prices increase with income per capita of the origin country. Schott (2004) presents evidence on positive variation of US import prices depending on the exporter's income per capita. Furthermore, it is found that import prices are positively related to income per capita, as well as that countries of different income per capita import goods of different prices from the same exporter. This evidence suggests that rich countries not only specialize in the production and export of relatively higher quality goods, but that they devote larger share of income on high quality imports and possibly high quality total consumption.[1] Most of the literature that proposes a theoretical basis for this analysis starts from either non-homothetic preferences, where different income levels generate different demand structures, or standard preferences with arbitrarily imposed different "love for quality" parameters in the North and the South. The supply side mechanisms result in a comparative advantage in the production of goods that are in high domestic demand. Non-homothetic preferences might be the immediate natural assumption for explaining reported increase in traded goods' prices with income per capita, but are certainly not the only factor. Although the arbitrary parametrization of preferences might be regarded as a way around modeling the black box of demand heterogeneity across countries, non-homothetic preferences do have some empirical support in the micro-level data. The purpose of this paper is not to contradict these findings, but to show that when the attention is shifted from modeling preferences to modeling technology more closely, standard preferences model with fixed operational and trade cost can yield the stated predictions as well.

[1]These findings, however, should not be taken as a straightforward support for the differences in expenditure distribution over quality in the North and the South, as traded goods might present only a minor share of total consumption.

 DOI: 10.2870/13739

We wish to give more weight to the supply side mechanisms and their role in shaping the demand structure and therefore, we use homothetic preference structure. Specifically, the focus is on the technology endowments of the North and the South which are the main determinants of the production and export specialization, and the relative income per capita of the two regions. The North has a higher level of technological development, while the South lags behind the North and uses a lower level of technology. Firms in each region are heterogeneous in two technology (productivity) dimensions: product quality and labor efficiency which together determine the firms' domestic and foreign market profitability. Existing models of trade and heterogeneous firms that introduce only one productivity dimension, such as Melitz (2003), predict a negative relation between export prices and income per capita since higher technological development implies higher cost efficiency and thus lower prices. Empirical evidence on export prices calls for the introduction of the quality dimension of heterogeneity in a way that it generates positive relation between quality and price. In this sense, Northern technology allows this region to produce relatively higher quality-higher price varieties, while the South specializes in the production of lower quality-lower price varieties.

In this framework, the export decision of any firm depends on its quality-efficiency level which determines the profitability and thus the ability to cover the fixed cost of exporting. Consumers place greater value on products of higher quality, but quality also generates higher marginal cost of production. Baldwin and Harrigan (2007) develops a model of trade and heterogeneous firms in the quality dimension. They assume that quality rises faster than marginal cost and thus high quality-high cost varieties are the most profitable ones. Therefore, export profitability is increasing in quality (and price) monotonically. In that set-up, lower aggregate expenditure of the South implies that only the most profitable firms can cover the fixed cost of trade and export to the South, while the pool of exporters to the North is larger. However, this does not match the empirical evidence, as it results in the negative relationship between income per capita and import prices conditional on exporter. We introduce a separate measure of cost efficiency which affects the marginal cost

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independently of the quality. Each firm (variety) is characterized by a quality level which affects positively both utility and the cost of production, and by a labor efficiency level which decreases the marginal cost. Quality and efficiency together determine the productivity level of the firms, which are distributed across quality-efficiency pairs, with the Southern joint distribution having a lower mean due to its technological lag behind the North. With the two dimensions of heterogeneity, less profitable firms that export only to the North, also include those with highest quality but lower efficiency, and therefore a higher price. This contributes to a rise in the average import price with income per capita conditional on exporter. In this sense, Northern average import price is higher not because it consumes higher quality than the South, but due to the fact that it consumes also the high priced - high quality varieties. Given the right-skewed distribution of firms in equilibrium, varieties of this type are relatively numerous and this amplifies the effect on the average import price and insures that North imports higher price varieties on average.

In aggregate terms, the greater income of the North compared to the South implies not only a greater expenditure on any good that is available in both regions, but higher levels in equal proportion across goods, due to homothetic preferences. However, with fixed cost of export only a subset of varieties is exported to foreign markets, and the resulting expenditure shares on certain quality are not equal across regions. The North spends a lower share of income on low quality varieties originated from the South, while the South spends a lower share on high quality produced in the North, both relative to the other region's share of expenditure on those varieties. If the income difference between the regions is sufficiently large, the statement above holds also in absolute terms. The South's larger share of income is allocated to domestic varieties of low quality, while the North spends more on the high quality produced domestically and imported from the other Northern country. Due to competition pressures from the South in the intermediate quality goods markets (lower quality portion of the production in the North), these varieties are only produced for the local market in the North, at a reduced scale. A part of these varieties are not exported by the South and thus not consumed by the North. More profitable varieties are exported by the South, but in a smaller share compared to those of a higher quality as they are in lower demand and are fewer.

The analysis of trade intensities within and across regions refers to the Linder hypothesis. Linder (1961) argues that on the demand side, countries with high (low) income per capita spend a larger fraction of their income on high (low) quality goods. On the supply side, countries develop a comparative advantage in the goods that are in high domestic demand, so high (low) income countries produce high (low) quality goods. Both these premises are predicted by our model, but Linder's hypothesis goes further. The demand and supply premises are combined in order to argue that the overlap of production and consumption patterns between countries of similar income per capita should induce them to trade more intensively with one another. Rich trade more with rich, while poor trade with poor. Our model predicts the highest intensity and value of the North-North trade. The ordering of the South-South and the North-South trade depends on the fixed and/or variable costs of trade, in particular on their asymmetries that are conditional on the origin and destination country. With symmetric costs, North-South trade is of higher value, but the result is reversed when stronger restrictions on Southern exports to the North are imposed. However, there is no robust empirical support of the Linder hypothesis. Namely, it is important to ascertain the level of aggregation at which the "Linder" mechanism might operate. Hallak (2008) shows that the trade intensities prediction is valid on both sides of income per capita distribution at the sectoral level (for some sectors), but is strongly rejected when data is aggregated over sectors.

The rest of the paper is organized as follows, Section 2 presents the model and define the equilibrium, Section 3 discusses the results of the numerical exercise, while Section 4 concludes.

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3.2 The Model

3.2.1 Consumers

We propose a two region North-South trade model where each region, the North and the South, consists of two symmetric countries (two symmetric North and two symmetric South). Consumers have equal, homothetic preferences across countries and regions. In every period, consumers choose consumption and supply labor inelastically at the wage rate w^N in the North and w^S in the South, with $w^N > w^S$. Labor is not mobile across regions and the aggregate measure of population in each country in the North and the South regions is L^N and L^S, respectively. Consumers allocate optimally the aggregate consumption X across differentiated varieties produced by domestic firms and those imported from abroad. The measure of available goods in each country is hence given by domestic goods of measure I^{JD}, imports from the other country of the same region, I^{JJ}, and from the two countries of the other region, I^{JK}, with $J = \{N, S\}, J \neq K$. Thus, $I^N = I^{ND} + I^{NN} + 2I^{SN}$ for the North and similarly for the South, $I^S = I^{SD} + I^{SS} + 2I^{NS}$. We use the same index to represent both the region and the country of a particular region, as we assume symmetry in all environment dimensions of the countries within a region. However, the varieties they produce are perceived as different by the consumers and thus are all in demand, i.e. each country's consumers demand varieties from the other country of the same region as well as the goods of both countries of the other region. The utility function for country J is given by a quality augmented Dixit-Stiglitz utility function,

$$U^J(t) = \left(\int_{i \in I^J} (q(i)x(i,t))^\alpha di \right)^{\frac{1}{\alpha}}, \tag{3.1}$$

where $x(i,t)$ is the quantity and $q(i)$ is the quality of a variety $i \in I^J$ consumed at time t. The standard CES utility index is augmented to account for the quality variation across products where quality acts as a utility shifter: a consumer prefers high quality over low quality products. The elasticity of substitution between any two goods is constant and equal to $\sigma = 1/(1-\alpha) > 1$, with $\alpha \in (0,1)$.

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Consumers derive the optimal demand for each good, both domestic and foreign, maximizing their utility subject to the individual budget constraint $E^J(t) = \int_{i\in I^J} p(i,t)x(i,t)di$, where $E^J(t)$ presents total expenditure in country J and $p(i,t)$ is the price of variety $i \in I^J$ at time t. The demand for product $x(i,t)$ is given by

$$x(i,t) = \left(\frac{P^J(t)q^\alpha(i)}{p(i,t)}\right)^{\frac{1}{1-\alpha}} X^J(t) = \left(\frac{q^\alpha(i)}{p(i,t)}\right)^{\frac{1}{1-\alpha}} P^J(t)^{\frac{\alpha}{1-\alpha}} E^J(t) \tag{3.2}$$

with $P^J(t)$ as the price-quality index defined by

$$P^J(t) = \left(\int_{i\in I^J} \left(\frac{p(i,t)}{q(i,t)}\right)^{\frac{\alpha}{\alpha-1}} \mathrm{d}i\right)^{\frac{\alpha-1}{\alpha}} \quad \text{and} \quad X_t = U_t. \tag{3.3}$$

Although consumer preferences are the same in both regions, the bundles of varieties consumed are different. Due to fixed cost of export, a subset of varieties in each region is not exported, resulting in a different consumption composition and price schedules across regions. This yields different price indices as averages of the quality weighted prices of all varieties consumed by a region, domestically produced and imported.

This paper focuses on the analysis of the steady-state equilibrium in which all variables are constant and we omit the time subscripts in the further text.

3.2.2 Firms

Firms in each region differ in two dimensions of firm heterogeneity. The first source of heterogeneity is *labor efficiency*(in further text, efficiency), $a(i) \in \mathbb{R}_{++}$, which increases the marginal productivity of labor, as in the seminal paper of Hopenhayn (1992). The second source is *quality* of a firm's variety, $q(i) \in \mathbb{R}_{++} \setminus (0,1)$, which decreases the marginal productivity of labor. In this respect, a higher quality variety implies a higher variable cost as in Verhoogen (2008), but contributes positively to consumers' utility. The production technology has the following form

$$x(i) = \frac{a(i)^\chi}{q(i)^\eta} n(i), \tag{3.4}$$

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where $n(i)$ is the production labor employed by firm i and $\chi, \eta \in (0,1)$. Firms in both regions distribute over quality and efficiency, and we assume that each firm produces only one variety so that the index i identifies both the firm and the corresponding variety it produces. Firms in the North lead in both productivity dimensions while firms in the South lag behind the more advanced Northern technology.

In both regions firms enter and exit the market and the industry is characterized at the steady-state equilibrium.

Production decision

Each firm is the monopolistic producer of its own variety. Firms pay a fixed operational cost, c_f, expressed in terms of labor in order to produce, and incur an iceberg export cost $\tau > 1$ in the units of output and a fixed export cost c_{ex}, expressed in terms of labor, in order to export.[2] The fixed operational cost is necessary to trigger exit while the fixed export cost generates the partition between exporter and non exporter firms. Given the same labor requirement for the fixed cost of operation and export in the North and the South, it follows that both costs are higher in the North due to its higher wage.

Solving the standard monopolistic problem, firms in each country J charge a price p^{JD} in the domestic market and a price p^{JX} in the foreign market which takes into account the iceberg cost. That is

$$p^{JD} = \frac{w^J q^\eta}{\alpha a^\chi} \tag{3.5}$$

for the products sold in the domestic market and

$$p^{JX} = \frac{\tau w^J q^\eta}{\alpha a^\chi} \tag{3.6}$$

for the products sold in the foreign markets. Substituting these expressions for prices in the demand function it follows that $x(i)$ is increasing in a and it is decreasing in q *iff* $\eta > \alpha$. We restrict our attention to the specification when this condition holds.

[2]In the benchmark model we assume symmetric τ across regions in order to abstract from this form of relative price distortion across regions and analyze only the effect of the fixed cost of export on the patterns of trade.

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Firms total profits are the sum of the profits obtained in the domestic market and the profits from the foreign markets when it is profitable to export. Hence the optimal profits with $J, K = \{N, S\}, J \neq K$ are given by

$$\begin{aligned}
\pi^J(a,q) &= \pi^{JD}(a,q) + \max\{0, \pi^{JJ}(a,q)\} + 2\max\{0, \pi^{JK}(a,q)\} \qquad (3.7)\\
\pi^{JD}(a,q) &= \left(\frac{a^{\chi} q^{1-\eta}\alpha}{w^J}\right)^{\frac{\alpha}{1-\alpha}} (1-\alpha) P^{J\frac{\alpha}{1-\alpha}} E^J - w^J c_f\\
\pi^{JJ}(a,q) &= \tau^{\frac{\alpha}{\alpha-1}} \left(\frac{a^{\chi} q^{1-\eta}\alpha}{w^J}\right)^{\frac{\alpha}{1-\alpha}} (1-\alpha) P^{J\frac{\alpha}{1-\alpha}} E^J - w^J c_{ex}\\
\pi^{JK}(a,q) &= \tau^{\frac{\alpha}{\alpha-1}} \left(\frac{a^{\chi} q^{1-\eta}\alpha}{w^J}\right)^{\frac{\alpha}{1-\alpha}} (1-\alpha) P^{K\frac{\alpha}{1-\alpha}} E^K - w^J c_{ex}
\end{aligned}$$

Since export profits depend on the aggregate variables of the foreign region, this is the channel through which the aggregate economy of the foreign region affects the profitability of the domestic firms.

The max operator in π^N and π^S indicates the choice of each firm to specialize only in the domestic market, or to open to foreign markets when the profits derived from exporting exceed the fixed cost of export, c_{ex}. This choice depends on both efficiency and quality of the variety produced by the firms. The specification of χ and η affects not only the concavity of profits in the two productivity dimensions, but also the ratio of the profit elasticities with respect to each dimension. With χ bigger (smaller) than $1-\eta$ the profits increase faster along the efficiency (quality) dimension, which shapes the isoprofit curves in the (a,q) space and thus the export productivity threshold functions.

The two sources of firm heterogeneity imply that the thresholds that characterize the border between export and not export are given by the infinite combinations of the (a,q) couples. For this reason, it becomes convenient to express the reservation values in terms of efficiency as a function of quality[3], $a(q)$, and to obtain a *cutoff function* rather than cutoff

[3] It is equivalent to express product quality as a function of efficiency, $q(a)$. Using a specific formulation for the cut-off function does not affect the implications of the model.

 DOI: 10.2870/13739

values as in one factor heterogeneous firm models. For a given $q \in Q$ it is possible to define the following export cutoff functions for the North and the South, with $J, K = \{N, S\}, J \neq K$,

$$a_{ex}^{JJ}(q) = \left[\left(\frac{w^J c_{ex}}{(1-\alpha) P^{J \frac{\alpha}{1-\alpha}} E^J} \right)^{\frac{1-\alpha}{\alpha}} \frac{1}{\alpha} \frac{w^J \tau}{q^{1-\eta}} \right]^{\frac{1}{\chi}} \tag{3.8}$$

$$a_{ex}^{JK}(q) = \left[\left(\frac{w^J c_{ex}}{(1-\alpha) P^{K \frac{\alpha}{1-\alpha}} E^K} \right)^{\frac{1-\alpha}{\alpha}} \frac{1}{\alpha} \frac{w^J \tau}{q^{1-\eta}} \right]^{\frac{1}{\chi}} \tag{3.9}$$

.

The cutoff functions are decreasing in quality which implies that a firm characterized by a low level of efficiency but a high quality may still find it optimal to export. However, with $\chi > 1 - \eta$, the cutoff efficiency is decreasing in quality at a decreasing rate. We assume this condition holds, as it captures the idea of increasing difficulty in keeping the export market shares for the firms that produce high quality varieties with low efficiency which results in a high price. In other words, this assumption represents minimum (cost) efficiency requirements for exporting.

Given that the export decision depends on the aggregate variables of the foreign country, the export cutoff functions depend on the foreign aggregates as well. The cutoff functions are increasing in the wage of the exporting country as higher wage implies higher fixed cost of export and higher export price, while they decrease in the total expenditure and the price index of the destination country. Higher expenditure (income) of the destination market implies higher purchasing power of the market, while higher price index represents lower competition pressures on the exporting firm. As the total expenditure depends on the size of the population in the destination country, it follows that a larger export market implies higher profitability and lower cutoff productivity levels. The order of the cutoffs for export to different regions is determined by the ratio of the aggregates of the two regions, $P^{\frac{\alpha}{1-\alpha}}E$. The condition that results in larger export cutoff compared to the operation cutoff productivity level in both regions, and the discussion on the effect of the aggregates is presented in Appendix A.

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The exit decision

Every firm faces an exogenous probability of a bad shock δ which forces the firm to exit the market. Besides this exogenous exit, firms exit the market when their profits are not enough to cover the fixed operational cost, c_f. The exit cutoff functions for given $q \in Q$ for both North and South, $J = \{N, S\}$, are given by

$$a_x^J(q) = \left[\left(\frac{w^J c_f}{(1-\alpha) P^{J \frac{\alpha}{1-\alpha}} E^J} \right)^{\frac{1-\alpha}{\alpha}} \frac{1}{\alpha} \frac{w^J}{q^{1-\eta}} \right]^{\frac{1}{\chi}}. \tag{3.10}$$

The exit cutoff functions are decreasing in quality produced: high quality allows for an easier survival. However, the exit cutoffs depend only on the domestic aggregates. In other words, for a given quality firm partition in both the North and the South is such that firms with low level of efficiency (a) exit the industry, firms with intermediate levels produce only for the domestic market, while the most efficient firms produce for both the domestic and the foreign markets, first for the market in the North and then for the foreign markets in both regions. The stated order of the firm partition is assured by the conditions on the fixed costs of operation and export.[4] The rest of the model is then derived assuming that these conditions hold, and hence only some of the firms in both the North and the South survive and only some of the successful firms export.

Firms entry

Each period, M^J firms enter the industry and pay a sunk entry cost, c_e, expressed in terms of labor. After paying the entry cost they draw the product quality and efficiency level (productivity vector (a,q)) from a bivariate distribution $G^J(a, q)$, $J = \{N, S\}$, with corresponding density $g^J(a, q)$. The density function in the North, $g^N(a, q)$, is assumed to be log-normal and exogenous while $g^S(a, q|\overline{\mu}^N)$ is log-normal but its mean, $\overline{g}^S$, is determined as a fraction of the incumbents joint mean in the North, $\overline{\mu}^N$, which will be defined in the next section.[5] The assumption attempts to capture the idea of imitative R&D in the South

[4] See Appendix A. for the discussion on exit and export cutoffs.

[5] This specification is similar to the one used in Gabler and Licandro (2005).

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which copies the technology of the North at a certain lag due to high difficulty of copying the advanced goods. As we don't model the R&D process endogenously, we might justify this assumption by the evidence on differences in North-South TFP levels documented in the literature.[6]

We assume that the free entry condition holds in equilibrium. Firms in the North and the South enter the industry until the expected value of the firm, $\overline{v}$, is equal to the entry costs. With the value of the firm given as the discounted future flow of profits, and with no time discounting as in Melitz (2003), the free entry condition reads

$$\overline{v}^J = \int_{a_x^J(q)} \int_Q \frac{\pi^J(a,q)}{\delta} g^J(a,q) \mathrm{d}q \mathrm{d}a = w^J c_e, \tag{3.11}$$

3.2.3 Cross sectional distribution and aggregates

The density of firms conditional on successful entry is computed as

$$\mu^N(a,q) = \begin{cases} \frac{g^N(a,q)}{P_{in}^N} & \text{if } a \geq a_x^N(q) \\ 0 & \text{otherwise} \end{cases} \tag{3.12}$$

for the North firms and similarly for the South firms,

$$\mu^S(a,q) = \begin{cases} \frac{g^S(a,q)}{P_{in}^S} & \text{if } a \geq a_x^S(q) \\ 0 & \text{otherwise,} \end{cases} \tag{3.13}$$

where $P_{in}^N = \int_{a_x^N(q)} \int_Q g^N(a,q)\mathrm{d}q\mathrm{d}a$ and $P_{in}^S = \int_{a_x^S(q)} \int_Q g^S(a,q|\overline{\mu}^N)\mathrm{d}q\mathrm{d}a$ are the ex-ante probabilities of surviving for the firms in the North and the South, respectively. In a similar way we can define the ex-ante probability that a successful firm exports. That is, $P_{ex}^{NN} = \frac{1-G(a_{ex}^{NN}(q),q)}{P_{in}^N}$, $P_{ex}^{NS} = \frac{1-G(a_{ex}^{NS}(q),q)}{P_{in}^N}$, $P_{ex}^{SN} = \frac{1-G(a_{ex}^{SN}(q),q)}{P_{in}^S}$ and $P_{ex}^{SS} = \frac{1-G(a_{ex}^{SS}(q),q)}{P_{in}^S}$ for North and South.

To compute the weighted mean of Northern productivity, necessary to determine the distribution of the firms in the South, we need to define the mass of incumbents in each

[6] See for example, Cordoba and Ripoll (2008), Jerzmanowski (2007), Hall and Jones (1999).

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country. Hence, I^{ND} and I^{SD} also represent the measure of varieties produced in each country of the North and the South, so $I_{ex}^{NN} = P_{ex}^{NN} I^{ND}$, $I_{ex}^{NS} = P_{ex}^{NS} I^{ND}$, $I_{ex}^{SN} = P_{ex}^{SN} I^{SD}$ and $I_{ex}^{SS} = P_{ex}^{SS} I^{SD}$ are the masses of exporting firms and exported varieties in the North and the South, respectively. This means that the mass of available varieties in each country is given by the mass of varieties produced domestically plus the mass of varieties imported: $I^N = I^{ND} + I_{ex}^{NN} + 2I_{ex}^{SN}$ for the North, and $I^S = I^{SD} + I_{ex}^{SS} + 2I_{ex}^{NS}$ for the South.

The average weighted productivity for the North is computed taking into account not only the output share of the domestic firms, but the additional export share of the better firms and the proportion τ of output lost during the export transit:

$$\overline{\mu}^J = \left(\frac{I^{JD}}{(I^{JD} + I_{ex}^{JJ} + 2I_{ex}^{JK})} \overline{\mu}_x^{JD \frac{\alpha}{1-\alpha}} + \frac{I_{ex}^{JJ}}{(I^{JD} + I_{ex}^{JJ} + 2I_{ex}^{JK})} \left(\frac{\overline{\mu}_{ex}^{JJ}}{\tau} \right)^{\frac{\alpha}{1-\alpha}} \right. \tag{3.14}$$

$$\left. + \frac{2I_{ex}^{JK}}{(I^{JD} + I_{ex}^{JJ} + 2I_{ex}^{JK})} \left(\frac{\overline{\mu}_{ex}^{JK}}{\tau} \right)^{\frac{\alpha}{1-\alpha}} \right)^{\frac{1-\alpha}{\alpha}} \tag{3.15}$$

where $J, K = \{N, S\}$, J≠K and

$$\overline{\mu}_x^{JD} = \left(\int_{a_x^J(q)} \int_Q (a^\chi q^{1-\eta})^{\frac{\alpha}{1-\alpha}} \mu^J(a,q) \mathrm{d}q \mathrm{d}a \right)^{\frac{1-\alpha}{\alpha}} \tag{3.16}$$

$$\overline{\mu}_{ex}^{JJ} = \left(\int_{a_{ex}^{JJ}(q)} \int_Q (a^\chi q^{1-\eta})^{\frac{\alpha}{1-\alpha}} \tilde{\mu}_{ex}^{JJ}(a,q) \mathrm{d}q \mathrm{d}a \right)^{\frac{1-\alpha}{\alpha}}$$

$$\overline{\mu}_{ex}^{JK} = \left(\int_{a_{ex}^{JK}(q)} \int_Q (a^\chi q^{1-\eta})^{\frac{\alpha}{1-\alpha}} \tilde{\mu}_{ex}^{JK}(a,q) \mathrm{d}q \mathrm{d}a \right)^{\frac{1-\alpha}{\alpha}}.$$

Variables $\tilde{\mu}_{ex}^{JJ}(a,q)$ and $\tilde{\mu}_{ex}^{JK}(a,q)$ are the conditional distributions of firms exporting to the North and of firms exporting to both regions, respectively, given that the firm survives in the market.

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3.2.4 Steady-state equilibrium

The steady state equilibrium is characterized by prices (p^{JD}, p^{JX}), wages (w^J), exit and export cutoff functions $(a_x^J(q), a_{ex}^{JJ}(q), a_{ex}^{JK}(q))$, firm distributions (μ^J), number of firms in each region (I^{JD}) and the aggregate expenditure and price indices (E^J, P^J) such that

- consumers choose consumption optimally and firms choose prices to maximize their profits
- exit and export cutoff functions satisfy the conditions given in section 2.2.1 and 2.2.2
- entry and exit are such that the condition $\delta I^{JD} = P_{in}^J M^J$ and the free entry condition are satisfied
- distribution of firms in the North and the South are given by equations in section 2.3
- number of operating firms is such that the labor markets clear, i.e. total labor is used for domestic and export production and also for the fixed cost of entry, operation and export

$$\begin{aligned} L^J &= \int_{a_x^J(q)} \int_Q n(a,q)\mu^J(a,q) I^{JD} \mathrm{d}q\mathrm{d}a + \int_{a_{ex}^{JJ}(q)} \int_Q n(a,q)\mu^J(a,q) I^{JD} \mathrm{d}q\mathrm{d}a \quad (3.17) \\ &+ \int_{a_{ex}^{JK}(q)} \int_Q n(a,q)\mu^J(a,q) I^{JD} \mathrm{d}q\mathrm{d}a + c_e M^J + c_{ex}(P_{ex}^{JJ} + P_{ex}^{JK}) I^{JD} + c_f I^{JD} \end{aligned}$$

- the trade balance condition is satisfied, implying that the bilateral North-North, South-South, North-South and South-North trade is balanced.[7]

We solve the model numerically using the value of parameters which are calibrated to match the recent data on the aggregate trade values (shares of North-North, North-South and South-South exports in the total world exports, relative wage of the South compared to the North) and the firm-level variables.

[7] Due to symmetry between the countries of the same region, trade balance depends only on the values of export flows between countries of different regions in equilibrium.

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3.2.5 Calibration

In our quantitative exercise we choose the preference parameter, α, exponents on productivity and quality in the production function, χ and η, exogenous exit probability, δ, the variable trade cost, τ, the size of the countries, L^N and L^S, and the mean of the entrants in the North, $\overline{g}^N$. α is set equal to 0.73 to match a mark-up over the marginal cost of 36%.[8] χ and η are equal to 0.5 and 0.86, respectively. The results do not change qualitatively if χ and η change as long as the conditions on these two exponent are satisfied. The exogenous death probability is fixed equal to 0.5% and hence firms's life expectancy is *a priori* of 200 years.[9] We assume that τ is symmetric across the four countries and equal to one to avoid exogenous price distortions. Finally, L^N, L^S, and $\overline{g}^N$ scale and locate the economy in the space (a, q). The population is assumed to be the same in both the North and the South and normlized to one while $\overline{g}^N$ is set equal to 4.

The remaining parameters are the technological gap between the North and the South, θ, the fixed cost of entry, c_e, the fixed operational cost, c_f, the fixed cost of export, c_{ex}, and the entrants distribution variance for the North and the South (assuming equal variance over productivity and quality and across countries). These parameters are calibrated to match a number of salient feature related to the 2006 data on the within and across region export shares in the total world exports, exit and entry rates in the manufacturing industry and the South-North relative wage. The data on export shares are taken from The OECD Policy Brief "South-South Trade:Vital for Development", August 2006, available at: www.oecd.org/publications/Policybriefs and Goksel 2008. The reported export shares are 52.69% for the North-North trade, 40.86% for the North-South and 6.45% for the South-South exports. Bartelsman et al. (2004) compute that the average firms exit rate in the data for the North is around 10%, while it is slightly higher in the South, 20%. Accordingly to the World Bank, International Comparison Program database, online edition, 2009 the

[8]For more details on mark-ups in models with heterogenous firms and fixed costs see Ghironi and Melitz 2005.

[9]Atkeson and Burstein 2007 and Luttmer 2007 find the same value calibrating δ.

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relative South-North wage in the manufacturing sector is on average 0.4.

Table 3.2 in Appendix B summarizes the parameters values both exogenously set and calibrated, the empirical targets used for the calibration and the corresponding model moments.

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3.3 Results

This section presents the numerical results of the North-South trade model with four countries, two symmetric Norths and two symmetric Souths. Given the productivity lag of the entrants in the South behind the incumbents in the North, the selection of the firms in the equilibrium results in the distribution of operating firms over productivity vectors in the North and the South as presented in Figure 3.1. The equilibrium productivity lag of the South results in the positive North-South wage differential in equilibrium.

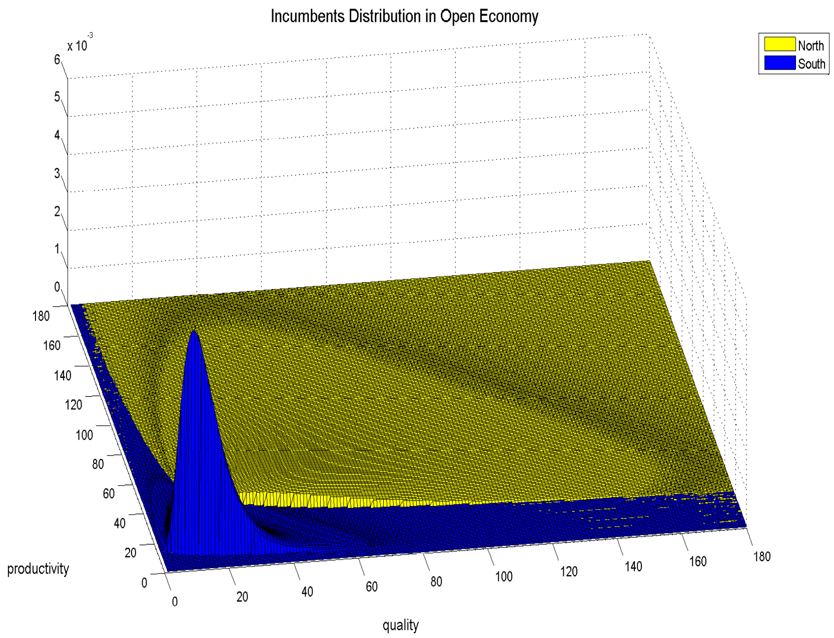

Figure 3.1: Incumbents distribution over productivity and quality

When the North and the South are open to trade, the South produces the low productivity varieties that are demanded domestically but also by the North whose international competitiveness in this portion of the distribution is weakened due to lower production cost in the South. On the other hand, Northern firms are more spread out on the whole remaining area of the productivity space, higher efficiency and higher quality. Few firms in the South reach these productivity levels and thus the North specializes in the production and export of higher (a, q) varieties.

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Figure 3.2 presents the partitioning of the firms across the (a, q) space into exiting firms, domestic producers and exporters of two types, those that export only to the North and those that export both to the North and the South. Analyzing the partition over the efficiency dimension, the lowest a firms exit the industry in both regions, but the exit cutoff in the North is higher than in the South due to higher absolute value of the fixed operational cost. Therefore, it can be observed that the low efficiency varieties are consumed exclusively by the South as the North exits this market, and as the South does not export due to low profitability. The North-South head-on competition occurs in the intermediate efficiency range of varieties. Southern varieties are more competitive and are exported to the North, while the North produces them only for the domestic consumption at a reduced scale. At even higher levels of efficiency, the number of Southern firms (varieties) decreases. This is principally the market for Northern exporters who employ a large share of the total labor force in the North. Details on labor (size) distribution of firms and the values of average productivities across different areas of the (a, q) space in the North and the South are presented in Appendix C.

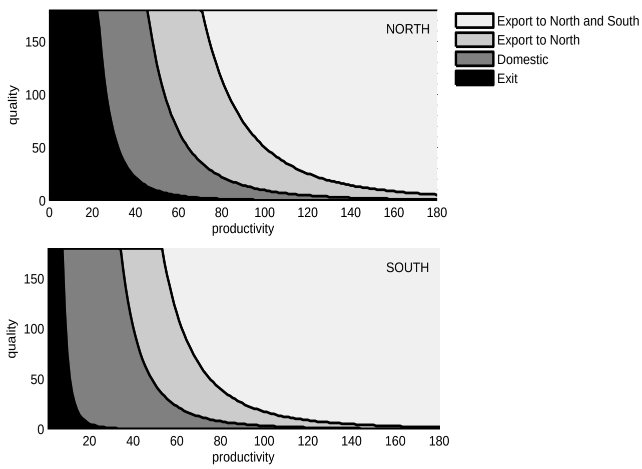

Figure 3.2: Firms partition

Bearing in mind the price schedule over the (a, q) space, the partitioning graph provides a graphical explanation for positive relationship between the average export and import prices on one side and income per capita on the other. With $\chi > 1 - \eta$ the profits increase faster along the efficiency dimension, which shapes the isoprofit curves (cutoff functions) in the (a, q) space as presented in Figure 3.3.

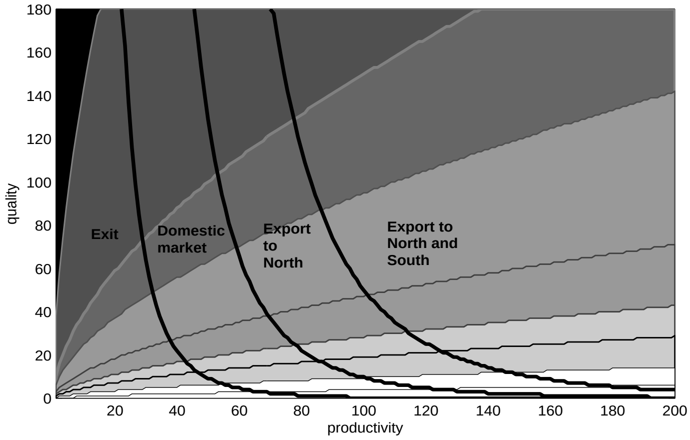

Figure 3.3: Distribution of prices

The shape of the cutoff functions determines the quality and price composition of the domestic and import bundles of the two regions. The most profitable firms export both to the North and the South, while less profitable export only to the North. With $\chi > 1-\eta$, the bigger share of the relatively higher priced varieties (high q and low a) are not exported from the North to the South and are shipped only to the North.[10] Thus, the resulting average import price is higher for the North. Moreover, given the exporting country, Northern imports are of higher average quality relative to the imports of the South as more high quality varieties are included in its import bundle. This effect is not present with only one dimension of firms heterogeneity as the profits are just a monotonic transformation of the price and the unique productivity measure. The North abandons the export of low price varieties due to competition from the South, which results in higher export prices of the North. However, it imports goods of higher average price not as it consumes higher quality than the South but due to the fact that it additionally consumes the high priced high quality

[10]As opposed to the case with $\chi < 1 - \eta$ when relatively low priced varieties are excluded from exports to the South in a larger share than the high priced varieties.

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varieties. The analogue reasoning applies to the imports from the South. Average prices of export and import are presented in Table 3.1.

Average Price	**North**	**South**
Exports	4.0739	0.9495
Imports	1.0072	0.9101
Imports from North	4.2514	3.9861
Imports from South	1.0008	0.9054

Table 3.1: Average Import Prices

The following graph (Figure 3.4) presents the expenditure shares distribution of the two regions across different levels of quality for a given efficiency of the firm. Northern demand is relatively higher for the varieties produced by the high quality firms, and the South is demanding relatively more of the goods in the lower quality portion of the distribution, which is the effect of the fixed cost of trade. With no fixed cost, the homothetic preferences would result in a lower demand from the South but still in levels exactly proportional to those of the North. Once the fixed cost of export is introduced in both the North and the South, this results in subsets of firms with only domestic sales, which subsequently distorts the proportionality of the consumption shares of the two regions across varieties.

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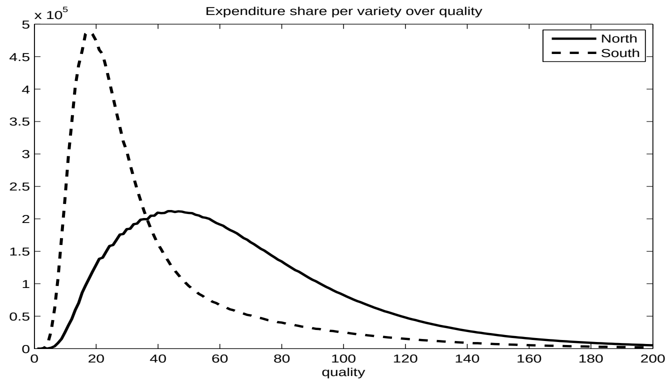

Figure 3.4: Expenditure shares distribution over quality

Figure 3.5 shows the total trade values within and across two groups of countries with no asymmetries in the variable costs of trade. The model implies that larger shares of Northern export revenue is coming from the North due to higher profitability requirements for the export to the South and low absolute expenditure of the South. This implies higher import between countries of the North. As a result, the North-North trade is the largest compared to the other trade flows, North-South and South-South. In this set-up North-South trade is of higher value than the South-South trade, but the ranking reverses when the asymmetric variable costs of trade are introduced, with the highest cost imposed on Southern exports to the North. Some empirical evidence points to these asymmetries in the form of higher export barriers imposed on the exporters from the South (such as iceberg trade cost, quality requirements, tariffs). In sectors with these asymmetries, our model's results might support the final conjecture of the Linder hypothesis, besides predicting the demand and supply premises.

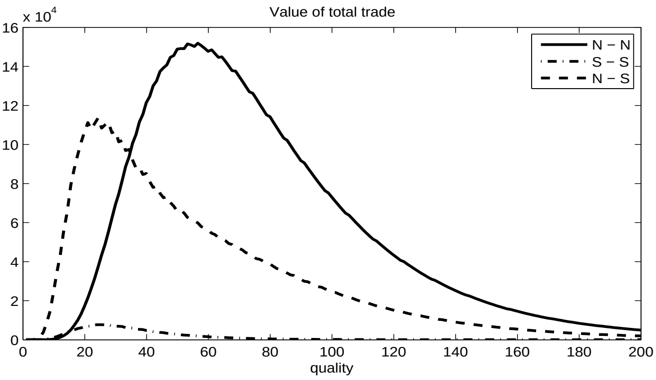

Figure 3.5: Total trade values within and across regions

3.4 Conclusion

This paper analyzes the role of efficiency and quality in shaping the trade patterns and trade intensities within and across two groups of countries, the developed and richer North and the developing South. We employ a four country North-South trade model with two dimensions of firm heterogeneity. Matching the empirical values of within and across region export shares in the total world exports, we show that the equilibrium results support the ranking of the average prices of tradables within and across regions as found in the data. This result is not previously found in the literature since using only one technology dimension does not simultaneously allow for increasing relation between export prices, import prices and import prices conditional on exporter on one side and income per capita on the other.

Furthermore, we find differences in the consumption bundles across regions even though the preferences are of standard, homothetic form. Namely, the resulting total expenditure allocation across quality shows that the North spends a larger share of its income on high quality while the South allocates more of its expenditure on low quality varieties. Therefore, we wish to stress that the trade patterns in this model are not determined by the non-homotheticity of preferences and therefore do not originate exclusively from the demand structures. The results mainly come from the supply side through the productivity distri-

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bution of incumbents and its effect on prices. This in turn allows the fixed cost of exporting to act in a way that the empirically observed trading pattern is replicated. In other words, it is not that the consumers alone have different preferences over qualities based on their income but differences in productivity and income (coming endogenously from the productivity level) are the principal deciding factors.

The future research agenda calls for the development of an endogenous R&D mechanism which will determine technology level of the North and the South in equilibrium. In this hypothetical set-up, firm would choose the level of their investment in technology, which would affect the initial productivity draw through the innovation in the North and technology adoption in the South. R&D incentives would come partly from the domestic demand structure but also as a response to foreign demand, which would together shape the comparative advantage of each region over quality segments. This allows for the analysis of several issues such as trade liberalization, income inequality and R&D subsidies to promote welfare. Furthermore, it should be noted that the set-up is easily extendable to include n countries which allows for more empirically testable predictions.

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3.5 Appendix A: Conditions on fixed costs and technological lag

The setup of the model requires that the exit cutoff in any region, $a_x^J(q)$, is lower than the export cutoff, $a_{ex}^{JK}(q)$, in order to rule out the possibility of firms not operating domestically, and producing only for the export market. To insure this we impose conditions on the fixed costs of production and export, and on the level of the technological lag of the South behind the North. With fixed export cost c_{ex} higher than the fixed operational cost c_f, the cutoff for exporting to the other country of the same region (North-North and South-South trade) will be higher than the exit cutoff. However, to insure higher cutoff for exporting to the other region (North-South trade) than the exit cutoff, the following condition is required

$$\frac{c_f}{c_{ex}} < \frac{P^{N\frac{\alpha}{1-\alpha}} L^N w^N}{P^{S\frac{\alpha}{1-\alpha}} L^S w^S} < \frac{c_{ex}}{c_f} \tag{3.18}$$

As the equilibrium wage and price indices are functions of the technological lag θ, it follows that the three parameters together determine whether the condition above holds. The relative size of the population in the two regions affects the relative size of the aggregates and therefore the ratio of exit cutoffs in the North and the South, and the ordering of export cutoffs conditional on the destination country. In general, if the South is sufficiently larger than the North, the aggregates of the South might be larger than those of the North even with the relative wage smaller than one. However, the calibration exercise shows that such a large South would neither match the data on the actual size of trading partners in the North and the South nor the model could be considered as the model of North-South trade as the share of the Southern firms exporting to the North would be approaching zero. Therefore, without the loss of generality, we assume equal sizes of the regions. We find that under the wide range of c_f, c_{ex} and θ that satisfy the stated condition, the resulting ordering of the cutoffs is such that the exit cutoff is higher in the North than in the South. Moreover, the exporters of relatively lower productivity export only to the North, while the highest productivity firms export also to the South.

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3.6 Appendix B: Calibration

Table 3.2: Targets and Parameters

Targets	**Data**	**Model**
North-North Export Share	52.69%	54.95%
North-South Export Share	40.86%	42.49%
North Exit Rate	10%	10.43%
South Exit Rate	20%	23.43%
Wage Ratio w^s/w^N	0.4	0.41
Calibrated Parameters		
θ	0.18	
σ	0.5	
c_f	11.42%	of avg North domestic employment
c_{ex}	29.51%	of avg North domestic employment
c_e	38%	of avg North domestic employment
Other Parameters		
α	0.73	
ξ	0.5	
η	0.86	
δ	0.5%	
τ	1	
$\overline{g}^N$	4.1	
$L^N = L^S$	1	

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3.7 Appendix C: Size distribution and average productivities

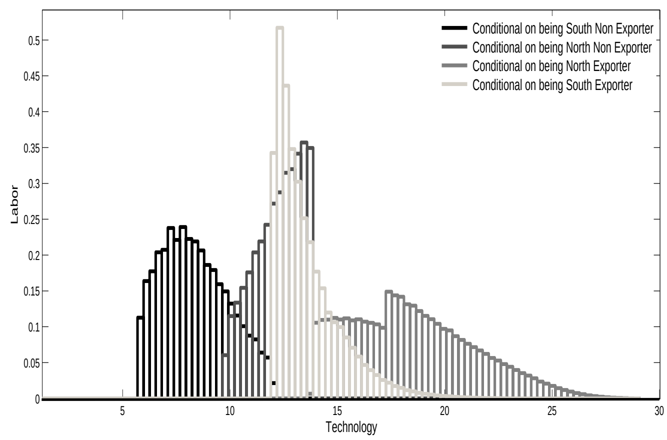

Figure 3.6: Conditional Labor Distribution over Technology

Weighted Average Technology	North	South
Total	16.76	8.38
Domestic	15.01	8.05
Export to North	17.23	13.29
Export to N and S	19.79	16.18

Table 3.3: Weighted Average Technology Across Firm Partition

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