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ABSTRACT

A Theory of North-South Trade and Globalization*

This Paper develops a dynamic general equilibrium model of North-South trade with scale-invariant growth. 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. Both innovation and imitation rates are endogenously determined as well as the degree of wage inequality between Northern and Southern workers. The steady-state effects of globalization and stronger protection of intellectual property are analysed. It is shown that globalization leads to more copying of Northern products, faster technological change, and less wage inequality between Northern and Southern workers. Stronger intellectual property protection has the opposite steady-state effects and thus serves to moderate the effects of globalization.

JEL Classification: F12, F43, O31 and O34
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1 Introduction

The question that motivates this paper is the following: What are the effects for advanced countries of China joining the world trading system? 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 to external trade. Because China is such a large country (20 percent of the world population), China's decision to join the world trading system could potentially have large ramifications for advanced countries. We present a dynamic, general equilibrium model of North-South trade with scale-invariant growth to shed light on this issue.

To model the effects for advanced countries of China joining the world trading system, we adopt the approach illustrated in Figure 1. We think of the world economy as consisting of three

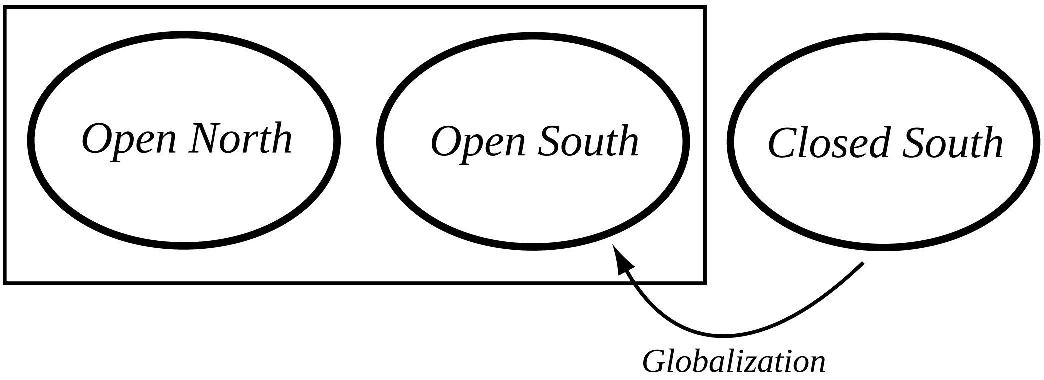

Figure 1: The World Economy

regions: an *Open North* consisting of developed countries that have "open" trade policies (United States, France, Germany, Sweden, etc.), an *Open South* consisting of developing countries that have "open" trade policies (South Korea, Taiwan, China today, etc.) and a *Closed South* consisting of developing countries that have "closed" trade policies (North Korea, Afghanistan, China under Mao, etc.). Then China's decision to join the world trading system is illustrated by the globalization arrow in Figure 1. More generally, we define *globalization* as countries moving from the Closed South to the Open South by changing their trade policies.[1]

Although there are different degrees of openness in the real world (even North Korea does

[1]Globalization can take various forms. For example, it can be modelled as a reduction in trade barriers between developed countries [as in Dinopoulos and Segerstrom (1999)] or as the international movement of resources (labor migration and/or the formation of multinationals). This paper focuses on one particular form of globalization: developing countries joining the world trading system.

export some military products, for example), for theoretical simplicity, we assume that countries in the open regions (the Open North and the Open South) adopt free trade policies and countries in the Closed South do not trade with the rest of the world. Since the Closed South does not interact with the rest of the world (by assumption), we leave the Closed South unmodelled and present a model of trade between the Open North and the Open South. This modelling choice is illustrated by the rectangle in Figure 1. To simplify terminology, we will usually refer to the Open South as simply "the South" and the Open North as simply "the North". Then globalization corresponds to an increase in the population size of the South.

In our dynamic general equilibrium model of North-South trade, 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. Both innovation and imitation rates are endogenously determined based on expected discounted profit maximization considerations. The degree of wage inequality between Northern and Southern workers is also endogenously determined based on labor market clearing considerations. We use the model to study the steady-state equilibrium effects of globalization and stronger protection of intellectual property.[2]

The implications of China's entry into the world trading system is a topic of considerable current public policy interest. The concerns that people have are clearly expressed in a recent article in *The Economist* (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?"

The model presented in this paper captures these considerations. It is a North-South trade model where the location of industries changes over time. 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, countries like China are "gobbling up" microwaves, fridges, air conditioners, etc., products that used to be produced in developed countries.

[2]The terminology West-East may be more appropriate that 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).

While people in developed countries are concerned about China's entry into the world trading system, they also see potential benefits and these are clearly expressed in the same article:

> "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."

The model presented in this paper also captures these benefits of globalization. In the model, the profit flows earned by Northern quality leaders directly increase when these firms are able to sell to a larger Southern market of consumers and Northern consumers directly benefit from copying because product prices drop when production shifts from the "high wage" North to the "low wage" South.

Because there are both pluses and minuses associated with China's entry into the world trading system, it is not obvious how China's entry affects the wages earned by advanced country workers and in particular the North-South wage gap. On the one hand, globalization (China's entry) means that there are more Southern workers copying Northern products and this should cut into both the profits earned by Northern firms and the wages earned by Northern workers, reducing North-South wage inequality. On the other hand, globalization (China's entry) means that firms in the North have a larger Southern market to sell to and this should push up Northern wages, increasing North-South wage inequality. Both considerations are present in the model and we solve for how globalization (China's entry) affects the steady-state equilibrium wage gap between Northern and Southern workers.

The main result in the paper is Theorem 1 about the effects of globalization. We show that globalization (an increase in the population size of the South) has no effect on the long run innovation rate in each industry but causes a temporary increase in the innovation rate along the transition path from the old to the new steady-state equilibrium. In contrast, globalization causes the rate of copying of Northern products to permanently increase. And this has important implications for the wages of workers. We show that globalization unambiguously reduces the steady-state degree of wage inequality between Northern and Southern workers.[3] Alternatively stated, globalization leads to temporarily higher rates of economic growth in the South than in the North.

[3] In the static Ricardian model of North-South trade, an increase in the size of the South results in a deterioration in the South's terms of trade and hence increases North-South wage inequality.

The intuition behind the result that globalization reduces North-South wage inequality is as follows: Although globalization means that Northern firms have a larger Southern market to sell to, the Northern relative wage is not pushed up because Southern firms also have a larger Southern market to sell to. What matters in determining how the Northern relative wage changes is how globalization affects the reward for innovating *relative* to the reward for imitating. Since globalization increases the rate of copying of Northern products by Southern firms, globalization unambiguously reduces the reward to innovating relative to the reward for imitating. The relative wage of Northern workers has to fall as a consequence to maintain full employment of labor in both regions.

The second main result in the paper is Theorem 2 about the effects of stronger intellectual property protection. We show that stronger intellectual property protection has no effect on the long run innovation rate but causes a temporary decrease in the innovation rate along the transition path from the old to the new steady-state equilibrium. Stronger intellectual property protection also causes the rate of copying of Northern products to permanently decrease and the North-South wage gap to permanently increase. Thus stronger intellectual property protection has the opposite steady-state effects compared to globalization. Interestingly, at the same time that globalization has been occurring, developed countries have been pushing for stronger intellectual property protection and this is reflected in the TRIPs (Trade Related Intellectual Property Rights) agreement that was part of the Uruguay Round completed in 1994. Given our model, stronger intellectual property protection can be interpreted as moderating the steady-state effects of globalization.

Although China's entry into the world trading system is the motivating example, the model presented in this paper has broader applicability. In recent decades, many developing countries have opened their economies to international trade. These developments are documented in a recent paper by Wacziarg and Welch (2002). They use the Sachs-Warner (1995) criterion to categorize all countries in the world as being either "open" or "closed" for each year between 1950 and 2000.[4] Wacziarg and Welch's dates of trade liberalization (the years when specific countries switched from being "closed" to being "open") are shown for selected countries in Table 1. This table shows that in recent decades, many developing countries (Mexico, Turkey, Poland, etc.) have become open, effectively increasing the population size of the Open South.[5]

[4]The Sachs-Warner criterion for openness takes into account average tariff rates, non-tariff barriers and other means that countries use to restrict international trade (monopoly export boards and foreign currency exchange restrictions).

[5]Starting from autarky, China has made considerable progress at opening up since 1978. Wacziarg and Welch (2002) find that China is still "closed" as of the year 2000 but is getting close to satisfying the Sachs-Warner criterion for being "open".

Table 1: Dates of Trade Liberalization

Country	Year	Country	Year
United States	before 1950	Phillipines	1988
United Kingdom	before 1950	Turkey	1989
Switzerland	before 1950	Hungary	1990
Sweden	1960	Poland	1990
Japan	1964	Czech Republic	1991
Chile	1976	India	after 2000
Mexico	1986	China	after 2000

This paper is related to a large literature on North-South trade and endogenous growth, including Segerstrom, Anant and Dinopoulos (1990), Grossman and Helpman (1991a,b), Helpman (1993), Lai (1998), Yang and Maskus (2001), Glass and Saggi (2002) and Gancia (2003). One thing that distinguishes our model from all of the above-mentioned models is the issue of scale effects. In an important critique of endogenous growth theory, Jones (1995a) pointed out that all of the first-generation R&D-driven endogenous growth models (including all of the above-mentioned North-South trade models) have a counterfactual scale effect property, namely, that larger economies grow faster. In response to this critique, a variety of second-generation R&D-driven endogenous growth models have been developed that do not have the scale effect property, including Jones (1995b), Kortum (1997), Young (1998), Dinopoulos and Thompson (1998), Segerstrom (1998), Howitt (1999) and Li (2002).[6] But little progress has been made at developing models of North-South trade without the scale effect property. This paper shows how the Segerstrom (1998)-Li (2002) closed economy framework can be extended to allow for North-South trade. Scale effects are removed by assuming increasing R&D difficulty.

The only other paper about North-South trade without scale effects that we are aware of is a recent paper by Sener (2003). Sener presents a model where scale effects are removed by assuming rent protection activities (instead of increasing R&D difficulty). Successful innovators in the North engage in rent protection activities to deter the innovation and imitation efforts of their rivals. In Sener's model, stronger intellectual property protection decreases the steady-state rates of imitation and innovation, and increases North-South wage inequality. The only difference in results is that the decrease in the innovation rate is temporary in our model, not a steady-state effect. Sener also studies the effects of increasing the size of the South and there he obtains significantly different results

[6]For a survey of this literature, see Dinopoulos and Thompson (1999).

compared to our Theorem 1. Sener finds that globalization decreases the steady-state innovation rate and increases North-South wage inequality, whereas we find that globalization temporarily increases the innovation rate and decreases North-South wage inequality.

The rest of the paper is organized as follows: In section 2, the dynamic general equilibrium model of North-South trade with scale-invariant growth is presented and four steady-state equilibrium conditions are derived. In section 3, we show that the model has a unique steady-state equilibrium and the two main results in the paper are derived: the steady-state equilibrium effects of globalization (Theorem 1) and stronger intellectual property protection (Theorem 2). Finally, section 4 offers some concluding comments. In the appendix, we study two extensions of the model: incorporating R&D subsidies and trade costs. We show that both Northern and Southern R&D subsidies have normal steady-state effects (Theorems 3 and 4), in particular, both types of R&D subsidies promote technological change. We also study the effects of lowering trade costs between the North and the South. Globalization as we have define it is essentially an autarky versus free trade comparison, so by studying the effects of lower trade costs, we gain some insights into the marginal effects of lowering trade barriers (Theorem 5).

2 The Model

2.1 Overview

We consider a model where there is free trade between two regions: the North and the South. The North and the South are distinguished by their abilities to conduct R&D. Workers in the North are assumed to be capable of conducting both innovative and imitative R&D whereas workers in the South can only conduct imitative R&D. We focus on steady-state equilibria in which all innovative activity takes place in the North and all imitative activity takes place in the South. Innovation takes the form of improvements in the quality of products and in each industry, product quality potentially can be improved an infinite number of times. Imitation takes the form of copying state-of-the-art quality products. In each industry, production shifts back and forth between the North and the South over time resulting in product-cycle trade. 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). There are three significant differences between the two models. First, instead of assuming zero population growth, we assume that there is positive population growth in the world economy. Second, instead of assuming Cobb-Douglas consumer preferences, we assume CES consumer preferences and restrict attention to the case where the elasticity of substitution exceeds one (products are gross substitutes). Third, instead of assuming time-invariant R&D technologies, we assume that as the quality of products increases over time and products become more complex, both innovating and imitating become more difficult. Because of these differences in assumptions, our model has significantly different properties. For example, whereas Grossman and Helpman (1991a) show that increasing the size of the South has no effect on the Northern relative wage (in the main case that they study), we find that the Northern relative wage unambiguously falls when the size of the South is increased (globalization reduces North-South wage inequality).

2.2 Industry Structure

In both the North and the South, 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. In contrast, Grossman and Helpman (1991a) assume that there is no population growth ($n = 0$). 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. Then, within the context of the present model, globalization corresponds to an increase in the constant term $\bar{L}_S$.

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

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

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

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

is the utility per person at time t. Equation (2) is a quality-augmented Dixit-Stiglitz 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. Whereas Grossman and Helpman (1991a) restrict attention to the Cobb-Douglas case where $\sigma = 1$, we analyze the CES case where $\sigma > 1$ and products produced in different industries are gross substitutes.

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

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

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

$$\frac{\dot{c}(t)}{c(t)} = r(t) - \rho, \tag{4}$$

which implies that in a steady-state equilibrium where individual consumer expenditure c is constant over time, the market interest rate r must be equal to the subjective discount rate ρ.

2.4 Product Markets

In each industry, active firms engage in Bertrand price competition. Firms can choose to exit their industries at any point in time and shut down their production facilities (that is, become inactive). Firms enter industries in the North by discovering the next higher-quality product and firms enter industries in the South by imitating state-of-the-art quality products.[7]

Labor markets are perfectly competitive in both regions. Let w_N and w_S denote the equilibrium wage rates in the North and South, respectively. Labor is the only factor of production and manufacturing of output is characterized by constant returns to scale. In each industry, one unit of labor produces one unit of output independently of its quality level or geographic location. Thus, each active firm in the North has a constant marginal cost equal to w_N and each active firm in the South has a constant marginal cost equal to w_S. We restrict attention to analyzing the model's properties when $w_N > w_S > w_N/\delta$. The first inequality guarantees that production shifts from the North to

[7] Kind (2003) has developed a North-South trade model where Southern firms choose whether to conduct imitative R&D, innovative R&D or specialize in agricultural production.

the South when a Southern firm imitates and the second inequality guarantees that production shifts back to the North when a Northern firm innovates.

Consider first the situation faced by a Northern firm that wins an innovative R&D race. This firm becomes the only firm that knows how to manufacture the highest-quality product in its industry. The firm's closest competitor is the producer one step below in the industry's quality ladder (the previous quality leader). That firm can reside in the North (if the product one step below in the quality ladder has not been copied) or in the South (if that product has been copied). In a static Bertrand price equilibrium, the new quality leader either charges the unconstrained monopoly price or engages in limit pricing (charging a price just low enough so that the previous quality leader gets no consumers, as in Grossman and Helpman (1991a)). Which of these two cases occurs depends on whether the innovation is drastic or non-drastic ($\delta > 1$ is large or small). In either case, the previous quality leader gets no consumers and is indifferent between remaining active or exiting the industry (the previous quality leader would strictly prefer exiting if there were any costs associated with maintaining unused production facilities). We solve the model for a steady-state equilibrium where following each innovation, the previous quality leader immediately exits the industry, as in Howitt (1999). In the case of a drastic innovation, the new quality leader immediately charges the unconstrained monopoly price and continues to do so. In the case of a non-drastic innovation, the new quality leader adopts a type of trigger strategy: it charges the limit price initially and immediately reverts to charging the unconstrained monopoly price once it learns that the previous quality leader has exited the market. Since the previous quality leader exits the market immediately in equilibrium (it is profit-maximizing to do so), except for the point in time when innovation occurs, a Northern firm that innovates charges the unconstrained monopoly price and earns monopoly profits from selling to both Northern and Southern consumers.[8]

Omitting the arguments of functions for notational simplicity, a Northern quality leader's profits are given by $\pi_N = (p_N - w_N)(d_N L_N + d_S L_S)$ where p_N is the Northern firm's price, d_N is the quantity demanded by the representative consumer in the North and d_S is the quantity demanded by the representative consumer in the South. Maximizing π_N with respect to p_N and taking into account that equation (3) determines both d_N and d_S yields the unconstrained monopoly price $p_N = [\sigma/(\sigma - 1)]w_N$, which is the standard monopoly markup of price over marginal cost.

[8]The question arises, what if a firm that has exited an industry chooses to reenter? Then at best (when innovation is non-drastic), the new entrant earns positive profits for a point in time before the current quality leader reverts to limit pricing. Thus if there are positive costs of reentering, however small, it will not be profitable to reenter. We assume that this is the case.

Similar considerations apply to Southern firms that win imitative R&D races. In the absence of multinational activities, these Southern quality leaders enjoy a cost advantage over their Northern competitors since $w_N > w_S$. Under the assumption of Bertrand price competition, each winner of an imitative R&D race has the ability to undercut the previous Northern quality leader and take away all of its consumers. Consequently, it is a profit-maximizing choice for Northern firms whose products have been copied to immediately exit and we solve for a steady-state equilbrium where this occurs. Thus, each Southern quality leader maximizes the flow of global monopoly profits $\pi_S = (p_S - w_S)(d_N L_N + d_S L_S)$ by charging the unconstrained monopoly price $p_S = [\sigma/(\sigma-1)]w_S$.

Before deriving an expression for the value of monopoly profits, it is helpful to introduce some additional notation. Let $c_N(t)$ denote consumption expenditure of the representative Northern consumer at time t and let $c_S(t)$ denote consumption expenditure of the representative Southern consumer at time t. Then global consumption expenditure is given by $E(t) = c_N(t)L_N(t) + c_S(t)L_S(t)$. Taking into account that $L_N(t) = \bar{L}_N e^{nt}$ and $L_S(t) = \bar{L}_S e^{nt}$, global consumption expenditure can be written alternatively as $E(t) = \bar{c}(t)L(t)$ where $\bar{c}(t) = c_N(t)\bar{L}_N/(\bar{L}_N + \bar{L}_S) + c_S(t)\bar{L}_S/(\bar{L}_N + \bar{L}_S)$ is global per-capita consumption expenditure.[9] Also, let $Q(t) = \int_0^1 q(\theta,t)\, d\theta$ denote the average quality level across all industries at time t. Then (3) implies that

$$y_N(t) = \frac{Q(t)p_N^{-\sigma}\bar{c}(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta} \tag{5}$$

is the per-capita global demand for a Northern product with average quality $Q(t)$ and

$$y_S(t) = \frac{Q(t)p_S^{-\sigma}\bar{c}(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta} \tag{6}$$

is the per-capita global demand for a Southern product with average quality $Q(t)$.

Equation (3) implies that a Northern quality leader in industry θ at time t earns the flow of monopoly profits

$$\pi_N(\theta,t) = (p_N - w_N)\frac{q(\theta,t)p_N^{-\sigma}E(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta}.$$

Using the above-mentioned notation, the profits of a Northern quality leader can be written more simply as

$$\pi_N(\theta,t) = \left[\frac{w_N}{\sigma-1}\right]\frac{q(\theta,t)}{Q(t)}y_N(t)L(t). \tag{7}$$

The profits earned by a Northern quality leader are an increasing function of the profit margin $\frac{w_N}{\sigma-1}$, the relative quality of the firm's product $\frac{q(\theta,t)}{Q(t)}$, and the market size $y_N L$. Similarly, a Southern

[9] Strictly speaking, $\bar{c}$ is per-capita consumption expenditure in the open part of the global economy since it does not include consumption expenditure in the Closed South.

quality leader in industry θ at time t earns the flow of monopoly profits

$$\pi_S(\theta,t) = (p_S - w_S)\frac{q(\theta,t)p_S^{-\sigma}E(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta}.$$

Using the above-mentioned notation, the profits of a Southern quality leader can be written more simply as

$$\pi_S(\theta,t) = \left[\frac{w_S}{\sigma-1}\right]\frac{q(\theta,t)}{Q(t)}y_S(t)L(t). \tag{8}$$

The profits earned by a Southern quality leader are an increasing function of the profit margin $\frac{w_S}{\sigma-1}$, the relative quality of the firm's product $\frac{q(\theta,t)}{Q(t)}$, and the market size $y_S L$.

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)

$$I_i = \frac{\ell_i}{\gamma q(\theta,t)} \tag{9}$$

where $\gamma > 0$ is a Northern R&D productivity parameter. The presence of the term $q(\theta,t)$ in (9) captures the idea that as products improve in quality and become more complex, innovating becomes more difficult.

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)

$$C_i = \frac{\ell_i}{\beta q(\theta,t)}, \tag{10}$$

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 (10) captures the idea that as products improve in quality and become more complex, imitating also becomes more difficult.[10]

[10]Mansfield, 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.

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 innovative and imitative R&D technologies (9) and (10) differ from those assumed in Grossman and Helpman (1991a) due to the presence of the R&D difficulty term $q(\theta, t)$, which is introduced to remove the property of scale effects.[11] All of the first generation R&D-driven endogenous growth models, including Grossman and Helpman (1991a), have the scale effect property that large economies exhibit faster per-capita income growth. However, Jones (1995a) has argued persuasively that the scale effect property is inconsistent with time series evidence for several advanced countries. This paper follows Segerstrom (1998), who showed that scale effects can be removed from quality ladders models by assuming increasing R&D difficulty. The precise form of increasing R&D difficulty that is assumed is due to Li (2002).

The equilibrium pattern of innovation and imitation is illustrated in Figure 2. At each point in

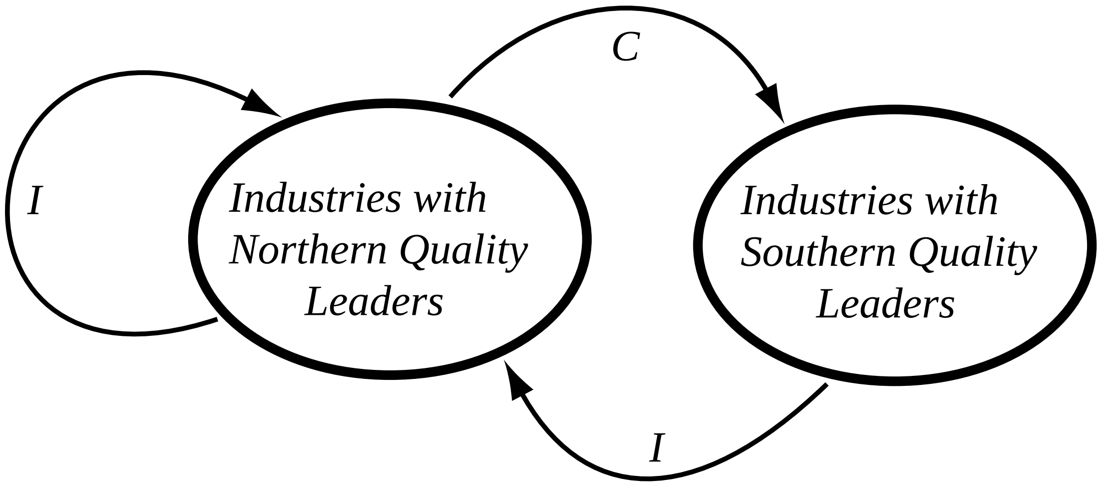

Figure 2: The pattern of innovation and imitation

time, a measure m_N of industries have Northern quality leaders and a measure m_S of industries have Southern quality leaders. All state-of-the-art quality products are either produced in the North by Northern quality leaders or produced in the South by Southern quality leaders, so $m_N + m_S = 1$. Northern firms do innovative R&D in all industries and Southern firms do imitative R&D in the m_N

[11] If we had made the same assumptions about R&D as in Grossman and Helpman (1991a), namely, $I_i = \ell_i/\gamma$ and $C_i = \ell_i/\beta$, our model would not have a steady-state equilibrium. Instead positive population growth would imply exploding rates of economic growth over time. The assumption of increasing R&D difficulty is needed to slow down the North-South economy so there exists a steady-state equilibrium with a constant rate of economic growth.

industries where production is currently in the North. No imitative R&D occurs in the m_S industries because it is not profitable to imitate in these 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. When Southern firms are successful in copying the products of Northern quality leaders, production shifts to the South where labor costs are lower ($w_N > w_S$). On the other hand, when Northern firms are successful in innovating in the m_S industries with Southern quality leaders, then production shifts back to the North. When Northern firms are successful in innovating in the m_N industries with Northern quality leaders, then production stays in the North. Thus, many products experience cycles, as Vernon (1966) has argued. These products are initially discovered in developed countries and exported to developing countries. As the techniques of production become more standardized, production shifts to developing countries due to lower labor costs. These older products are then exported back to developed countries.

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

$$m_N = \frac{I}{I+C} \qquad \text{and} \qquad m_S = \frac{C}{I+C}. \tag{11}$$

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 (9), 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.[12]

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 (9) 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

$$v_I(\theta,t) = w_N \gamma q(\theta,t) \tag{12}$$

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 next 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 (10) 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

$$v_C(\theta,t) = w_S \beta q(\theta,t). \tag{13}$$

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.

2.7 The Stock Market

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

[12] The property that only industry followers engage in innovative R&D is a common property of endogenous growth models. To get that industry leaders invest in innovative R&D, one needs to assume that industry leaders have some R&D cost advantages, as in Segerstrom (2002).

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 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:

$$\frac{\pi_N(\theta,t)}{v_I(\theta,t)} + \frac{\dot{v}_I(\theta,t)}{v_I(\theta,t)} - I - C = r. \tag{14}$$

Equation (14) 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 r.

We let Southern labor be the numeraire good (so $w_S = 1$ for all t) and solve for a steady-state equilibrium where the Northern wage w_N is also constant over time. 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), (12) implies that $v_I(\theta,t)$ is constant during an innovative R&D race and $\frac{\dot{v}_I}{v_I} = 0$. Also (4) implies that the market interest rate r equals the subjective discount rate ρ in a steady-state equilibrium where individual consumer expenditure is constant over time. Thus, solving (14) for the steady-state equilibrium reward for innovating yields

$$v_I(\theta,t) = \frac{\pi_N(\theta,t)}{\rho + I + C}. \tag{15}$$

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

$$\frac{\pi_S(\theta,t)}{v_C(\theta,t)} + \frac{\dot{v}_C(\theta,t)}{v_C(\theta,t)} - I = r. \tag{16}$$

and solving for the steady-state equilibrium reward for imitating yields

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

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).

2.8 Steady-State R&D Conditions

First, we solve for a steady-state R&D condition that must be satisfied if Northern firms are making profit-maximizing innovative R&D choices. Equations (7), (12) and (15) together imply that

$$v_I(\theta,t) = \frac{\frac{w_N}{\sigma-1}\frac{q(\theta,t)}{Q(t)}y_N(t)L(t)}{\rho+I+C} = w_N\gamma q(\theta,t). \tag{18}$$

Let $x_N(t) = Q(t)/L_N(t)$ be a measure of relative R&D difficulty. We solve for a steady-state equilibrium where both x_N and y_N are constants over time. Then $L(t)/Q(t) = (\bar{L}_N + \bar{L}_S)/(x_N\bar{L}_N)$ and (18) simplifies to

$$\frac{\frac{y_N}{\sigma-1}(\bar{L}_N + \bar{L}_S)}{\rho+I+C} = \gamma x_N\bar{L}_N, \tag{19}$$

which is the *steady-state innovative R&D condition*. Equation (19) 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 y_N increases (the average consumer buys 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).

Second, we solve for a steady-state R&D condition that must be satisfied if Southern firms are making profit-maximizing imitative R&D choices. Equations (8), (13) and (17) together imply that

$$v_C(\theta,t) = \frac{\frac{w_S}{\sigma-1}\frac{q(\theta,t)}{Q(t)}y_S(t)L(t)}{\rho+I} = w_S\beta q(\theta,t) \tag{20}$$

Solving for a steady-state equilibrium where y_S is also constant over time, (20) simplifies to

$$\frac{\frac{y_S}{\sigma-1}(\bar{L}_N + \bar{L}_S)}{\rho+I} = \beta x_N\bar{L}_N, \tag{21}$$

which is the *steady-state imitative R&D condition*. Equation (21) 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 y_S increases (the average consumer buys 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).

2.9 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

$$\dot{Q}(t) = \int_0^1 \left[\lambda^{j(\theta,t)+1} - \lambda^{j(\theta,t)}\right] I\, d\theta = (\lambda - 1) I Q(t). \tag{22}$$

The growth rate of average product quality $\frac{\dot{Q}}{Q}$ is proportional to the innovation rate I in each industry. Equation (22) implies 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

$$I = \frac{n}{\lambda - 1}. \tag{23}$$

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 $Q_N(t)$ is a measure of product quality in the North and $Q_S(t)$ is a measure of product quality in the South.[13] We can also calculate how $Q_N(t)$ and $Q_S(t)$ evolve over time in a steady-state equilibrium. Referring back to Figure 2, 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

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

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 $\frac{Q_S}{Q_N} = \frac{C}{\lambda I}$. It follows that

$$Q_N(t) = \frac{\lambda I}{\lambda I + C} Q(t) \qquad \text{and} \qquad Q_S(t) = \frac{C}{\lambda I + C} Q(t). \tag{24}$$

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).

2.10 The Northern Labor Market

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. It follows from (3) that in a Northern industry θ, production employment is

$$d(\theta,t)L(t) = \frac{q(\theta,t)p_N^{-\sigma}E(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta} = \frac{q(\theta,t)}{Q(t)} y_N L(t)$$

Thus total Northern production employment is

$$\int_{m_N} d(\theta,t)L(t)d\theta = \frac{y_N L(t)}{Q(t)} \int_{m_N} q(\theta,t)d\theta = y_N L(t)\frac{\lambda I}{\lambda I + C}.$$

[13] We 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. In the integrals, m_N and m_S have the second interpretation.

In industry θ at time t, Northern R&D employment is $\sum_i \ell_i = \gamma I q(\theta, t)$. Thus, total Northern R&D employment is

$$\int_0^1 \gamma I q(\theta, t) d\theta = \gamma I Q(t).$$

Putting things together, full employment of Northern labor implies that

$$L_N(t) = y_N L(t) \frac{\lambda I}{\lambda I + C} + \gamma I Q(t).$$

Dividing both sides of this equation by $L_N(t)$ yields the *steady-state Northern labor condition*

$$1 = y_N \frac{\bar{L}_N + \bar{L}_S}{\bar{L}_N} \frac{\lambda I}{\lambda I + C} + \gamma I x_N. \tag{25}$$

Equation (25) has a natural economic interpretation. The two terms on the right-hand-side are the shares of Northern labor in production and R&D activities, respectively. The Northern production employment share increases when y_N increases (the average consumer buys more of each Northern product), $(\bar{L}_N + \bar{L}_S)/\bar{L}_N$ increases (there are relatively more Southern consumers) or $\lambda I/(\lambda I + C)$ increases (there are more products produced in the North). The Northern R&D employment share increases when I increases (there is a higher innovation rate) or x_N increases (innovating becomes relatively more difficult).

2.11 The Southern Labor Market

Similar calculations apply for the Southern labor market. It follows from (3) that in a Southern industry θ, production employment is

$$d(\theta, t) L(t) = \frac{q(\theta, t) p_S^{-\sigma} E(t)}{\int_0^1 q(\theta, t) p(\theta, t)^{1-\sigma} d\theta} = \frac{q(\theta, t)}{Q(t)} y_S L(t).$$

Thus total Southern production employment is

$$\int_{m_S} d(\theta, t) L(t) d\theta = \frac{y_S L(t)}{Q(t)} \int_{m_S} q(\theta, t) d\theta = y_S L(t) \frac{C}{\lambda I + C}.$$

In industry θ at time t, Southern R&D employment is $\sum_i \ell_i = \beta C q(\theta, t)$. Thus, total Southern R&D employment is

$$\int_{m_N} \beta C q(\theta, t) d\theta = \beta C Q_N(t).$$

Putting things together, full employment of Southern labor implies that

$$L_S(t) = y_S L(t) \frac{C}{\lambda I + C} + \beta C \frac{\lambda I}{\lambda I + C} Q(t).$$

Dividing both sides of this equation by $L_S(t)$ yields the *steady-state Southern labor condition*

$$1 = y_S \frac{\bar{L}_N + \bar{L}_S}{\bar{L}_S} \frac{C}{\lambda I + C} + \beta C \frac{\lambda I}{\lambda I + C} \frac{x_N \bar{L}_N}{\bar{L}_S}. \tag{26}$$

Equation (26) has a similar economic interpretation. The two terms on the right-hand-side are the shares of Southern labor in production and R&D activities, respectively. The Southern production employment share increases when y_S increases (the average consumer buys more of each Southern product), $(\bar{L}_N + \bar{L}_S)/\bar{L}_S$ increases (there are relatively more Northern consumers) 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 $x_N \bar{L}_N/\bar{L}_S$ increases (imitating becomes relatively more difficult).

This completes the description of the model.

3 The Steady-State Equilibrium

3.1 Existence of the Steady-State Equilibrium

We solve the model for a balanced growth (or steady-state) equilibrium where all endogenous variables grow at constant (not necessarily the same) rates over time. In this balanced growth equilibrium, variables that are constant over time include per-capita consumption expenditures c_N and c_S, global per-capita consumption expenditure $\bar{c}$, the prices of products p_N and p_S, the wage rates for labor w_N and $w_S = 1$, the quantities produced for the average consumer y_N and y_S, the market interest rate $r = \rho$, the industry-level innovation rate $I = \frac{n}{\lambda - 1}$, the industry-level imitation rate C, and the measure of relative R&D difficulty $x_N = \frac{Q(t)}{L_N(t)}$. Variables that grow over time at the rate n include the populations of workers L_N and L_S, aggregate consumer expenditure $E(t)$, and the average quality of products $Q(t)$.

As we have shown, solving the model for a steady-state equilibrium reduces to solving a system of four nonlinear equations [the innovative R&D condition (19), the imitative R&D condition (21), the Northern labor condition (25) and the Southern labor condition (26)] in four unknowns [x_N, C, y_N and y_S]. In this respect, the North-South trade model is similar to Grossman and Helpman (1991a), who also obtain a system of four nonlinear equations in four unknowns (see their Appendix B). Grossman and Helpman proceed by totally differentiating the four equation system and then using matrix methods to try to sign the comparative steady-state effects of parameter changes.

Fortunately, the North-South trade model in this paper is analytically more tractable. We can reduce the system of four equations in four unknowns to a system of two equations in two unknowns and then solve for comparative steady-state effects of parameter changes using simple graphical techniques.

Solving the innovative R&D condition (19) for how much the average consumer buys y_N and then substituting into the Northern labor condition (25) yields the *Northern steady-state condition*

$$1 = \gamma x_N \left[(\sigma - 1)(\rho + I + C) \frac{\lambda I}{\lambda I + C} + I \right] \tag{27}$$

which is upward-sloping in (x_N, C) space with a positive x_N intercept.[14] The intuition behind this upward slope is as follows: 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 (19), an increase in C must be matched by a corresponding increase in y_N, 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 that 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).

Solving the imitative R&D condition (21) for how much the average consumer buys y_S and then substituting into the Southern labor condition (26) yields the *Southern steady-state condition*

$$1 = \beta \frac{x_N \bar{L}_N}{\bar{L}_S} \left[(\sigma - 1)(\rho + I) \frac{C}{\lambda I + C} + C \frac{\lambda I}{\lambda I + C} \right] \tag{28}$$

[14] To 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 $\frac{\partial}{\partial C} \left[\frac{\rho + I + C}{\lambda I + C} \right] = \frac{n - \rho}{(\lambda I + C)^2} < 0$.

which is downward-sloping in (x_N, C) space with no intercepts.[15] The intuition behind this downward slope is as follows: 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 (21), we can also see that an increase in x_N is associated with an increase in y_S and 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).

The Northern and Southern steady-state conditions are illustrated in Figure 3 and are labeled "North" and "South," respectively. These two curves have a unique intersection at point A and thus the steady-state values of x_N and C are uniquely determined.

To verify that we have indeed found a steady-state equilibrium, we need to check that the remaining endogenous variables are completely determined and satisfy previously specified properties. Given the steady-state values of x_N and C, (19) determines y_N and (21) determines y_S. Given x_N and $L_N(t) = \bar{L}_N e^{nt}$, the definition of relative R&D difficulty $x_N = \frac{Q(t)}{L_N(t)}$ determines the time path of $Q(t)$. To solve for the steady-state North relative wage $w = w_N = \frac{w_N}{w_S}$, we first divide (19) by (21) to obtain a *mutual R&D condition*

$$\frac{y_N(\rho + I)}{y_S(\rho + I + C)} = \frac{\gamma}{\beta}.$$

Equations (5) and (6) together with the prices $p_N = \frac{\sigma}{\sigma-1} w_N$ and $p_S = \frac{\sigma}{\sigma-1} w_S$ imply that $\frac{y_N}{y_S} = w^{-\sigma}$. Thus, the mutual R&D condition can be rewritten as

$$w^{\sigma} \frac{\gamma}{\beta} = \frac{\rho + I}{\rho + I + C} \tag{29}$$

[15] To determine the slope of the Southern steady-state condition, we use the fact that $\frac{\partial}{\partial C}\left[\frac{C}{\lambda I + C}\right] = \frac{\lambda I}{(\lambda I + C)^2} > 0.$

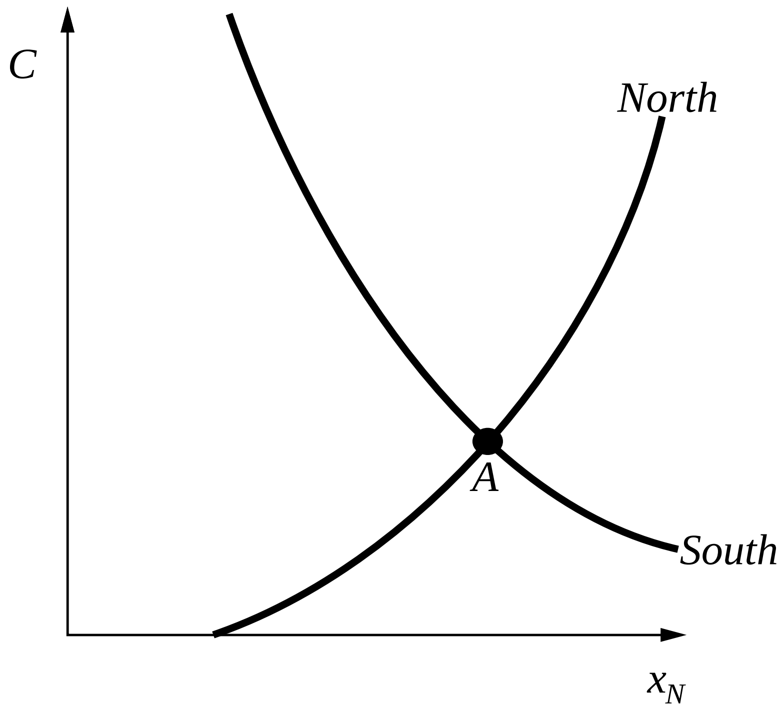

Figure 3: The steady-state equilibrium

and this equation determines w given C. To solve for $\bar{c}$, we first note that

$$\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta = p_N^{1-\sigma}Q_N(t) + p_S^{1-\sigma}Q_S(t).$$

It follows then from (5), (6) and (24) that

$$y_N = \frac{p_N^{-\sigma}\bar{c}}{p_N^{1-\sigma}\frac{\lambda I}{\lambda I+C} + p_S^{1-\sigma}\frac{C}{\lambda I+C}}$$

and

$$y_S = \frac{p_S^{-\sigma}\bar{c}}{p_N^{1-\sigma}\frac{\lambda I}{\lambda I+C} + p_S^{1-\sigma}\frac{C}{\lambda I+C}}$$

Thus, $\bar{c}$ is determined given C, w and y_N (or y_S). Also both y_N and y_S are constant over time as was earlier claimed.[16] Thus, we have indeed solved for a steady-state equilibrium.

The mutual R&D condition (29) has important implications. It implies that the North-South wage gap w is directly related to $\frac{\rho+I}{\rho+I+C}$, which is the reward for innovating *relative* to the reward for imitating. Other things being equal, a decrease in the rate of copying C (which increases the

[16]Although steady-state average consumer expenditure $\bar{c}$ is uniquely determined, the model says nothing about the representative consumer's expenditure in the North or South (c_N or c_S). These values depends on who owns the firms that are earning monopoly profits. Since the same steady-state equilibrium emerges regardless of the ownership distribution of assets between the North and the South, we have left the ownership distribution unspecified.

reward for innovating relative to the reward for imitating) is associated with an increase in the North-South wage gap w.

3.2 Main Properties of the Steady-State Equilibrium

We are now in a position to state and answer the main question in the paper: what are the steady-state effects of globalization (China's entry into the world trading system)? Does globalization increase wage inequality between the North and the South or does globalization have the opposite effect of contributing to convergence in wages between Northern and Southern workers? Also, does globalization stimulate technological progress or does globalization induce a productivity slowdown?

An increase in $\bar{L}_S$ (an increase in the size of the South) has no effect on the Northern steady-state condition (27) but implies that x_N increases for given C in (28). Thus the Southern steady-state condition shifts to the right in (x_N, C) space and this is illustrated in Figure 4. Starting

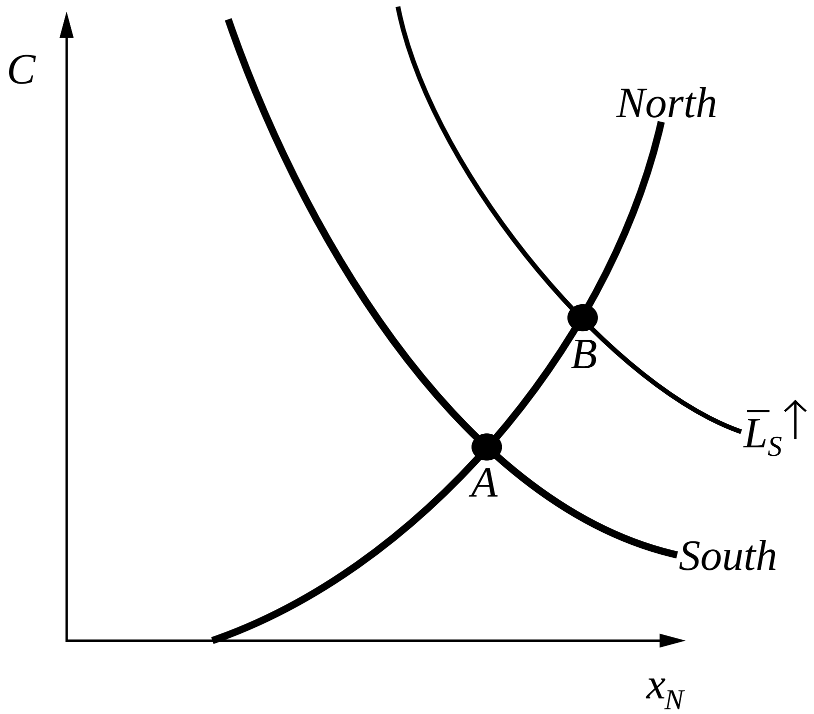

Figure 4: The Steady-State Effects of Globalization

from the steady-state equilibrium given by point A, an increase in $\bar{L}_S$ leads to a new steady-state equilibrium given by point B. Thus globalization leads to an increase in both x_N and C. The measure of relative R&D difficulty $x_N = \frac{Q(t)}{L_N(t)}$ can only permanently increase if the average quality of products $Q(t)$ temporarily grows at a faster than usual rate.[17] The increase in the rate of copying C means that production shifts to the South in the sense that the measure of industries with Southern quality leaders $m_S = \frac{C}{I+C}$ increases and the measure of industries with Northern quality leaders $m_N = \frac{I}{I+C}$ decreases. From the mutual R&D condition (29), the increase in C implies that wage inequality w decreases. We have established

Theorem 1 *Globalization ($\bar{L}_S \uparrow$) leads to a permanent increase in the rate of copying of Northern products ($C \uparrow$), a short-run increase in the innovation rate ($x_N \uparrow$), no change in the long-run innovation rate ($I = \frac{n}{\lambda-1}$) and a permanent decrease in the degree of wage inequality between Northern and Southern workers ($w = \frac{w_N}{w_S} \downarrow$).*

The steady-state equilibrium effects of globalization are quite intuitive. Since globalization represents an expansion in the size of the South and the South copies technologies developed in the North, globalization naturally increases the rate of copying C of Northern products. This faster rate of technology transfer from the North to the South hurts Northern workers (in the sense that the Northern relative wage w falls) because the 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 lower Northern relative wage w makes it more attractive for Northern firms to expand their R&D activities. In the short-run, globalization 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, globalization 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.[18]

Has wage inequality in fact decreased between Northern and South workers during the past sev-

[17]Although we do not analyze the equilibrium transition path from one steady-state to another in this paper, convergence to a new steady-state equilibrium tends to be very slow in models of endogenous growth without scale effects. For example, when Steger (2003) calibrates the Segerstrom (1998) model, he finds that it takes 38 years to go half the distance to the steady-state and this rate is consistent with the majority of cross-country studies on the speed of convergence (e.g., Barro and Sala-i-Martin, 1992). Thus, the "temporary" increase in the rate of technological change caused by globalization can be expected to last a long time.

[18]Gancia (2003) has developed a model where globalization sometimes increases North-South wage inequality and decreases the world economic growth rate. In his model, the North and the South are distinguished by exogenous industry productivity differences and imitation occurs immediately (in the sense that new products are produced in the South whenever production costs are lower there). Grossman and Helpman (1991a) find that increasing the size of the South has no effect on North-South wage inequality. Grossman and Helpman (1991b) obtain very similar results to Theorem 1 in their North-South trade model based on expansion in the variety of products. They find that increasing the size of the South increases the rates of innovation and imitation and decreases North-South wage inequality. The only difference is that Grossman and Helpman (1991b) find that the increase in the rate of innovation is permanent (instead of temporary).

eral decades of globalization, as Theorem 1 implies? 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.[19] 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. Thus, the finding of declining global income inequality reported in Jones (1997) and Sala-i-Martin (2002) provides some support for Theorem 1.

Another piece of evidence that supports Theorem 1 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 the declining wage gap between the Open North and the Open South implied by Theorem 1.[20]

[19] It is worth bearing in mind that Theorem 1 only implies that globalization decreases wage inequality between the Open North and the Open South, not for the world as a whole.

[20] The 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.

The second main result in the paper concerns the effects of stronger intellectual property rights. Stronger intellectual property rights can be interpreted as an increase in the imitative R&D parameter β, since this increase means that it is harder for Southern firms to copy ideas developed in the North [this is how stronger intellectual property rights are modelled in Glass and Saggi (2002)]. An increase in β has no effect on the Northern steady-state condition (27) but implies that x_N decreases for given C in (28). Thus the Southern steady-state condition shifts to the left in (x_N, C) space and this is illustrated in Figure 5. Starting from the steady-state equilibrium given by point A,

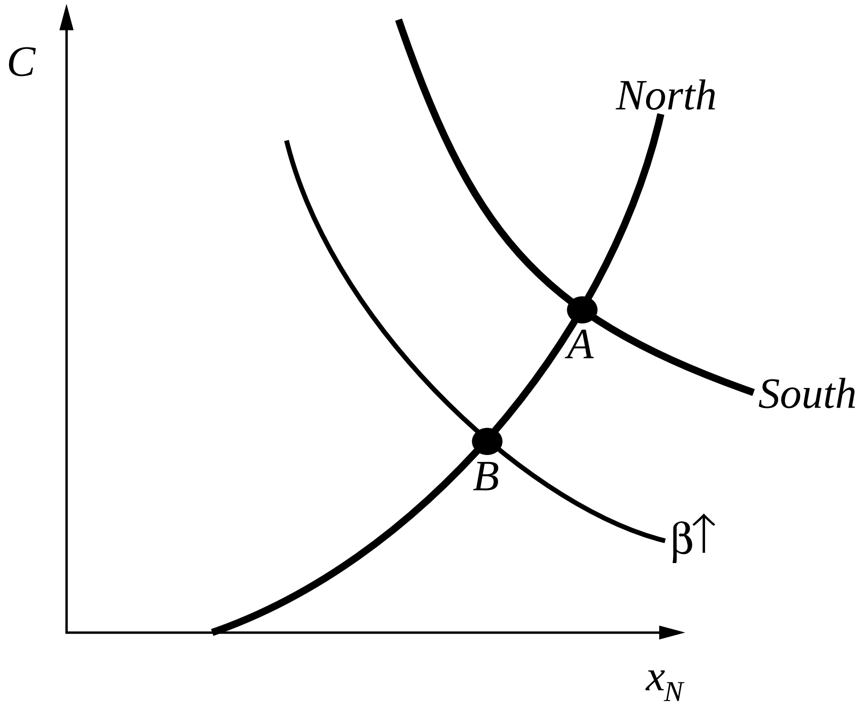

Figure 5: The Steady-State Effects of Stronger Intellectual Property Protection

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. The measure of relative R&D difficulty $x_N = \frac{Q(t)}{L_N(t)}$ can only permanently decrease if the average quality of products $Q(t)$ temporarily grows at a slower than usual rate. The decrease in the rate of copying C means that production shifts to the North in the sense that the measure of industries with Northern quality leaders $m_N = \frac{I}{I+C}$ increases and the measure of industries with Southern quality leaders $m_S = \frac{C}{I+C}$ decreases. From the mutual R&D condition (29), the decrease in C implies that wage inequality w increases. Thus, stronger intellectual property protection serves to moderate the effects of globalization: stronger intellectual property protection has the opposite steady-state effects. We have established

Theorem 2 *Stronger intellectual property protection ($\beta \uparrow$) leads to a permanent decrease in the rate of copying of Northern products ($C \downarrow$), a short-run decrease in the innovation rate ($x_N \downarrow$), no change in the long-run innovation rate ($I = \frac{n}{\lambda - 1}$) and a permanent increase in the degree of wage inequality between Northern and Southern workers ($w = \frac{w_N}{w_S} \uparrow$).*

The surprising result in Theorem 2 is that stronger intellectual property protection 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.[21]

In negotiations about the protection of intellectual property rights at the World Trade Organiztion (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 2 provides support for this position taken by developing countries.

4 Conclusions

This paper develops a dynamic, general-equilibrium model of North-South trade with scale-invariant growth. In each industry, both the innovation rate by Northern firms and the imitation rate by Southern firms are endogenously determined. The model is utilized to analyze the effects of globaliza-

[21] Other models where stronger intellectual property protection stimulates innovation include Segerstrom, et. al. (1990), Helpman (1993), Lai (1998), and Yang and Maskus (2001). Two notable exceptions are Glass and Saggi (2002) and Sener (2003). Glass and Saggi (2002) find that stronger intellectual property protection decreases innovation but has no effect on North-South wage inequality. In their model, the Northern relative wage is exclusively determined by labor productivity parameters in manufacturing and does not respond to changes in intellectual property rights. Sener (2003) obtains results similar to our Theorem 2 with the only exception being that the steady-state innovation rate decreases.

tion and intellectual property rights protection on wage inequality (between Northern and Southern workers) and the rate of global technological change.

We show that globalization (measured by an increase in the population size of the Open South) leads to a faster imitation rate by Southern firms, faster technological change in the short run, and less wage inequality between Northern and Southern workers. Stronger intellectual property rights protection has the opposite effects. These findings imply that TRIPs agreements might serve as one device which mitigates the effects of globalization due to the entrance of China and other developing countries into the open trading system.

The theoretical framework developed in this paper can be extended to analyze the effects of several other dimensions of globalization. Northern and/or Southern tariffs, the establishment of Northern multinationals in the South, and labor migration from South to North can be readily incorporated into the model, and their effects on technological progress and wage inequality can be examined. In addition, welfare considerations could be introduced into the theoretical framework. The latter would allow the analysis of optimal policies that can be used to provide policy recommendations for managing North-South international linkages. These important issues represent avenues for further research.

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Appendix: Extensions of the Model

In the appendix, we explore some extensions of the model. First, we study the effects of subsidizing R&D activities. Common sense suggests that R&D subsidies should promote technological change, so this exercise represents a check that the model is well-behaved.

R&D Subsidies

Let s_I denote the innovative R&D subsidy rate in the North and let s_C denote the imitative R&D subsidy rate in the South. In the North, expected profits from engaging in innovative R&D are $v_I(\theta,t)I_i dt - (1-s_I)w_N\ell_i dt$, which yields the free entry condition $v_I(\theta,t) = (1-s_I)w_N\gamma q(\theta,t)$. In the South, expected profits from engaging in imitative R&D are $v_C(\theta,t)C_i dt - (1-s_C)w_S\ell_i dt$, which yields the free entry condition $v_C(\theta,t) = (1-s_C)w_S\beta q(\theta,t)$. Following exactly the same procedure for solving the model as in the previous section yields the Northern steady-state condition

$$1 = \gamma x_N \left[(\sigma-1)(\rho+I+C)(1-s_I)\frac{\lambda I}{\lambda I + C} + I\right] \tag{30}$$

the Southern steady-state condition

$$1 = \beta\frac{x_N \bar{L}_N}{\bar{L}_S}\left[(\sigma-1)(\rho+I)(1-s_C)\frac{C}{\lambda I + C} + C\frac{\lambda I}{\lambda I + C}\right] \tag{31}$$

and the mutual R&D condition

$$w^\sigma \frac{(1-s_I)\gamma}{(1-s_C)\beta} = \frac{\rho+I}{\rho+I+C}. \tag{32}$$

What are the steady-state effects of higher R&D subsidies in the North? An increase in s_I has no effect on the Southern steady-state condition (31) but implies that x_N increases for given C in (30). Thus the Northern steady-state condition shifts to the right in (x_N, C) space and this is illustrated in Figure 6. Starting from the steady-state equilibrium given by point A, an increase in s_I leads to a new steady-state equilibrium given by point B. Thus an increase in the Northern R&D subsidy rate s_I leads to a permanent increase in x_N and a permanent decrease in C. The measure of relative R&D difficulty $x_N = \frac{Q(t)}{L_N(t)}$ can only permanently increase if the average quality of products $Q(t)$ temporarily grows at a faster than usual rate. The decrease in the rate of copying C means that production shifts to the North in the sense that the measure of industries with Northern quality leaders $m_N = \frac{I}{I+C}$ increases and the measure of industries with Southern quality leaders $m_S = \frac{C}{I+C}$ decreases. From the mutual R&D condition (32), the decrease in C and increase in

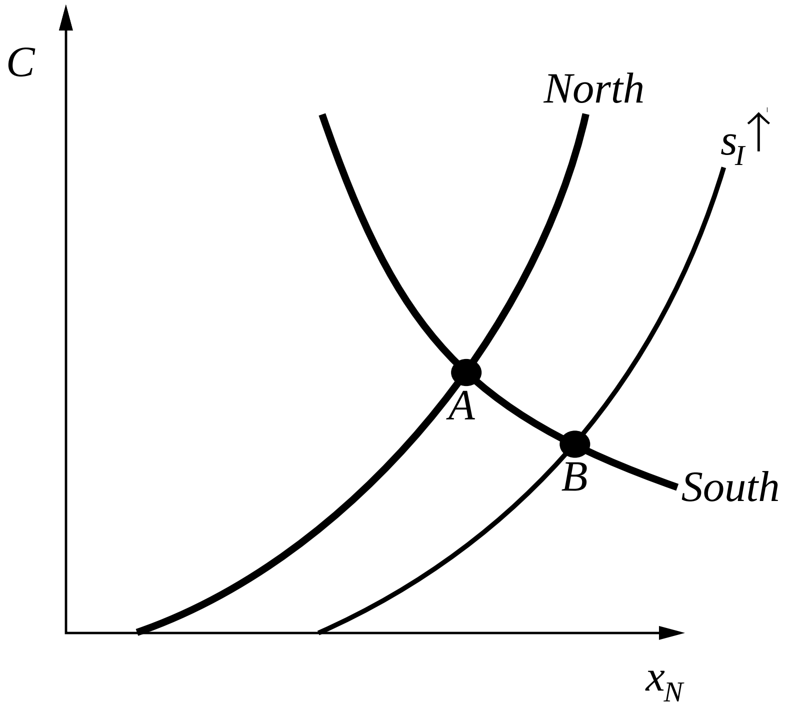

Figure 6: The Steady-State Effects of Higher Northern R&D Subsidies

s_I together implies that wage inequality w increases. Thus Northern R&D subsidies have similar steady-state effects to intellectual property protection with one exception: higher Northern R&D subsidies lead to faster technological change whereas stronger intellectual property protection leads to slower technological change. We have established

Theorem 3 *An increase in the Northern R&D subsidy rate ($s_I \uparrow$) leads to a permanent decrease in the rate of copying of Northern products ($C \downarrow$), a short-run increase in the innovation rate ($x_N \uparrow$), no change in the long-run innovation rate ($I = \frac{n}{\lambda-1}$) and a permanent increase in the degree of wage inequality between Northern and Southern workers ($w = \frac{w_N}{w_S} \uparrow$).*

In contrast, what are the steady-state effects of higher R&D subsidies in the South? An increase in s_C has no effect on the Northern steady-state condition (30) but implies that x_N increases for given C in (31). Thus the Southern steady-state condition shifts to the right in (x_N, C) space and this is illustrated in Figure 7. Starting from the steady-state equilibrium given by point A, an increase in s_C leads to a new steady-state equilibrium given by point B. Thus an increase in the Southern R&D subsidy rate s_C leads to an increase in both x_N and C. The measure of relative R&D difficulty $x_N = \frac{Q(t)}{L_N(t)}$ can only permanently increase if the average quality of products $Q(t)$ temporarily grows at a faster than usual rate. The increase in the rate of copying C means that

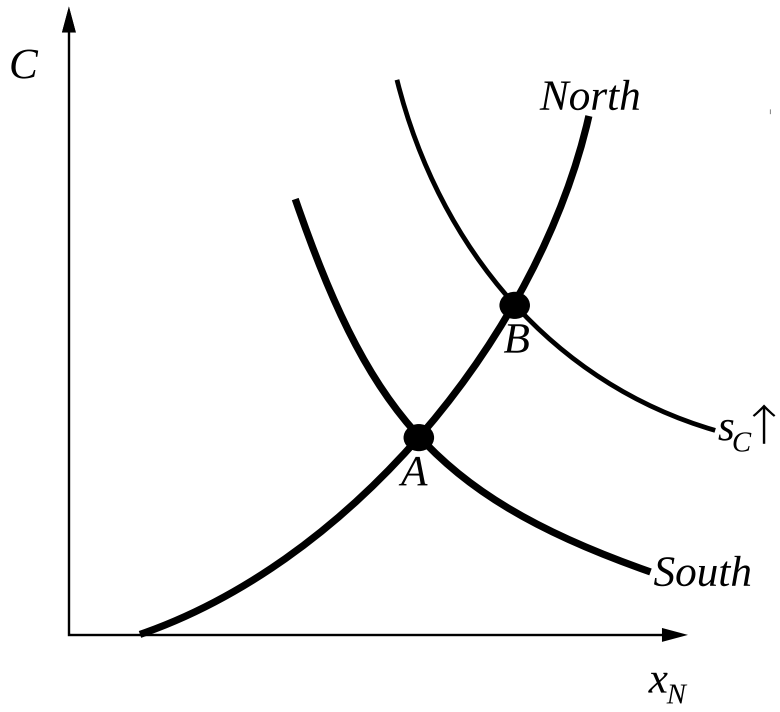

Figure 7: The Steady-State Effects of Higher Southern R&D Subsidies

production shifts to the South. From the mutual R&D condition (32), the increase in C and increase in s_C together implies that wage inequality w decreases. We have established

Theorem 4 *An increase in the Southern R&D subsidy rate (s_C ↑) leads to a permanent increase in the rate of copying of Northern products (C ↑), a short-run increase in the innovation rate (x_N ↑), no change in the long-run innovation rate ($I = \frac{n}{\lambda-1}$) and a permanent decrease in the degree of wage inequality between Northern and Southern workers ($w = \frac{w_N}{w_S}$ ↓).*

Thus, the model appears to be well-behaved. Both Northern and Southern R&D subsidies have the expected effect of promoting technological change. Interestingly, Northern and Southern R&D subsidies have different long-run effects on wage inequality: Northern R&D subsidies increase the North-South wage gap whereas Southern R&D subsidies reduce the North-South wage gap.

Trade Costs

As a second extension of the model, we suppose that there are frictional trade costs of the "iceberg" form associated with trade between the North and the South. In order for one unit of a good from the North (South) to arrive in the South (North), $\tau > 1$ units must be shipped. We explore how the model's properties change when there are trade costs.

We assume that the trade cost parameter τ is relatively small so production shifts from the North to the South when a Southern firm imitates ($w_N > \tau w_S$) and production shifts back to the North when a Northern firm innovates ($w_N \tau < \delta w_S$). Then it follows from (3) that the profit flow earned by a Northern quality leader is

$$\pi_N = (p_N - w_N)\frac{q p_N^{-\sigma} c_N L_N}{P_N} + (p_N^* - \tau w_N)\frac{q(p_N^*)^{-\sigma} c_S L_S}{P_S}$$

where $P_N = \int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta$ is a price index for Northern consumers and P_S is the corresponding price index for Southern consumers. Profit maximization implies that the Northern quality leader charges the price $p_N = \frac{\sigma w_N}{\sigma-1}$ to Northern consumers, the price $p_N^* = \frac{\sigma \tau w_N}{\sigma-1}$ to Southern consumers and earns the profit flow

$$\pi_N = \left[\frac{w_N}{\sigma-1}\right]\frac{q}{Q}\left[y_N L_N + \tau y_N^* L_S\right]$$

where y_N denotes per capita Northern demand for a Northern product of average quality and y_N^* denotes per capita Southern demand for a Northern product of average quality. In a similar fashion, we derive that a Southern quality leader charges the price $p_S = \frac{\sigma w_S}{\sigma-1}$ to Southern consumers, the price $p_S^* = \frac{\sigma \tau w_S}{\sigma-1}$ to Northern consumers and earns the profit flow

$$\pi_S = \left[\frac{w_S}{\sigma-1}\right]\frac{q}{Q}\left[y_S L_S + \tau y_S^* L_N\right]$$

where y_S denotes per capita Southern demand for a Southern product of average quality and y_S^* denotes per capita Northern demand for a Southern product of average quality.

Following the same procedure for solving the model as in sections 2 and 3, we obtain the innovative R&D condition

$$\frac{\frac{y_N \bar{L}_N + \tau y_N^* \bar{L}_S}{\sigma-1}}{\rho + I + C} = \gamma x_N \bar{L}_N, \tag{33}$$

the imitative R&D condition

$$\frac{\frac{y_S \bar{L}_S + \tau y_S^* \bar{L}_N}{\sigma-1}}{\rho + I} = \beta x_N \bar{L}_N, \tag{34}$$

the Northern labor condition

$$1 = \left[y_N + \tau y_N^* \frac{\bar{L}_S}{\bar{L}_N}\right]\frac{\lambda I}{\lambda I + C} + \gamma I x_N, \tag{35}$$

and the Southern labor condition

$$1 = \left[y_S + \tau y_S^* \frac{\bar{L}_N}{\bar{L}_S}\right]\frac{C}{\lambda I + C} + \beta C \frac{\lambda I}{\lambda I + C}\frac{x_N \bar{L}_N}{\bar{L}_S}. \tag{36}$$

Note that the trade cost parameter τ appears in each one of these four steady-state equations. However, when we substitute (33) into (35) to obtain the Northern steady-state condition, τ disappears and we obtain exactly (27). Likewise, when we substitute (34) into (36) to obtain the Southern steady-state condition, τ disappears and we obtain exactly (28). Thus Figure 3 becomes relevant and a marginal reduction in τ does not cause either the Northern steady-state condition or the Southern steady-state condition to shift. Surprisingly, a marginal reduction in τ does not have any effect on the steady-state values of x_N and C.

A marginal reduction in τ does however have an effect on the steady-state value of the Northern relative wage w. Dividing (33) into (34) yields the mutual R&D condition

$$\frac{y_N \bar{L}_N + \tau y_N^* \bar{L}_S}{y_S \bar{L}_S + \tau y_S^* \bar{L}_N} = \frac{\gamma}{\beta} \left[\frac{\rho + I + C}{\rho + I} \right]. \tag{37}$$

In general, the effect of a decrease in τ on w is theoretically ambiguous since the left-hand side of (37) is a very complicated function of w and τ (due to the CES preference structure). However, we can make some progress analytically by studying polar extreme cases. When the South is very small ($\bar{L}_S/\bar{L}_N \approx 0$), then the left-hand side of (37) simplifies to $w^{-\sigma}\tau^{\sigma-1}$ and a decrease in τ causes w to decrease. On the other hand, when the North is very small ($\bar{L}_N/\bar{L}_S \approx 0$), then the left-hand side of (37) simplifies to $w^{-\sigma}\tau^{1-\sigma}$ and a decrease in τ causes w to increase. We have established

Theorem 5 *A decrease in trade costs between the North and the South ($\tau \downarrow$) leads to no change in the steady-state rate of copying of Northern products (C), no change in the steady-state rate of innovation (I), no change in the steady-state level of relative R&D difficulty (x_N) and has an ambiguous effect on the steady-state relative wage of Northern workers ($w = \frac{w_N}{w_S}$). When the South is relatively small ($\bar{L}_S/\bar{L}_N \approx 0$), a decrease in trade costs ($\tau \downarrow$) causes the relative wage of Northern workers to fall ($w = \frac{w_N}{w_S} \downarrow$) and when the North is relatively small ($\bar{L}_N/\bar{L}_S \approx 0$), a decrease in trade costs ($\tau \downarrow$) causes the relative wage of Northern workers to rise ($w = \frac{w_N}{w_S} \uparrow$).*

Theorem 5 shows that the effects of lowering trade costs between the North and the South are fundamentally different from the effects of increasing the size of the Open South (globalization). Globalization always hurts Northern workers in the sense that the Northern relative wage w falls. In contrast, who benefits from lower trade costs depends on the relative size of the two regions. When the South is relatively small, lower trade costs benefit the South (decrease the Northern relative wage) because lower trade costs primarily mean better access to the Northern market. On the other hand, when the North is relatively small, lower trade costs benefit the North (increase the Northern relative wage) because lower trade costs primarily mean better access to the Southern market.