

North-South Trade and Economic Growth

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Abstract: This paper develops a dynamic general equilibrium model of North-South trade and economic growth. Both innovation and imitation rates are endogenously determined as well as the degree of wage inequality between Northern and Southern workers. Northern firms devote resources to innovative R&D to discover higher quality products and Southern firms devote resources to imitative R&D to copy state-of-the-art quality Northern products. The steady-state equilibrium and welfare implications of three aspects of globalization are studied: increases in the size of the South (i.e., countries like China joining the world trading system), stronger intellectual property protection (i.e., the TRIPs agreement that was part of the Uruguay Round) and lower trade costs.

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1 Introduction

From 1949 to 1978, China's communist regime prohibited private enterprise and largely sealed the country off from international trade. But then in 1978, Chinese policy took a surprising turn. Declaring that "to grow rich is glorious", the communist party opened the doors to internal private enterprise and then later to external trade. Because China is such a large country (20 percent of the world population), its decision to join the world trading system is a topic of considerable public policy interest. The concerns that people have are clearly expressed in an article from *The Economist* magazine (February 15-21, 2003):

"Businesses all over the world have seen China gobble up the toy industry, and they now look on in horror as it does the same for shoes, fridges, microwaves and air conditioners. This country of 1.3 billion people has an apparently inexhaustible supply of workers, willing to work long hours for pitifully low pay...How can anybody compete against this gigantic new workshop of the world?"

In the same article though, potential benefits of China's entry into the world trading system are also expressed:

"The focus, though, should not be on such obstacles, but on the great benefits of China's growth. Millions of consumers in other countries are gaining from the low prices and high quality of Chinese goods. A billion Chinese are escaping the dire poverty of the past. Businesses across the globe will profit from supplying a vast new market."

This paper presents a conceptual framework for thinking about these issues: a dynamic general equilibrium model of North-South trade and economic growth. In the model, both innovation and imitation rates are endogenously determined as well as the degree of wage inequality between Northern and Southern workers. Northern firms devote resources to innovative R&D to discover higher quality products and Southern firms devote resources to imitative R&D to copy state-of-the-art quality Northern products. In each industry, new products are initially produced in the North by Northern quality leaders but then when copying occurs, production shifts to the South. Along the model's equilibrium path, Southern (developing) countries like China are "gobbling up" microwaves, fridges, air conditioners, etc., products that used to be produced in Northern (developed) countries. The model also captures the potential benefits of China's entry into the world trading system. The profit flows earned by Northern quality leaders increase when these firms are able to sell

to a larger Southern market of consumers and Northern consumers benefit from copying because product prices drop when production shifts from the “high wage” North to the “low wage” South.¹

Many models of North-South trade and economic growth have already been developed, including Segerstrom, Anant and Dinopoulos (1990), Grossman and Helpman (1991a,b), Lai (1998), Yang and Maskus (2001), and Glass and Saggi (2002).² So the question naturally arises: why do we need another model of North-South trade and economic growth? For thinking about issues like China’s entry into the world trading system, why not just use a model that has already been developed? Our decision to develop a new analytical framework is based on the following two considerations.

First, all of the above-mentioned North-South trade models have clearly counterfactual implications for economic growth. For example, these model all imply that any increase in the size of the South permanently increases the economic growth rate in the North. Since 1950, the South has increased dramatically in size, both due to population growth and to developing countries like China opening up to international trade. But as Jones (1995a) has pointed out, there has not been any upward trend in the economic growth rates of advanced countries since 1950. Furthermore, the counterfactual growth implications of these models are clearly linked to assumptions about R&D. All of these models imply that the Northern economic growth rate is proportional to the Northern R&D employment level. If Northern R&D employment doubles, the Northern economic growth rate should also double. Since 1950, R&D employment has more than doubled in the US and other advanced countries without generating any upward trend in economic growth rates.

Second, all of the above-mentioned papers focus on the steady-state equilibrium properties of North-South trade models and do not study the welfare implications. But as *The Economist* quotations illustrate, people are interested not only in knowing about the equilibrium implications of changes in the economic environment, they are also interested in knowing about the welfare implications. For example, do people benefit from China’s decision to join the world trading system? Do people benefit when trade costs between the North and the South fall?

In this paper, we present a model of North-South trade that avoids both of these drawbacks. To rule out the counterfactual growth implications of earlier North-South trade models, we assume that

¹The terminology West-East may be more appropriate than North-South since China is located in the East. Nevertheless, we stick with the usual North-South terminology for describing trade between developed and developing countries. Furthermore, by the South we do not mean all developing countries. Most technological imitation is done by newly industrialized countries while the majority of developing countries engage in this activity only marginally (see Helpman, 1993).

²For a survey of the literature on North-South trade and economic growth, see Chui, Levine, Murshed and Pearlman (2002).

innovating becomes more difficult as products improve in quality and become more complex. This assumption was first employed by Li (2003) to study economic growth in a closed-economy setting but has not been used before to study North-South trade.³ The model is suitable for analyzing both the equilibrium and welfare implications of changes in the economic environment. To illustrate the model's potential, we explore the implications of three aspects of "globalization": increases in the size of the South (i.e., countries like China joining the world trading system), stronger intellectual property protection (i.e., the TRIPs agreement that was part of the Uruguay Round), and lower trade costs.

Focusing on trade costs first, we show that a decrease in trade costs between the North and the South has no effect on either the rate of copying of Northern products or the Northern innovation rate. When trade costs fall, Northern firms earn higher profits from exporting to the South but their profits fall from selling their products in the North because the Northern market becomes more competitive. Overall profits do not change, so lower trade costs do not affect the incentives to either innovate or imitate. However they do lead to a reallocation of resources within both regions since firms respond by producing less for the domestic market and exporting more. For firms in the larger Northern market, the first consideration is more important for labor demand and lower trade costs lead to a permanent decrease in the relative wage of Northern workers. Thus lower trade costs contribute to reducing North-South income inequality.

Turning to the welfare implications, we show that lower trade costs unambiguously benefit consumers in both regions. Even though the relative wage of Northern workers falls, this effect of lower trade costs is more than offset by the fact that consumers face lower prices for both domestically produced and imported products.

When it comes to an increase in the size of the South, we show that this leads to a permanent increase in the rate of copying of Northern products and a temporary increase in the Northern innovation rate. When there are more Southern workers, the faster rate of technology transfer that results means that more production jobs move from the high-wage North to the low-wage South. There is a reallocation of resources within the North away from production employment and towards R&D employment. The increase in the size of the South also leads to a permanent decrease in the relative wage of Northern workers. Interestingly, both lower trade costs and increases in the size of the South are associated with decreasing North-South income inequality, consistent with the evidence

³Other closed-economy R&D-driven endogenous growth models that do not have the counterfactual "scale effect" property include Jones (1995b), Kortum (1997), Young (1998), Dinopoulos and Thompson (1998), Segerstrom (1998), and Howitt (1999). For a survey of this literature, see Dinopoulos and Thompson (1999).

reported in Jones (1997) and Sala-i-Martin (2002).

When it comes to the welfare implications of an increase in the size of the South, things are more complicated (than for lower trade costs) because both rates of innovation and imitation are affected. Northern consumers are hurt by the fall in their wage and interest income but on the other hand, they benefit from being able to buy higher quality products at lower prices. The overall effect on Northern consumer welfare of an increase in the size of the South is ambiguous. In contrast with the author of *The Economist* quotes, who concluded that the benefits for advanced countries of China joining the world trading system exceed the costs, we find no presumption that Northern consumers benefit in the long run from a larger South. We do find though that Southern consumers unambiguously benefit. Due to an increase in the size of the South, Southern consumers are able to buy higher quality products at lower prices and they also benefit from the increase in the Southern relative wage.

Finally, in comparison with an increase in the size of the South, stronger intellectual property protection has the exact opposite steady-state equilibrium and long-run welfare implications. Stronger intellectual property protection leads to a permanent decrease in the rate of copying of Northern products and a temporary decrease in the Northern innovation rate. Fewer production jobs move to the South and there is a reallocation of resources within the North away from R&D employment. Stronger intellectual property protection also leads to a permanent increase in the relative wage of Northern workers. Northern consumers benefit from the increase in their wage and interest income but on the other hand, they are hurt by the slower rate of technological change, leaving the overall effect on the welfare of Northern consumers ambiguous. We do find though that Southern consumers are unambiguously made worse off by stronger intellectual property protection. They are hurt both by the slower rate of technological change and the decrease in the Southern relative wage.

The rest of the paper is organized as follows: In section 2, the dynamic general equilibrium model of North-South trade and economic growth is presented. Section 3 studies the steady-state equilibrium properties of the model and Section 4 studies the corresponding welfare implications. Section 5 concludes.

2 The Model

2.1 Overview

We consider a model where there is trade between two regions: North and South. The North and the South are distinguished by their R&D capabilities. Workers in the North are capable of conducting both innovative and imitative R&D whereas workers in the South can only conduct imitative R&D. We focus on the steady-state equilibrium properties of the model where all innovative activity takes place in the high-wage North and all imitative activity takes place in the low-wage South. Innovation takes the form of improvements in the quality of products and imitation takes the form of copying state-of-the-art quality products. In each industry where production is currently in the South, production shifts to the North when a Northern firm innovates and in each industry where production is currently in the North, production shifts to the South when a Southern firm imitates. Both innovation and imitation rates are endogenously determined as well as the degree of wage inequality between Northern and Southern workers.

The model builds on an earlier model of North-South trade by Grossman and Helpman (1991a) but differs in several important respects. First, to avoid the counterfactual growth implications of the earlier literature, we assume that innovating becomes more difficult as products improve in quality, building on Li (2003). Second, we assume that consumer preferences are CES (instead of Cobb-Douglas). Third, we assume that the rate of population growth is positive (instead of zero). Finally, we allow for positive trade costs between the North and the South.

2.2 Industry Structure

There is a continuum of industries indexed by $\theta \in [0, 1]$. In each industry θ , firms are distinguished by the quality of the products they produce. Higher values of the index j denote higher quality products and j is restricted to taking on integer values. At time $t = 0$, the state-of-the-art quality product in each industry is $j = 0$, that is, some firm in each industry knows how to produce a $j = 0$ quality product and no firm knows how to produce any higher-quality product. To learn how to produce higher-quality products, Northern firms in each industry participate in innovative R&D races. In general, when the state-of-the-art quality product in an industry is j , the next winner of an innovative R&D race becomes the sole producer of a $j + 1$ quality product. Thus, over time, products improve as innovations push each industry up its “quality ladder.”

2.3 Workers and Consumers

In both the North and the South, there is a fixed measure of households that provide labor services in exchange for wage payments. Each individual member of a household lives forever and is endowed with one unit of labor, which is inelastically supplied. The size of each household, measured by the number of its members, grows exponentially at a fixed rate $n > 0$, the population growth rate. Normalizing the initial size of each household to unity, the number of household members at time t is given by e^{nt} . Let $L_N(t) = \bar{L}_N e^{nt}$ denote the supply of labor in the North at time t , let $L_S(t) = \bar{L}_S e^{nt}$ denote the supply of labor in the South at time t and let $L(t) = L_N(t) + L_S(t)$ denote the supply of labor in the North and South combined at time t .

Households in both the North and the South share identical preferences. Each household is modeled as a dynastic family that maximizes discounted lifetime utility

$$U \equiv \int_0^{\infty} e^{-(\rho-n)t} \ln u(t) dt \quad (1)$$

where $\rho > n$ is the constant subjective discount rate and

$$u(t) = \left\{ \int_0^1 \left[\sum_j \delta^j d(j, \theta, t) \right]^{(\sigma-1)/\sigma} d\theta \right\}^{\sigma/(\sigma-1)} \quad (2)$$

is the utility per person at time t . Equation (2) is a quality-augmented CES consumption index; $d(j, \theta, t)$ denotes the quantity demanded (or consumed) per person of a j quality product produced in industry θ at time t , parameter $\sigma > 1$ is the constant elasticity of substitution between products across industries, and $\delta > 1$ is an innovation size parameter. Because δ^j is increasing in j , (2) captures in a simple way the idea that consumers prefer higher quality products.

For each household, the discounted utility maximization problem can be solved in three steps. The first step is to solve the within-industry static optimization problem

$$\max_{d(\cdot)} \sum_j \delta^j d(j, \theta, t) \text{ subject to } \sum_j p(j, \theta, t) d(j, \theta, t) = c(\theta, t)$$

where θ and t are fixed, $p(j, \theta, t)$ is the price of the j quality product produced in industry θ at time t , and $c(\theta, t)$ is the individual consumer's expenditure in industry θ at time t . The solution to this problem is to only buy the product with the lowest quality-adjusted price $p_j(\theta)/\delta^j$. When two products have the same quality-adjusted price so consumers are indifferent, we restrict attention to equilibria where consumers only buy the higher quality product.

The second step is to solve the across-industry static optimization problem

$$\max_{d(\cdot)} \int_0^1 \left[\delta^{j(\theta,t)} d(\theta,t) \right]^{(\sigma-1)/\sigma} d\theta \text{ subject to } \int_0^1 p(\theta,t) d(\theta,t) d\theta = c(t)$$

where t is fixed, $d(\theta,t)$ is the individual's quantity demanded of the product with the lowest quality-adjusted price in industry θ at time t , $j(\theta,t)$ is the quality index of the product with the lowest quality-adjusted price in industry θ at time t , $p(\theta,t)$ is the price of this product, and $c(t)$ is the consumer's expenditure at time t . Solving this optimal control problem yields the individual consumer's demand function

$$d(\theta,t) = \frac{q(\theta,t)p(\theta,t)^{-\sigma}c(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta} \quad (3)$$

for the product in industry θ at time t with the lowest quality adjusted price, where $q(\theta,t) = \delta^{(\sigma-1)j(\theta,t)}$ is an alternative measure of product quality. The quantity demanded for all other products is zero.

The third step is to solve the dynamic optimization problem by maximizing discounted utility (1) given (2), (3), and the intertemporal budget constraint $\dot{A}(t) = w(t) + r(t)A(t) - c(t) - nA(t)$, where $A(t)$ is the individual's assets at time t , $w(t)$ is the individual's wage rate at time t , and $r(t)$ is the market interest rate at time t . The solution to this optimal control problem yields the well-known differential equation

$$\frac{\dot{c}(t)}{c(t)} = r(t) - \rho. \quad (4)$$

Individual consumer expenditure c grows over time if and only if the market interest rate r exceeds the subjective discount rate ρ .

Let w_N and w_S denote the equilibrium wage rates in the North and South, respectively. Likewise, let c_N and c_S denote the representative consumer's expenditure in the North and South, respectively. We solve the model for a steady-state equilibrium where w_N , w_S , c_N and c_S are all constant over time. Then (4) implies that the steady-state market interest rate is also constant over time and given by $r(t) = \rho$.

2.4 Product Markets

In each industry, firms compete in prices and maximize profits. Labor is the only factor of production and manufacturing of output is characterized by constant returns to scale. Labor markets are perfectly competitive in both regions. For each firm that knows how to produce a product, one unit of labor produces one unit of output independently of its quality level or location of production.

Thus, each firm in the North has a constant marginal cost equal to w_N and each firm in the South has a constant marginal cost equal to w_S . There are also trade costs separating the two regions that take the “iceberg” form: $\tau \geq 1$ units of a good must be produced and exported in order to have one unit arriving at destination. This applies to goods produced in both the North and the South.⁴

Taking into account the trade costs, production only completely shifts from the North to the South when a Southern firm imitates if $w_N > \tau w_S$. Likewise, production only completely shifts from the South to the North when a Northern firm innovates if $\tau w_N < \delta w_S$. We solve the model for a steady-state equilibrium where both inequalities hold, that is, the Northern relative wage $w \equiv w_N/w_S$ satisfies $\tau < w < \delta/\tau$.

At each point in time, a firm can choose to shut down its manufacturing facilities and once it has done so, this decision can only be reversed by incurring a positive entry cost. Furthermore, each firm that fails to attract any consumers (has zero sales) incurs a positive cost of maintaining its unused manufacturing facilities, in addition to the constant marginal cost of production mentioned above. Thus firms that are not able to attract any consumers (because of the low relative quality of their products) choose to shut down their manufacturing facilities in equilibrium and do not play any role in determining market prices, as in Segerstrom (2005). If production is currently in the South and a Northern firm innovates, the Southern firm immediately shuts down. Likewise, if production is currently in the North and a Southern firm imitates, the Northern firm immediately shuts down.

In the presence of trade costs, Northern consumers face different prices than Southern consumers and we need to take this into account. Using (3), the Northern consumer’s demand for a domestically produced good is

$$d_N(\theta, t) = \frac{q(\theta, t)p_N(\theta, t)^{-\sigma}c_N}{P_N(t)} \quad (5)$$

and the Northern consumer’s demand for an imported good (exported by the South) is

$$d_S^*(\theta, t) = \frac{q(\theta, t)p_S^*(\theta, t)^{-\sigma}c_N}{P_N(t)}, \quad (6)$$

where a star denotes exports and subscripts denote production location. In equations (5) and (6), the Northern price index is $P_N(t) = \int_{m_N} q(\theta, t)p_N(\theta, t)^{1-\sigma}d\theta + \int_{m_S} q(\theta, t)p_S^*(\theta, t)^{1-\sigma}d\theta$, where m_N is the set of industries with Northern production, m_S is the set of industries with Southern

⁴Anderson and Wincoop (2004) report that the international component of trade barriers including transport costs and border barriers but not local distribution costs is estimated in the range of 40-80 percent of the final price paid by consumers in industrialized countries. Obstfeld and Rogoff (2000) focus on trade costs as the common cause of several “puzzles” in international macroeconomics.

production. Similarly, the Southern consumer's demand for a domestically produced good is

$$d_S(\theta, t) = \frac{q(\theta, t)p_S(\theta, t)^{-\sigma}c_S}{P_S(t)} \quad (7)$$

and the Southern consumer's demand for an imported good (exported by the North) is

$$d_N^*(\theta, t) = \frac{q(\theta, t)p_N^*(\theta, t)^{-\sigma}c_S}{P_S(t)}, \quad (8)$$

where the Southern price index is $P_S(t) = \int_{m_N} q(\theta, t)p_N^*(\theta, t)^{1-\sigma}d\theta + \int_{m_S} q(\theta, t)p_S(\theta, t)^{1-\sigma}d\theta$.

Consider now the profit-maximization decision of a Northern quality leader in industry θ at time t . Omitting the arguments of functions, export profits are given by $\pi_N^* = p_N^*d_N^*L_S - w_N\tau d_N^*L_S$. The firm supplies $d_N^*L_S$ units to Southern consumers but has to produce $\tau d_N^*L_S$ units and pay its workers the Northern wage rate w_N for each unit produced. Maximizing π_N^* with respect to p_N^* yields the profit-maximizing export price $p_N^* = \frac{\sigma\tau}{\sigma-1}w_N$, which is the standard monopoly markup of price over marginal cost. Domestic profits are given by $\pi_N^d = p_N d_N L_N - w_N d_N L_N$. Maximizing π_N with respect to p_N^d yields the profit-maximizing domestic price $p_N = \frac{\sigma}{\sigma-1}w_N$. Taking into account both domestic and export profits, the total profit flow $\pi_N = \pi_N^d + \pi_N^*$ of a Northern quality leader is

$$\pi_N(\theta, t) = q(\theta, t) \frac{p_N^{-\sigma} w_N}{\sigma - 1} \left\{ \frac{c_N L_N(t)}{P_N(t)} + \frac{\tau^{1-\sigma} c_S L_S(t)}{P_S(t)} \right\}. \quad (9)$$

Similar considerations apply to the calculation of Southern profits. For a Southern quality leader, export profits are given by $\pi_S^* = p_S^*d_S^*L_N - w_S\tau d_S^*L_N$. The firm supplies $d_S^*L_N$ units to Northern consumers but has to produce $\tau d_S^*L_N$ units and pays its workers the Southern wage rate w_S for each unit produced. Maximizing π_S^* with respect to p_S^* yields the profit-maximizing export price $p_S^* = \frac{\sigma\tau}{\sigma-1}w_S$. Domestic profits are given by $\pi_S^d = p_S d_S L_S - w_S d_S L_S$. Maximizing π_S^d with respect to p_S yields the profit-maximizing domestic price $p_S = \frac{\sigma}{\sigma-1}w_S$. Taking into account both domestic and export profits, the total profit flow $\pi_S = \pi_S^d + \pi_S^*$ of a Southern quality leader is

$$\pi_S(\theta, t) = q(\theta, t) \frac{p_S^{-\sigma} w_S}{\sigma - 1} \left\{ \frac{\tau^{1-\sigma} c_N L_N(t)}{P_N(t)} + \frac{c_S L_S(t)}{P_S(t)} \right\}. \quad (10)$$

Equations (9) and (10) have similar properties. In both the North and the South, profits are increasing in product quality $q(\theta, t)$, Northern consumer expenditure $c_N L_N(t)$ and Southern consumer expenditure $c_S L_S(t)$. Since $\tau^{1-\sigma}$ decreases as τ increases, higher trade costs cut into the profits that firms earn from exporting. For Northern firms, higher trade costs cut into the profits that they earn from selling to Southern consumers and for Southern firms, higher trade costs cut into the profits that they earn from selling to Northern consumers.

2.5 Innovation and Imitation

Labor is the only factor of production used by firms that engage in either innovative or imitative R&D activities. When a Northern firm i in industry θ at time t hires ℓ_i workers to do innovative R&D, this firm is successful in discovering the next higher-quality product with instantaneous probability (or Poisson arrival rate)

$$I_i = \frac{\ell_i}{\gamma q(\theta, t)} \quad (11)$$

where $\gamma > 0$ is a Northern R&D productivity parameter. As in Li (2003), the presence of the term $q(\theta, t)$ in (11) captures the idea that as products improve in quality and become more complex, innovating becomes more difficult.⁵

Firms in the South can do imitative R&D to copy products developed in the North. When a Southern firm i in industry θ at time t hires ℓ_i workers to do imitative R&D, this firm is successful in discovering how to produce the state-of-the-art quality product in industry θ with instantaneous probability (or Poisson arrival rate)

$$C_i = \frac{\ell_i}{\beta q(\theta, t)}, \quad (12)$$

where $\beta > 0$ is a Southern R&D productivity parameter. A higher value β can be interpreted as stricter enforcement of intellectual property rights. The presence of the term $q(\theta, t)$ in (12) captures the idea that as products improve in quality and become more complex, imitating also becomes more difficult.⁶

The returns to both innovative and imitative R&D are assumed to be independently distributed across firms, industries, and over time. Consequently, the instantaneous probability that some Northern firm innovates in an industry is given by $I = \sum_i I_i$ and the instantaneous probability that some Southern firm imitates in an industry is given by $C = \sum_i C_i$.

The equilibrium pattern of innovation and imitation is illustrated in Figure 1. Northern firms do innovative R&D in all industries and Southern firms do imitative R&D in the measure m_N of industries where production is currently in the North. No imitative R&D occurs in the measure m_S of industries where production is currently in the South because it is not profitable to imitate in these

⁵Evidence that innovating is becoming more difficult is provided by data on patenting. Kortum (1993, 1997) documents a decreasing patent-per-researcher ratio in a large set of countries. Looking at industry data, Kortum (1993) finds that the patenting per unit of real R&D ratio has declined in all 20 industries for which data could be obtained. Also, Jones (2005) finds evidence of an increasing knowledge burden over time that leads researchers to choose narrower expertise and to compensate for their reduced individual capacities by working in larger teams.

⁶Mansfield, Schwartz and Wagner (1981) have found that imitation costs are substantial, of the order of 65 percent of innovation costs. They also found that patents rarely hinder imitation but typically make it more expensive, which is consistent with our interpretation of β .

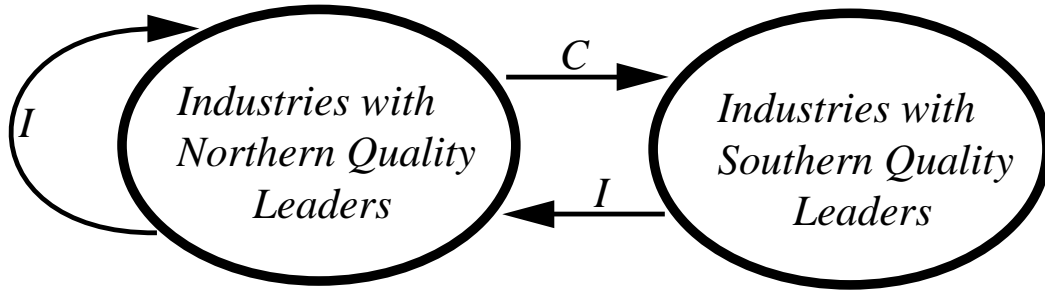


Figure 1: The pattern of innovation and imitation

industries. If a Southern firm were successful in copying a product produced by a Southern quality leader, Bertrand price competition would drive profits of both firms down to zero.⁷

We solve the model for a steady-state equilibrium where the innovation and imitation rate (I and C) do not vary across industries or over time. Since m_N is constant over time in a steady-state equilibrium, the flow into the m_N -industry state must equal the flow out of the m_N -industry state, that is, $m_N C = m_S I$. Using $m_N + m_S = 1$, it follows immediately that

$$m_N = \frac{I}{I+C} \quad \text{and} \quad m_S = \frac{C}{I+C}. \quad (13)$$

The measure of industries with Northern quality leaders m_N is an increasing function of the rate of innovation I and a decreasing function of the rate of imitation C . The converse is true for the measure of industries with Southern quality leaders m_S .

2.6 R&D Optimization

We assume that all firms maximize expected discounted profits and that there is free entry into innovative R&D races in the North. Since all Northern firms have access to the same linear innovative R&D technology (11), Northern quality leaders (the incumbents) do not engage in R&D activities. Instead all innovative R&D in the North is done by other firms (the challengers) and the identity of the quality leader in an industry changes every time innovation occurs. Northern quality leaders have less to gain by innovating since they are already earning monopoly profits and with challengers entering innovative R&D races until their expected discounted profits equal zero, it is not profitable for Northern quality leaders to do any innovative R&D.⁸

⁷We let m_N denote both the measure of industries with Northern quality leaders and the set of industries with Northern quality leaders. Likewise, we let m_S denote both the measure of industries with Southern quality leaders and the set of industries with Southern quality leaders.

⁸The property that only industry followers engage in innovative R&D is a common property of R&D-driven endogenous growth models. One can avoid this outcome and obtain that industry leaders invest in innovative R&D by assuming

Consider now the incentives that a Northern challenger firm i has to engage in innovative R&D in industry θ at time t . The expected benefit from engaging in innovative R&D is $v_I(\theta, t)I_i dt$, where $v_I(\theta, t)$ is the expected discounted profits or reward for innovating and $I_i dt$ is firm i 's probability of innovating during the infinitesimal time interval dt . The expected cost of engaging in innovative R&D is equal to $w_N \ell_i dt$, where ℓ_i is firm i 's innovative R&D employment. Equation (11) implies that the expected cost can be rewritten as $w_N I_i \gamma q(\theta, t) dt$. Thus, since expected benefit equals expected cost in a steady-state equilibrium with free entry into innovative R&D races, it follows that

$$v_I(\theta, t) = w_N \gamma q(\theta, t) \quad (14)$$

As the quality of products increases over time, innovating becomes more difficult and the reward for innovating must correspondingly increase to induce innovative effort by Northern firms.

We assume that there is also free entry into all imitative R&D races in the South. Consider the incentives that a Southern firm i has to engage in imitative R&D in industry θ at time t (where there is a Northern quality leader). The expected benefit from engaging in imitative R&D is $v_C(\theta, t)C_i dt$, where $v_C(\theta, t)$ is the expected discounted profits or reward for imitating and $C_i dt$ is firm i 's probability of imitating during the infinitesimal time interval dt . The expected cost of engaging in imitative R&D is equal to $w_S \ell_i dt$, where ℓ_i is firm i 's imitative R&D employment. Equation (12) implies that the expected cost can be rewritten as $w_S C_i \beta q(\theta, t) dt$. Thus, since expected benefit equals expected cost in a steady-state equilibrium with free entry into imitative R&D races, it follows that

$$v_C(\theta, t) = w_S \beta q(\theta, t). \quad (15)$$

As the quality of products increases over time, copying also becomes more difficult and the reward for copying must correspondingly increase to induce imitative effort by Southern firms.

We assume that there is a stock market that channels consumer savings to Northern and Southern firms that engage in R&D and helps households to diversify the risk of holding stocks issued by these firms. We can calculate directly the rewards for innovating and imitating by solving for the stock market values of Northern and Southern quality leaders.

Since there is a continuum of industries and the returns to engaging in R&D races are independently distributed across firms and industries, each investor can completely diversify away risk by holding a diversified portfolio of stocks. Thus, the return from holding the stock of a Northern

that industry leaders have some R&D cost advantages, as in Aghion et al (2001) and Segerstrom (2005).

quality leader must be the same as the return from an equal-sized investment in a riskless bond and we obtain the following no-arbitrage condition:

$$\frac{\pi_N(\theta, t)}{v_I(\theta, t)} + \frac{\dot{v}_I(\theta, t)}{v_I(\theta, t)} - I - C = \rho.$$

This equation states that the dividend rate from the stock of a Northern quality leader $\frac{\pi_N}{v_I}$ plus the capital gains rate $\frac{\dot{v}_I}{v_I}$ minus the instantaneous probabilities of experiencing total capital losses due to further innovation I and imitation C equals the market interest rate ρ . Since the quality level $q(\theta, t)$ is constant during an innovative R&D race and only jumps up when the race ends (innovation occurs), it follows that $v_I(\theta, t)$ is constant during an innovative R&D race and $\frac{\dot{v}_I}{v_I} = 0$. Thus, for the steady-state equilibrium reward for innovating is

$$v_I(\theta, t) = \frac{\pi_N(\theta, t)}{\rho + I + C}. \quad (16)$$

The profits earned by each Northern quality leader π_N are appropriately discounted using the market interest rate ρ , the instantaneous probability I of being driven out of business by Northern firms which develop higher quality products and the instantaneous probability C of being driven out of business by Southern firms which copy the Northern firm's product (and have lower wage costs).

The stock market value of a Southern quality leader can be similarly calculated. The corresponding no-arbitrage condition is

$$\frac{\pi_S(\theta, t)}{v_C(\theta, t)} + \frac{\dot{v}_C(\theta, t)}{v_C(\theta, t)} - I = \rho.$$

Setting $\dot{v}_C = 0$ and solving for the steady-state equilibrium reward for imitating yields

$$v_C(\theta, t) = \frac{\pi_S(\theta, t)}{\rho + I}. \quad (17)$$

The profits earned by each Southern quality leader π_S are appropriately discounted using the market interest rate ρ and the instantaneous probability I of being driven out of business by Northern firms which develop higher quality products. A Southern quality leader does not have to worry about its product being copied by another Southern firm since there is no reward for copying already copied products (if copying resulted in two Southern quality leaders in an industry, then under Bertrand price competition, the market price would fall down to marginal cost and both profits and the reward for copying would equal zero).

Let $Q(t) \equiv \int_0^1 q(\theta, t) d\theta$ denote the average quality level across industries at time t and let $x_N(t) \equiv Q(t)/L_N(t)$ denote average quality relative to the size of the North. We solve for a

steady-state equilibrium where x_N is constant over time. As product quality improves over time and $Q(t)$ increases, innovating becomes more difficult. On the other hand, as the North increases in size over time and $L_N(t)$ increases, there are more resources that can be devoted to innovating. Thus x_N is a natural measure of “relative R&D difficulty”: R&D difficulty relative to the size of the Northern economy.⁹

We are now ready to state an innovative R&D condition that must be satisfied if Northern firms are making profit-maximizing innovative R&D choices. Equations (9), (14) and (16) together imply that

$$\frac{\frac{p_N^{-\sigma}}{\sigma-1} \left\{ c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + \tau^{1-\sigma} c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right\}}{\rho + I + C} = \gamma x_N \bar{L}_N. \quad (18)$$

Equation (18) has a natural economic interpretation. The left-hand side is related to the benefit (expected discounted profits) from innovating and the right-hand side is related to the cost of innovating. The benefit from innovating increases when c_N or c_S increase (individual consumers buy more), when \bar{L}_N or \bar{L}_S increase (there are more consumers to sell to), when ρ decreases (future profits are discounted less), and when I or C decrease (the Northern quality leader is less threatened by further innovation or imitation). The cost of innovating increases when $x_N \bar{L}_N$ increases (innovative R&D becomes relatively more difficult).

Likewise, we can state an imitative R&D condition that must be satisfied if Southern firms are making profit-maximizing imitative R&D choices. Equations (10), (15) and (17) together imply that

$$\frac{\frac{p_S^{-\sigma}}{\sigma-1} \left\{ \tau^{1-\sigma} c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right\}}{\rho + I} = \beta x_N \bar{L}_N. \quad (19)$$

Equation (19) also has a natural economic interpretation. The left-hand side is related to the benefit (expected discounted profits) from imitating and the right-hand side is related to the cost of imitating. The benefit from imitating increases when c_N or c_S increases (individual consumers buy more), when \bar{L}_N or \bar{L}_S increase (there are more consumers to sell to), when ρ decreases (future profits are discounted less), and when I decrease (the Southern quality leader is less threatened by further innovation). The cost of imitating increases when $x_N \bar{L}_N$ increases (imitative R&D becomes relatively more difficult).

⁹In Segerstrom (1998) and Li (2003), it is shown in a closed-economy setting that, regardless of initial conditions, relative R&D difficulty necessarily converges to a constant value over time. Steger (2003) calibrates the Segerstrom (1998) model and studies the speed of convergence to the steady-state. In this paper, we focus on the steady-state properties of the model and do not try to characterize the transition path leading to the steady-state.

2.7 Quality Dynamics

By definition, the average quality of products at time t is

$$Q(t) = \int_0^1 q(\theta, t) d\theta = \int_0^1 \lambda^{j(\theta, t)} d\theta$$

where $\lambda = \delta^{\sigma-1} > 1$. We can calculate how $Q(t)$ evolves over time in a steady-state equilibrium. Since $j(\theta, t)$ jumps up to $j(\theta, t) + 1$ when innovation occurs in industry θ , and the innovation rate I is constant across industries and over time, we obtain that the time derivative of $Q(t)$ is

$$\dot{Q}(t) = \int_0^1 [\lambda^{j(\theta, t)+1} - \lambda^{j(\theta, t)}] I d\theta = (\lambda - 1)IQ(t).$$

The growth rate of average product quality $\frac{\dot{Q}}{Q}$ is proportional to the innovation rate I in each industry. It follows that the measure of relative R&D difficulty $x_N = Q(t)/L_N(t)$ can only be constant over time if $\frac{\dot{Q}}{Q} = (\lambda - 1)I = n$, from which it follows that the steady-state innovation rate is

$$I = \frac{n}{\lambda - 1}. \quad (20)$$

Thus, the steady-state innovation rate depends only on the population growth rate n and the R&D difficulty parameter λ , as in Segerstrom (1998). In a steady-state equilibrium, individual researchers are becoming less productive and firms compensate for this by increasing the number of employed researchers over time. This compensation is only feasible for firms in general if there is positive population growth, so positive population growth is needed to sustain technological change in the long run.

The average quality of products $Q(t)$ can be broken up into two parts

$$Q(t) = \int_0^1 q(\theta, t) d\theta = Q_N(t) + Q_S(t) = \int_{m_N} q(\theta, t) d\theta + \int_{m_S} q(\theta, t) d\theta,$$

where Q_N denotes the aggregate quality of Northern products and Q_S denotes the aggregate quality of Southern products. We can calculate how Q_N and Q_S evolve over time in a steady-state equilibrium. Referring back to Figure 1, the time derivative of Q_S is

$$\dot{Q}_S = \int_{m_N} \lambda^{j(\theta, t)} C d\theta - \int_{m_S} \lambda^{j(\theta, t)} I d\theta = CQ_N - IQ_S$$

and the time derivative of Q_N is

$$\begin{aligned} \dot{Q}_N &= \int_{m_S} \lambda^{j(\theta, t)+1} I d\theta - \int_{m_N} \lambda^{j(\theta, t)} C d\theta + \int_{m_N} [\lambda^{j(\theta, t)+1} - \lambda^{j(\theta, t)}] I d\theta \\ &= I\lambda Q_S - CQ_N + (\lambda - 1)IQ_N. \end{aligned}$$

It follows that the growth rates of Q_N and Q_S are constant over time only if they are identical.

Solving

$$\frac{\dot{Q}_S}{Q_S} = C \frac{Q_N}{Q_S} - I = \frac{\dot{Q}_N}{Q_N} = I \lambda \frac{Q_S}{Q_N} - C + (\lambda - 1)I$$

yields $C \frac{Q_N + Q_S}{Q_S} = \lambda I \frac{Q_S + Q_N}{Q_N}$, which simplifies to $\frac{Q_S}{Q_N} = \frac{C}{\lambda I}$. It follows that

$$Q_N(t) = \frac{\lambda I}{\lambda I + C} Q(t) \quad \text{and} \quad Q_S(t) = \frac{C}{\lambda I + C} Q(t). \quad (21)$$

Combining (13) with (21) yields $\frac{Q_N(t)}{m_N} = \frac{\lambda Q_S(t)}{m_S}$. The average quality of products produced in the North $\frac{Q_N(t)}{m_N}$ is somewhat higher than the average quality of products produced in the South $\frac{Q_S(t)}{m_S}$ since shifts in production from the South to the North are always associated with increases in product quality (innovation).

2.8 Labor Markets

We assume that workers can move freely and instantaneously across firms and activities in each region. Consequently, at each instant in time full employment of labor prevails in each region and wages adjust instantaneously to equalize labor demand and supply.

Full employment of labor in the North holds at time t when the supply of labor $L_N(t)$ equals the demand for labor in manufacturing plus the demand for labor in R&D. In industry θ with a Northern industry leader, manufacturing employment is $d_N(\theta, t)L_N(t) + \tau d_N^*(\theta, t)L_S(t)$. Thus, the total demand for manufacturing labor in the North is $\int_{m_N} [d_N(\theta, t)L_N(t) + \tau d_N^*(\theta, t)L_S(t)] d\theta$. Likewise, Northern R&D employment in industry θ is $\sum_i \ell_i = \gamma I q(\theta, t)$ and total Northern R&D employment is $\int_0^1 \gamma I q(\theta, t) d\theta = \gamma I Q(t)$. Substituting using (5), (8) and (21) yields the Northern full employment condition

$$1 = \frac{p_N^{-\sigma}}{\bar{L}_N} \left\{ c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + \tau^{1-\sigma} c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right\} \frac{\lambda I}{\lambda I + C} + \gamma I x_N. \quad (22)$$

The two terms on the right-hand-side of (22) are the shares of Northern labor in production and R&D activities, respectively. The Northern production employment share increases when $c_N \bar{L}_N$ or $c_S \bar{L}_S$ increase (aggregate consumer expenditure is higher in the North or South), or $\lambda I / (\lambda I + C)$ increases (more products are produced in the North). The Northern R&D employment share increases when I increases (there is a higher innovation rate) or $x_N \bar{L}_N$ increases (innovating becomes relatively more difficult).

Similar calculations apply for the Southern labor market. Full employment of labor in the South holds at time t when the supply of labor $L_S(t)$ equals the demand for labor in manufacturing plus the

demand for labor in R&D. In industry θ with a Southern industry leader, manufacturing employment is $d_S(\theta, t)L_S(t) + \tau d_S^*(\theta, t)L_N(t)$. Thus, the total demand for manufacturing labor in the South is $\int_{m_S} [d_S(\theta, t)L_S(t) + \tau d_S^*(\theta, t)L_N(t)] d\theta$. Likewise, Southern R&D employment in industry θ is $\sum_i \ell_i = \beta C q(\theta, t)$ and total Southern R&D employment is $\int_{m_N} \beta C q(\theta, t) d\theta = \beta C Q_N(t)$. Substituting using (6), (7) and (21) yields the Southern full employment condition

$$1 = \frac{p_S^{-\sigma}}{\bar{L}_S} \left\{ \tau^{1-\sigma} c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right\} \frac{C}{\lambda I + C} + \beta C \frac{\lambda I}{\lambda I + C} \frac{x_N \bar{L}_N}{\bar{L}_S}. \quad (23)$$

The two terms on the right-hand-side of (23) are the shares of Southern labor in production and R&D activities, respectively. The Southern production employment share increases when $c_N \bar{L}_N$ or $c_S \bar{L}_S$ increase (aggregate consumer expenditure is higher in the North or South), or $C/(\lambda I + C)$ increases (there are more products produced in the South). The Southern R&D employment share increases when C increases (there is a higher rate of copying), $\lambda I/(\lambda I + C)$ increases (there are more Northern products to copy) or $x_N \bar{L}_N$ increases (imitating becomes relatively more difficult).

The full employment conditions can be greatly simplified by incorporating information about R&D optimization. Consider the North first. Equation (18) implies that $(\sigma - 1)(\rho + I + C)\gamma x_N \bar{L}_N = p_N^{-\sigma} \left\{ c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + \tau^{1-\sigma} c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right\}$. Substituting this into (22) yields

$$1 = \gamma x_N \left[(\sigma - 1)(\rho + I + C) \frac{\lambda I}{\lambda I + C} + I \right], \quad (24)$$

which we will call the *Northern steady-state condition*. It is a Northern full employment condition that takes into account the implications of profit-maximizing R&D behavior by Northern firms.

Similarly for the South, equation (19) implies that $p_S^{-\sigma} \left\{ \tau^{1-\sigma} c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right\} = (\sigma - 1)(\rho + I)\beta x_N \bar{L}_N$. Substituting this into (23) yields

$$1 = \beta \frac{x_N \bar{L}_N}{\bar{L}_S} \left[(\sigma - 1)(\rho + I) \frac{C}{\lambda I + C} + C \frac{\lambda I}{\lambda I + C} \right] \quad (25)$$

which we will call the *Southern steady-state condition*. It is a Southern full employment condition that takes into account the implications of profit-maximizing R&D behavior by Southern firms.

The Northern and Southern steady-state conditions are illustrated in Figure 2 and are labeled “North” and “South,” respectively. The Northern steady-state condition is upward-sloping in (x_N, C) space with a positive x_N intercept, while the Southern steady-state condition is downward-sloping in (x_N, C) space with no intercepts.¹⁰ These two curves have a unique intersection at point *A* and thus the steady-state equilibrium values of x_N and C are uniquely determined.

¹⁰To determine the slope of the Northern steady-state condition, we use the result that $I = \frac{n}{\lambda - 1}$ and the assumption $\rho > n$ to obtain $\frac{\partial}{\partial C} \left[\frac{\rho + I + C}{\lambda I + C} \right] = \frac{n - \rho}{(\lambda I + C)^2} < 0$. To determine the slope of the Southern steady-state condition, we use the fact that $\frac{\partial}{\partial C} \left[\frac{C}{\lambda I + C} \right] = \frac{\lambda I}{(\lambda I + C)^2} > 0$.

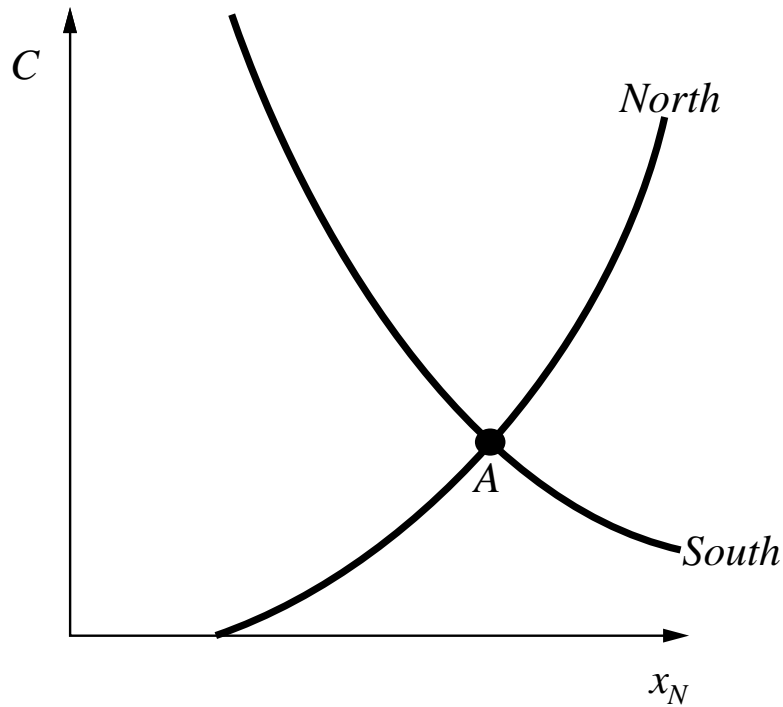


Figure 2: The steady-state equilibrium

In Figure 2, the vertical axis measures the rate of technology transfer from the North to the South since any increase in the rate of copying C is associated with faster technology transfer. For the horizontal axis, it is useful to think of it as measuring the rate of technological change in the North although this is not exactly true. Movements to the right on the horizontal axis are associated with temporary increases in the Northern innovation rate I and permanent increases in the relative size of the Northern R&D sector.

Why is the Northern steady-state condition upward-sloping? The intuition behind this upward-slope is rather involved but important for understanding the model: When the rate of copying C increases, there are two steady-state effects in the North. First, a faster rate of copying means that more industries move to the South and this contributes to reducing production employment in the North ($m_N = \frac{I}{I+C}$ decreases). Second, when Northern industry leaders are exposed to a faster rate of copying, they must earn higher profit flows while in business for Northern firms to break even on their R&D investments [in (18), an increase in C must be matched by a corresponding increase in c_N and/or c_S , holding all other variables fixed]. Northern industry leaders earn higher profit flows when consumers buy more of their products and these higher sales are associated with increased production employment in individual Northern industries. Given our assumption that $\rho > n$ (the real interest rate is higher than the population growth rate), the first effect unambiguously dominates,

so aggregate Northern production employment falls when the rate of copying goes up. To maintain full employment of Northern labor, the fall in Northern production employment must be matched by a correspond increase in Northern R&D employment. This implies that x_N must increase (R&D becomes relatively more difficult) since only then are more workers needed in the Northern R&D sector to maintain the steady-state innovation rate $I = \frac{n}{\lambda-1}$. Thus, to satisfy both Northern profit-maximization and full employment conditions, any increase in the rate of copying C (which reduces Northern production employment) must be matched by an increase in relative R&D difficulty x_N (which raises Northern R&D employment).

The intuition behind the downward slope of the Southern steady-state condition is also rather involved: When the rate of copying C decreases, there are two steady-state effects in the South. First, a slower rate of copying C means that more industries move to the North and this contributes to lowering production employment in the South ($m_S = \frac{C}{I+C}$ decreases). Second, a slower rate of copying C directly contributes to lowering R&D employment in the South ($m_N C = \frac{IC}{I+C}$ decreases). Of course, both Southern production and R&D employment cannot simultaneously decrease because there is a given supply of labor in the South at any point in time. To maintain full employment of Southern labor, a decrease in the rate of copying C must be matched by an increase in relative R&D difficulty x_N so more Southern R&D labor is needed to maintain any given imitation rate. From (19), we can also see that an increase in x_N is associated with an increase in c_N and/or c_S (holding all other variables fixed) and hence, with an increase in Southern production employment. When R&D is relatively more difficult, Southern industry leaders must earn higher profit flows while in business to break even on their R&D investments. Thus, to satisfy both Southern profit-maximization and full employment conditions, any decrease in the rate of copying C (which reduces both Southern production and R&D employment) must be matched by an increase in relative R&D difficulty x_N (which raises both Southern production and R&D employment).

2.9 The Market Value of Firms

Let V_N denote the total market value of all Northern firms at time $t = 0$ and let V_S denote the total market value of all Southern firms at time $t = 0$. To solve the model, we need to determine what these market values are in steady-state equilibrium.

First, consider how the price indexes evolve over time. Using (21), we obtain that $P_N(t) = \int_{m_N} q(\theta, t)(p_N)^{1-\sigma} d\theta + \int_{m_S} q(\theta, t)(p_S^*)^{1-\sigma} d\theta = \left(\frac{\sigma w_N}{\sigma-1}\right)^{1-\sigma} \frac{\lambda I}{\lambda I+C} Q(t) + \left(\frac{\sigma \tau w_S}{\sigma-1}\right)^{1-\sigma} \frac{C}{\lambda I+C} Q(t)$.

Thus the Northern price index $P_N(t)$ increases over time with product quality $Q(t)$ and $P_N(t)/Q(t)$ is constant over time. The same holds for the Southern price index: $P_S(t) = (\frac{\sigma\tau w_N}{\sigma-1})^{1-\sigma} \frac{\lambda I}{\lambda I + C} Q(t) + (\frac{\sigma w_S}{\sigma-1})^{1-\sigma} \frac{C}{\lambda I + C} Q(t)$ increases over time with product quality $Q(t)$ and $P_S(t)/Q(t)$ is constant over time.

Next consider the profit flows earned by a typical Northern firm. During the lifetime of the firm, $q(\theta, t)$ is constant, $p_N = \frac{\sigma w_N}{\sigma-1}$ is constant since w_N is constant, $P_N(t)/Q(t)$ and $P_S(t)/Q(t)$ are constants, and $\frac{\dot{Q}(t)}{Q(t)} = (\lambda - 1)I = n$, so $P_N(t)/L_N(t)$ and $P_S(t)/L_S(t)$ are also constants over time. Thus, it immediately follows from (9) that the firm's profit flow $\pi_N(\theta, t)$ is constant over time.

Consequently, the market value of a Northern firm $\frac{\pi_N(\theta, t)}{\rho + I + C}$ does not change over the course of the firm's lifetime and $\frac{\pi_N(\theta, t)}{\rho + I + C} = w_N \gamma q(\theta, t)$ holds not just at the time of innovation but during the entire lifetime of a Northern firm. Using this information, $V_N = \int_{m_N} w_N \gamma q(\theta, 0) d\theta = w_N \gamma Q_N(0)$. Substituting using (21) and $Q(0) = x_N \bar{L}_N$, we obtain that the market value of all Northern firms at $t = 0$ is

$$V_N = w_N \gamma \frac{\lambda I}{\lambda I + C} x_N \bar{L}_N. \quad (26)$$

Using similar reasoning, (10), (15) and (17) imply that the market value of all Southern firms at $t = 0$ is

$$V_S = w_S \beta \frac{C}{\lambda I + C} x_N \bar{L}_N. \quad (27)$$

Other things being equal, the market value of firms in a region is higher when workers earn higher wages and when innovating is relatively more difficult. This is because profit flows are proportional to wages and increasing in product quality [see (9) and (10)].

2.10 Consumer Expenditures

Having determined the market value of firms, we are in a position to solve for consumer expenditures. Let $A_N(t)$ denote the financial assets of the representative Northern consumer. The intertemporal budget constraint of the representative Northern consumer $\dot{A}_N(t) = w_N + \rho A_N(t) - c_N - n A_N(t)$ can be rewritten as $\frac{\dot{A}_N(t)}{A_N(t)} = \frac{w_N - c_N}{A_N(t)} + \rho - n$. Since the growth rate of $A_N(t)$ must be constant over time in any steady-state equilibrium, the intertemporal budget constraint implies that $A_N(t)$ must be constant over time and

$$c_N = w_N + (\rho - n)A_N. \quad (28)$$

The representative Northern consumer's expenditure c_N is wage income w_N plus interest income on financial assets $(\rho - n)A_N$, appropriately adjusted to take into account the splitting of financial

assets that results from population growth. Using similar reasoning, we obtain that the representative Southern consumer's expenditure is

$$c_S = w_S + (\rho - n)A_S, \quad (29)$$

where A_S is the financial assets of the representative Southern consumer.

To pin down exactly what consumer expenditures are, we need to specify who owns the firms. For simplicity, we assume that Northern consumers own the Northern firms and Southern consumers own the Southern firms, that is, $A_N = V_N/\bar{L}_N$ and $A_S = V_S/\bar{L}_S$. This assumption is consistent with the Feldstein and Horioka (1980) finding that domestic savings finance domestic firms. Then, taking into account (26) and (27), (28) and (29) determine c_N and c_S . Of more interest for solving the model, the ratio of Northern to Southern consumer expenditure $\phi_N \equiv (c_N\bar{L}_N)/(c_S\bar{L}_S)$ is

$$\phi_N = w \left[\frac{\bar{L}_N + (\rho - n)\gamma \frac{\lambda I}{\lambda I + C} x_N \bar{L}_N}{\bar{L}_S + (\rho - n)\beta \frac{C}{\lambda I + C} x_N \bar{L}_N} \right] \quad (30)$$

Note that ϕ_N is a well-defined function of the relative wage $w \equiv \frac{w_N}{w_S}$ only, since everything else in the bracketed expression is determined in steady-state equilibrium.

2.11 The relative Wage

To determine the steady-state equilibrium value of the relative wage w , we divide the imitative R&D condition (19) by the innovative R&D condition (18) to obtain

$$\frac{p_S^{-\sigma} \left[\tau^{1-\sigma} c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right]}{p_N^{-\sigma} \left[c_N \bar{L}_N \frac{Q(t)}{P_N(t)} + \tau^{1-\sigma} c_S \bar{L}_S \frac{Q(t)}{P_S(t)} \right]} = \frac{\beta(\rho + I)}{\gamma(\rho + I + C)}.$$

Substituting for p_N , p_S , $P_N(t)$ and $P_S(t)$ yields the *steady-state wage equation*

$$\frac{(\tau^{\sigma-1} + \phi_N \tau^{1-\tau}) \frac{\lambda I}{C} + w^{\sigma-1} (1 + \phi_N)}{\frac{1 + \phi_N}{w} w^{1-\sigma} \frac{\lambda I}{C} + \frac{\tau^{1-\sigma} + \phi_N \tau^{\sigma-1}}{w}} = \frac{\beta(\rho + I)}{\gamma(\rho + I + C)}. \quad (31)$$

Since $\frac{\phi_N}{w}$ does not depend on w and is completely pinned down by previous steady-state equilibrium calculations, the denominator on the LHS of the wage equation (31) is decreasing in w and the numerator is increasing in w . Hence, the LHS of the wage equation is increasing in w . Furthermore, the LHS converges to zero as w converges to zero and the LHS converges to infinity as w converges to infinity. Thus, the wage equation (31) uniquely determines w .

The model's steady-state equilibrium is uniquely determined by the Northern condition (24), the Southern condition (25) and the wage condition (31). These equations uniquely determine steady-state equilibrium values of x_N , C and w . Of course, to verify that we really have found a steady-state equilibrium, we always need to check that w lies in the wage interval $\tau < w < \frac{\delta}{\tau}$.

2.12 Steady-State Utility Paths

We turn now to solving for the steady-state utility paths of representative consumers in the North and South, respectively.

For the typical Northern consumer, (2) implies that utility at time t is

$$u_N(t) = \left\{ \int_{m_N} q(\theta, t)^{1/\sigma} d_N(\theta, t)^{(\sigma-1)/\sigma} d\theta + \int_{m_S} q(\theta, t)^{1/\sigma} d_S^*(\theta, t)^{(\sigma-1)/\sigma} d\theta \right\}^{\sigma/(\sigma-1)}.$$

Substituting using (5) and (6) yields $u_N(t) = c_N P_N(t)^{1/(\sigma-1)}$. Further substituting for steady-state c_N and $P_N(t)$, we obtain an expression for steady-state utility of the typical Northern consumer:

$$u_N(t) = \left[1 + (\rho - n)\gamma \frac{\lambda I}{\lambda I + C} x_N \right] \frac{\sigma - 1}{\sigma} \left\{ Q(t) \left[\frac{\lambda I}{\lambda I + C} + \left(\frac{w}{\tau} \right)^{\sigma-1} \frac{C}{\lambda I + C} \right] \right\}^{\frac{1}{\sigma-1}}.$$

Following the same procedure for the typical Southern consumer yields

$$u_S(t) = \left[1 + (\rho - n)\beta \frac{C}{\lambda I + C} \frac{x_N \bar{L}_N}{\bar{L}_S} \right] \frac{\sigma - 1}{\sigma} \left\{ Q(t) \left[(w\tau)^{1-\sigma} \frac{\lambda I}{\lambda I + C} + \frac{C}{\lambda I + C} \right] \right\}^{\frac{1}{\sigma-1}}.$$

In both the North and the South, consumer utility grows over time entirely because of growth in the quality $Q(t)$ of products. Furthermore, because $x_N = \frac{Q(t)}{L_N(t)}$ is constant in steady-state equilibrium and the growth rate of Q is n , there is a common steady-state rate of economic growth g given by

$$g \equiv \frac{\dot{u}_N(t)}{u_N(t)} = \frac{\dot{u}_S(t)}{u_S(t)} = \frac{1}{\sigma - 1} \frac{\dot{Q}(t)}{Q(t)} = \frac{n}{\sigma - 1}. \quad (32)$$

$x_N = \frac{Q(t)}{L_N(t)}$ constant also implies that $Q(0) = x_N \bar{L}_N$, from which it follows that the steady-state utility of the typical Northern consumer at time $t = 0$ is

$$u_N(0) = \left[1 + (\rho - n)\gamma \frac{\lambda I}{\lambda I + C} x_N \right] \frac{\sigma - 1}{\sigma} \left\{ x_N \bar{L}_N \left[\frac{\lambda I}{\lambda I + C} + \left(\frac{w}{\tau} \right)^{\sigma-1} \frac{C}{\lambda I + C} \right] \right\}^{\frac{1}{\sigma-1}} \quad (33)$$

and the steady-state utility of the typical Southern consumer at time $t = 0$ is

$$u_S(0) = \left[1 + (\rho - n)\beta \frac{C}{\lambda I + C} \frac{x_N \bar{L}_N}{\bar{L}_S} \right] \frac{\sigma - 1}{\sigma} \left\{ x_N \bar{L}_N \left[(w\tau)^{1-\sigma} \frac{\lambda I}{\lambda I + C} + \frac{C}{\lambda I + C} \right] \right\}^{\frac{1}{\sigma-1}}. \quad (34)$$

Equations (33) and (34) will prove useful for studying the long-run welfare effects of policy changes. Taking as given that the economy always converges over time to its steady-state equilibrium, whenever there is a change in the economic environment (for example, trade costs fall), this leads to convergence to a new steady-state equilibrium. Since the old and the new steady-state equilibrium paths involve the same rate of economic growth, we just have to compare utility levels at time $t = 0$ in the old and new steady-states to determine whether the change makes consumers better off in the long run. If $u_N(0)$ is higher in the steady-state equilibrium with lower trade costs, this means that eventually the typical Northern consumer will be happier on the new equilibrium path with lower trade costs than on the old equilibrium path with higher trade costs.

This completes the description of the model's steady-state equilibrium.

3 Steady-State Equilibrium Properties

In this section, we study the steady-state equilibrium properties of the model. To illustrate the model's potential, we study the implications of three aspects of "globalization": increases in the size of the South (i.e., countries like China joining the world trading system), stronger intellectual property protection (i.e., the TRIPs agreement that was part of the Uruguay Round) and lower trade costs (i.e., improvements in transportation technology or reductions in trade barriers). An increase in the size of the South is captured by increasing \bar{L}_S , the size of the South at time $t = 0$.¹¹ Stronger intellectual property protection is captured by increasing β , the parameter that governs how hard it is for Southern firms to copy ideas developed in the North.¹² Lower trade costs are captured by decreasing τ .

3.1 General Results

First, an increase in the size of the South \bar{L}_S has no effect on the Northern steady-state condition (24) but implies that x_N increases for given C in (25). Thus the Southern steady-state condition shifts to the right in (x_N, C) space and this is illustrated in Figure 3. Starting from the steady-

¹¹An increase in the relative size of the South \bar{L}_S can also be thought of as capturing the effects of a higher population growth rate in the South. In the model, we have assumed a common population growth rate in both regions and this assumption is necessary to obtain a steady-state equilibrium. However, in the real world, Southern population growth has clearly exceeded Northern population growth in recent decades.

¹²This is how stronger intellectual property rights are modelled in Glass and Saggi (2002).

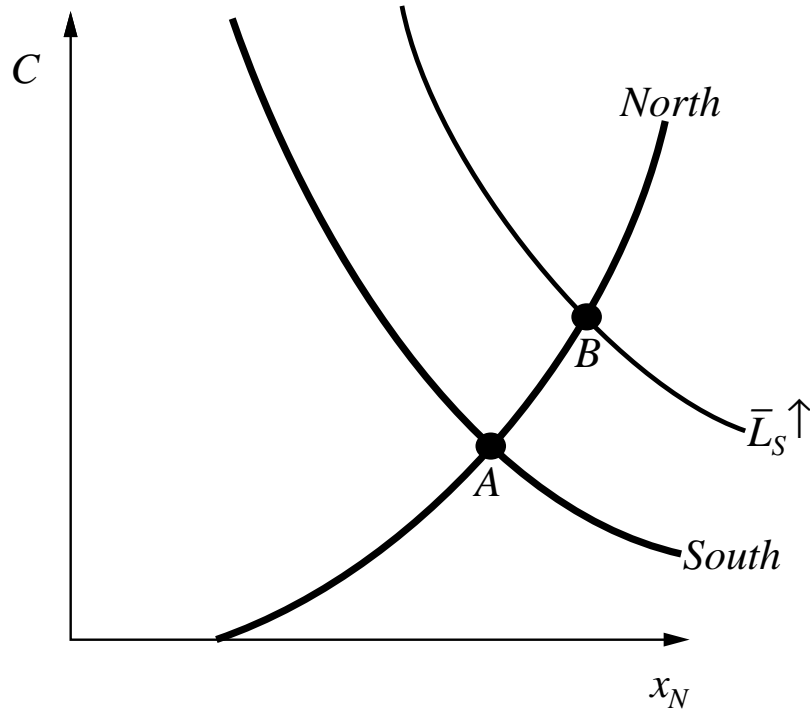


Figure 3: The Steady-State Effects of Increasing the Size of the South

state equilibrium given by point A , an increase in \bar{L}_S leads to a new steady-state equilibrium given by point B . Thus, the increase in \bar{L}_S leads to an increase in both x_N and C . The measure of relative R&D difficulty $x_N = \frac{Q(t)}{\bar{L}_N(t)}$ can only permanently increase if the average quality of products $Q(t)$ temporarily grows at a faster than usual rate. This means that a permanent increase in x_N is associated with a temporary increase in the Northern innovation rate I .

Second, an increase in β has no effect on the Northern steady-state condition (24) but implies that x_N decreases for given C in (25). Thus the Southern steady-state condition shifts to the left in (x_N, C) space and this is illustrated in Figure 4. Starting from the steady-state equilibrium given by point A , an increase in β leads to a new steady-state equilibrium given by point B . Thus stronger intellectual property protection leads to a decrease in both x_N and C .

Finally, a decrease in τ has no effect on the Northern steady-state condition (24) and no effect on the Southern steady-state condition (25). Thus, decreasing τ has no effect on either x_N or C .

We have established

Theorem 1 (i) A permanent increase in the size of the South ($\bar{L}_S \uparrow$) leads to a permanent increase in the rate of copying of Northern products ($C \uparrow$) and a temporary increase in the Northern innovation rate ($x_N \uparrow$). (ii) A permanent increase in intellectual property protection ($\beta \uparrow$) leads to a permanent

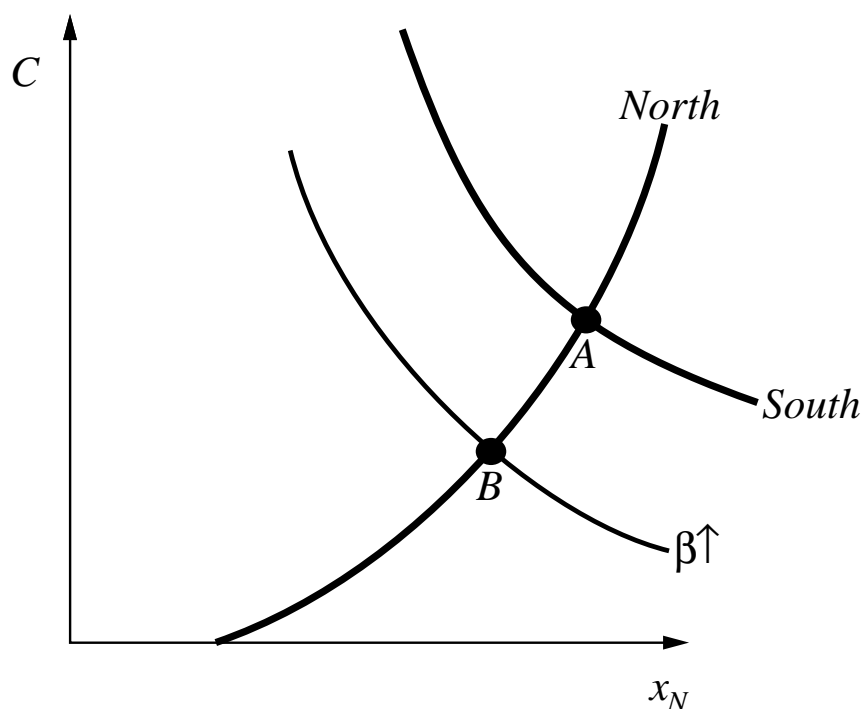


Figure 4: The Steady-State Effects of Stronger Intellectual Property Protection

decrease in the rate of copying of Northern products ($C \downarrow$) and a temporary decrease in the Northern innovation rate ($x_N \downarrow$). (iii) A permanent decrease in trade costs ($\tau \downarrow$) leads to no change in the rate of copying of Northern products (C constant) and no change in the Northern innovation rate (x_N constant).

Interestingly, all three aspects of globalization have different steady-state equilibrium effects. We discuss now the intuition underlying these effects.

An increase in the size of the South naturally leads to more copying of Northern products and this faster rate of technology transfer means that production (and jobs) move from the high wage North to the low wage South. With production jobs moving to the South, more Northern workers become available for employment in the Northern R&D sector and the Northern wage must adjust to make it attractive for Northern firms to expand their R&D activities. In the short-run, an increase in the size of the South causes the industry-level innovation rate I to jump up and technological change to accelerate, but the industry-level innovation rate gradually falls back to the original steady-state level $I = n/(\lambda - 1)$ as R&D becomes relatively more difficult. In the long run, an increase in the size of the South does not change the innovation rate but increases relative R&D difficulty x_N and the fraction of Northern labor employed in R&D activities.

A increase in intellectual property protection naturally leads to less copying of Northern products. What is perhaps surprising is that it also slows technological change. In economic models, stronger patent enforcement often promotes innovative activity. For example, Horowitz and Lai (1996) show in a closed economy setting that increasing the patent length raises the rate-of-innovation except when the patent length exceeds the welfare-maximizing patent length. But in this North-South trade setting, the lower rate of copying that stronger intellectual property protection generates has important implications for the Northern labor market. The slower rate of technology transfer from the North to the South directly increases the demand for Northern production workers (because fewer production jobs get transferred to the South). However, since Northern workers were fully employed to begin with, there are no additional Northern workers to hire (at any given point in time). Thus, the Northern wage must increase enough so that the increase in demand for Northern production workers is completely offset by a decrease in demand for Northern R&D workers. In negotiations about the protection of intellectual property rights at the World Trade Organization (WTO), developing countries have been arguing that stronger intellectual property rights protection would simply generate substantial rents for Northern innovators at the expense of Southern consumers and would not stimulate faster technological change (see Maskus, 2000). Theorem 1 provides support for this position taken by developing countries.

The result in Theorem 1 that is perhaps the most surprising is that lower trade costs between the North and the South have no effect on the rate of technology transfer or rate of innovation. The reason is that when trade costs fall, Northern firms make higher profits from exporting to the South but their profits fall from selling their products locally in the North because the Northern market becomes more competitive. Given the assumption of Dixit-Stiglitz consumer preferences, these two opposing effects exactly cancel. Thus lower trade costs do not change either the profits earned from innovating or the profits earned from imitating. Consequently, there is no change in either C or x_N . Baldwin and Forslid (2000) obtain the same type of result in the context of North-North trade.

While it is straightforward to obtain general results about how different aspects of globalization affect C and x_N , the same is not true for what happens to the relative wage w and consumer welfare. The reason is that the wage condition (31) is quite complicated. One way to proceed is to study the remaining properties of the model using computer simulations and this is certainly feasible. However, in the interest of obtaining more analytical results, we focus in the rest of the paper on a special case, namely, when there is costless trade ($\tau = 1$). To obtain further analytical results about the effects of lowering trade costs, we focus on the marginal effects of moving towards costless

trade.

3.2 The Costless Trade Special Case

When there is costless trade between the North and the South ($\tau = 1$), the wage interval that must be satisfied becomes $1 < w < \delta$. Furthermore, the wage condition (31) simplifies considerably to

$$w^\sigma = \frac{\beta(\rho + I)}{\gamma(\rho + I + C)}. \quad (35)$$

Since the innovation rate is given by $I = \frac{n}{\lambda-1}$, this wage equation implies that the relative wage w is a decreasing function of the rate of copying C . Other things being equal, when the rate of copying increases, this decreases the reward for innovating relative to the reward for imitating and results in a fall in the relative wage of Northern workers.

We will first establish conditions under which the model has a steady-state equilibrium when there is costless trade, that is, when the wage interval $1 < w < \delta$ is satisfied.

As we have already shown in Theorem 1, steady-state C is an increasing function of \bar{L}_S , holding all other parameters fixed. Let $C = f(\bar{L}_S)$ denote this increasing function. If $\bar{L}_S = 0$, then (24) and (25) imply that only $C = 0$ satisfies both conditions, so $0 = f(0)$.

From the wage equation (35), since C is an increasing function of \bar{L}_S , w is a decreasing function of \bar{L}_S . It follows that $w < \delta$ is satisfied for all $\bar{L}_S > 0$ if $w \leq \delta$ when $\bar{L}_S = 0$. However, (35) implies that $w = (\beta/\gamma)^{1/\sigma}$ when $\bar{L}_S = 0$ and $C = 0$. Thus $w = (\beta/\gamma)^{1/\sigma} \leq \delta$ holds when $\bar{L}_S = 0$ if and only if $\beta \leq \gamma\delta^\sigma$. We will assume that this inequality holds.

Since w is a decreasing function of \bar{L}_S , $1 < w$ is satisfied if \bar{L}_S is not too large. Solving (35) for w , $1 < w$ is satisfied if and only if $C = f(\bar{L}_S) < \bar{C}$ where $\bar{C} \equiv (\rho + I)(\frac{\beta}{\gamma} - 1)$. Alternatively stated, $1 < w$ is satisfied if and only if $\bar{L}_S < f^{-1}(\bar{C})$. We assume that $\gamma < \beta$ holds to guarantee that $\bar{C} > 0$ and $f^{-1}(\bar{C}) > 0$.

We have established

Theorem 2 *Given that $\beta \in (\gamma, \gamma\delta^\sigma]$ and $\tau = 1$ hold, the model has a unique steady state equilibrium if $\bar{L}_S < f^{-1}(\bar{C})$.*

Theorem 2 establishes the existence of a unique steady-state equilibrium under costless trade if the initial size of the South \bar{L}_S is not too large. When the South becomes sufficiently large relative to the North ($\bar{L}_S \geq f^{-1}(\bar{C})$), then factor price equalization results ($w = 1$) and the model ceases to be a model of North-South trade.

Consider next the steady-state equilibrium effects of different aspects of globalization on the relative wage w . Since an increase in \bar{L}_S increases C , (35) implies that w falls. In contrast, since an increase in β decreases C , (35) implies that w rises. We have established

Theorem 3 *When there is costless trade, a permanent increase in the size of the South ($\bar{L}_S \uparrow$) leads to a permanent decrease in the Northern relative wage ($w \equiv \frac{w_N}{w_S} \downarrow$), while a permanent increase in intellectual property protection ($\beta \uparrow$) leads to a permanent increase in the Northern relative wage ($w \equiv \frac{w_N}{w_S} \uparrow$).*

The intuition behind these steady-state effects is quite intuitive. An increase in the size of the South \bar{L}_S leads to a faster rate of copying C of Northern products by Southern firms. Consequently, with more production jobs moving from the high-wage North to the low-wage South, to restore full employment of labor in the North, the Northern relative wage w must fall enough so that the loss of Northern production employment is fully offset by an increase in Northern R&D employment. For stronger intellectual property protection, we just run this intuition in the opposite direction. An increase in the intellectual property protection β leads to a slower rate of copying C of Northern products by Southern firms. Consequently, fewer production jobs move from the high-wage North to the low-wage South, increasing the demand for Northern labor. The Northern relative wage w must rise enough so that the gain in Northern production employment is fully offset by a loss in Northern R&D employment.

Solving for the steady-state equilibrium effect of lower trade costs τ on the Northern relative wage w involves more work. Since a change in τ has no effect on I , C and x_N , the LHS of the wage equation (31) can be viewed as a function of just τ and w . Let $g(\tau, w)$ denote this function. We proceed by totally differentiating the wage equation (31) with respect to w and τ and then using the implicit function theorem. Evaluating the derivatives at $\tau = 1$ and using the fact that $g(1, w) = w^\sigma$, this yields

$$\left. \frac{\partial g(\tau, w)}{\partial \tau} \right|_{\tau=1} = \frac{(\sigma - 1)(1 - \phi_N)}{1 + \phi_N} w^\sigma, \quad \left. \frac{\partial g(\tau, w)}{\partial w} \right|_{\tau=1} = \sigma w^{\sigma-1},$$

and

$$\left. \frac{dw}{d\tau} \right|_{\tau=1} = - \frac{\left. \frac{\partial g(\tau, w)}{\partial \tau} \right|_{\tau=1}}{\left. \frac{\partial g(\tau, w)}{\partial w} \right|_{\tau=1}} = \frac{(\sigma - 1)(\phi_N - 1)w}{\sigma(1 + \phi_N)}. \quad (36)$$

Increasing trade costs τ on the margin starting from costless trade increases the relative wage w if $\phi_N > 1$ and decreases the relative wage w if $\phi_N < 1$. The condition $\phi_N > 1$ means that

aggregate Northern consumer expenditure is larger than aggregate Southern consumer expenditure ($\bar{L}_N c_N > \bar{L}_S c_S$), or the Northern market is larger than the Southern market (in terms of purchasing power).

We are mainly interested in the result going in the reverse direction, which can be stated as:

Theorem 4 *In the neighborhood of costless trade, a permanent decrease in the trade costs ($\tau \downarrow$) leads to a permanent decrease in the Northern relative wage ($w \equiv \frac{w_N}{w_S} \downarrow$) if the Northern market is larger than the Southern market ($\phi_N > 1$), and has the opposite effect on the Northern relative wage ($w \equiv \frac{w_N}{w_S} \uparrow$) if the Northern market is smaller than the Southern market ($\phi_N < 1$).*

When trade costs τ decrease on the margin, there is no effect on the innovation rate I , the copying rate C or relative R&D difficulty x_N . Referring back to (24) and (25), the relative size of the Northern R&D sector $\gamma x_N I$ does not change and the relative size of the Southern R&D sector $\beta \frac{x_N \bar{L}_N}{L_S} C \frac{\lambda I}{\lambda I + C}$ does not change either. But the reduction in trade costs does lead to a reallocation of resources in both the North and the South. Firms respond by exporting more, employing more workers to produce goods for the export market and employ fewer workers to produce goods for the domestic market. Lower trade costs mean that firms face stiffer competition in their domestic markets since the prices charged by other firms fall. For firms in the larger market, this stiffer domestic competition is more important in lowering labor demand than the increase in exporting is in raising labor demand. Thus lower trade costs tend to depress the relative wage of workers in the larger market.

In the real world, the North is clearly larger than the South when it comes to aggregate income and purchasing power. Thus we interpret Theorem 4 as implying that lower trade costs permanently reduce the Northern relative wage w . An increase in the size of the South also lowers the relative wage, while an increase in intellectual property protection raises the relative wage. Thus, two of the three aspects of globalization that we have studied in this paper lower the relative wage of Northern workers.

Has wage inequality in fact decreased between Northern and South workers during the past several decades of globalization? There is a growing empirical literature that looks at how income inequality has been changing over time for the world as a whole and the results depend critically on how income inequality is measured. For example, if income inequality is measured by GDP per capita across countries, then global income inequality has increased considerably since 1980. Pritchett (1997) reports that during the period 1980-1994, the mean per annum growth rate of GDP

per capita was 1.5% for 17 advanced capitalist countries and only 0.34% for 28 less developed countries. But this way of measuring income inequality has been criticized because it takes countries as its unit of analysis rather than people, so the 1.3 billion citizens of China count for no more than do the 0.0004 billion citizens of Luxembourg. Jones (1997) shows that global income inequality has in fact decreased if each country's average income is weighted by its population, mainly because of the good growth performance of the world's two largest countries China and India. And when within-country income inequality is also taken into account, Sala-i-Martin (2002) still finds that global inequality has decreased substantially since 1980.

Another piece of evidence is provided by Wacziarg and Welch (2002). They ask the question, do countries tend to experience faster or slower economic growth rates following trade liberalization? Wacziarg and Welch find that trade-centered reform (countries switching from being "closed" to being "open" using the Sachs-Warner (1995) criterion) has on average robust positive effects on economic growth rates within countries. For the typical country that switches from being closed to being open, the growth rate of real per capita GDP increases by 1.4% (see Table 13 in Wacziarg and Welch (2002) and the regression with both country and year fixed effects). This estimate is both highly statistically significant and economically significant. It means that for a typical country growing at an average annual rate of 1.1% before trade liberalization, its average annual growth rate jumps up to $1.1\% + 1.4\% = 2.5\%$ after trade liberalization. Since it is exclusively developing countries that have become "open" in the last three decades and these countries tend to grow faster as a result, the findings in Wacziarg and Welch (2002) are consistent with a declining wage gap between the North and the South.¹³

Some other models of North-South trade and economic growth have recently been developed that do not have the counterfactual growth implications mentioned in the introduction. Building on an earlier version of this paper, Gustafsson (2004) has developed a North-South trade model where innovations increase product variety (instead of product quality) and scale effects are ruled out by using the same R&D technology as in Jones (1995b). Sener (2006) has developed a North-South trade model where scale effects are removed by assuming that successful innovators engage in rent protection activities to deter the innovation and imitation efforts of their rivals, building on the closed economy model by Dinopoulos and Syropoulos (2006). Also of interest, Parello (2004) has developed a North-South trade model where scale effects are removed by assuming

¹³The empirical literature of trade and growth using cross sectional data has been heavily criticized in an influential paper by Rodriguez and Rodrick (2000). However, Wacziarg and Welch (2002) use panel data and look at the within-country growth effects of trade liberalization, something that had not been done in the earlier literature.

that R&D difficulty increases over time based either on cumulative R&D effort [as in Segerstrom (1998)] or on the size of the market [as in Dinopoulos and Thompson (1999)]. None of these papers look at the welfare implications of changes in the economic environment or study the effects of lower trade costs. Gustafsson (2004) shows that the results derived in this paper about the effects of a larger South and stronger intellectual property rights also hold when innovations are variety-increasing. In contrast, Sener (2006) finds that a larger South increases North-South wage inequality and stronger intellectual property protection permanently decreases the innovation rate. Parello (2004) just studies the effects of stronger intellectual property protection and finds that this increases the innovation rate if and only if the Northern human capital stock is relatively low.

In this paper and all of the above-mentioned papers, all technology transfer takes the form of Southern firms copying Northern products. We have also written a companion paper, Dinopoulos and Segerstrom (2005), which studies the polar opposite case where all technology transfer is done by the Northern firms themselves. Northern firms engage in adaptive R&D to learn how to produce their products in the lower-wage South. In the environment with foreign direct investment and multinational firms, most of the results derived in the present paper continue to hold but there are some differences. In particular, an increase in the size of the South no longer has the steady-state effect of decreasing the Northern relative wage when all technology transfer is done by the Northern firms themselves.

4 Welfare Implications

In this section, we study the welfare implications of the model. We continue to study the implications of three aspects of globalization: increases in the size of the South, stronger intellectual property protection and lower trade costs.

Consider first the welfare implications of lower trade costs. A change in τ has no steady-state effect on I , C or x_N . Hence, an immediate jump to the new steady-state equilibrium is feasible and the long run welfare effects of a change in τ are also the short run welfare effects. Equation (33) implies that a change in τ only benefits the typical Northern consumer if it leads to an increase in $\frac{w}{\tau}$. Likewise, (34) implies that a change in τ only benefits the typical Southern consumer if it leads to a decrease in $w\tau$. Using (36), we can differentiate both of these terms with respect to τ . This

yields

$$\left. \frac{d[w/\tau]}{d\tau} \right|_{\tau=1} = \frac{(\sigma-1)(\phi_N-1)w}{\sigma(1+\phi_N)} - w < 0$$

and

$$\left. \frac{d[w\tau]}{d\tau} \right|_{\tau=1} = \frac{(\sigma-1)(\phi_N-1)w}{\sigma(1+\phi_N)} + w > 0,$$

taking into account that $\phi_N > 0$. Thus, regardless of the value of ϕ_N , an increase in trade costs τ makes the typical Northern consumer worse off and makes the typical Southern consumer worse off. We are mainly interesting in the result going in the reverse direction, which can be stated as:

Theorem 5 *In the neighborhood of costless trade, a permanent decrease in the trade costs ($\tau \downarrow$) makes the typical Northern consumer better off ($u_N(0) \uparrow$), and makes the typical Southern consumer better off ($u_S(0) \uparrow$).*

Theorem 5 is surprising in light of the ambiguous effect of lower trade costs on the relative wage. Even though lower trade costs τ can either increase or decrease the relative wage w depending on the value of ϕ_N (Theorem 4), the proof of Theorem 5 shows that this wage effect is always dominated by the effect on prices. Lower trade costs lead to lower prices for goods in both the North and the South. Consumers benefit from lower prices and these price benefits always dominate the possibly negative effects of lower trade costs on their wages.

Consider next the welfare implications of an increase in the size of the South \bar{L}_S when there is costless trade. Things are more complicated now because an increase in the size of the South \bar{L}_S has the steady-state effects of increasing C and x_N , as well as decreasing w . In what follows, we set $w_S = 1$ and treat the Southern wage as the numeraire.

Focusing first on the North and using $u_N(t) = c_N P_N(t)^{1/(\sigma-1)}$, it proves to be convenient to rewrite (33) as $u_N(0) = c_N P_N(0)^{1/(\sigma-1)}$ where the typical consumer's expenditure is

$$c_N = w_N \left[1 + (\rho - n)\gamma \frac{\lambda I}{\lambda I + C} x_N \right]$$

and the Northern price index is

$$P_N(0) = \left(\frac{\sigma-1}{\sigma} \right)^{1-\sigma} x_N \bar{L}_N \left[w_N^{1-\sigma} \frac{\lambda I}{\lambda I + C} + \frac{C}{\lambda I + C} \right].$$

From the Northern condition (24), since an increase in \bar{L}_S raises both C and x_N , $\frac{x_N}{\lambda I + C}$ decreases unambiguously. It follows immediately that an increase in \bar{L}_S lowers consumer expenditure c_N because both the consumer's wage income w_N and interest income $w_N(\rho - n)\gamma \frac{\lambda I}{\lambda I + C} x_N$ fall. It also follows immediately that an increase in \bar{L}_S raises the Northern price index $P_N(0)$ because

both the average quality of products increase ($x_N \uparrow$) and the average price level becomes more favorable for consumers ($w_N^{1-\sigma} \frac{\lambda I}{\lambda I + C} + \frac{C}{\lambda I + C} \uparrow$). The overall effect on Northern consumer welfare is ambiguous.

Focusing next on the South, we can use the same general procedure for determining the welfare effects. Using $u_S(t) = c_S P_S(t)^{1/(\sigma-1)}$, it proves to be convenient to rewrite (34) as $u_S(0) = c_S P_S(0)^{1/(\sigma-1)}$ where the typical consumer's expenditure is

$$c_S = 1 + (\rho - n)\beta \frac{C}{\lambda I + C} \frac{x_N \bar{L}_N}{\bar{L}_S}$$

and the Southern price index $P_S(0)$ is the same as the Northern price index $P_N(0)$ since costless trade prevails. From the Southern condition (25), an increase in \bar{L}_S has no effect on $\frac{C}{\lambda I + C} \frac{x_N \bar{L}_N}{\bar{L}_S}$. It follows immediately that an increase in \bar{L}_S has no effect on consumer expenditure c_S but it does raise the Southern price index $P_S(0)$ for the same reasons as in the North. The overall effect on Southern consumer welfare is unambiguously positive. To summarize, we have established

Theorem 6 *When there is costless trade, a permanent increase in the size of the South ($\bar{L}_S \uparrow$) has an ambiguous effect on the long run welfare of the typical Northern consumer but unambiguously makes the typical Southern consumer better off in the long run ($u_S(0) \uparrow$).*

An increase in the size of the South \bar{L}_S results in a faster steady-state rate of copying C of Northern products. This stimulates technological change in the North but also depresses the wages of Northern workers. The overall effect on Northern welfare in the long run is ambiguous. On the one hand, Northern consumers are hurt by the fall in their wage and interest income but on the other hand, they benefit from being able to buy higher quality products at lower prices. For Southern consumers, the long-run welfare effects of an increase in the size of the South are unambiguously positive. Southern consumers are able to buy higher quality products at lower prices and there is no change in their wage or interest income.

Consider finally the welfare implications of an increase in intellectual property protection β when there is costless trade. Things are complicated in this case as well because an increase in β has the steady-state effects of decreasing C and x_N , as well as increasing w . We set $w_S = 1$ as before.

From the Northern condition (24), since an increase in β lowers both C and x_N , $\frac{x_N}{\lambda I + C}$ increases unambiguously. It follows immediately that an increase in β raises Northern consumer expenditure c_N because both the consumer's wage income w_N and interest income $w_N(\rho - n)\gamma \frac{\lambda I}{\lambda I + C} x_N$ rise.

It also follows immediately that an increase in β lowers the Northern price index $P_N(0)$ because both the average quality of products decrease ($x_N \downarrow$) and the average price level becomes less favorable for consumers ($w_N^{1-\sigma} \frac{\lambda I}{\lambda I + C} + \frac{C}{\lambda I + C} \downarrow$). The overall effect on Northern consumer welfare is ambiguous.

From the Southern condition (25), an increase in β has no effect on $\beta \frac{C}{\lambda I + C} \frac{x_N \bar{L}_N}{L_S}$. It follows immediately that an increase in β has no effect on Southern consumer expenditure c_S but it does lower the Southern price index $P_S(0)$ for the same reasons as in the North. The overall effect on Southern consumer welfare is unambiguously negative. To summarize, we have established

Theorem 7 *When there is costless trade, a permanent increase in intellectual property protection ($\beta \uparrow$) has an ambiguous effect on the long run welfare of the typical Northern consumer but unambiguously makes the typical Southern consumer worse off in the long run ($u_S(0) \downarrow$).*

An increase in intellectual property protection β results in a slower steady-state rate of copying C of Northern products. This slows technological change in the North but also raises the wages of Northern workers. The overall effect on Northern welfare in the long run is ambiguous. On the one hand, Northern consumers benefit from the rise in their wage and interest income but on the other hand, they are hurt from having to buy lower quality products at higher prices. For Southern consumers, the long-run welfare effects of an increase in intellectual property protection are unambiguously negative. Southern consumers end up buying lower quality products at higher prices and there is no change in their wage or interest income.

5 Conclusions

This paper develops a dynamic, general-equilibrium model of North-South trade and economic growth. Both innovation and imitation rates are endogenously determined as well as the degree of wage inequality between Northern and Southern workers. Northern firms devote resources to innovative R&D to discover higher quality products and Southern firms devote resources to imitative R&D to copy state-of-the-art quality Northern products. The model does not have the counterfactual growth implications of earlier North-South trade models and can be used to study the long-run welfare implications of changes in the economic environment. We have used the model to study the equilibrium and welfare implications of three aspects of globalization: increases in the size of the South (i.e., countries like China joining the world trading system), stronger intellectual property

protection (i.e., the TRIPs agreement that was part of the Uruguay Round) and lower trade costs.

Because the theoretical framework developed in this paper is quite tractable, it could prove useful for analyzing other issues. For example, the model only has one factor of production. By extending the model to allow for two factors of production (low and high-skilled labor), one could study how different aspects of globalization affect wage inequality within regions. The effects of Northern and/or Southern tariffs, technology transfer by means of licensing agreements, and international labor migration could also be studied using this framework. These are all possible directions for further research.

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