Technology Transfer with Competitive Markets in the South

Faruk A. Khan*

Williams College

This version: October 2002

Abstract

This paper develops a model of technology transfer in an environment where firms in developing countries are unable to recover the costs of imitation and adaptation, because a competitive market structure in the South rules out any monopoly rents accruing to Southern firms. In such an environment, the technology transfer must be initiated by a Northern firm which risks its technology being copied widely throughout the South because of lower production costs in the South and because its markets in the North are protected by strong intellectual property rights or by natural means. Examples of technology transfer under such an environment include subcontracting by Northern firms to firms in the South and the adaptation of "freely observable" technologies that are difficult to keep proprietary without strong intellectual property rights protection. The results of the paper suggest (in contrast to the previous work) that in such an environment, developing countries do not experience the endogenous increase in their relative wages by accumulating factors of production. While improvements in the productivity of the technology transfer process can restore the endogenous increase in relative wages from accumulation over some range, continued accumulation will eventually cause the relative wage of the South to fall. This provides us with a possible explanation for why some developing countries have been unable to sustain the high rates of factor accumulation that we have observed in the East Asian miracle economies.

*I would like to thank Robert Barro, Elhanan Helpman, and participants at the international, development and macroeconomics workshops at Harvard for useful comments and suggestions. All errors are my own.

Questions and comments are welcome at fkhan@williams.edu.

1 Introduction.

The common theme underlying existing models technology transfer based on imitation is that the technology transfer (involving the costs of imitation and adaptation) is carried out by imitating firms in the receiving country because it yields them a stream of monopoly profits.[1] However, the concept of monopoly profits for firms in developing countries (the South) is difficult to justify in environments where we observe tough competition between large numbers of Southern firms using new technology from developed countries (the North) to produce the same or very similar products. In the absence of any rents or monopoly profits, it is difficult to imagine why the costs of imitation would be incurred. Indeed, under such an environment of competitive markets in the South, without any monopoly rents or profits for imitating Southern firms (and in the face of costly imitation), we are left with no explanation for technology transfer from North to South.[2]

This paper, therefore, develops a model of technology transfer in an environment where firms in developing countries are unable to recover the costs of imitation and adaptation, because a competitive market structure in the South rules out any monopoly rents accruing to Southern firms.[3] We propose a model where the technology transfer is initiated by the Northern firm. The Northern firm risks its technology being copied in the South because of lower production costs in the South and because its market in the North is protected by strong patents or other natural means. Examples of technology transfer under such an environment include subcontracting by Northern firms to firms in the South and the adaptation of "freely observable" technologies that are difficult to keep proprietary without strong intellectual property rights (IPR) protection in the South. The results of the paper suggest (in contrast to the previous work) that in such an environment, developing countries do not experience the endogenous increase in their relative wages by accumulating factors of production. While improvements in the productivity of the technology transfer process

[1] See, for example, Grossman and Helpman (1991) and Helpman (1993).

[2] Yet, as we will argue, such environments are empirically important and we do observe much technology transfer with "very competitive" markets in the South.

[3] The concept of technology transfer we use throughout this paper is the migration of additional production processes to developing country locations (the South). Thus, technology is specific to product lines and essentially reflects knowledge and expertise to competitively organize production of a particular product and deliver it to buyers on the world market.

can restore the endogenous increase in relative wages from accumulation over some range, continued accumulation will eventually cause the relative wage of the South to fall. This provides us with a possible explanation for why some developing countries have been unable to sustain the high rates of factor accumulation that we have observed in the East Asian miracle economies.

The debate over the issue of intellectual property rights (IPR) enforcement in developing countries has featured prominently in recent World Trade Organization (WTO) rounds. Industry representatives from developed countries and multinational corporations have complained about staggering losses resulting from the lack of IPR protection in developing countries. PhRMA–the US pharmaceutical industry association–has estimated that losses for US drug companies attributable to deficient IPRs amount to $500m per year from India alone.[4] However, much of the recent work on this topic has focussed on how the lack of IPR protection in developing countries (the South) affects the incentives for innovation by firms in developed countries (the North).[5] The model in this paper, on the other hand, allows us to focus instead on the effect of poor Southern intellectual property rights protection on firms located in the South. Existing models of transfer based on imitation abstract from this issue. In the imitation model, poor Southern IPR affects only Northern firms and hence affects only the incentives for innovation. There is no effect on firms operating in the South and hence no effect on the incentives to transfer technology.[6] In this paper, poor Southern IPR protection has two types of effects on firms operating in the South: (i) it denies Southern imitating firms any profits; (ii) for Northern firms, it means producing in the South will lose them part of their profits. This paper is, therefore, able to capture the effect of poor Southern IPR protection on the incentives to transfer technology to the South.

The results of this paper suggest that for reasonably low costs of technology transfer, the

[4]PhRMA (1999).

[5]Lanjouw and Cockburn (1999) and Kremer (1999). US International Trade Commission (1993) estimates that global patent piracy reduces the R&D investment of US pharmaceutical firms by $720–$900 million per year.

[6]In the existing imitation model, while poor Southern IPR protection allows a Northern firm's technology to be imitated by the Southern firm, once the imitated technology is in place in the South, poor Southern IPR protection poses no problems for the firm producing in the South.

potential for shifting production to the South raises the world rate of product development. Second, if there is an exogenous decline in the cost of transfer (through, for example, a reduction in the bureaucratic hassles associated with investing in developing countries), then the rate of innovation, the share of products in the South, and the Southern relative wage all rise. These results are consistent with the existing imitation-based technology transfer models.

A significant result which emerges in this paper is that given the environment of competitive markets in the South, factor accumulation in the South puts downward pressure on the Southern relative wage. This is because while a larger scale of the South leads to a higher share of products produced in the South, we can get a high share of products in the South (i.e. a high rate of transfer) only if the Southern wage is low enough relative to the North.[7] If there is an explicit cost of technology transfer in the model, having a high share of products in the South can also raise the productivity of the transfer process. In that case, a higher share of products in the South in steady-state can also be associated with higher wages in the South over some range. Then, accumulation in the South can be associated with a higher Southern relative wage, because accumulation increases the share of products produced in the South, which in turn improves the productivity (reduces the costs) of technology transfer. However, even in this case, continued accumulation in the South will eventually cause the relative wage of the South to fall.

2 Supporting Observations & Case Study.

There exists good empirical support for the kind of environment described above. Simple observations of the process of technology flow to developing countries suggest that in certain instances, the transfer is in the form of technologies or "production processes" which do not yield the Southern producer any particular monopoly profit or rent stream. Why not? For some reason or the other, such production processes become freely available to any Southern producer, with the result that tough competition between Southern firms producing the

[7] Of course, both relative wages and the share of products in the South are endogenously determined in steady-state.

same product drives them to marginal cost pricing. We can think of a number of different situations where this is the case:

Production processes are often subcontracted out by Northern firms to firms in the South. In such arrangements, the Northern firm will make its technology freely available to the subcontractor. If the subcontractor fails to supply at marginal cost, the Northern firm can simply make the production processes available to another subcontractor who will supply at marginal cost. We can also look beyond purely subcontracting relationships: exporters in developing countries often receive product designs from their importers in industrialized countries and these designs are an important source of learning for exporting firms.[8]

Certain products are such that the production process is common knowledge. In such cases, the cost of "technology transfer" can be thought of as an adaptation cost; that is, the cost of figuring out how to implement that production process under local conditions. Once someone adapts the technology to local conditions, the adapted production process also becomes common knowledge and hence, freely available to Southern producers. Suppose, for illustrative purposes, that everyone knows how the production process for cement is organized. However, cement is only produced in Japan and so, we only know how the production process is organized in Japan. In order to produce cement in Thailand, we need to figure out how to adapt the production process to local conditions in Thailand. However, once someone does figure out how to organize cement production in Thailand, the adapted production process becomes common knowledge, just as the original production process was common knowledge.

A case in point: In the early 1980s, Bangladesh had virtually no garments industry. Jute was the principal export. At the time, however, a number of South Korean entrepreneurs, faced with an exhausted Korean quota for apparel exports to the United States (under the Multi-Fibre Agreement), set up units in Bangladesh for a certain line of products. Soon, large numbers of Bangladeshi entrepreneurs flocked to the apparel industry and set up units for a diverse variety of product lines to serve the world market. Currently, the garments industry in Bangladesh employs one and a quarter million people and the industry

[8]See Tybout, et. al. (1998).

is Bangladesh's principal export.

Why don't Bangladeshi entrepreneurs enter the export market for products in a wholly different industry? Why do they not produce such items as an alarm clock or a lamp; items which have similarly labor-intensive production processes; items which are being produced in China, Indonesia, etc.? When asked such questions, the Bangladeshi entrepreneur will tell you that when he goes about entering a product line in the garments industry, there exists a well-established formula for how to go about doing it: he knows how to contact buyers in the U.S. and Europe, he knows how to set up shop, etc. If he were to enter a product line in a wholly different industry, he would have no idea how to go about doing it. The well established formula implies that the production processes for products in the garments industry are freely available or costlessly imitated (because of the initial transfer) whereas imitation of a product in a wholly different industry involves imitation and adaptation costs. Since imitating a wholly new product will not lead to any rents or profits, local enterpreneurs are reluctant to incur the imitation cost.

A crucial issue for the empirical environment examined in this paper is that firms are unable to charge markups in LDC markets but are able to do so in developed country markets. This is a simple result of the asymmetry in IPRs protection between North and South. Table A provides price comparisons for a number of "on-patent" drugs in India, the U.K. and the U.S. Quiet clearly, in India, firms are unable to charge the large markups that are common in US and UK markets. This suggests that markets in the South are competitive, whereas those in the North are well protected by strong IPR protection (or by natural means, such as the importance of marketing and advertising networks).

3 The Model.

Preferences.

There are two regions: North and South. Households in both North and South consume a variety of differentiated products. They have identical preferences so that we can really think of one representative world consumer.[9] A representative household's preferences are given by an infinite discounted sum of all future utility flows:

$$U_t = \int_t^{\infty} e^{-\rho(\tau - t)} \log(u_\tau)\, d\tau \tag{1}$$

where $\log(u_\tau)$ is instantaneous utility level at time τ and ρ is the subjective discount rate.

Utility at each point in time reflects a preference for product diversity and is given by the following standard function with a constant and equal elasticity of substitution between pairs of products:

$$u_\tau = \left[\int_0^n x(j)^\alpha\, dj\right]^{\frac{1}{\alpha}} \quad , \quad 0 < \alpha < 1 \tag{2}$$

where $x(j)$ is consumption of brand j.[10] Note that the elasticity of substitution is $\varepsilon = \frac{1}{1-\alpha}$. These preferences give us a demand for each product. So, a household which maximizes instantaneous utility, spends amount E, and faces prices $p(j)$ will have the following resulting demand function:

$$x(j) = \frac{p(j)^{-\varepsilon}}{\int_0^n p(i)^{1-\varepsilon}\, di} E \tag{3}$$

Note that the price elasticity of demand for each product is simply given by ε.

Production.

There are two types of possible activities:

[9] We will, however, see later that we need to think about consumption by Northern and Southern consumers separately. This is because, in the environment which we describe, consumers in the two regions face different relative prices for products produced in the North and South.

[10] We could have very well used an alternative interpretation of u_τ, where the CES function would be viewed as a production function for a final consumption good assembled from the (measure) n intermediate products.

(1) Firms must figure out the production plan for a product by consciously investing resources in a research and product development effort.
(2) Once a firm figures out the production plan, it can produce one unit of the product using one unit of labor.

Products are invented in the North. We assume that no innovation takes place in the South. Innovation involves a one time R&D fixed cost. Once invented, a product is manufactured in the North using one unit of labor per unit of output. The Northern economy has a standard monopolistic competition market structure. Each product is produced by one firm. A Northern firm faces competition only from other horizontally differentiated brands. Given the constant elasticity demand function (3) for each product, the typical Northern firm maximizes profits $\pi_N = p_j x_j - w_N x_j$ by charging the following price:

$$p_N = \frac{w_N}{\alpha} \tag{4}$$

The Northern monopolist's sales are x^N units of the product and its profits are given by the following:

$$\pi_N = (1-\alpha)\, p_N x^N \tag{5}$$

Technology Transfer.

The production plan for any product may be transferred to the South. In principle, this transfer can be carried out either by the Northern firm, which has property rights over the technology, or by a Southern firm which imitates the product. We will, however, show that the latter will not take place in practice. In either case, the process of technology transfer involves resources: there is a cost associated with tailoring a production process to local conditions in the South.[11]

We will make the following assumptions:

(A1) Patent protection is very strong in the North, so much so that even if a Southern firms learns a production plan for a certain product, it cannot sell the product directly in

[11] We would expect the transfer costs to be greater (at least in terms of units of labor required) for an imitating Southern firm than for a Northern firm which is in possession of the technology. However, this difference does not matter for us.

the Northern market. Rather, it must sell back to the original Northern innovator. In this sense, the relationship between the Southern firm and the innovator North firm resembles a subcontracting relationship.

The inability of Southern firms to sell directly to the Northern market and capture market share in the North can also be motivated by an alternative interpretation of what constitutes a "brand" or "product". We can reasonably think that developing a new product in the North also involves setting up an extensive marketing and advertising network. Thus, if a firm in Indonesia shipped Polo shirts without the official Polo labels and approached the U.S. market through channels outside of Polo's distribution network, it would be hard pressed to find buyers at usual Polo prices.

(A2) On the other hand, patent protection is nonexistent in the South. In other words, once a South-tailored production plan is in operation in the South, knowledge about that production plan flows freely within the South. As discussed in section 2, the free availability of technology transferred to the South can also be motivated by either a subcontracting relationship or by thinking of technology transfer as essentially a process of adapting production processes to local conditions in the South.

Assumption ($A2$) implies that tough competition between Southern firms will drive them to marginal cost pricing so that market structure in the South will essentially be perfect competition. As such, all goods produced in the South (whether by a Southern or by a Northern firm) *and sold in the South* will be priced at marginal cost:

$$p_S = w_S \tag{6}$$

In addition, assumption ($A1$)–in conjunction with assumption ($A2$)–implies that any Southern firm wishing to sell its product in the North must sell to the original Northern innovator at a price given by (6). Competition between Southern firms supplying to the original Northern innovator drives prices down to marginal cost.

Marginal cost pricing by Southern firms implies that Southern firms are unable to capture any profits from production. As a result, Southern firms will *not* undertake any imitation activity. The transfer of technology from North to South can, therefore, only be initiated by firms in the North. In fact, in our model, all production in the South will be the result of Northern firms transferring their technology to the South and hence becoming multinational corporations (MNCs).

What are the consequences for a Northern firm which shifts its production–or decides to subcontract production–to the South? First, it immediately loses its market share in the South. That is, it loses its profits from sales to Southern consumers. This is because a Southern firm can costlessly copy the transferred production process and start supplying the Southern market at marginal cost. The MNC, however, maintains its market share in the North and is able to continue to charge a markup over marginal cost in the Northern market. The price charged (in the Northern market) by a MNC is given by the following:

$$p_{NS} = \frac{w_S}{\alpha}, \tag{7}$$

which reflects the lower production costs in the South. The profits of a MNC firm are given by the following:

$$\begin{aligned} \pi_{NS} &= (p_{NS} - w_S)\, c_N^S \\ &= (1-\alpha)\, p_{NS} * c_N^S \end{aligned} \tag{8}$$

where c_N^S denotes consumption of a product *produced in the South* by *consumers in the North*, with the superscript denoting the region in which the product was produced and the subscript denoting the region to which the consumers belong.

Demand Functions & Regional Expenditure. In arriving at a demand function for a purely Northern firm (x^N), we need to separate demand from Northern consumers $\left(c_N^N\right)$ and demand from Southern consumers $\left(c_S^N\right)$. While all consumers face the same price ($p_N = \frac{w_N}{\alpha}$) for a purely Northern good, the price paid by a Northern consumer for a Southern good is different from that paid by a Southern consumer. Since the two sets of consumers face different relative prices, their demand functions assume different forms. In particular, the demand functions are given by the following:

$$\text{(Northern Good).} \qquad c_N^N = \left[\frac{p_N^{-\varepsilon}}{n_N p_N^{1-\varepsilon} + n_{NS} p_{NS}^{1-\varepsilon}}\right] E_N \tag{9}$$

$$c_S^N = \left[\frac{p_N^{-\varepsilon}}{n_N p_N^{1-\varepsilon} + n_{NS} p_S^{1-\varepsilon}}\right] E_S \qquad (10)$$

(Southern Good).
$$c_N^S = \left[\frac{p_{NS}^{-\varepsilon}}{n_N p_N^{1-\varepsilon} + n_{NS} p_{NS}^{1-\varepsilon}}\right] E_N \qquad (11)$$

$$c_S^S = \left[\frac{p_S^{-\varepsilon}}{n_N p_N^{1-\varepsilon} + n_{NS} p_S^{1-\varepsilon}}\right] E_S \qquad (12)$$

where n_N and n_{NS} are respectively the number of products being produced in the North and South and E_N and E_S are respectively what the North and South spend on consumption goods.[12] Note that $c_N^N + c_S^N = x^N$ and $c_N^S + c_S^S = x^S$. E_i is defined as country i's income minus its investment expenditure where income in each country is simply wage income plus profits. We arrive at the following expressions for each country's expenditure[13]:

$$E_N = p_N n_N x^N + (1-\alpha) p_{NS} n_{NS} c_N^S \qquad (13)$$

$$E_S = w_S L_S = p_S n_{NS} x^S \qquad (14)$$

where L_S is the size of the labor force in the South.

R&D Costs of Product Development and Technology Transfer.

Products are invented in the North by paying a one-time R&D fixed cost equal to $\frac{a}{K_n}$, where K_n rises with n, the total number of products ever developed ($n = n_N + n_{NS}$). This is simply the standard formulation to capture knowledge spillovers from R&D activity. We consider the simple case with $K_n = n$. Let v_N denote the present discounted value of the profit stream enjoyed by a typical Northern firm. Free entry into innovation R&D implies

$$v_N = \frac{a w_N}{n}. \qquad (15)$$

Northern firms transfer their technology to the South by paying a one-time adaptation cost of $\frac{a_f}{K_{NS}}$, where K_{NS} rises with n_{NS}. If technology transfer is the process of adapting production processes to local conditions in the South, the rise of K_{NS} with n_{NS} captures

[12] We use the subscript 'NS' on the number of products being produced in the South (n_{NS}) because these are really the result of Northern firms transferring their technology to the South.

[13] These expressions were obtained using resource constraints presented later in the paper.

the notion that the larger the number of products that have been adapted to Southern conditions, the easier it is to figure out how to adapt the next production process. In other words, each production process transferred to the South contributes to a knowledge pool about local conditions in the South and how to tailor production processes to such conditions. We consider the simple case with $K_{NS} = n_{NS}$. Let v_{NS} be the present discounted value of profits emanating from a MNC firm. Then, by paying a one-time cost of $\frac{a_f}{n_{NS}}$, a firm can give up v_N and acquire v_{NS}. Since all Northern firms are free to undertake this transaction, there will be no excess returns. This implies

$$v_{NS} - v_N = \frac{a_f w_N}{n_{NS}}. \tag{16}$$

Capital Market Equilibrium.

Capital market equilibrium requires that the returns to different assets be equated in each economy. Note that there is no investment in the Southern economy. In the North, there are three different assets: a riskless bond paying r_N, equity in a firm which has shifted its production to the South (the so-called "MNC" or "NS" firms), and equity in a firm which has not shifted to the South (the "N" firms). An "NS" firm will remain an "NS" firm forever whereas an "N" firm has the option to convert itself into an "NS" firm.

Let us first consider the simpler example of an "NS" firm. Equityholders in such a firm earn profits $\pi_{NS}dt$ during a time interval of dt and also experience a capital gain of $\dot{v}_{NS}dt$. The total return to the equityholders must equal the riskless return on the value of the firm $r_N v_{NS} dt$. We, therefore, have the following no-arbitrage condition:

$$\frac{\pi_{NS}}{v_{NS}} + \frac{\dot{v}_{NS}}{v_{NS}} = r_N \ . \tag{17}$$

Now, let us think of the "N" firm. During a time interval dt, equityholders in such a firm earn profits $\pi_N dt$ and experience a capital gain of $\dot{v}_N dt$. In addition, at every point in time, a "N" firm has the option to pay a cost $\frac{a_f w_N}{n_{NS}}$ in order to exchange v_N for v_{NS}. Suppose that the Northern firm exercises the option with probability $\frac{\dot{n}_{NS}}{n_N}dt$ during a time interval dt.[14] Then, the no-arbitrage condition for the Northern firm is

[14] Though Northern firms are themselves in control of the decision to transfer to the South, equation (16) tells us that Northern firms will be indifferent between transferring to the South and remaining a Northern

$$\pi_N dt + \frac{\dot{n}_{NS}}{n_N} dt \left(v_{NS} - v_N - \frac{a_f w_N}{n_{NS}} \right) + \left(1 - \frac{\dot{n}_{NS}}{n_N} dt \right) \dot{v}_N dt = r_N v_N dt$$

Substituting equation (16) and getting rid of second order terms, the no-arbitrage condition for the Northern firm simplifies to

$$\frac{\pi_N}{v_N} + \frac{\dot{v}_N}{v_N} = r_N \ . \tag{18}$$

Thus, we see that the option to shift to the South is valueless for the Northern firm. This makes sense because equation (16) tells us that there are no excess returns and because there is no uncertainty in the model.

Labor Market Equilibrium.

Finally, labor market clearing requires that the employment of labor resources in each country equals the available supply. In the South, labor is used only for manufacturing whereas in the North, labor is used for manufacturing as well as R&D activity in innovation and technology transfer. The labor market constraints are the following:

$$L_N = n_N x_N + a \frac{\dot{n}}{n} + a_f \frac{\dot{n}_{NS}}{n_{NS}} = n_N x_N + ag + a_f g_{NS} \tag{19}$$

$$L_S = n_{NS} x^S \ . \tag{20}$$

Intertemporal Optimization.

Intertemporal optimization by households in the North implies that expenditure in the North evolves according to

$$\frac{\dot{E}_N}{E_N} = r_N - \rho \ . \tag{21}$$

We normalize world spending $(E_N + E_S) = 1$ at each point in time.

firm. Because of this indifference, we can assume that they undertake the transfer with probability $\frac{\dot{n}_{NS}}{n_N} dt$ during a time interval dt.

4 Steady-State Equilibrium with Technology Transfer

We will solve for a steady-state equilibrium with fixed intersectoral allocation of labor (between manufacturing, new product development, and product transfer) in the North and with a constant share of products ($\varsigma^S = \frac{n_{NS}}{n}$ and $\varsigma^N = \frac{n_N}{n}$) in each region. Note that a constant share of products in each region requires that both types of products grow at the same rate in steady-state: i.e. g_{NS} $(= \frac{\dot{n}_{NS}}{n_{NS}}) = g_N$ $(= \frac{\dot{n}_N}{n_N}) = g$ $(= \frac{\dot{n}}{n})$. Notice also that $\frac{\dot{\varsigma}^S}{\varsigma^S} = \frac{\dot{n}_{NS}}{n_{NS}} - \frac{\dot{n}}{n} = f * \left(\frac{1-\varsigma^S}{\varsigma^S}\right) - g$, where $f = \frac{\dot{n}_{NS}}{n_N}$ is the rate of technology transfer. Then, with a constant steady-state share of products in the South, in steady-state, $\varsigma^S = \left(\frac{f}{f+g}\right)$. We will solve for the steady-state values of g and ς^S. This will then also give us the steady-state rate of technology transfer f.

We can show that in steady state, $\frac{E_N}{E_S}$ is constant (see appendix). Then, given the normalization of aggregate world consumption expenditure to a constant, E_N will also be constant. This, together with (21), gives us that

$$r_N = \rho \ . \tag{22}$$

Differentiating the free entry condition (15), we get $\frac{\dot{v}_N}{v_N} = \frac{\dot{w}^N}{w^N} - \frac{\dot{n}}{n}$. With relative wages $\left(\frac{w^S}{w^N}\right)$ constant in steady-state and with nominal expenditure normalized to a constant, w^N must be constant in steady-state. Then, the value of Northern firms which have not shifted their production processes (henceforth, "N" firms or simply "Northern" firms) must diminish in steady-state at the rate of product development: $\frac{\dot{v}_N}{v_N} = -g$. Substituting this into the no-arbitrage condition (18) for "N" firms, and making use of (5), (15), and (22), we obtain the following expression:

$$\frac{(1-\alpha)p_N x^N n}{aw^N} - g = \rho \ . \tag{23}$$

Substituting in for x^N from the labor resource constraint of the North (19) and for p^N from the pricing relation (4), it follows that

$$\frac{(1-\alpha)}{\alpha a}\left(L_N - (a_f + a)g\right)\left(\frac{1}{1-\varsigma^S}\right) = \rho + g \ . \tag{24}$$

This gives us our first steady-state relation between g and ς^S. The intuition behind this relation is clear: a higher share of products in the South $\left(\varsigma^S\right)$ means that there are fewer products being produced in the North. That in turn means that the output (and hence profits) of each particular Northern firm is higher. However, higher profits (π_N) for a typical Northern firm means that the value of a Northern firm (v^N) must also diminish at a faster rate to satisfy the asset arbitrage condition in equilibrium. In other words, we must have a higher rate of product development g to restore equilibrium in capital markets.

To obtain our second relation, we need to notice that the value of an NS (or MNC) firm which has transferred its production process to the South (v_{NS}) also declines at the rate g in steady state.[15] Then, since the value of both types of firms decline at the same rate, their profit rates must also be equal to satisfy the asset arbitrage conditions. So, we have that

$$\frac{\pi_{NS}}{v_{NS}} = \frac{\pi_N}{v_N} \ . \tag{25}$$

Notice that in the case where technology transfer is costless ($a_f = 0$), this condition implies that profits for the two types of firms must be equal.[16] Substituting in for profits using (5) and (8) and for firm values using (15) and (16), it follows that

$$\frac{x^N}{c_N^S} = \left(\frac{w^S}{w^N}\right)\left(\frac{1}{1+\frac{a_f}{a}(\frac{n}{n_{NS}})}\right) \ . \tag{26}$$

This essentially gives us an equation for the relative *profitable* sales of Northern and MNC firms, which must hold in order for the profit rates of the two types of firms to be equal. Recall that *profitable* sales of firms which locate production in the North include sales to all consumers (x^N), whereas *profitable* sales of firms which have transferred production to the South include sales to only Northern consumers (c_N^S). Another point worth noticing is that with costly technology transfer ($a_f \neq 0$), if the share of Southern products (ς^S) rises, the productivity of technology transfer rises. Then, because the cost of transfer determines the difference between v_{NS} and v_N–refer to equation(16)–the value of a MNC firm relative to that of a Northern firm can fall. The lower ($\frac{v_{NS}}{v_N}$) means that the relative profits of a MNC firm ($\frac{\pi_{NS}}{\pi_N}$) can also be lower.

[15]This can be shown quite easily by differentiating the condition for no excess returns from technology transfer (16) and noting that $\frac{\dot{n}}{n} = \frac{\dot{n}_{NS}}{n_{NS}}$ in steady-state.

[16]Note that costless technology transfer does not lead to factor price equalization between the two regions because Northern firms still lose profits from sales to Southern consumers when they transfer their production to the South.

The profitable sales of each type of firm will obviously depend on demand. We can manipulate the demand functions (9)-(12) to obtain the following ratio of demands[17]:

$$\frac{x^N}{c_N^S} = \alpha \left(\frac{n_{NS}}{n_N}\right) \left(\frac{w^S}{w^N}\right) + \left(\frac{w^S}{w^N}\right)^{\varepsilon} \tag{27}$$

So, the *profitable* sales of a firm producing in a particular region rise as the relative wage of that region falls. Indeed, relative *profits* of a firm producing in a particular region rise as the relative wage of that region falls. This is the expected result of *cost reduction*, though it is not trivial here because the MNC firm receives profits from sales to only Northern consumers. In addition, as the share of Southern products rises, the profitable sales and profits of an N firm rise relative to that of an MNC firm. This is easy to understand: recall that when a Northern firm converts itself into an MNC firm, it loses profits from sales to Southern consumers. As ς^S rises, the relative purchasing power of Southern consumers rises.[18] Then, as ς^S rises, the profit loss for MNC firms is greater. Combining this relative demand expression (27) with (26), it follows that

$$\frac{w^S}{w^N} = \left(\frac{1}{1 + \frac{a_f}{a}(\frac{1}{\varsigma^S})} - \alpha \frac{\varsigma^S}{1 - \varsigma^S} \right)^{\frac{1}{\varepsilon - 1}} . \tag{28}$$

We therefore have an expression for the relative wage in terms of ς^S, which must hold so that the profit rates of the two types of firms are equal. The relative wage responds to a rise in ς^S for two separate reasons:

- First, as ς^S rises, the relative profits of MNC firms fall because, as explained above, the *Southern market loss* from transferring to the South is higher. As a result, the relative wage of the South must fall in order to raise the relative profits of MNC firms back up, so that the profit rates are once again equal. Through this channel, therefore, $\frac{w^S}{w^N}$ falls in response to a rise in ς^S.

[17]Refer to the appendix to see how we obtain this expression for relative demands. Essentially, $\frac{x^N}{c_N^S} = \frac{x^N}{c_N^N} * \frac{c_N^N}{c_N^S}$, where $\frac{c_N^N}{c_N^S}$ is relative demands of Northern and Southern products *by same type of consumers* and hence depends only on relative prices. On the other hand, $\frac{x^N}{c_N^N} = 1 + \frac{c_S^N}{c_N^N}$ compares the part of the Northern good consumed by Southern consumers to that consumed by Northern consumers. This rises with the size of the Southern market, which in turn rises with $\frac{n_{NS}}{n_N}$.

[18]This is because, as ς^S rises, the price index of products falls more for Southern consumers than for Northern consumers, since the difference between N and NS prices is greater for Southern consumers than for Northern consumers. Thus, Southern consumers become richer relative to Northern consumers as ς^S rises.

- Second, as ς^S rises, the productivity of technology transfer rises and hence results in the value of an MNC firm falling relative to the value of an N firm. This implies that the relative profits of an MNC firm must also fall in order for the profit rates to remain equal. In order for the relative profits of an MNC firm to fall, the relative wage in the South must rise. Through this channel, therefore, $\frac{w^S}{w^N}$ rises in response to a rise in ς^S.

Next, we write down an expression for the relative demand of a good produced in the South in terms of relative wages and the share of products in the South:

$$\frac{x^S}{x^N} = \left[\alpha^{\varepsilon-1}\left(\frac{n_N}{n_{NS}}\right)\left(\frac{w^S}{w^N}\right)^{\varepsilon-1} + 1\right]\left(\frac{w^S}{w^N}\right)^{-\varepsilon}\left[\frac{1}{\alpha^{\varepsilon-1}\left(\frac{n_N}{n_{NS}}\right)\left(\frac{w^S}{w^N}\right)^{\varepsilon-1} + \alpha^{\varepsilon}}\right]. \tag{29}$$

Substituting in for relative wages using (28), we obtain the following expression for relative demand only in terms of the share of products in the South:

$$\frac{x^S}{x^N} = \left[1 + \frac{\left(\varsigma^S + \frac{a_f}{a}\right)\left(\alpha^{1-\varepsilon} - \alpha\right)}{1 - \varsigma^S}\right]\left[\frac{1}{1 + \frac{a_f}{a}\left(\frac{1}{\varsigma^S}\right)} - \alpha\frac{\varsigma^S}{1 - \varsigma^S}\right]^{-\frac{\varepsilon}{\varepsilon-1}}. \tag{30}$$

Equating this to the relative supply of a good produced in the South–from the labor constraints of the two regions–to obtain our second steady-state relation g and ς^S:

$$\frac{L_S}{L_N - (a_f + a)g} = \frac{\varsigma^S}{1 - \varsigma^S}\left[1 + \frac{\left(\varsigma^S + \frac{a_f}{a}\right)\left(\alpha^{1-\varepsilon} - \alpha\right)}{1 - \varsigma^S}\right]\left[\frac{1}{1 + \frac{a_f}{a}\left(\frac{1}{\varsigma^S}\right)} - \alpha\frac{\varsigma^S}{1 - \varsigma^S}\right]^{-\frac{\varepsilon}{\varepsilon-1}}. \tag{31}$$

Equations (24) and (31) together give us our steady-state solution for g and ς^S. It is not possible to obtain explicit solutions for g and ς^S for general parameter values.[19] We can, however, diagrammatically represent the steady-state relations and the implicit steady-state solution. Figure 1 does exactly this, with curve AA depicting equation (24) and curve LL representing equation (31).[20]

The shape of the AA curve (equation 24) has been explained previously. The shape of LL can be explained as follows: as ς^S rises, the relative demand for Southern labor surely rises.

[19]Note that equation (31) contains terms raised to the power of a general parameter.

[20]In order for the two curves to intersect in the positive quadrant, we essentially need L_S large relative to L_N or a_f small relative to a.

This creates an excess supply of Northern labor, which allows more resources in the North to be devoted to product development. As a result, g rises. However, the extent of the response of g to a rise in ς^S depends on the extent of the increase in relative demand for Southern labor, which in turn depends on how the relative demand for a typical Southern product $\left(\frac{x^S}{x^N}\right)$ responds to the rise in ς^S. If there is no explicit cost of transfer (i.e. $a_f = 0$), a rise in ς^S will surely be associated with a drop in the relative wage of the South (see equation 28). This will then lead to an increase in $\left(\frac{x^S}{x^N}\right)$, which means that the increase in relative demand for Southern labor will be greater. It follows that the response of the rate of innovation will be greater. On the other hand, if there exists an explicit cost of transfer (i.e. $a_f \neq 0$), the relative wage of the South may rise as ς^S rises. This would lead to a decline in $\left(\frac{x^S}{x^N}\right)$ and hence dampen the increase in the relative demand for Southern labor. It follows that the response of the rate of innovation would be smaller.

Isolation vs. an integrated world.

Let us now examine how the rate of product development g with technology transfer compares with the rate which would have been obtained if the North were in isolation. Inspecting our steady-state solution, we see that the intersection of the AA curve with the vertical axis is given by

$$g^{AA}(\varsigma^S = 0) = \frac{a}{(1-\alpha)a_f + a}\left((1-\alpha)\frac{L_N}{a} - \alpha\rho\right) = \frac{a}{(1-\alpha)a_f + a}\left(g^{ISOL}\right) < g^{ISOL}$$

where g^{ISOL} is the rate of innovation in the North under isolation. Note that the intersection of the AA curve with the vertical axis is a lower bound on the possible rate of innovation in an integrated world. While the steady-state innovation rate with technology transfer is indeed to the right and greater than the value of g at the intersection, we are not guaranteed that the steady state g is greater than g^{ISOL}, because $g^{AA}(\varsigma^S = 0) < g^{ISOL}$. However, if the explicit cost of technology transfer (a_f) is small compared to the cost of innovation (a), the rate of innovation with technology transfer is likely to be greater than g^{ISOL}. Indeed, if technology transfer is costless ($a_f = 0$), the rate of innovation with technology transfer is certain to be greater than g^{ISOL}.

Table 1 presents some comparisons of the rates of product development under the two regimes, using a variety of parameter values. In most cases, the rate of product development is greater in an integrated world. This is a scale result: in an integrated world, the transfer of product lines to the South frees up resources in the North which can be devoted to product development. This brings about a faster rate of innovation.[21]

Only when the cost of technology transfer is considerable does the rate of innovation under isolation exceed that in an integrated world in table 1. If a_f is substantially high, this perverse result follows because the share of products in the South (ς^S) is very low as a result. With a low ς^S, the resources freed up from moving product lines to the South is less than the substantial resources that the North spends (since a_f is high) on transferring products to the South in an integrated world. As a result, less resources are available for product development in an integrated world. While this outcome is a possibility, it is unlikely because the costs of transfer are not likely to be so perversely high. Thus, we conclude that for reasonably low costs of technology transfer, the potential to shift products to the South increases the rate of product development.

A reduction in the costs of technology transfer.

Let us now look at the effects of an exogenous decline in the explicit costs of transfer (a_f). A lower cost of transfer can result from, for example, an improvement in Southern infrastructure or greater access to information about conditions in the South. In our model a decline in a_f shifts the AA curve up and the LL curve to the right. As a result, both the rate of innovation and the share of products in the South rise. Table 2 demonstrates the effects of a decline in transfer costs for a variety of parameter values. Note that the relative wage of the South also rises in response to the decline in transfer costs.

The increase in the rate of innovation g in response to the decline in the costs of technology transfer a_f is a scale result. This scale result works through two channels. First, a decline in a_f means that fewer resources in the North need to be devoted to technology transfer, so that more resources are available for product development. As a result, the AA curve shifts up (i.e. g increases for a given ς^S). Second, the increase in ς^S means that more resources are freed up from manufacturing in the North, so that even more can be devoted

[21] Moreover, the faster rate of decline of the value of Northern firms accompanying higher g is compensated for by higher (sales and) profits for each Northern firm when product lines migrate to the South.

to product development. This is represented by movement to the right along the AA curve, again producing an increase in g.

On the other hand, the increase in ς^S resulting from the rightward shift of the LL curve can be explained as follows: a decline in the costs of transfer a_f means that in equilibrium, the value of an MNC firm (v_{NS}) will fall relative to the value of an N firm (v_N). This means that relative profits of an MNC firm ($\frac{\pi_{NS}}{\pi_N}$) will also fall in steady-state. This can occur through either a higher share of products in the South (a higher ς^S) or a rise in the relative wage of the South. In fact, both must take place. This is because a rise in ς^S alone would raise the relative demand for Southern labor above relative supply and hence lead to an increase in relative wage of the South. On the other hand, a rise in $\frac{w^S}{w^N}$ alone would lower the relative demand for Southern labor below relative supply (by lowering the relative demand for a typical Southern product $\frac{x^S}{x^N}$) and hence lead to a rise in ς^S. Thus, in response to a decline in the costs of transfer, we get both a higher share of products in the South and a rise in the relative wage of the South.

Relative wages

For a given cost of transfer, the steady-state relative wages in this model are determined fully by the steady-state share of products in the South. Equation (28) tells us how the relative wage varies with the steady-state ς^S: this depends crucially on whether or not there exists an explicit cost of transfer in the model. Figure 2 presents a number of plots of the relative wage of the South against the steady-state share of products in the South. Note that these plots involve two variables which are both endogenously determined in steady-state. So, they should be interpreted as the locus of (relative wage, ς^S) combinations that we trace out as we move between different steady-states (for a given cost of transfer a_f). We can move across steady-states by varying some parameter in our model–in the next section, we will examine the effects of changing region size.

Turning to figure 2, consider first the case of costless technology transfer ($a_f = 0$). In this case, a higher steady-state share of products in the South must be associated with a lower relative wage for the South. As previously explained, this is because a higher ς^S means that the *Southern market loss* effect is greater for firms transferring their production to the South. Then, the Southern relative wage must be low enough to induce firms to transfer: a lower Southern relative wage allows transferring firms to experience a greater *cost reduction* effect. This negative relation between the Southern relative wage and the steady-state share of products in the South can be attributed to poor–in our case completely absent–Southern intellectual property rights protection. Since firms are choosing between two locations of production, they will choose to locate in the region with poor IPR protection only if that region is poor enough.

Now, consider the case where there exists an explicit cost of technology transfer. Figure 2 shows that with $a_f \neq 0$, the Southern relative wage can rise over some range of values of ς^S. Moreover, the higher the cost of transfer, the larger the range over which the Southern relative wage rises with ς^S. This can be explained as follows: as ς^S rises, the productivity of technology transfer rises so that profits from production in the South need not be all that much higher than those from production in the North. The decline in relative profits of NS firms is brought about by a rise in the relative wage of the South. Thus, with an explicit cost of technology transfer, higher steady-state values of ς^S (i.e. higher rates of transfer) can also be associated with higher Southern relative wages because a higher ς^S improves the productivity of the transfer process. To think about what this means in practice, suppose that a Northern firm can choose between one of two Southern locations (S1 and S2). The wages in S1 are slightly lower than S2, but there are many more products being produced in S2. Then, the Northern firm may choose to produce in S2 even though its wages are higher, because the costs of transferring to S2 will be lower. On the other hand, if technology transfer were costless, the Northern firm would choose to produce in S1.

Accumulating Resources in the South: the effects of scale.

One of the predominant themes in models of endogenous growth is that scale matters for growth rates. In models with technology transfer, the effect of scale on the world distribution of income (i.e. on relative wages) is also an important concern. Let us examine here the effects of scale in our model.

Tables 3 and 4 demonstrate the effects of increasing the size of the South and North respectively. An increase in the size of any region raises the rate of product development and the share of products being produced in that region. An increase in the size of the South shifts the LL curve to the right and leaves the AA curve unaffected. Thus, g and ς^S both increase unambiguously. An increase in the size of the North shifts both the LL and AA curves up. While this does not unambiguously tell us that g and ς^N will rise, in all the numerical examples that we have examined, this turns out to be the case.

The effect of an increase in region size on relative wages of that region depends on whether or not there exists an explicit cost of transfer. With costless transfer ($a_f = 0$), as the size of a region rises, the relative wage of that region falls unambiguously. Suppose that the size of the South (L_S) becomes larger. This induces an increase in ς^S which, however, means that the Southern market loss (as a result of transferring to the South and becoming an MNC) is larger. In steady-state, therefore, relative wages in the South ($\frac{w^S}{w^N}$) must fall to induce firms to still transfer their technology. So, in response to an increase in the size of the South, we get an increase in the share of Southern products at the expense of lower wages in the South.

With costly transfer ($a_f \neq 0$), the relative wage of the South can rise with its size over some range. This is because the induced increase in ς^S raises the productivity of the transfer process and hence allows Southern profits to fall relative to Northern profits. As a result, the relative wage of the South ($\frac{w^S}{w^N}$) can rise as ς^S increases. In the case of costly transfer, therefore, in response to an increase in the size of the South, we can get an increase in the share of Southern products as well as an increase in Southern wages. However, as the size of the South continues to expand, the relative wage of the South eventually declines (see table 3).

The effects of scale in this model are different from those in previous models of technology transfer. Table 5 presents a comparison with Krugman (1979) and Grossman and Helpman (1991). In Krugman (1979), the share of products in the South is determined from exogenous rates of innovation and transfer. An increase in the size of the South has no effect on the share of products in the South. The increase in supply of resources in the South must, therefore, be accompanied by a fall in $(\frac{w^S}{w^N})$–a simple supply, price response. In the Grossman and Helpman (1991) model of transfer based on imitation, the rates of innovation and the share of products in the South *are* endogenously determined. An increase in the size of the South induces a more-than-proportional rise in the share of Southern products (ς^S), which raises relative demand for Southern labor more than relative supply. As a result, the relative wage of the South $(\frac{w^S}{w^N})$ rises. In our model, an increase in the size of the South induces a rise in ς^S as well. However, the rise in ς^S must be accompanied by a fall in $(\frac{w^S}{w^N})$ in steady-state. The fall in $(\frac{w^S}{w^N})$ itself raises the demand for Southern labor, so that the increase in ς^S here is less-than-proportional, in contrast to GH (1991).

It is interesting to consider the implications of these results for factor accumulation in developing countries. Note that the effect of an increase in scale considered here can be interpreted as the effect of factor accumulation. The model in this paper has one factor of production, which can be broadly interpreted as either physical or human capital. Then, $(\frac{w^S}{w^N})$ would be interpreted as the (relative) returns to capital in the South.[22] In this light, the results above suggest that capital accumulation in the South will put downward pressure on the returns to capital in the South.

One of the basic ideas of growth theory is that technological progress allows countries to escape diminishing returns to capital and hence sustain capital accumulation. Both GH (1991) and the model in the current paper are models where the rate of technological progress (and the rate of technology transfer to the South) are endogenously determined.[23] However, whereas capital accumulation in GH (1991) puts upward pressure on the return to capital, in this paper, capital accumulation puts downward pressure on the return to capital. This suggests that capital accumulation is likely to be more sustainable in developing countries where technology transfer is achieved through imitation activity by Southern firms, which is the case in GH (1991). On the other hand, developing countries where firms are unable to engage in imitation activity–where the country must rely on technology transfer at the initiative of Northern firms–capital accumulation is less likely to be sustainable.

[22]If we want to think of physical capital accumulation, then L_S would simply be the stock of physical capital in the South. If we want to think of human capital, L_S would be the number of effective workers in the South and w^S would be the wage of an effective worker.

[23]On the other hand, in Krugman (1979), the rates of technological progress and technology transfer are exogenous.

This could be one explanation for why the East Asian miracle economies–and not other developing countries–were able to sustain such high rates of capital accumulation.

5 Concluding thoughts & further work

In developing countries, the primary mode of technological progress is the transfer of technology from more advanced areas. Technological progress is, of course, crucial in allowing developing countries to maintain their rates of return to capital and hence sustain capital accumulation and growth. The primary contribution of this paper has been (i) to develop a model of technology transfer in an environment where indigenous imitation activity is ruled out by a competitive market structure in the South; and (ii) to show that in such an environment, capital accumulation will run into diminishing returns in the South, even though technology is being continuously transferred to the South.[24]

The paper does *not* claim that this competitive Southern market structure is the only environment in which technology transfer takes place. In fact, a comparison with imitation-based models of technology transfer shows that when the technology transfer is carried out by profit-making indigenous imitators, capital accumulation tends to actually increase the rate of return to capital.

The paper also does not make strong claims about why firms in certain developing countries may be less likely to recover the costs of imitation. However, one possibility that is mentioned is that the lack of IPR protection would make it more difficult for imitating firms to keep freely observable adapted technology proprietary. Thus, countries with better IPR protection for domestic imitating firms are less likely to run into diminishing returns to capital accumulation. An interesting agenda for further work, therefore, would be to empirically examine the relationship between capital accumulation and the degree of IPR protection. More broadly, investigating the empirical relationship between capital accumulation and the degree of domestic imitation activity should also make an interesting agenda

[24] Not only is technology being continuously transferred to the South, but accumulation in the South also increases the endogenously determined rate of technology transfer.

for further work.

On the policy front, since indigenous Southern firms are unable to recover the costs of imitation, a case can be made for supporting commercial research directed toward establishing new product lines in developing countries. In contrast to the infant industry argument, however, the prescription here is for a one-time reward to entrepreneurs demonstrating success in exporting *new* product lines. Since we have not explicitly performed the associated welfare analysis, this policy recommendation must be considered tentative.

References

[1] Grossman, Gene and Elhanan Helpman. *Innovation and Growth in the Global Economy*. Cambridge: MIT Press, 1991.

[2] Helpman, Elhanan. "Innovation, Imitation, and Intellectual Property Rights," *Econometrica*, November 1993.

[3] Kremer, Michael. "Purchase Pre-Commitments for New Vaccines: Rationale and Proposed Design," Brookings Institution draft, 1999.

[4] Krugman, Paul. "A Model of Innovation, Technology Transfer, and the World Distribution of Income," *Journal of Political Economy*, April 1979.

[5] Lanjouw, Jean and Iain Cockburn. "Do Patents Matter?: Empirical Evidence after GATT," NBER Working Paper #7495, 1999.

[6] Lanjouw, Jean. "The Introduction of Pharmaceutical Product Patents in India: Heartless Exploitation of the Poor and Suffering?", NBER Working Paper #6366, 1998.

[7] PhRMA. *Industry Profile*, 1999.

[8] Tybout, James, et al. "Micro Foundations of Technology Transfer: Proposal," World Bank mimeo, 1998.

[9] U.S. International Trade Commission. "Potential Impact on the U.S. Economy and Selected Industries of the North American Free Trade Agreement," U.S. ITC Publication 2-596, January 1993.

Table A. Price Comparisons for 'On-Patent' Drugs

Drug Name	Dosage	Price (in Rupees) in:		
		India	UK	USA
Ranitidine	300 tabs/ 10 pack	18.5	483.6	1050.7
Famotidine	40 tabs/ 10 pack	18.6	504.3	1004.9
Ciprofloxacin	500 mg/ 4 pack	28.4	292.5	437.4
Norfloxacin	400 mg/ 10 pack	39.0	253.5	904.8

Source: Lanjouw (1998); data from 1995, various sources.

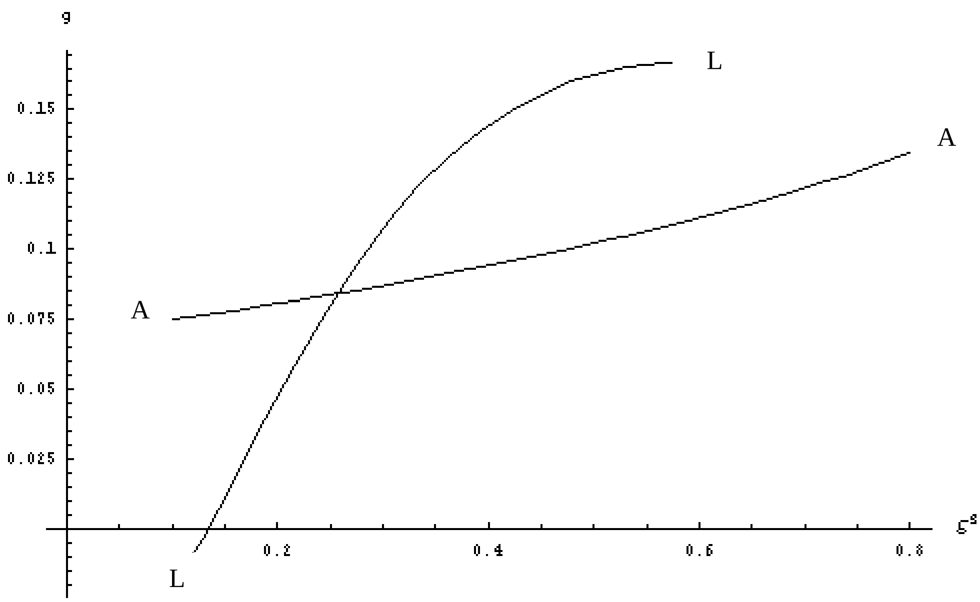
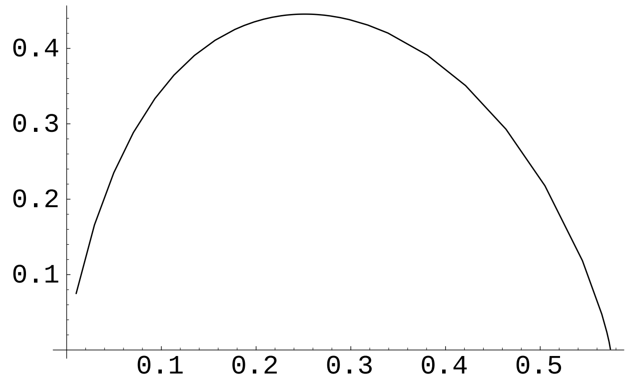


Figure 1. The Steady-State Relations

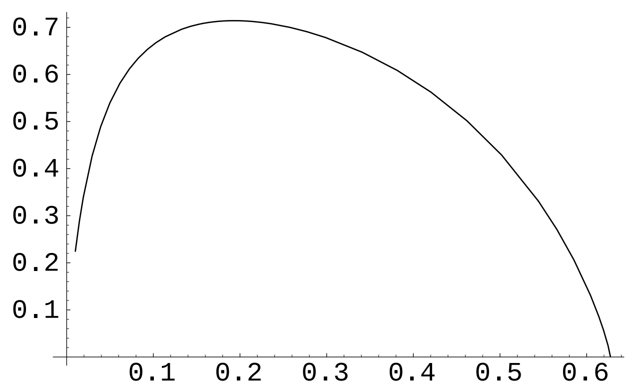
Note:	Vertical axis is g Horizontal axis is ζ^S.

■ FIGURE 2. (Plot Relative Wage of South against ζ_S). Note: Vertical Axis is (w_S / w_N); Horizontal Axis is ζ_S.

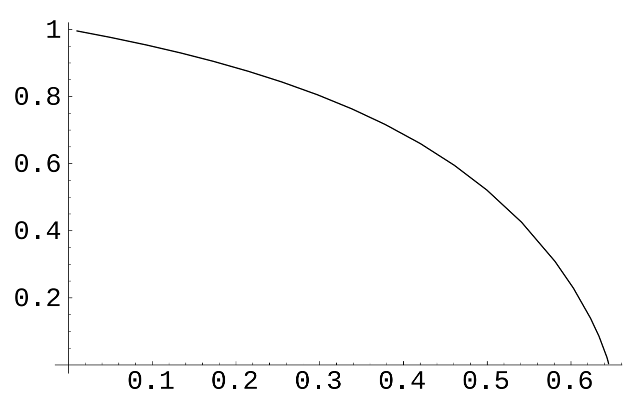
■ **α=0.55; af=2**



■ **α=0.55; af=0.5**

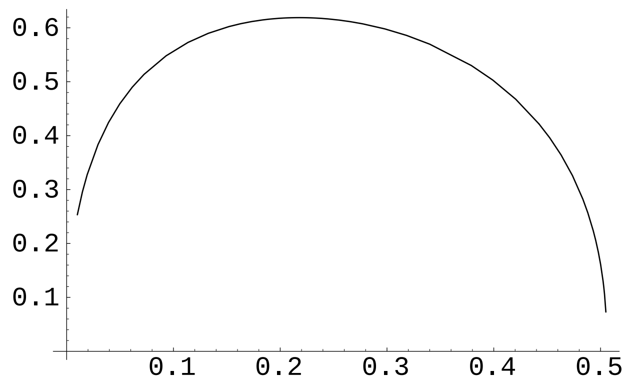


■ **α=0.55; af=0**

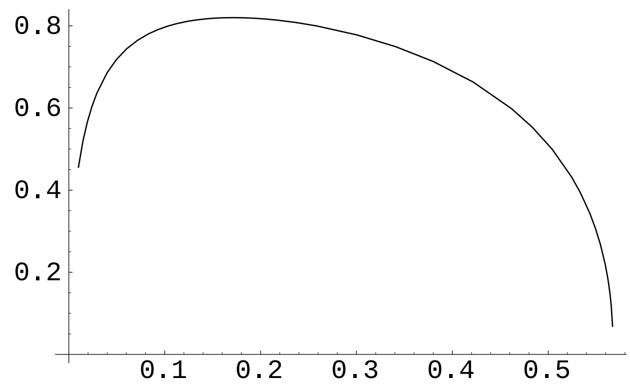


■ FIGURE 2 (Contd)... (Plot Relative Wage of South against ζ_S).

■ α=0.7; af=2



■ α=0.7; af=0.5



■ α=0.7; af=0

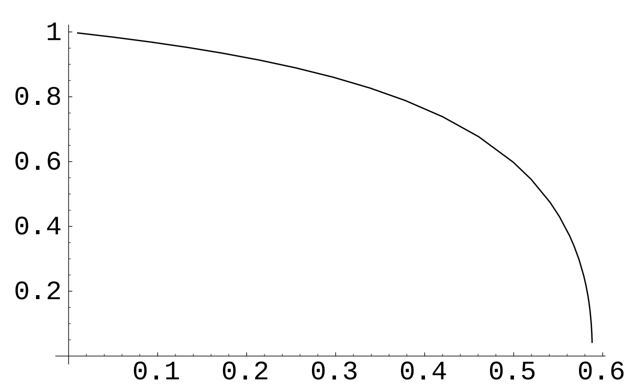


Table 1.

	Isolation	Integrated world
* L_N=2, L_S=5, ρ=.05, a=10		
α=0.40, a_f = 2	0.100	0.105
α=0.55, a_f = 2	0.063	0.074
α=0.70, a_f = 2	0.025	0.038
* L_N=2, L_S=5, ρ=.05, a=10		
α=0.40, a_f = 0	0.100	0.137
α=0.55, a_f = 0	0.063	0.099
α=0.70, a_f = 0	0.025	0.054
* L_N=2, L_S=10, ρ=.025, a=10		
α=0.70, a_f = 5	0.043	0.041

Table 2.

	g	ζ^S	w^S/w^N
α=0.7			
a_f = 2	0.038	0.248	0.616
a_f = 1	0.046	0.328	0.693
a_f = 0.5	0.050	0.365	0.728
a_f = 0	0.054	0.401	0.762
α=0.55			
a_f = 2	0.074	0.272	0.444
a_f = 1	0.086	0.363	0.540
a_f = 0.5	0.092	0.403	0.584
a_f = 0	0.099	0.442	0.627
α=0.4			
a_f = 2	0.105	0.290	0.280
a_f = 1	0.120	0.405	0.386
a_f = 0.5	0.128	0.450	0.433
a_f = 0	0.137	0.492	0.479

* L_N=2, L_S=5, ρ=.05, a=10

Table 3.

	g	ζ^S	w^S/w^N
COSTLY TRANSFER			
α=**0.70, a_f = 2**			
L_S = 2	0.046	0.126	0.585
L_S = 3	0.050	0.193	0.617
L_S = 4	0.052	0.235	0.618
L_S = 5	0.054	0.264	0.612
L_S = 6	0.055	0.286	0.603
L_S = 8	0.057	0.318	0.586
α=**0.55, a_f = 2**			
L_S = 2	0.075	0.109	0.358
L_S = 3	0.081	0.207	0.439
L_S = 4	0.084	0.256	0.445
L_S = 5	0.086	0.290	0.441
L_S = 6	0.088	0.315	0.432
L_S = 8	0.090	0.350	0.414
COSTLESS TRANSFER			
α=**0.70, a_f = 0**			
L_S = 2	0.062	0.319	0.843
L_S = 3	0.065	0.362	0.805
L_S = 4	0.068	0.390	0.775
L_S = 5	0.070	0.411	0.750
L_S = 6	0.071	0.427	0.730
L_S = 8	0.074	0.450	0.695
α=**0.55, a_f = 0**			
L_S = 2	0.101	0.359	0.740
L_S = 3	0.105	0.402	0.685
L_S = 4	0.108	0.430	0.644
L_S = 5	0.110	0.451	0.611
L_S = 6	0.111	0.467	0.584
L_S = 8	0.114	0.490	0.541

* L_N=2, ρ=.025, a=10

Table 4.

	g	ζ^N	w^N/w^S
COSTLY TRANSFER			
α**=0.70, a_f = 2**			
$L_N = 1$	0.022	0.672	1.726
$L_N = 2$	0.054	0.736	1.634
$L_N = 3$	0.084	0.785	1.616
$L_N = 4$	0.113	0.824	1.633
$L_N = 5$	0.140	0.859	1.679
$L_N = 6$	0.167	0.891	1.762
α**=0.55, a_f = 2**			
$L_N = 1$	0.041	0.639	2.460
$L_N = 2$	0.086	0.710	2.270
$L_N = 3$	0.129	0.766	2.250
$L_N = 4$	0.170	0.815	2.330
$L_N = 5$	0.210	0.864	2.549
$L_N = 6$			
COSTLESS TRANSFER			
α**=0.70, a_f = 0**			
$L_N = 1$	0.030	0.542	1.469
$L_N = 2$	0.070	0.589	1.330
$L_N = 3$	0.107	0.624	1.265
$L_N = 4$	0.144	0.651	1.223
$L_N = 5$	0.179	0.673	1.195
$L_N = 6$	0.214	0.692	1.173
α**=0.55, a_f = 0**			
$L_N = 1$	0.052	0.501	1.909
$L_N = 2$	0.110	0.549	1.636
$L_N = 3$	0.165	0.583	1.504
$L_N = 4$	0.218	0.611	1.423
$L_N = 5$	0.271	0.634	1.368
$L_N = 6$	0.323	0.653	1.327

* L_S=5, ρ=.025, a=10

Table 5. The Effects of an Increase in the Size of the South

	g	ζ^S	w^S/w^N
Krugman (1979)	No Effect	No Effect	Decrease
Grossman and Helpman (1991)	Increase	Increase	Increase
This paper[1]	Increase	Increase	Decrease
This paper[2]	Increase	Increase	Increase / Decrease

1. With costless transfer
2. With costly transfer