Multinational Firms and Economic Growth

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Abstract: This paper develops a dynamic North-South model of trade and multinational firms. New higher quality products are discovered in the high-wage North through innovative R&D races and Northern firms engage in adaptive R&D to transfer their manufacturing operations in the low-wage South. Adaptive R&D determines the rate of multinational-firm formation and can be interpreted as an index of Foreign Direct Investment. The model generates product-cycle trade, scale-invariant growth and an endogenous North-South wage gap. Globalization, measured by a geographic expansion of the South, leads to faster international technology transfer and faster technological change but has no effect on the steady-state North-South wage gap. In contrast, policies that encourage the formation of multinationals increase temporarily the rate of global innovation and reduce permanently the North-South income disparity.

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1 Introduction

The standard cliché that “trade is the engine of growth” masks the important role of multinationals as perhaps the dominant channel of international technology transfer that fuels total factor productivity growth.¹ By 2001 more than 65,000 parent companies had more than 850,000 affiliates in foreign markets and accounted for about $19 trillion in global sales annually (Hill, 2005); and about 30 percent of global trade was intra-firm trade by the early 1990’s (Brainard, 1993). The growth of foreign direct investment (FDI) has accelerated faster than the growth of commodity trade especially during the 1980’s and 1990’s. And although historically the majority of FDI has been directed towards advanced countries, the share of developing countries in global FDI flows has been increasing rapidly: China and Latin America have been popular destinations of FDI.² The increase in rate of multinational firm formation has been closely related to improvements in transportation and communication technologies; the geographic expansion of the market economy after the collapse of the communism and China’s open-door policy adopted in 1978; and government policies resulting in the reduction of trade and investment barriers. These structural changes constitute the main forces that have contributed to the acceleration of the globalization process.

This paper develops a dynamic theory of multinationals by combining basic element from the dynamic North-South trade model developed by Dinopoulos and Segerstrom (2004), Helpman’s (1984) model of multinationals and the model of FDI developed by Glass and Saggi (2002). In doing so, it manages to incorporate the ownership-location-internalization (OLI) framework in a dynamic general-equilibrium model of North-South trade, growth, and international technology transfer.³ In the present model the ownership advantage arises from the endogenous discovery of higher-quality products by Northern firms and a firm-specific asset called headquarter services which is modeled as a local public good as in Helpman (1984). The location advantage arises from an endogenous North-South wage gap which creates an incentive for Northern firms to locate their manufacturing facilities to the South. Following Glass and Saggi (2002), we assume that


²Hill (2005) reports that in the period 1985-90, developing countries accounted for about 17.5 percent of global FDI flows, whereas their share of global FDI reached 37 percent by 1997 (before the East Asian financial crisis), with the largest amount (about 10 percent of global FDI) going to China. By 2002 the FDI flow from advanced to developing countries reached 185 billions annually and 35 percent of the total share of FDI.

³Dunning (1981) was the first one to propose the OLI framework for developing a theory of multinationals.
the process of becoming a multinational is costly and uncertain. Northern firms have to engage in adaptive R&D to research the Southern market and to overcome language and other cultural barriers, establishing distribution channels and training foreign workers. We assume that due to the complexity of technology associated with new products, the return to this intangible asset is exploited internally.

Having developed a dynamic model of a growing global economy populated by multinationals that engage in trade and international transfer of technology from North to South, we use the model to address the following questions: What are the effects of globalization on the pattern of multinational formation? More specifically, is globalization responsible for an expansion in the population of multinational firms? In the presence of endogenous FDI, what are the effects of globalization on the process of international technology transfer from North to South, on the rate of global innovation and on the wage income distribution between Northern and Southern workers? We focus on the following components of globalization: (i) a geographic expansion of the South measured by an increase in its population size, which is motivated by China’s entry into the world trading system, (ii) an increase in the efficiency of adaptive R&D which can be attributed to either FDI-friendly policies (tax-holidays, etc.) adopted by several developing countries, or developments in communication technologies (internet, email services, fax services etc) that have made the establishment and management of foreign subsidiaries easier.

The analysis produces the following novel findings: Globalization captured with an increase in the size of the South (measured by its population size) accelerates the formation of multinational firms and leads to a temporary increase in the global innovation rate. However, when multinational firms play a central role in the transfer of technology from North to South, globalization neither contributes to nor reduces the degree of global wage inequality (Theorem 1). The latter feature of the model stands in contrast to the result obtained in Dinopoulos and Segerstrom (2004), where technology transfer from North to South takes the form of endogenous imitation (as opposed to multinational-firm formation) of Northern products by Southern firms: Globalization leads to a long-run decrease in the North-South wage gap. Consequently, apart from short-term employment losses associated with the migration of Northern production to low-wage Southern countries, globalization in the presence of multinationals maintains the Northern relative wage. In addition, an

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4Identifying the determinants of FDI patterns is important in developing a political-economy approach to understanding the behavior of international institutions and the rules that are designed to manage the process of globalization. Bhagwati (2004) and Deardorff (2004) among others argue that corporations (domestic and multinationals) have influenced the development of the rules of the international trading system.
increase in the efficiency of adaptive R&D increases the long-run rate of multinational-firm formation, leads to a temporary increase in the global rate of innovation and reduces permanently North-South wage inequality measured by the North-South wage gap (Theorem 2). In a global economy with lower costs of technology transfer from North to South, Northern firms become multinationals more frequently, and the demand for Southern labor rises (to facilitate the faster rate of technology transfer). As a result, the relative wage of Southern workers rises.

The rest of the paper is organized as follows: Section 2 develops the components of the model and the steady-state equilibrium conditions are derived. Section 3 establishes the uniqueness of the steady-state equilibrium and presents the main results of the analysis summarized in Theorems 1 and 2. Section 4 offers some concluding remarks and avenues for further research.

2 The Model

2.1 Overview

We consider a global economy consisting of two regions: a high-wage North and a low-wage South. Labor is the only factor of production and grows at an exogenous rate over time in both regions. There are four activities that labor is employed in: manufacturing production, headquarter services, innovative R&D and adaptive R&D. Headquarter services are necessary for the production of any good. Headquarter services must be produced in the North, whereas manufacturing production can be done either in the North or the South depending on the circumstances. All innovative R&D is done in the North and all adaptive R&D is done in the South. There is free trade between the two regions.

In this global economy, firms can hire Northern workers to engage in innovative R&D with the goal of learning how to produce higher-quality products. When successful, a firm earns global monopoly profits from producing the state-of-the-art quality product in its industry. We call such a firm a Northern industry leader (or Northern quality leader) because all production takes place in the North (both headquarter services and manufacturing production).

Once successful in innovative R&D, firms can hire Southern workers to engage in adaptive R&D with the goal of transferring their manufacturing operations to the South. When successful in adaptive R&D, a firm earns even higher global monopoly profits because of the lower wage costs in the South. We call such a firm a multinational firm because production takes place both in the
North (headquarter services) and in the South (manufacturing production). Adaptive R&D can be interpreted as one type of FDI because it requires an outflow of financial capital from North to South equal to the wage payments of Southern workers engaged in this activity.\(^5\)

Any analysis of FDI must identify the advantageous conditions that can outweigh the inherent disadvantages of foreign production. According to the ownership, location and internalization (OLI) framework proposed by Dunning (1981), three conditions are necessary for a firm to undertake FDI.\(^6\) First, a firm must have an *ownership advantage*. In our model, a firm that discovers a new product receives a perfectly enforceable global patent. Second, the foreign market must offer a *location advantage*. In our model, the lower wage rate for labor in the South represents the reason why a Northern industry leader wants to transfer manufacturing operations to the South. Third, the multinational firm must have an *internalization advantage*. In our model, we assume that problems associated with writing and enforcing licensing contracts make it unattractive for a Northern industry leader to license its technology to a Southern firm.

Although the model shares common features with earlier models developed by Helpman (1984), Glass and Saggi (2002) and Dinopoulos and Segerstrom (2004), it complements these important studies in several respects. For instance, unlike Helpman (1984) which focus on North-North trade and where FDI equalizes factor prices across countries, the present model has FDI taking place in the context of North-South trade. Unlike Glass and Saggi (2002), the present model introduces headquarter services and positive population growth, generates scale-invariant long-run economic growth and has different comparative steady-state properties. Finally, unlike Dinopoulos and Segerstrom (2004), who treat multinationals only tangentially, the present model focuses on FDI as the mode of international technology transfer.

### 2.2 Households

The global economy is populated by a fixed measure of identical households that are modeled as dynastic families. The typical member of a household lives forever and is endowed with one unit of labor, which is inelastically supplied. The size of each household grows exponentially at a fixed growth rate.

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\(^5\) Strictly speaking, a Northern industry leader is also a multinational firm because it employs both Northern workers (production) and Southern workers (adaptive R&D).

\(^6\) See Markusen (1995) for an excellent survey of the theoretical literature on multinationals based on the OLI framework.
rate \( g_L > 0 \), which is the world population growth rate.\(^7\) Assuming that the initial size of each household is unity, the size of each household at time \( t \), measured by the number of members, is \( e^{gLt} \). Let \( \bar{L}_N \) and \( \bar{L}_S \) denote the initial number of households in the North and South respectively, and let \( \bar{L} = \bar{L}_N + \bar{L}_S \). Then \( L_N(t) = \bar{L}_Ne^{gLt} \) denotes the supply of labor in the North at time \( t \), \( L_S(t) = \bar{L}_Se^{gLt} \) denotes the South’s supply of labor, and \( L(t) = \bar{L}e^{gLt} = L_N(t) + L_S(t) \) denotes the world labor supply.

There is a continuum of industries indexed by \( \theta \in [0, 1] \) producing final consumption goods. In each industry \( \theta \), 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.

Each household is modeled as a dynastic family that maximizes discounted lifetime utility

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

where \( \rho > g_L \) 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 per-capita utility at time \( t \). Equation (2) is a standard quality-augmented Dixit-Stiglitz utility function, where \( d(j, \theta, t) \) is the per-capita quantity demanded of a \( j \) quality product in industry \( \theta \) at time \( t \), parameter \( \delta > 1 \) captures the size of the quality increment generated by each innovation and parameter \( \sigma > 1 \) is the constant elasticity of substitution. The assumption \( \sigma > 1 \) means that products across industries are gross substitutes.

Following Dinopoulos and Segerstrom (2004), we solve the consumer problem in three steps. The first step is to solve the within-industry static optimization problem. Letting \( p(j, \theta, t) \) denote the price of the \( j \) quality product in industry \( \theta \) at time \( t \), each household allocates its budget within each industry by buying the product with the lowest quality-adjusted price \( p(j, \theta, t)/\delta^j \). If two products

\(^7\)Helpman (1984) and Glass and Saggi (2002) have analyzed the case of \( g_L = 0 \).
have the same quality-adjusted price, we assume that consumers buy only the higher quality product. The second step is to solve the across-industry static optimization problem

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

where \( j(\theta,t) \) is the quality index of the product with the lowest quality-adjusted price in industry \( \theta \) at time \( t \), \( p(\theta,t) \) is the price of this product, \( d(\theta,t) \) is the corresponding quantity demanded, and \( c(t) \) is the individual consumer’s expenditure at time \( t \). Solving this static optimization problem using standard optimal control techniques yields the individual consumer’s demand function

\[
d(\theta,t) = \frac{q(\theta,t)p(\theta,t)^{-\sigma} c(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma} d\theta}
\]

for the product with the lowest quality-adjusted price in industry \( \theta \) at time \( t \), where \( q(\theta,t) = \delta j(\theta,t)^{(\sigma-1)} \) is an alternative measure of product quality. The quantity demanded for each of the remaining products in each industry is zero. The third step is to determine the allocation of each consumer’s income between consumption and savings that are used to finance various R&D investments. Substituting (3) into (2) and inserting the resulting expression into (1), one can express the per-capita discounted utility \( U \) as a function of the time path of per-capita consumer expenditure \( c(t) \). Maximizing (1) subject to the standard intertemporal budget constraint yields the well-known differential equation

\[
\frac{\dot{c}(t)}{c(t)} = r(t) - \rho,
\]

where \( r(t) \) is the market interest rate at time \( t \). Equation (4) implies that in a steady-state equilibrium with constant per-capita consumption expenditure \( c \), the market interest rate \( r \) must be equal to the subjective discount rate \( \rho \).

2.3 Output Markets

We begin by describing manufacturing production. In each industry, we assume that there is constant returns to scale and one unit of labor produces one unit of output, independently of the quality level. Thus, in any industry where manufacturing production takes place in the North, the Northern industry leader has constant marginal cost equal to the Northern wage rate \( w_N \). Likewise, in any industry where manufacturing production takes place in the South, the multinational firm has constant marginal cost equal to the South wage rate \( w_S \).
We solve the model for a steady-state equilibrium where the wage rates $w_N$ and $w_S$ are both constant over time. We also restrict attention to the range of parameter values that generate the following inequalities in the steady-state equilibrium: $w_N > w_S > w_N/\delta$. The first inequality implies that the North has a higher wage rate than the South and that the marginal cost of a multinational firm is lower than its Northern counterpart. Then manufacturing production shifts to the South when a Northern industry leader is successful in adaptive R&D. The second inequality implies that if manufacturing production is in the South and a new higher quality product is discovered in the North, then the Northern firm has lower marginal cost than the multinational firm and manufacturing production shifts back to the North.

In order to produce products, headquarter services are also needed and they must be produced in the North, the region of product discovery. Headquarter services constitute a firm-specific public good in a sense that, regardless of how much output a firm produces, a fixed amount of headquarter services is needed to maintain the efficiency of manufacturing activities (i.e., management, marketing, product-quality control). More specifically, we assume that, for each firm and product, the number of Northern workers devoted to production of headquarter services is given by

$$\ell_h(\theta, t) = h \cdot q(\theta, t),$$

where $h$ is a fixed parameter denoting the level of headquarter services at time zero, $\ell_h(\theta, t)$ is the labor employed in producing headquarter services and $q(\theta, t)$ is the relevant quality level in industry $\theta$ at time $t$. The production of a fixed level of headquarter services becomes more difficult as the complexity of each product [measured by the quality level $q(\theta, t)$] increases. This formulation constitutes a dynamic generalization of Helpman’s (1984) pioneering work.

We assume that in each industry, firms are Bertrand price-setters. To understand what this implies, consider a Northern firm that wins an innovative R&D race and becomes the only firm in the world that knows how to produce the state-of-the-art quality product in its industry. This firm faces a competitor that can produce a product with quality one step below, with manufacturing production located in either the North or the South depending on the past history of the industry. It is profit-maximizing for the new quality leader to either engage in limit pricing [as in Grossman and Helpman (1991)] or charge the unconstrained monopoly price. In either case, the closest competitor cannot compete and is priced out of business. We restrict attention to equilibrium behavior where the closest competitor chooses to immediately exit the market and then the new quality leader charges
the unconstrained monopoly price, as in Howitt (1999). 8

We proceed by omitting all the arguments of functions in order to simplify the exposition. A Northern quality leader that manufactures its product in the North earns the flow of global monopoly profits

\[ \pi_N = (p_N - w_N)(d_N L_N + d_S L_S) - w_N h q, \]

where \( p_N \) is the price charged, \( d_N \) and \( d_S \) are the per-capita quantities demanded by Northern and Southern consumers, and \( h q \) is the labor employed in the production of headquarter services. At each instant in time, the Northern quality leader maximizes the flow of global monopoly profits with respect to \( p_N \) taking into account equation (3), which is used to determine \( d_N \) and \( d_S \). It is straightforward to verify that the unconstrained monopoly price is

\[ p_N = \left[ \frac{\sigma}{\sigma - 1} \right] w_N, \]

that is, each Northern quality leader charges the standard monopoly markup of price over marginal cost.

Likewise, when a Northern quality leader becomes a multinational firm by transferring its manufacturing activities to the South, it earns the flow of global monopoly profits

\[ \pi_F = (p_F - w_S)(d_N L_N + d_S L_S) - w_N h q, \]

where \( p_F \) is the price charged and the subscript \( F \) stands for “foreign.” By charging the unconstrained monopoly price \( p_F = \left[ \frac{\sigma}{\sigma - 1} \right] w_S \), each multinational firm maximizes the flow of global monopoly profits.

The above analysis implies that \( p_N > p_F \), that is, when a product shifts from being produced by a Northern firm to a multinational firm, the equilibrium price of that product declines. This price pattern is consistent with Vernon’s (1966) description of the product life cycle, in which multinational firms play a central role.

The next step in the analysis is to derive expressions for the value of global monopoly profits. To facilitate this, we first introduce additional notation which simplifies the algebraic exposition. Denote by

\[ E(t) = c_N(t)L_N(t) + c_S(t)L_S(t) \]

the global consumption expenditure, where \( c_N(t) \) and \( c_S(t) \) are the consumption expenditures of typical Northern and Southern consumers, respectively. Denote by

\[ L_N(t) = \bar{L}_N e^{gL_N} \text{ and } L_S(t) = \bar{L}_S e^{gL_S} \]

the population sizes in the North and the South, respectively. One can then write the global consumption expenditure as

\[ E(t) = c(t)L(t), \]

where

\[ L(t) = (\bar{L}_N + \bar{L}_S)e^{gL_N} = \bar{L} e^{gL_N} \]

is the level of global population at time \( t \) and

\[ c(t) = \left[ c_N(t)\bar{L}_N / \bar{L} \right] + \left[ c_S(t)\bar{L}_S / \bar{L} \right] \]

is per-capita global consumption expenditure at time \( t \). In addition, denote with

\[ Q(t) = \int_0^1 q(\theta, t) d\theta \]

the average quality level across industries at time \( t \). Using equation

\[ Q(t) = \int_0^1 q(\theta, t) d\theta \]

8In the case of drastic innovations (\( \delta > 1 \) is sufficient large), the new quality leader charges the unconstrained monopoly price and drives the previous quality leader out of business. In the case of non-drastic innovations (\( \delta > 1 \) is small), the new quality leader charges the limit price initially and immediately reverts to the unconstrained monopoly price once it learns that the previous quality leader has gone out of business. In the presence of positive costs of reentering the market, the above mentioned trigger strategy allows each new quality leader to charge the unconstrained monopoly price except for an instance in time when innovation occurs.
(3), one can then define per-capita global demand for a product with average quality $Q(t)$ produced by a Northern firm

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

and per-capita global demand for a product with average quality $Q(t)$ produced by a multinational firm

$$y_F(t) = \frac{Q(t)p_F^\sigma c(t)}{\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma}d\theta}.\tag{7}$$

We solve the model for a steady-state equilibrium where both $y_N$ and $y_F$ are constant over time. We can then write the flow of global monopoly profits earned by a Northern quality leader firm $\pi_N = (p_N - w_N)(d_N L_N + d_S L_S) - w_Nhq$ as

$$\pi_N(\theta,t) = \left[\frac{w_N}{\sigma - 1}\right] \frac{q(\theta,t)}{Q(t)} y_N L(t) - w_Nhq(\theta,t).\tag{8}$$

Equation (8) states that the profit flow earned by a Northern quality leader is increasing in the per unit profit margin $w_N/(\sigma - 1)$, the relative quality of the firm’s product $q(\theta,t)/Q(t)$, and the global demand for a typical Northern firm’s product $y_N L(t)$. On the other hand, this profit flow is decreasing in the costs of headquarter services $w_Nhq(\theta,t)$. The global monopoly profit flow earned by a multinational firm in industry $\theta$ at time $t$ can be similarly expressed as

$$\pi_F(\theta,t) = \left[\frac{w_S}{\sigma - 1}\right] \frac{q(\theta,t)}{Q(t)} y_F L(t) - w_Nhq(\theta,t).\tag{9}$$

A multinational firm has marginal cost $w_S$, a typical market size $y_F L(t)$, and incurs a cost $w_Nhq(\theta,t)$ to maintain its Northern headquarters.

2.4 Innovative and Adaptive R&D

The flow of temporary monopoly profits provides an incentive for firms in the North to engage in innovative R&D aimed at discovering new higher-quality products in each industry. Northern quality leaders can increase the flow of monopoly profits by transferring their manufacturing facilities to the South, but to learn how to produce in the South, they must engage in adaptive R&D, as in Glass and Saggi (2002). Both types of investment activities are costly and involve uncertain returns.9

9Fors (1997) documents that a major reason for R&D investment by Swedish multinationals is to decrease the necessary technology transfer costs related to foreign production by adapting their technologies to local conditions. Teece (1977) and Norback (2001) provide more evidence for the magnitude and effects of such technology transfer costs.
instantaneous probability (or Poisson arrival rate)

\[ I_{Ni}(\theta,t) = \frac{\ell_{Ni}(\theta,t)}{\gamma q(\theta,t)}, \quad (10) \]

where \( \gamma > 0 \) is an innovation productivity parameter. Thus, a firm’s innovation rate is higher when the firm employs more R&D workers. The term \( q(\theta,t) \) captures the notion that the productivity of each R&D worker declines as the complexity of each product (measured by its quality level) increases. Following Segerstrom (1998) and in particular Li (2003), increasing R&D difficulty is assumed to remove the counterfactual scale effect property that is shared by all the first-generation R&D-driven endogenous growth models.\(^{10}\)

The returns to innovative R&D are independently distributed across firms, industries and over time. Therefore, the industry-wide instantaneous probability of innovation (the Poisson arrival rate of innovations) is \( I_N(\theta,t) = \sum_i I_{Ni}(\theta,t) \). If a Northern quality leader firm in industry \( \theta \) at time \( t \) hires \( \ell_F(\theta,t) \) Southern workers to engage in adaptive R&D, then it is successful in shifting its production activities to the South with instantaneous probability (or Poisson arrival rate)

\[ I_F(\theta,t) = \frac{\ell_F(\theta,t)}{\alpha q(\theta,t)}, \quad (11) \]

where \( \alpha > 0 \) is an adaptive R&D productivity parameter. Thus, a Northern quality leader firm is more likely to be successful in transferring its manufacturing production to the South when it employs more adaptive R&D workers. The term \( q(\theta,t) \) captures the notion that it is more difficult to transfer the production of more complex products.\(^{11}\)

Our modeling of adaptive R&D is intended to capture the substantial resource costs and inherent uncertainty associated with international technology transfer, including the training of foreign workers, learning about local customs, culture and regulations, etc. For instance, Fors (1997) reports that in a sample of Swedish multinationals, the share of R&D performed abroad was about 25%. Norback (2001) uses regression analysis to establish that Swedish multinationals that have established R&D labs in a foreign country are more likely to transfer technology and production to such a country.

\( ^{10} \)See Jones (1999) and Dinopoulos and Sener (2004) for more details on the scale-effect property and the relevant empirical evidence.

\( ^{11} \)This assumption differentiates the present model from earlier endogenous growth models with FDI, in particular, Glass and Saggi (2002). Following Glass and Saggi, we have also explored the model’s implications when Southern firms can engage in imitative R&D to copy the products produced by multinational firms. However, we found that the model with imitative R&D (modelled as in Glass and Saggi) generates unreasonable results: the only equilibrium with a finite imitation rate has counterintuitive comparative steady-state properties, which suggests that this equilibrium might be unstable. Finding a reasonable way of incorporating imitation by Southern firms is an important task for future research.
All firms maximize expected discounted profits and there is free entry into each innovative R&D race. Consider first the incentive of Northern challenger firm $i$ to engage in innovative R&D in industry $\theta$ at time $t$. The expected benefit from engaging in innovative R&D is $v_N(\theta, t)I_{Ni}(\theta, t)dt$, where $v_N(\theta, t)$ is the expected discounted profits that the Northern firm would get from innovating (the value of being a Northern quality leader) and $I_{Ni}(\theta, t)dt$ is the firm’s probability of innovating during the infinitesimal time interval $dt$. During this time interval, firm $i$ also incurs the innovative R&D cost $w_N\ell_{Ni}(\theta, t)dt = w_N\gamma q(\theta, t)I_{Ni}(\theta, t)dt$ using equation (10). Free entry in each innovative R&D race means that the expected benefit from innovative R&D must be equal to the corresponding R&D cost. This yields the following zero-profit condition for innovative R&D:

$$v_N(\theta, t) = w_N\gamma q(\theta, t).$$  \hspace{1cm} (12)

Next consider the incentives of a Northern quality leader to engage in adaptive R&D in industry $\theta$ at time $t$. If successful, the expected discounted profits earned by the firm increase by $[v_F(\theta, t) - v_N(\theta, t)]$, where $v_F(\theta, t)$ is the market value associated with being a multinational firm. Thus, the expected benefit from engaging in adaptive R&D is $[v_F(\theta, t) - v_N(\theta, t)]I_F(\theta, t)dt$, where $I_F(\theta, t)dt$ is the Northern firm’s probability of successfully transferring its production to the low-wage South during the infinitesimal time interval $dt$. The corresponding cost of adaptive R&D during this time interval is $w_S\ell_F(\theta, t)dt = w_S\alpha I_F(\theta, t)q(\theta, t)dt$ using equation (11). Since the net benefit of adaptive R&D is linear in $I_F(\theta, t)$, a Northern quality leader engages in a positive amount of adaptive R&D if and only if the following equilibrium condition holds:

$$v_F(\theta, t) - v_N(\theta, t) = w_S\alpha q(\theta, t).$$  \hspace{1cm} (13)

Equation (13) implies that what matters for adaptive R&D is not the expected discounted profits from transferring production $v_F$ but the gain in expected discounted profits $v_F - v_N$. Northern quality leader firms are already earning positive profit flows and this needs to be taken into account in evaluating their incentives to engage in adaptive R&D.\textsuperscript{12}

We solve the model for a steady-state equilibrium where both $I_N$ and $I_F$ are constant over time and do not vary across industries.

\textsuperscript{12}Equation (13) can be supported using a standard stability argument. If the left-hand-side (LHS) exceeds the right-hand-side (RHS), then it is profitable for Northern quality leaders to employ more adaptive R&D workers, which increases the demand for Southern labor and the Southern wage $w_S$. This process of Northern quality leaders hiring more adaptive R&D workers continues until the RHS increases enough to restore equality. Likewise, if the LHS is less than the RHS, then it is profitable for Northern quality leaders to employ less adaptive R&D workers, which decreases the demand for Southern labor and the Southern wage $w_S$. This process of Northern quality leaders laying off adaptive R&D workers continues until the RHS decreases enough to restore equality.
2.5 The Stock Market

Consumer savings finance all types of R&D investments. There is a global stock market which helps households to diversify the risks associated with holding stocks issued by firms participating in R&D races. Because the returns to R&D investments are independent across firms and over time, consumers can completely diversify the idiosyncratic risk by holding a diversified portfolio of stocks. At each instant in time, the rate of return from holding a stock must be the same as the rate of return from holding a riskless bond: the market interest rate \( r \).

We can solve for the stock market valuation of each type of firm. For a Northern quality leader, the relevant no-arbitrage condition is

\[
\frac{\pi_N - w_S \alpha q I_F}{v_N} + I_N \left[ \frac{0 - v_N}{v_N} \right] + I_F \left[ \frac{v_F - v_N}{v_N} \right] = r,
\]

where the time and industry arguments of functions have been omitted. The LHS of the above equation equals the expected rate of return on a stock issued by a Northern quality leader and the RHS equals the market interest rate \( r \). By investing in the stock, the investor receives the dividend \((\pi_N - w_S \alpha q I_F)/v_N\). However, with instantaneous probability \( I_N \), a higher quality product is discovered, the incumbent quality leader goes out of business and the investor suffers a total capital loss. Also, with instantaneous probability \( I_F \), the Northern quality leader becomes a multinational firm and the investor reaps the additional capital gain \((v_F - v_N)/v_N\). Since the quality level in an industry only jumps up at the end of the R&D race when innovation occurs, (12) implies that \( v_N \) is constant during a R&D race and there is no capital gain associated with just staying in business.

Equation (13) implies that the capital gain associated with adaptive R&D success is exactly offset by the cost of doing adaptive R&D. It follows that, in a steady-state equilibrium, the stock-market valuation of a Northern quality leader is

\[
v_N = \frac{\pi_N}{r + I_N}. \tag{14}
\]

The stock-market value of a Northern quality leader \( v_N \) equals the flow of global monopoly profits \( \pi_N \) discounted by the market interest rate \( r \) plus the innovation rate \( I_N \).

Similar considerations apply for calculating the stock-market valuation of a multinational firm \( v_F \). The no-arbitrage condition in this case can be written as

\[
\frac{\pi_F}{v_F} + I_N \left[ \frac{0 - v_F}{v_F} \right] = r.
\]

By investing in the stock of a multinational firm, the investor receives the dividend \( \pi_F/v_F \). However, with instantaneous probability \( I_N \), a higher quality product is discovered, the incumbent multi-
national firm gets driven out of business by the new Northern quality leader and the investor suffers a total capital loss. The sum of these two effects must equal the return for holding a riskless bond \( r \) since the investor has a fully diversified portfolio.

Equations (12) and (13) together imply that \( v_F \) is constant during a R&D race and there is no capital gain associated with a multinational firm just staying in business. The no-arbitrage condition for a multinational firm simplifies to

\[
v_F = \frac{\pi_F}{r + I_N}.
\]

(15)

The stock-market valuation of a multinational firm \( v_F \) equals the flow of its global monopoly profits \( \pi_F \) discounted by the market interest rate \( r \) plus the probability of default, which is captured by the Poisson arrival rate of innovations \( I_N \).

### 2.6 Industry Composition and Quality Dynamics

At each instant in time, there is a measure of industries \( n_N \) where manufacturing production takes place in the North by Northern quality leader firms and a measure of industries \( n_F = 1 - n_N \) where manufacturing production takes place in the South by multinational firms. Each industry can switch randomly across these two categories with transition probabilities that depend on the Poisson arrival rates associated with innovative and adaptive R&D.

Since \( n_N \) is constant over time in any steady-state equilibrium, the flow into the \( n_N \)-industry state must equal the flow out of the \( n_N \)-industry state, that is, \( n_N I_F = n_F I_N \). Together with \( n_N + n_F = 1 \), this implies that

\[
n_N = \frac{I_N}{I_N + I_F} \quad \text{and} \quad n_F = \frac{I_F}{I_N + I_F}.
\]

(16)

The measure of industries with Northern quality leaders \( n_N \) is an increasing function of the rate of innovation \( I_N \) and a decreasing function of the rate of adaptation or FDI \( I_F \). The converse is true for the measure of industries with multinational firms \( n_F \).

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

\[
Q(t) = \int_0^1 q(\theta, t) d\theta = \int_0^1 \lambda^{i(\theta, t)} d\theta,
\]

where \( \lambda = \delta^{\sigma - 1} > 1 \) is a parameter that is positively related to innovation size \( \delta \). The average quality can be decomposed in two parts, \( Q(t) = Q_N(t) + Q_F(t) \), where \( Q_N(t) = \int_{n_N} q(\theta, t) d\theta \) is a
measure of product quality for products manufactured by Northern firms and 
\[ Q_F(t) = \int_{n_F} q(\theta, t) d\theta \]
is a measure of product quality for products manufactured in the South by multinational firms.  

To determine the allocation of labor across various activities, we need to solve for how \( Q_N \) and \( Q_F \) evolve over time. The time derivative of \( Q_F \) is

\[
\dot{Q}_F(t) = \int_{n_N} \lambda^{\theta(t)} I_F d\theta - \int_{n_F} \lambda^{\theta(t)} I_N d\theta = I_F Q_N(t) - I_N Q_F(t),
\]

and the time derivative of \( Q_N \) is

\[
\dot{Q}_N(t) = \int_{n_N} [\lambda^{\theta(t)}+1 - \lambda^{\theta(t)}] I_N d\theta + \int_{n_F} \lambda^{\theta(t)}+1 I_N d\theta - \int_{n_N} \lambda^{\theta(t)} I_F d\theta,
\]

which simplifies to \( \dot{Q}_N(t) = (\lambda - 1) I_N Q_N(t) + \lambda I_N Q_F(t) - I_F Q_N(t) \). It follows that the growth rates of \( Q_N \) and \( Q_F \) are constant over time (a steady-state equilibrium requirement) only if they are identical. Solving

\[
\frac{\dot{Q}_N(t)}{Q_N(t)} = (\lambda - 1) I_N - I_F + \lambda I_N \frac{Q_F(t)}{Q_N(t)} = \frac{\dot{Q}_F(t)}{Q_F(t)} = I_F Q_N(t) - I_N
\]
yields

\[
\lambda I_N \frac{Q_N(t)+Q_F(t)}{Q_N(t)} = I_F \frac{Q_N(t)+Q_F(t)}{Q_F(t)} \quad \text{or} \quad \frac{Q_F(t)}{Q_N(t)} = I_F / \lambda I_N.
\]

It then follows, using \( Q(t) = Q_N(t) + Q_F(t) \), that

\[
\frac{Q_N(t)}{Q(t)} = \frac{\lambda I_N}{\lambda I_N + I_F} \quad \text{and} \quad \frac{Q_F(t)}{Q(t)} = \frac{I_F}{\lambda I_N + I_F}.
\]

Equation (17) implies that the product quality measures \( Q_N \) and \( Q_F \) must grow at the same rate over time as overall product quality \( Q \). The Northern product quality measure \( Q_N \) represents a larger share of overall product quality \( Q \) when the innovation rate \( I_N \) is higher and more products are manufactured in the North. Note the similarities between equations (16) and (17). The only difference is that the Northern product quality share \( Q_N/Q \) is somewhat higher than the Northern industries share \( n_N \) due to the quality increment \( \lambda > 1 \). The reason for this is that manufacturing only shifts from the South to the North when innovation occurs and thus Northern-manufactured products tend to have somewhat higher quality than Southern-manufactured products.

### 2.7 The Northern Labor Market

We assume that there is perfect labor mobility across activities in both regions. Full employment of labor prevails at each instant in time and wages adjust to equate labor demand and supply. Northern
labor is employed in three activities: manufacturing of final consumption goods, production of headquarter services, and innovative R&D.

Equations (3) and (6) imply that a Northern quality leader in industry \( \theta \in n_N \) employs \( d(\theta, t) L(t) = q(\theta, t) y_N L(t)/Q(t) \) workers in manufacturing production. Consequently total demand for Northern manufacturing labor is given by

\[
\int_{n_N} d(\theta, t) L(t) d\theta = \int_{n_N} q(\theta, t) L(t) \frac{Q_N(t)}{Q(t)} = y_N L(t) \frac{\lambda I_N}{\lambda I_N + I_F}.
\]

Because headquarter services have to be produced in the North by assumption, all industries populated by multinational or Northern firms must employ \( h_q(\theta, t) \) workers per industry. Therefore the aggregate demand for labor employed in headquarters services is given by

\[
\int_0^1 h_q(\theta, t) d\theta = h_Q(t).
\]

Also, because all industries are targeted by Northern firms doing innovative R&D, the aggregate demand for innovative R&D workers is given by

\[
\int_0^1 \gamma I_N q(\theta, t) d\theta = \gamma I_N \int_0^1 q(\theta, t) d\theta = \gamma I_N Q(t),
\]

where equation (10) has been used.

Putting all these results together, the aggregate demand for Northern labor equals its supply \( L_N(t) \) and there is full employment when

\[
L_N(t) = y_N \frac{\lambda I_N}{\lambda I_N + I_F} L(t) + h Q(t) + \gamma I_N Q(t).
\]

Dividing both sides of this equation by \( L_N(t) \) and using

\[
L(t)/Q(t) = (\bar{L}_N + \bar{L}_S)/(x_N \bar{L}_N)
\]

(18)

where \( x_N = Q(t)/L_N(t) \) is a measure of relative R&D difficulty, we obtain the per-capita Northern full-employment of labor condition

\[
1 = \frac{y_N \lambda I_N (\bar{L}_N + \bar{L}_S)}{(\lambda I_N + I_F) L_N} + h x_N + \gamma I_N x_N.
\]

(19)

The three terms on the RHS of equation (19) are the shares of Northern workers employed in manufacturing production, production of headquarter services and innovative R&D, respectively. The share of Northern workers employed in manufacturing production is increasing in the per-capita global demand for Northern products \( y_N \) and is increasing in the relative size of the Southern market
\( \frac{L_S}{L_N} \) (since larger exports to the South increase the demand for Northern production workers). The shares of Northern workers employed in headquarter services and R&D are both increasing in \( x_N \), which captures both the relative difficulty of conducting R&D and the relative difficulty of producing headquarter services. Both activities become more difficult when product quality \( q(\theta, t) \) increases.

### 2.8 The Southern Labor Market

Similar considerations apply in the Southern labor market. At each instant in time, there is perfect labor mobility across activities in the South. Southern workers can be employed in manufacturing by multinational firms and they can be hired by Northern quality leaders to do adaptive R&D.

A multinational firm in industry \( \theta \in n_F \) employs \( d(\theta, t)L(t) = q(\theta, t)y_FL(t)/Q(t) \) Southern workers, using (3) and (7). Consequently the aggregate manufacturing employment in the South is

\[
\int_{n_F} d(\theta, t)L(t)d\theta = \frac{I_F}{\lambda I_N + I_F} y_FL(t).
\]

In each industry \( \theta \in n_N \), a Northern quality leader employs \( \ell_F(\theta, t) = I_F \alpha q(\theta, t) \) Southern workers to perform adaptive R&D. Thus aggregate R&D employment in the South is

\[
\int_{n_N} I_F \alpha q(\theta, t)d\theta = I_F \alpha Q_N(t) = I_F \alpha \frac{\lambda I_N}{\lambda I_N + I_F} Q(t).
\]

Putting the above results together yields the full-employment of labor condition in the South

\[
L_S(t) = \frac{I_F}{\lambda I_N + I_F} y_FL(t) + I_F \alpha \frac{\lambda I_N}{\lambda I_N + I_F} Q(t).
\]

Dividing both sides of this equation by \( L_S(t) \) and using (18) yields the per-capita Southern full-employment of labor condition:

\[
1 = \frac{I_F y_F(\bar{L}_N + \bar{L}_S)}{(\lambda I_N + I_F) L_S} + \frac{\lambda \alpha I_N \ell_F x_N \bar{L}_N}{(\lambda I_N + I_F) L_S}. (20)
\]

The two terms on the RHS of equation (20) are the shares of Southern workers employed in manufacturing production and adaptive R&D, respectively. The share of Southern workers employed in manufacturing production is increasing in the per-capita global demand for multinational products \( y_F \), and is increasing in the relative size of Northern market \( \frac{L_N}{L_S} \) (since larger exports to the North increase the demand for Southern production workers). The shares of Southern workers employed in adaptive R&D is increasing in the measure of relative R&D difficulty \( x_N \). This completes the description of the model.
3 The Steady-State Equilibrium

In this section, we solve the model for a steady-state equilibrium where the R&D discovery rates $I_N$ and $I_F$ are constant over time, as well as the nominal wage rates $w_N$ and $w_S$.\textsuperscript{14} We show that this steady-state equilibrium is uniquely determined and analyze its main properties.

We begin by focusing on what other endogenous variables must be constant over time. In any steady state equilibrium, the share of Northern labor devoted to production must be constant over time, as is the case for the share of Northern labor devoted to R&D. It immediately follows from (19) that $y_N$ and $x_N$ must be constant over time. Likewise, the shares of Southern labor devoted to production and R&D must be constant over time in any steady-state equilibrium. It immediately follows from (20) that $y_F$ must be constant over time.

The property that $y_N$ is constant over time has an important implication. Referring back to equation (6), we can calculate the denominator in this expression:

\[
\int_0^1 q(\theta,t)p(\theta,t)^{1-\sigma} d\theta = \int_{n_N} q(\theta,t)p_N^{1-\sigma} d\theta + \int_{n_F} q(\theta,t)p_F^{1-\sigma} d\theta = \frac{p_N^{1-\sigma} \lambda I_N + p_F^{1-\sigma} I_F Q(t)}{\lambda I_N + I_F},
\]

where we have used (17). It immediately follows from the fact that $y_N$ is constant over time in equation (6) that per capita consumer expenditure $c$ must be constant over time. But then equation (4) implies that the market interest rate must equal the consumer subjective discount rate: $r(t) = \rho$. In any steady-state equilibrium, it is optimal for each consumer to choose a constant expenditure path over time.\textsuperscript{15}

The property that $x_N = Q(t)/L_N(t)$ is constant over time also has an important implication. Referring back to the definition of the product quality index,

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

we can calculate how $Q(t)$ evolves over time. When a new product is discovered in industry $\theta$, the index $j(\theta,t)$ jumps up to $j(\theta,t) + 1$ and this occurs with instantaneous probability $I_N$. Thus, the time derivative of average quality is

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

\textsuperscript{14}Although nominal wages are constant over time, real wages grow over time due to the rising quality of products.

\textsuperscript{15}The same argument could be made using the property that $y_F$ is constant over time and equation (7). Although nominal consumer expenditure is constant over time, real consumer expenditure grows over time due to the rising quality of products.
The growth rate of average quality $\dot{Q}/Q$ is proportional to the rate of innovation $I_N$ and depends positively on the innovation size parameter $\lambda$. Next using the definition of $x_N$ and equation (21), we obtain that $\dot{x}_N/x_N = \dot{Q}/Q - \dot{L}_N/L_N = (\lambda - 1)I_N - g_L = 0$, from which it follows that the steady-state equilibrium innovation rate is

$$I_N = \frac{g_L}{\lambda - 1}. \tag{22}$$

As in Segerstrom (1998), the steady-state innovation rate $I_N$ is completely determined by the world population growth rate $g_L$ (or more generally, the world human capital growth rate\(^{16}\)) and the innovation size parameter $\lambda$.

The intuition behind equation (22) is as follows: Along any steady-state equilibrium path, there is a constant innovation rate $I_N$ and rising product quality in every industry. But as product quality rises, products become more complex and it gets harder for researchers to find further improvements. Thus, to maintain a constant innovation rate over time, firms need to continually increase their R&D employment, compensating for the fact that R&D workers are becoming less productive by increasing the number of R&D workers. This can only be done at an economy-wide level if there is positive population growth. The higher is the population growth rate $g_L$, the higher is the innovation rate $I_N$ that can be sustained over time, while the higher is the rate $\lambda$ at which innovations increase R&D difficulty, the lower is the innovation rate $I_N$ that can be sustained over time.

The equation $\dot{x}_N/x_N = (\lambda - 1)I_N - g_L$ has important implications for how to interpret the main results in this paper (Theorems 1 and 2). Any permanent increase in the value of $x_N$ over time must be associated with a temporary increase in $I_N$ above its steady-state value given by (22). Thus, any parameter change that causes the steady-state value of $x_N$ to increase is associated with a temporary acceleration in the rate of technological change.\(^{17}\)

The next step in the analysis is to solve for the steady-state equilibrium value of the Northern relative wage $\omega = w_N/w_S$. It turns out that the incentives to conduct innovative and adaptive R&D completely determine $\omega = w_N/w_S$.

Combining the monopoly mark-up pricing conditions $p_N = [\sigma/(\sigma - 1)]w_N$ and $p_F = [\sigma/(\sigma - 1)]w_F$, we have

$\omega = \frac{q_g}{q_L}$

\(^{16}\)Using a closely related model of R&D-driven growth, Arnold (1998) shows that the property that public policy choices do not affect the steady-state economic growth rate is preserved when the assumption of exogenous population growth is replaced by endogenous human capital accumulation.

\(^{17}\)Since convergence to a steady-state equilibrium tends to be very slow in models of R&D-driven growth without scale effects, we should expect these temporary effects to last a long time. For example, using a calibrated version of the Segerstrom (1998) model, Steger (2003) finds that it takes 38 years to go half the distance to the steady-state.
Equation (23) states that the Northern relative wage is an increasing function of North’s terms of trade (relative price of Northern exports expressed in units of Northern imports). Alternatively stated, the relative demand for Southern-manufactured products $y_F/y_N$ is a decreasing function of the relative price of Southern-manufactured products $p_F/p_N$. The elasticity of the relative demand curve is $\sigma > 1$.

Substituting (8) and (18) into (14) and the resulting expression into (12) yields a steady-state innovative R&D condition:

$$\frac{y_N(L_N + L_S)}{(\sigma - 1)x_N L_N} - h = \frac{\rho + I_N - \gamma}{\rho}.$$

The LHS of (24) is related to the benefit (expected discounted profits) from innovating and the RHS 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 $\bar{L}_S$ increases (there are more consumers to sell to), when $x_N \bar{L}_N$ decreases (firms in other industries sell lower quality products), when $\rho$ decreases (future profits are discounted less), when $h$ decreases (headquarter services can be more efficiently provided), and when $I_N$ decreases (the Northern firm is less threatened by further innovation). The cost of innovating increases when $\gamma$ increases (it takes more R&D workers to generate any given innovation rate).

Similar calculations using (9), (12), (13), (15) and (18) yield a steady-state adaptive R&D condition:

$$\frac{y_F(L_F + L_S)}{(\sigma - 1)x_N L_N} - h\omega = \frac{\rho + I_N - \gamma\omega}{\rho}.$$

The LHS of (25) is related to the benefit a Northern firm obtains from transferring its manufacturing operations to the low-wage South and the RHS is related to the cost of doing so. The benefit from transferring production to the South increases when $y_F$ increases (the average consumer buys more of Southern-manufactured products), when $\bar{L}_N$ or $\bar{L}_S$ increases (there are more consumers to sell to), when $x_N \bar{L}_N$ decreases (firms in other industries sell lower quality products), when $\rho$ decreases (future profits are discounted less), when $h$ decreases (headquarter services can be more efficiently provided), when $\omega = w_N/w_S$ decreases (the firm earns lower profits prior to becoming a multinational firm) and when $I_N$ decreases (the firm is less threatened by further innovation after it becomes a multinational firm). The cost of transferring production increases when $\alpha$ increases (it takes more R&D workers to generate any given transfer rate).
Solving (23) for \( y_F \), solving (24) for \( y_N \) and then substituting into (25) yields

\[
\left[ \gamma + \frac{h}{\rho + I_N} \right] [\omega^\sigma - \omega] = \alpha. \tag{26}
\]

Now \( \sigma > 1 \) guarantees that \( \omega^\sigma - \omega \) is monotonically increasing in \( \omega \). Thus equation (26) uniquely determines the steady-state equilibrium value of the Northern relative wage \( \omega = w_N/w_S > 1 \).

Equation (26) reveals how the steady-state Northern relative wage \( \omega \) depends on the innovative and adaptive R&D incentives. The steady-state Northern relative wage \( \omega \) increases when \( \alpha \) increases (it is costlier to transfer production to the South because adaptive R&D workers are less productive) and when \( \gamma \) decreases (it is less costly to develop better products in the North because innovative R&D workers are more productive).

Equation (26) is also useful for thinking about stability issues: how the economy adjusts over time to reach the steady-state equilibrium. For example, if the LHS of (26) exceeds the RHS, then it is profitable for firms to increase adaptive R&D employment, which increases the demand for Southern labor, drives up the Southern wage \( w_S \) and drives down \( \omega = w_N/w_S \). The reduction in \( \omega \) lowers the LHS of (26) and represents a movement toward the steady-state equilibrium. This process continues until equality is restored in (26).

Based on what we have accomplished so far, solving the model for a steady-state equilibrium reduces to solving four equations [(19), (20), (24), (25)] in four unknowns \([x_N, I_F, y_N, y_F]\), taking into account that (22) determines \( I_N \) and (26) determines \( \omega \).

We can make further progress by solving the innovative R&D condition (24) for \( y_N \) and substituting into the Northern labor condition (19). This yields the \textit{Northern steady-state condition}

\[
1 = x_N \left\{ (\sigma - 1)[\gamma(\rho + I_N) + h] \frac{\lambda I_N}{\lambda I_N + I_F} + h + \gamma I_N \right\}, \tag{27}
\]

which is an upward-sloping curve in \((x_N, I_F)\) space with a positive \( x_N \) intercept.

The intuition behind the positive slope of the Northern steady-state condition is as follows: An increase in relative R&D difficulty \( x_N \) increases the demand for Northern labor in R&D (more R&D workers are needed to maintain the steady-state innovation rate \( I_N \)), increases the demand for Northern labor employed producing headquarter services (more headquarter services are needed for more complex products) and increases the demand for Northern labor employed in manufacturing production (stronger consumer demand for products is needed to justify R&D effort when R&D is more difficult). In contrast, an increase in the FDI rate \( I_F \) decreases Northern production employment (more production moves to the South). Thus, to satisfy both Northern profit-maximization and
full employment conditions, any increase in relative R&D difficulty \( x_N \) (which raises Northern production, headquarter services and R&D employment) must be matched by an increase in the FDI rate \( I_F \) (which reduces Northern production employment). Solving the adaptive R&D condition (25) for \( y_F \) and substituting into the Southern labor condition (20) yields the Southern steady-state condition

\[
1 = \frac{x_N I_F \bar{L}_N}{(\lambda I_N + I_F) L_S} \{ (\sigma - 1) \left[ (\gamma \omega + \alpha) (\rho + I_N) + h \omega \right] + \lambda \alpha I_N \}.
\] (28)

which is a downward-sloping curve in \((x_N, I_F)\) space with no intercepts.

The intuition behind the negative slope of the Northern steady-state condition is as follows: An increase in relative R&D difficulty \( x_N \) increases the demand for Southern R&D labor (more adaptive R&D workers are needed to maintain the FDI rate \( I_F \)) and increases the demand for Southern production labor (stronger consumer demand for products is needed to justify R&D effort when R&D is more difficult). In contrast, a decrease in the FDI rate \( I_F \) decreases Southern production employment (less production shifts to the South) and decreases Southern R&D employment (less resources are devoted to transferring production to the South). Thus, to satisfy the Southern full employment condition, any increase in relative R&D difficulty \( x_N \) (which raises Southern R&D and production employment) must be matched by a decrease in the FDI rate \( I_F \) (which reduces Southern R&D and production employment).

The Northern and Southern steady-state conditions are illustrated in Figure 1 and are labeled “North” and “South.” Their intersection at point A determines the unique steady-state equilibrium values for the FDI rate \( I_F \) and relative R&D difficulty \( x_N \).

We are now in a position to analyze the steady-state equilibrium effects of globalization. Globalization has several dimensions. We focus on the effects of globalization captured by an increase in the South’s size measured by its initial population level \( \bar{L}_S \), as in Dinopoulos and Segerstrom (2004).\(^{18}\) This exercise is designed to capture the effects of developing countries (for example, 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 then to external trade. Because China is such a large country (20 percent of the world population), its decision to join the world trading system

\(^{18}\) There are several other ways of modeling the effects of globalization: for instance, globalization can be modeled as a reduction of trade barriers as in Dinopoulos and Segerstrom (1999), a move from autarky to free trade as in Dinopoulos and Syropoulos (2004), or as a reduction in transport costs.
represented a significant increase in the size of the (open) South.

An increase in the size of the South $\bar{L}_S$ does not affect the Northern steady-state condition (27) but implies that $x_N$ increases for given $I_F$ in (28). Thus the Southern steady-state condition shifts to the right in Figure 1 (not shown). Consequently, an increase in $\bar{L}_S$ raises the long-run rate of multinational formation $I_F$ and relative R&D difficulty $x_N$. The permanent increase in $x_N$ is associated with a temporary increase in the innovation rate above its steady-state value $I_N = g_L/(\lambda - 1)$. Since $\bar{L}_S$ does not appear in (26), the steady-state value of the Northern relative wage $\omega = w_N/w_S$ is not affected. We have established:

**Theorem 1.** Globalization measured by an increase in the size of the South ($\bar{L}_S \uparrow$) generates a permanent increase in the rate at which Northern firms become multinationals ($I_F \uparrow$), a temporary increase in the Northern innovation rate ($x_N \uparrow$), and no long-run change in North-South wage inequality ($\omega = w_N/w_S$).

The first two steady-state equilibrium effects of globalization are quite intuitive. Since globalization represents an expansion in the size of the South and it is Southern workers that engage in adaptive R&D, having more workers available to engage in adaptive R&D naturally leads to a
higher steady-state adaptive R&D intensity $I_F$. The increase in the size of the South also means that there are more Southern consumers around to buy the products developed by innovative Northern firms. It becomes more profitable for Northern firms to innovate and firms respond by innovating more frequently. However, when firms innovate more frequently, R&D difficulty rises at a faster than usual rate and the increase in R&D difficulty serves to gradually slow the economy’s growth. The increase in profitability leads to a permanent increase in relative R&D difficulty ($x_N \uparrow$), a temporary increase in the innovation rate $I_N$ but no change in the permanent (or steady-state) innovation rate $I_N = g_L/\lambda$. 

The third steady-state equilibrium effect of globalization (no change in North-South wage inequality) needs some explanation. This result differ from the corresponding result obtained in our earlier paper, Dinopoulos and Segerstrom (2004, Theorem 1), where the only mode of technology transfer was Southern firms imitating technologies developed in the North. In that paper, we found that globalization hurts Northern workers (in the sense that their relative wage $\omega = w_N/w_S$ falls). The reason for the difference in results is that when technology transfer takes the form of Southern firms copying Northern products, technology transfer brings to an end the profits earned by innovative Northern firms, whereas when technology transfer takes the form of Northern firms transferring their own production to the South, these firms earn higher profits after their production moves to the lower-wage South, with the increase in profits being exactly offset by the adaptive R&D costs that were incurred. With no change in the revenues earned from manufacturing in the North relative to the revenues earned from manufacturing in the South and no change in the expected duration of monopoly profits, there is no change in the steady-state degree of wage inequality $\omega = w_N/w_S$. When multinational firms play the central role in transferring technology internationally, globalization neither contributes to nor alleviates global wage inequality.

As a second comparative steady-state exercise, we consider what happens when $\alpha$ is permanently decreased. We think of a decrease in $\alpha$ as representing developing countries adopting more FDI-friendly policies, making it less costly for Northern firms to transfer their manufacturing operations to the South. Hill (2005), for instance, reports that according to a United Nations report, in the period 1991-2001 about 95 percent of the 1393 changes in FDI laws and regulations created a more favorable environment for multinational firms. In addition, governments have encouraged more FDI by engaging in a number of bilateral investment treaties designed to protect and promote investment between two countries: As of 2002, there were 2,099 such bilateral investment treaties in the world involving more than 160 countries.
A decrease in $\alpha$ does not affect the Northern steady-state condition (27) but implies that $x_N$ increases for given $I_F$ in (28). Thus the Southern steady-state condition shifts to the right in Figure 1 (not shown). Consequently, an increase in $\alpha$ raises the long-run rate of multinational formation $I_F$ and relative R&D difficulty $x_N$. The permanent increase in $x_N$ is associated with a temporary increase in the innovation rate above its steady-state value $I_N = g_L/(\lambda - 1)$. Finally, the decrease in $\alpha$ is associated with a decrease in $\omega = w_N/w_S$ in (26). We have established:

**Theorem 2.** When the South adopts a more FDI-friendly policy ($\alpha \downarrow$), this generates a permanent increase in the rate at which Northern firms become multinationals ($I_F \uparrow$), a temporary increase in the Northern innovation rate ($x_N \uparrow$), and a permanent decrease in North-South wage inequality ($\omega = w_N/w_S \downarrow$).

The steady-state equilibrium effects of a more FDI-friendly policy in the South are quite intuitive. When there are lower costs of technology transfer to the South, Northern firms naturally respond by transferring their manufacturing production to the South more frequently ($I_F \uparrow$). More rapid technology transfer to the South increases the demand for Southern labor and the Southern wage rate $w_S$ increases as a consequence. This corresponds to a decrease in North-South wage inequality ($\omega = w_N/w_S \downarrow$). Finally, the lower costs of transferring manufacturing production to the low-wage South make it more profitable for firms to innovate and become quality leaders in the North. Firms respond by innovating more frequently, R&D difficulty rises at a faster that usual rate and the increase in R&D difficulty serves to gradually slow down technological change. The increase in profitability associated with innovating leads to a permanent increase in relative R&D difficulty ($x_N \uparrow$), a temporary increase in the innovation rate $I_N$ but no change in the permanent (or steady-state) innovation rate $I_N = g_L/(\lambda - 1)$.

### 4 Concluding Remarks

The present paper developed a dynamic model of North-South trade, scale-invariant growth and multinational firms. Higher-quality products are discovered in the North through stochastic and sequential innovative R&D races, and Northern quality leaders engage in adaptive R&D in order to transfer their manufacturing operations to the low-wage South. We showed that the model has unique steady-state equilibrium and generates endogenous product cycles as well as an endogenous
North-South wage gap. We utilize the model to study the effects of globalization on the rate of multinational-firm formation, the rate of global innovation, the relative wage of Northern workers.

Consider the determinants of foreign direct investment first. A geographic expansion of the open South such as the opening of China and other ex-communist countries encourages the formation of multinationals, the rate of international technology transfer, and the global rate of innovation. What is surprising is that globalization, measured by a geographic expansion of the South, does not affect the long-run wage gap. In other words, endogenous formation of multinationals equalizes (or rather freezes) North-South wage income inequality! However, when globalization takes the form of technological or policy-based changes in the efficiency of adaptive R&D, it leads to more multinationals, more international technology transfer, a temporarily higher rate of global innovation and a permanently higher North-South wage gap. These results complement the analysis of Dinopoulos and Segerstrom (2004) who study the effects of globalization in the absence of multinationals and found that a geographic expansion of the South results in a permanent decline in the North-South wage gap.

The analysis can be extended in several dimensions. For instance, the effects of commercial policies and transportation costs could be incorporated into the present model; the assumption that only one region can innovate could be relaxed and one could analyze the role of Northern and Southern multinational companies in the generation and international transfer of technology, and welfare analysis could provide valuable insights on the optimal management of globalization in the presence of multinational firms. Finally, the model could offer a useful template for analyzing empirically the static and dynamic determinants and effects of multinationals. All these important issues represent fruitful avenues for further research.

**References**


