Foreign direct investment and the nature of R&D

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Abstract. We find that the role FDI plays in international technology transfer (ITT) hinges on whether substitute channels of ITT – such as imitation – exist for the host country. If FDI is the sole channel of ITT, a faster flow of FDI to the South increases the rates of innovation, imitation, and ITT, so FDI generates dynamic benefits. If FDI and imitation coexist as channels of ITT, however, then FDI merely substitutes for imitation targeting Northern firms. A faster flow of FDI to the South then leaves the rates of innovation, imitation, and ITT essentially unaffected, so FDI generates mostly static benefits. JEL Classification: F21, F43

L'investissement direct de l'étranger et la nature de la R&D. Les auteurs montrent que le rôle que l'investissement direct de l'étranger (IDDE) joue dans le transfert international de technologie (TIT) dépend de l'existence de canaux de rechange pour le TIT – comme l'imitation – pour le pays récipiendaire. Si l'IDDE est le seul canal de TIT, un flux plus rapide d'IDDE vers le Sud accroît les taux d'innovation, d'imitation et de TIT, ce qui fait que l'IDDE engendre des avantages dynamiques. Cependant si l'IDDE et l'imitation sont deux canaux de TIT qui co-existent, alors l'IDDE est simplement un substitut pour l'imitation des firmes du Nord. Alors un flux plus rapide d'IDDE vers le Sud n'affecte pas les taux d'innovation, d'imitation et de TIT, ce qui fait que l'IDDE engendre surtout des avantages statiques.

1. Introduction

Many developing countries seek foreign direct investment (FDI) from countries on the technology frontier. Through the investments of multinationals, these countries hope to encourage technology transfer from industrialized countries to improve the

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technology available to their indigenous firms. In this paper we explore whether a faster flow of FDI does indeed accelerate international technology transfer (ITT).

We develop a model in which ITT occurs through both imitation and FDI and evaluate the role FDI plays in promoting technology transfer to the South. We construct a dynamic general equilibrium model to examine the effect of FDI on technology transfer from the North to the South, the rate of quality improvement of existing products through innovation in the North, and the rate of imitation by Southern firms. Our model is unique in allowing ITT to occur simultaneously through both FDI and imitation: technology crosses borders through both intrafirm (FDI) and interfirm (imitation) routes. This aspect of our model is important, because when ITT can occur through channels other than FDI, the role of FDI in promoting ITT includes not only the direct effect on the technology transferred through FDI, but also the indirect effect on the technology transferred through other channels

Grossman and Helpman (1991) construct a quality ladders product cycle model to study the role of imitation in transferring technology to the South in the absence of FDI (see also Segerstrom, Anant, and Dinopoulos 1990; Taylor 1993). Our model expands their model to include FDI, Northern firms locating production in the South (see also Helpman 1993). We construct our model to correspond with Vernon's (1966) view of the world: all Northern firms that escape imitation eventually shift their production to the South once their production process becomes sufficiently standardized.

Owing to differences between the North and the South, state-of-the-art products cannot be manufactured in the South immediately upon invention. We assume that the opportunity to undertake FDI arrives exogenously for all Northern firms. With the passage of time, production of each design eventually becomes suitable for production in the lower-cost country.

Changes in the flow of FDI may reflect increased ability of the South to host FDI, because the economic environment in the Southern economy is evolving over time. To cast FDI in the causal role and to keep its effect isolated from the effects of such other changes, however, we keep FDI exogenous.

Our results emphasize that the role of FDI in ITT and its impact on the rate of innovation depend crucially on whether imitation also serves as a channel of ITT. The option of imitating purely Northern firms creates the potential for substitution in imitation. We show that an increase in the flow of FDI has a significant impact on the rate of innovation only when FDI serves as the sole channel of ITT.

While the cost savings of FDI create higher instantaneous profits for Northern firms, imitation adjusts towards targeting multinationals and away from targeting Northern firms. The faster arrival of FDI brings a quicker increase in profits of Northern firms, but the profits are then terminated sooner because of the increased exposure to imitation that accompanies FDI. When the discount rate approaches zero, these two effects exactly offset each other.

While imitation of multinationals rises with increased FDI flows, imitation of firms still producing in the North falls. This *substitution in imitation* becomes perfect as the discount rate approaches zero, so that a faster flow of FDI to the South does not lead to a faster rate of imitation. Thus FDI fails to deliver the dynamic gains that are so often ascribed to it.

On the other hand, when imitation of products still being produced in the North is prohibitively difficult, FDI is the sole channel of ITT, and we do confirm the notion that FDI is important for ITT, imitation, and innovation. When Southern firms are unable to imitate products manufactured in the North, FDI provides an important source of ITT, owing to the lack of other channels. When ITT occurs through FDI alone, a faster flow of FDI to the South does lead to faster aggregate rates of innovation, imitation and ITT.

The substitution possibilities highlighted by our model are important and have not yet been recognized. The exactness of our various neutrality results stems from considering the case where the discount rate is trivial; the exact neutrality is of secondary importance to our general message that some tendency to dampen the dynamic effects of FDI can emerge in the presence of alternative channels of ITT.

The South comprises a very diverse group of countries with varying degrees of backwardness. Lagging countries can be separated into at least two groups. In one group are countries only slightly behind the most advanced countries, whose firms can imitate technologies developed in more advanced countries even without the assistance of the expanded spillovers generated by FDI. In the second group are countries much further behind the most advanced countries, whose firms can imitate only technologies that have already been transferred to the lagging country by multinationals from more advanced countries.

While FDI may initially be crucial to the development of a country, eventually FDI ceases to be so important as firms become able to directly transfer technology through imitating products still produced in the North. Our results indicate that the role of FDI in this later stage of development differs substantially from its role in earlier stages of development. When imitation can transfer technology to the South as well (without the assistance of FDI), FDI loses its crucial role in furthering the technology frontier in both countries.

Static benefits of FDI do persist even when FDI merely displaces imitation. Imitators of multinationals charge a lower price than imitators of Northern firms because multinationals have a lower marginal cost of production than Northern firms. Thus, the overall price level falls with an increase in the flow of FDI. This fall in the price level increases welfare of consumers worldwide. The key implication of our analysis is that the *benefits of FDI are largely dynamic when FDI is the sole channel of ITT, while the benefits of FDI are largely static when FDI and imitation coexist as channels of ITT.*

In section 2 we set up the model as optimal decisions made by consumers choosing purchases and firms choosing prices and R&D intensities. In section 3 we gather together the system of equations and derive a crucial condition on the cost of imitating multinationals relative to Northern firms that dictates whether imitation joins FDI as a channel of ITT. In section 4 we examine how the location of production (and hence the technology gap and product market prices), the rates of innovation and imitation, ITT, aggregate expenditure, and the relative wage respond (or essentially fail to respond) to FDI in the steady-state equilibrium with positive intensities of innovation and imitation. We conclude in section 5. The appendix contains proofs of results for the case in which ITT occurs through both imitation and FDI and the case in which ITT occurs through FDI alone.

2. Product cycles with foreign direct investment

Each country is composed of a representative consumer and many firms. By definition, consumers derive more utility from higher-quality products and so are willing to pay a premium for quality. This premium gives firms an incentive to improve the quality level of existing products. To produce a quality level of a good, a firm first must spend resources designing it. Owing to assumed differences in the technological capabilities of the two countries, firms in the North innovate (design new quality levels), while firms in the South imitate (redesign quality levels the North has invented).

We generate a product cycle in which shifts in production occur not only because of quality upgrading and imitation, but also because of FDI. In equilibrium, the wage in the South is less than the wage in the North, providing Southern firms with the cost advantage necessary to make imitation worthwhile. Meanwhile, Northern firms may also take advantage of the cost differential by moving their production facilities to the South, forming subsidiaries there. When a Northern firm becomes a multinational, its costs fall, but not by as much as if its subsidiary were a Southern firm. Thus, Southern firms have a cost advantage relative to multinationals and still seek to imitate Northern firms even after they become multinationals.

2.1. Consumers

Consumers live in one of two countries, North and South $i \in \{N, S\}$, and choose from a continuum of products indexed by j, available in discrete quality levels indexed by m. Normalize the Southern wage to 1 and the unit labour requirement in production to 1 in each country.

A consumer has additively separable intertemporal preferences given by lifetime utility

$$U_i = \int_0^{\infty} e^{-\rho t} \log u_i(t)\, dt, \tag{1}$$

where instantaneous utility is

$$\log u_i(t) = \int_0^1 \log \left[\sum_m \lambda^m x_{im}(j,t) \right] dj, \tag{2}$$

ρ is the common subjective discount factor, λ^m is the assessment by consumers of quality level m and $x_{im}(j,t)$ is consumption by consumers in country i of quality level m of product j at time t.

A consumer maximizes lifetime utility subject to an intertemporal budget constraint. Since preferences are homothetic, the aggregate demand of consumers in each country is found by maximizing lifetime utility subject to the aggregate intertemporal budget constraint

$$\int_0^{\infty} e^{-R(t)} E_i(t)dt \leqq A(0) + \int_0^{\infty} e^{-R(t)} Y_i(t), \tag{3}$$

where the aggregate income of consumers in country i is

$$Y_i(t) = L_i w_i(t), \tag{4}$$

the aggregate spending of consumers in country i is

$$E_i(t) = \int_0^1 \left[\sum_m p_m(j,t) x_{im}(j,t) \right] dj, \tag{5}$$

$R(t) = \int_0^t r(s)ds$ is the cumulative interest rate up to time t, $A(0)$ is the value of any initial asset holdings, $w_i(t)$ is the wage rate in country i at time t, L_i is the exogenous labour supply in country i, and $p_m(j,t)$ is the price of quality level m of product j at time t. Define aggregate spending as $E \equiv E_N + E_S$.

The consumer's maximization problem can be broken into three stages: allocation of lifetime wealth across time, allocation of expenditure at each instant across products, and allocation of expenditure at each instant for each product across available quality levels. In the first stage, each consumer evenly spreads lifetime spending for each product across time in the steady-state equilibrium. In the second stage, each consumer evenly spreads spending at each instant across products. In the final stage, each consumer allocates spending for each product at each instant to the quality level that has the lowest quality adjusted price.

For each product, the latest quality level is viewed as λ-times as good as the previous quality level so consumers are willing to pay a premium of λ for a one quality level improvement in a product. The willingness of consumers to pay more for higher quality levels, which do not cost firms any more to produce, creates an incentive for firms to spend resources developing higher-quality levels of existing products.[1]

While the increased utility consumers derive from consuming higher quality levels of products drives innovation, cost savings drive imitation. If a firm were to imitate an existing quality level of a product without any cost advantage relative to the incumbent firm, both firms would earn zero profits in the resulting Bertrand equilibrium. Therefore, costly imitation is undertaken only by firms with a sufficient cost advantage over incumbent firms.

1 We have confirmed that our results are unaffected by assuming most recent vintage is more costly than previous vintages by a factor $\vartheta < \lambda$.

2.2. Producers

To produce a quality level of a product, a firm must first design it. Firms are willing to endure the costs of developing higher quality levels because they earn profits in the product market if successful. While Northern firms push forward the quality frontier of existing products through innovation, Southern firms pursue the quality frontier through imitation. The potential for quality improvement is unbounded.

Assume R&D races occur simultaneously for all products, with all innovating firms able to target the quality level above the current highest quality level and all imitating firms able to target the current highest quality level for each product. Further, assume undertaking R&D intensity ι_{ik} for a time interval dt requires $a_{ik}\iota_{ik}dt$ units of labour at a cost of $w_i a_{ik}\iota_{ik}dt$ and leads to success with probability $\iota_i dt$. The three types of R&D are innovation by Northern firms (ι_N), imitation by Southern firms targeting Northern firms (ι_{SN}) and imitation by Southern firms targeting multinationals (ι_{SF}).

We make two key assumptions supported by the theory of the multinational firm. First, we assume that multinationals (Northern firms producing in the South) have production costs above the costs of Southern firms because their methods are not as well suited to the Southern economic environment. As a result, Southern imitation can still reap the remaining cost advantage.

A central tenet of the theory of the multinational firm is that multinationals face disadvantages with respect to local firms because they are operating in unfamiliar environments and coordinating decisions over larger distances (Markusen 1995). Such disadvantages suffered by multinationals must be offset by advantages derived from superior technologies, organizational structures, or reputations. In our model, active multinationals have a superior technology that enables them to produce higher quality products than their Southern competitors, so they can compete effectively despite their operating cost disadvantage (see also Barrell and Pain 1997).

Second, we assume that products are manufactured using propriety technology that generates some degree of national spillovers. When Northern firms move production to the South, they create additional knowledge spillovers for Southern firms (see Findlay 1978; Das 1987; Wang and Blomström 1992). These spillovers may arise because Northern firms adapt their technology to the Southern economic environment when undertaking FDI.

As a result of these spillovers, Southern imitation of multinationals is easier than imitation of Northern firms. The resource requirement for imitation targeting multinationals is less than the resource requirement for imitation targeting Northern firms: $a_{SF} < a_{SN}$. These spillovers are a crucial force behind the optimistic view many host country governments take of FDI from more advanced countries. Southern firms find targeting multinationals easier, owing to the knowledge spillovers that result from observing modifications or hiring away workers trained in producing the product.

The arrival rate of FDI opportunities is set exogenously to represent the exogenous standardization of production described by Vernon (1966): for each product

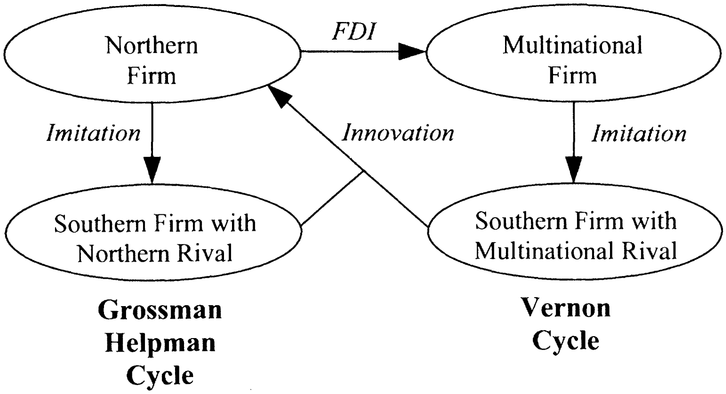

FIGURE 1 Concurrent product cycles

and at each instant, with probability ι_F, production becomes sufficiently standardized that the Northern firm becomes able to produce in the South by forming a subsidiary there.[2]

Our model generates two distinct, coexistent product cycles, illustrated in figure 1. The *Grossman-Helpman cycle* has quality levels invented by Northern firms being directly imitated by Southern firms. The *Vernon cycle* has Northern firms move production to the South by forming subsidiaries there before imitation shifts ownership but not location of production. A product follows the Vernon cycle if production becomes sufficiently standardized to permit FDI prior to imitation and follows the Grossman-Helpman cycle otherwise.

For simplicity, innovation targeting other Northern firms does not occur, as we make the necessary assumptions for such innovation to fail to earn the market rate of return. Following Grossman and Helpman, innovators can be separated into two groups: leaders and followers. Leaders are firms who developed the most recent quality improvement; followers are all other firms. We assume the labour requirement in innovation for followers is large relative to the labour requirement in innovation for leaders, so that innovation for each product is undertaken only by the firm that made the previous innovation. Provided the quality increment is sufficiently large, those incumbent firms do not innovate until the current quality level of their product has been imitated, when they no longer earn profits from their previous innovation.[3]

A firm's problem can be broken down into two stages. First, when undertaking R&D, the firm chooses its intensity of R&D to maximize its expected value, given

2 We have confirmed that our results are unaffected by choosing an alternative specification of FDI, where some fraction of new technologies are immediately capable of Southern production while the rest remain produced in the North.

3 We have confirmed that our results are unaffected by allowing innovation to target all market structures, including Northern production.

the R&D intensities of other firms and the exogenous arrival rate of FDI opportunities. Once successful in R&D, the firm then chooses the price of its product to maximize its value, given prices and R&D intensities of other firms.

Each non-producing firm chooses its intensity of R&D to maximize its expected value, given the R&D intensities of other firms and the exogenous arrival rate of FDI opportunities. To generate finite rates of R&D, expected gains must not exceed their cost, with equality when R&D occurs with positive intensity.

$$v_N \leqq wa_N, \ \iota_N > 0 \Longleftrightarrow v_N = wa_N \tag{6}$$

$$v_{SN} \leqq a_{SN}, \ \iota_{SN} > 0 \Longleftrightarrow v_{SN} = a_{SN} \tag{7}$$

$$v_{SF} \leqq a_{SF}, \ \iota_{SF} > 0 \Longleftrightarrow v_{SF} = a_{SF}. \tag{8}$$

In the above equations, v is the value the firm gains from successful R&D and $w \equiv w_N/w_S$ is the Northern wage relative to the Southern wage.[4] The subscripts denote the market structure: N for Northern production, F for FDI (multinational production), and SN or SF for Southern production.[5]

Once successful in R&D, each producing firm then chooses the price of its product to maximize its value, given the prices and R&D intensities of other firms. Southern firms are exposed only to innovation, since further imitation is not immediately possible, while Northern firms (including multinationals) are exposed only to imitation, since further innovation has been assumed to be prohibitively costly.

Northern firms that successfully innovate over a Southern firm earn the reward

$$v_N = \frac{\pi_N + \iota_F v_F}{\rho + \iota_F + \iota_{SN}}, \tag{9}$$

where π denotes instantaneous profits. Once production becomes sufficiently standardized, the Northern firm becomes a multinational with value

$$v_F = \frac{\pi_F}{\rho + \iota_{SF}}. \tag{10}$$

The reward to innovation is the discounted stream of profits from Northern production, where $\rho > 0$ is the common discount rate and at each instant the Northern firm becomes able to shift production to the lower-cost South and experiences a capital gain of $v_F - v_N > 0$ with probability ι_F.

Southern firms that successfully imitate a Northern firm earn the reward

$$v_{SN} = \frac{\pi_{SN}}{\rho + \iota_N}, \tag{11}$$

4 The relative wage is just the Northern wage $w = w_N$ due to normalizing the Southern wage to one.

5 The second letter denotes whether the Southern firm's rival is a multinational or a Northern firm, whether, before imitation occurred, the market structure was N or F.

while Southern firms that successfully imitate a multinational earn the reward

$$v_{SF} = \frac{\pi_{SF}}{\rho + \iota_N}. \tag{12}$$

Since all producing Southern firms face the same exposure to innovation, the difference in the rewards to success in imitation reflects only the difference in instantaneous profits.

Under Bertrand competition, the market outcomes depend on the extent of competition from rivals priced out of the market in equilibrium. Each type of firm engages in limit pricing behaviour to keep its closest rival from earning a positive profit from production. Northern firms successful in innovation have a one-quality-level lead over their rivals; Southern firms successful in imitation have no quality lead over their rivals. With a one-quality-level lead, choosing a price equal to λ times the rival's marginal cost (normalized to one) just keeps the rival out of the market and thus maximizes the value of a Northern firm. With no quality lead, choosing a price equal to the rivals' marginal cost just keeps the rival out of the market and thus maximizes the value of a Southern firm.

A successful innovator competes against a Southern firm, so the Northern firm charges the price $p_N = \lambda$ and makes sales $x_N = E/\lambda$ with marginal cost w, yielding instantaneous profits

$$\pi_N = E\left(1 - \frac{w}{\lambda}\right) \tag{13}$$

Once production becomes sufficiently standardized, the Northern firm becomes a multinational, still charges the price $p_F = \lambda$, and makes sales $x_F = E/\lambda$, but now has marginal cost ζ, yielding instantaneous profits

$$\pi_F = E\left(1 - \frac{\zeta}{\lambda}\right). \tag{14}$$

The marginal cost for multinationals is lower than the marginal cost for Northern firms $\zeta < w$, so multinationals earn larger instantaneous profits than Northern firms, $\pi_F > \pi_N$.

A successful imitator that targeted a Northern firm competes against a Northern firm at the same quality level, so the Southern firm charges the price $p_{SN} = w$ and makes sales $x_{SN} = E/w$ with marginal cost 1, yielding instantaneous profits

$$\pi_{SN} = E\left(1 - \frac{1}{w}\right). \tag{15}$$

A successful imitator that targeted a multinational competes against a multinational at the same quality level, so the Southern firm charges the price $p_{SF} = \zeta$ and makes sales $x_{SF} = E/\zeta$ with marginal cost 1, yielding instantaneous profits

$$\pi_{SF} = E\left(1 - \frac{1}{\zeta}\right). \tag{16}$$

The marginal cost for multinationals is lower than the marginal cost for Northern firms $\zeta < w$, so a Southern firm earns larger instantaneous profits when competing against a Northern firm than when competing against a multinational, $\pi_{SN} > \pi_{SF}$.

2.3. Resources

The fixed supply of labour is allocated between R&D and production in each country. Let n denote the percentage of markets having each market structure and define the measure of markets with production by Southern firms as $n_S \equiv n_{SN} + n_{SF}$. In the North, labour demand for innovation is $a_N \iota_N n_S$ and for production is $n_N E/\lambda$ (and similarly for the South). For equilibrium in the labour market, the demand for labour must equal the supply of labour in each country:

$$a_N \iota_N n_S + n_N \frac{E}{\lambda} = L_N \tag{17}$$

$$a_{SN} \iota_{SN} n_N + a_{SF} \iota_{SF} n_F + n_F \frac{E}{\lambda} + n_{SN} \frac{E}{w} + n_{SF} \frac{E}{\zeta} = L_S. \tag{18}$$

Increased production comes at the expense of decreased R&D in each country, owing to the fixed labour supply.

2.4. Constant measures of market structures

Whether a product is produced by a Southern firm, a Northern firm, or a multinational changes over time as innovation, imitation, or FDI occurs; the flows in must equal flows out of each market structure, however, so the measures of market structures remain constant in the steady-state equilibrium. The flows into multinational production are $\iota_F n_N$, while the flows out are $\iota_{SF} n_F$:

$$\iota_F n_N = \iota_{SF} n_F. \tag{19}$$

The flows into Southern production with Northern rivals are $\iota_{SN} n_N$, while the flows out are $\iota_N n_{SN}$:

$$\iota_{SN} n_N = \iota_N n_{SN}. \tag{20}$$

The flows into Southern production with multinational rivals are $\iota_{SF} n_F$, while the flows out are $\iota_N n_{SF}$:

$$\iota_{SF} n_F = \iota_N n_{SF}. \tag{21}$$

Additionally, the market measures must sum to one:

$$n_N + n_F + n_{SN} + n_{SF} = 1. \tag{22}$$

While the distribution of products over market structures remains constant in the steady-state equilibrium, each product cycles between market structures.

3. Channels of international technology transfer

In equilibrium, consumers in the North and South maximize their intertemporal utility subject to the intertemporal budget constraint, firms in the North and the South maximize their value given prices and R&D intensities of other firms and the arrival rate of FDI opportunities, and labour markets in the North and South clear. Define $\gamma \equiv a_{SF}/a_{SN} < 1$ as the resource requirement in imitation targeting multinationals relative to targeting Northern firms. We show that the value of γ dictates whether ITT occurs through both FDI and imitation, or through imitation alone.

3.1. Foreign direct investment and imitation

The key equations reduce to a system of five equations. The first two equations are the Northern and Southern resource constraints (17)–(18). The remaining three equations are the innovation and imitation valuation conditions (6)–(8) with the producing firm valuation equations (9)–(12) and profits (13)–(16) inserted

$$E\left[1 - w\delta + \frac{\iota_F}{\rho + \iota_{SF}}(1 - \zeta\delta)\right] = wa_N(\rho + \iota_F + \iota_{SN}) \tag{23}$$

$$E(w - 1) = wa_S(\rho + \iota_N) \tag{24}$$

$$E(\zeta - 1) = \zeta\gamma a_S(\rho + \iota_N), \tag{25}$$

where $\delta \equiv 1/\lambda$ and $a_S \equiv a_{SN}$. When imitation targets Northern firms as well as multinationals, the two imitation valuation conditions (24)–(25) determine the equilibrium relative wage,

$$w = \frac{a_{SF}\zeta}{a_{SF}\zeta - a_{SN}\zeta + a_{SN}} = \frac{\gamma\zeta}{\gamma\zeta - (\zeta - 1)} > 1, \tag{26}$$

which can take the place of one of the imitation valuation conditions.

Converting the system into the variables of greatest interest helps in describing the impact of FDI. The rate of innovation is $\iota = \iota_N n_S$, since each of the n_S products produced by Southern firms is targeted by innovation intensity ι_N. Similarly, the rate of imitation is $\mu = \iota_{SN} n_N + \iota_{SF} n_F$. In the steady-state equilibrium, the rate of innovation must equal the rate of imitation $\iota = \mu$, so that the same percentage of all markets have ownership shifted to Southern firms as have ownership returned to Northern firms.

Here, technology flows to the South through both imitation of Northern firms $\iota_{SN} n_N$ and FDI $\Phi \equiv \iota_F n_N$. The rate of technology transfer to the South is the sum $\Upsilon = \iota_{SN} n_N + \Phi$. The constant market measure condition (19) implies that the rate of ITT equals the rate of imitation, $\Upsilon = \mu$. By replacing the standardization probability $\iota_F \equiv \Phi/n_N$, we transform the system to using FDI flows Φ as the exogenous shift parameter instead, since FDI flows seem to be the more natural measurement of FDI.

Making these substitutions and solving the steady-state market measures conditions (19)–(22) gives expressions for the variables of less interest:

$$n_F = 1 - n_N - n_S \tag{27}$$

$$\iota_{SN} = \frac{\iota - \Phi}{n_N} \tag{28}$$

$$\iota_{SF} = \frac{\Phi}{n_F} = \frac{\Phi}{1 - n_N - n_S} \tag{29}$$

$$n_{SN} = \left(1 - \frac{\Phi}{\iota}\right) n_S \tag{30}$$

$$n_{SF} = \frac{\Phi}{\iota} n_S. \tag{31}$$

Substituting the above expressions into the system of equations yields a system of five equations (two resource constraints and three valuation conditions):

$$RN \equiv a_N \iota + E n_N \delta - L_N = 0 \tag{32}$$

$$RS \equiv [a_S \iota + E(1 - n_N)\delta + E n_S (1 - \delta) - L_S]\iota - a_S \iota (1 - \gamma)\Phi + E n_S \left(\frac{w - \zeta}{w\zeta}\right)\Phi = 0 \tag{33}$$

$$VN \equiv [E(1 - w\delta)n_N - w a_N(\rho n_N + \iota)][\rho(1 - n_N - n_S) + \Phi] + E(1 - \zeta\delta)(1 - n_N - n_S)\Phi = 0 \tag{34}$$

$$VSN \equiv E n_S (w - 1) - w a_S (\rho n_S + \iota) = 0 \tag{35}$$

$$VSF \equiv E n_S (\zeta - 1) - \zeta a_S (\rho n_S + \iota) = 0 \tag{36}$$

in the five variables $\{w, E, n_N, n_S, \iota\}$.[6]

3.2. Condition on relative imitation cost

In addition to the case where imitation targets both multinationals and Northern firms, imitation may target only multinationals, owing to the higher cost of imitation targeting Northern firms. As γ falls, imitation targeting multinationals becomes less expensive relative to imitation targeting Northern firms. The profit margin for successful imitators that targeted Northern firms must rise relative to the profit margin for successful imitators that targeted multinationals to assure that both earn the same return on their imitation investments. As γ falls, however, eventually the relative wage w may be pushed to its upper bound λ. The relative wage cannot

6 Alternatively, the solution for the relative wage (26) can take the place of (35) or (36).

exceed the quality increment, since Northern firms would earn a negative profit margin and thus not be willing to make costly investments in innovation.

Once the relative wage hits its upper bound and can rise no further, any further reduction in γ will cause Southern firms to stop targeting Northern firms, since targeting multinationals would yield a higher return. Solving for the value of γ that forces the relative wage up to its upper bound $w = \lambda$ provides the lower bound on γ for imitation to target Northern firms.[7]

$$\underline{\gamma} = \frac{\lambda}{\lambda - 1}\left(1 - \frac{1}{\zeta}\right) \tag{37}$$

Similarly, the upper bound, $\bar{\gamma} = 1$, ensures imitation always targets multinationals. Thus, in the upper range $\underline{\gamma} < \gamma < 1$, imitation targets both multinationals and Northern firms, but in the lower range $0 < \gamma \leqq \underline{\gamma}$, imitation targets only multinationals.

An increase in the cost of imitating multinationals relative to Northern firms, through a reduction in the cost of imitating Northern firms, is a likely property of economic development. When a developing country lags greatly behind the innovating countries, technologies require significant adaptation to be suitable for production there, and native firms are ill equipped to make the needed adjustments. Thus, imitating multinationals would be far easier than imitating firms still producing in the North, because multinationals would have made much of the needed adjustments to the production technique: γ is low. As such a lagging country develops, smaller adjustments to the production techniques are needed, and its firms become better able to perform some adjustments on their own: γ rises. The unit interval $\gamma \in (0, 1)$ orders lagging countries at different stages of development, from the lowest $\gamma \longrightarrow 0$ to the highest $\gamma \longrightarrow 1$. In the lower range $\gamma \in (0, \underline{\gamma}]$, ITT occurs exclusively through FDI; in the upper range $(\underline{\gamma}, 1)$, ITT occurs through both FDI and imitation of Northern firms.

3.3. Foreign direct investment alone

In the lower range of γ, the resource requirement in imitating Northern firms relative to multinationals is sufficiently high that no imitation of Northern firms occurs in equilibrium $\iota_{SN} = 0$, and consequently, no Southern firms have Northern firms as rivals $n_{SN} = 0$. The Northern resource constraint (17) remains the same, while the Southern resource constraint (18) has two terms drop out by assigning $\iota_{SN} = 0$ and $n_{SN} = 0$, leaving

$$\gamma a_S \iota_{SF} n_F + n_F E\delta + n_{SF}\frac{E}{\zeta} = L_S. \tag{38}$$

Similarly, the innovation valuation condition (23) has one term drop out by assigning $\iota_{SN} = 0$, leaving

$$E\left[1 - w\delta + \frac{\iota_F(1 - \zeta\delta)}{\rho + \iota_{SF}}\right] = w a_N(\rho + \iota_F). \tag{39}$$

7 For example, for $\zeta = 6/5$ and $\lambda = 3$, the lower bound is $\underline{\gamma} = 25$ per cent.

The imitation valuation condition for targeting multinationals (25) remains the same, and the imitation valuation condition for targeting Northern firms (26) becomes an inequality as costs exceed expected benefits.

In the lower range of γ, the rate of innovation is still $\iota = \iota_N n_S$, the rate of imitation is just $\mu = \iota_{SF} n_F$ but still equals the rate of innovation, and the rate of ITT is just $\Upsilon = \Phi$ but still equals the rate of imitation. The steady-state market measures conditions are the same as those in (19) and (21), with the sums-to-one condition (22) dropping a term by assigning $n_{SN} = 0$, leaving $n_N + n_F + n_{SF} = 1$. Solving the steady-state market measures conditions gives the same expressions for the measure of multinational production (27) and the imitation intensity targeting multinationals (29), but now the rate of innovation is identical to the flow of FDI $\iota = \Phi$, and all Southern firms have multinationals as rivals $n_{SF} = n_S$, since $n_{SN} = 0$. Substituting the above expressions into the system of equations (17, 38, 39, 25) yields a system of four equations (two resource constraints and two valuation conditions):

$$rn \equiv a_N \Phi + E n_N \delta - L_N = 0 \tag{40}$$

$$rs \equiv \gamma a_S \Phi + E\left[(1 - n_N)\delta + n_S\left(\frac{1}{\zeta} - \delta\right)\right] - L_S = 0 \tag{41}$$

$$\begin{aligned} vn \equiv {} & [E n_N (1 - w\delta) - w a_N (\rho n_N + \Phi)](\rho(1 - n_N - n_S) + \Phi) \\ & + E(1 - \zeta\delta)(1 - n_N - n_S)\Phi = 0 \end{aligned} \tag{42}$$

$$vsf \equiv E n_S (\zeta - 1) - \zeta a_S (\rho n_S + \iota) = 0 \tag{43}$$

in the four variables $\{w, E, n_N, n_S\}$.

Now we can examine the effects of an increase in the flows of FDI to the South Φ. In either case, by determining the effect of greater flows of FDI Φ on the aggregate rate of innovation ι, we determine the effect on the aggregate rate of imitation μ and the aggregate rate of ITT Υ as well. Contrasting the results when FDI serves as the sole channel of ITT ($\gamma \leqq \underline{\gamma}$) to when FDI and imitation serve as simultaneous channels of ITT ($\gamma > \underline{\gamma}$) helps to isolate the mechanism through which FDI can affect innovation, imitation, and ITT and, in particular, why that mechanism is essentially absent when FDI is not the sole channel of ITT.

4. Effects of foreign direct investment

Suppose the flows of FDI to the South Φ rise, owing to accelerated standardization. With faster flows of production to the South through FDI at each instant, the expected duration of production in the North prior to FDI becomes shorter. A larger proportion of products then goes around the Vernon cycle, where FDI serves as the channel of ITT, rather than the Grossman-Helpman cycle where imitation serves as the channel of ITT. Do the increased flows of FDI to the South increase the rates of ITT, imitation, and innovation?[8]

8 We provide proofs of the following results for the upper range of γ in Appendix A and for the lower range of γ in Appendix B.

4.1. Location of production

How do increased FDI flows affect the location of production? In the upper range of γ, faster flows of FDI to the South expose multinationals to relatively more imitation than they experienced as Northern firms. Greater FDI flows lead to a shift of imitation from targeting Northern firms towards targeting multinationals. As a result, the fraction of Southern production done by firms that imitated multinationals increases, while the fraction done by firms that imitated Northern firms decreases. Meanwhile, the overall measure of Southern production and measures of Northern and multinational production are essentially unchanged (derivatives become zero as $\rho \longrightarrow 0$).

PROPOSITION 1. *When imitation targets both multinationals and Northern firms, an increase in the flow of FDI increases the intensity of imitation targeting multinationals and the measure of Southern production with multinational rivals, decreases the intensity of imitation targeting Northern firms and the measure of Southern production with Northern rivals, and leaves the measure of Southern production essentially unchanged (unchanged in the limit as the discount rate approaches zero). When imitation of Northern firms is prohibitively costly, an increase in the flow of FDI increases the measure of Southern production.*

In the lower range of γ, there is no displacement of one form of imitation by another or displacement of imitation as a channel of ITT by FDI. Thus, the faster flow of FDI to the South helps to bring production to the South faster (as $\mu = \Phi$), which raises the measure of Southern production.

Whether FDI flows affect the measure of Southern production is important because the measure of Southern production varies inversely with the technology gap (see also Glass 1997, 1998). The technology gap is how far the Southern technology frontier lags behind the Northern (world) technology frontier. In markets with Northern or multinational production $(1 - n_S)$, the South lags one quality level behind; in markets with Southern production (n_S), the South does not lag behind. Thus, the technology gap equals the measure of non-Southern production $G = 1 - n_S$.

When the measure of Southern production rises, the technology gap shrinks as the South catches up the North for more markets. Thus, proposition 1 shows that *FDI helps to close the technology gap iff FDI serves as the sole channel of international technology transfer.* Once imitation co-exists with FDI in transferring technology to the South, FDI merely displaces imitation in helping to push forward the Southern technology frontier.

4.2. International technology transfer and innovation

In the upper range of γ, increased imitation of multinationals $\iota_{SF}n_F$ is offset by decreased imitation of Northern firms $\iota_{SN}n_N$, leaving the rate of imitation $\mu = \iota_{SF}n_F + \iota_{SN}n_N$ essentially constant. Also, increased FDI flows Φ are offset by decreased imitation of Northern firms $\iota_{SN}n_N$, leaving the rate of international technology transfer $\Upsilon = \iota_{SN}n_N + \Phi$ essentially constant.

PROPOSITION 2. *When imitation targets both multinationals and Northern firms, the rate of innovation, the rate of imitation, and the rate of international technology transfer essentially do not depend upon the flow of FDI (independent in the limit as the discount rate approaches zero). When imitation of Northern firms is prohibitively costly, the rate of innovation, the rate of imitation, and the rate of international technology transfer increase with an increase in the flow of FDI.*

In the lower range of γ, when the flow of FDI increases, the rate of imitation and rate of innovation must increase as well, since $\iota = \mu = \Upsilon = \Phi$ in equilibrium. Therefore, the effect of faster FDI flows is to send the products more quickly through the entire cycle of innovation, FDI, and imitation.

Why are there essentially no effects when FDI and imitation co-exist as channels of ITT? Why doesn't the rate of innovation rise, owing to the greater profits from FDI or the resources conserved by the adjustment towards more efficient imitation? The Southern resources freed from imitation get absorbed into Southern production. As Φ increases, the measure of markets where Southern firms successfully imitated multinationals increases. Since these firms charge lower prices than those that imitated Northern firms (owing to the lower cost of multinational production), they sell more and thus employ more resources in production. Therefore, the resource savings in imitation generated by the knowledge spillovers from FDI (reflected in the lower resource requirement in imitating multinationals) are offset by the increased resources demanded for Southern production.

When totally differentiating the system, we find the change in Southern resource demand (33) due to an increase in FDI flows is one causal force (see appendix A). Imposing the two imitation valuation conditions, however, generates an equivalent expression for the change in Southern resource demand:[9]

$$c_2 = -a_S\iota(1-\gamma) + En_S\left(\frac{w-\zeta}{w\zeta}\right) = -\rho a_S n_S(1-\gamma). \tag{44}$$

The term $-a_S\iota(1-\gamma)$ is the reduction in Southern resource demand for imitation, while the term $En_S(w-\zeta)/(w\zeta)$ is the expansion in Southern resource demand for production.

The new expression clearly indicates that the Southern resource savings from more efficient imitation are absorbed into greater Southern production (owing to the lower price of imitated goods) except for a term proportional to ρ. This offset is assured by both types of imitation co-existing in the initial equilibrium, that is, by being in the upper range of γ.

The other causal force is changes in the reward to innovation (34) due to an increase in FDI flows. Here, while the quicker arrival of FDI opportunities brings a quicker increase in profits due to the cost savings of FDI, the larger profits are then terminated more quickly. These two effects offset each other, so faster arrival

9 We add a term equal to $V_{SN}/w - V_{SF}/\zeta = 0$ to c_2, where $V_{SN} = 0$ and $V_{SF} = 0$ are the imitation valuation conditions (35) and (36).

of FDI opportunities leads to essentially no change in the value of a Northern firm, the reward to innovation. Similarly, imposing the innovation valuation condition generates an equivalent expression for the change in the value of an innovation[10]

$$c_3 = E(1 - w\delta)n_N - wa_N(\rho n_N + \iota) + E(1 - \zeta\delta)(1 - n_N - n_S)$$
$$= \rho\left(\frac{1 - n_N - n_S}{\Phi}\right)[En_N(1 - w\delta) - wa_N(\rho n_N + \iota)] \tag{45}$$

The term $E(1 - \zeta\delta)(1 - n_N - n_S)$ is the increase in value due to the faster arrival of the cost savings from FDI, while the remaining terms in the original expression are the decrease in value from the faster termination of the profits due to imitation.

Again, the new expression clearly indicates that the faster arrival of cost savings due to FDI is offset by the faster arrival of the termination of the profit stream due to imitation except for a term proportional to ρ. A term proportional to ρ remains because the cost savings arrive prior to the profit termination, so the profit termination is discounted by more than the cost savings. The discount rate is near zero, however, so any increase in the reward to innovation from cost savings preceding profit termination is negligible.

On the other hand, the causal forces for the lower range of γ do not disappear as $\rho \longrightarrow 0$ (see appendix B). Making a similar transformation for the lower range of γ leaves a term $wa_N\Phi$ in addition to a term proportional to ρ.[11] Thus, even as $\rho \longrightarrow 0$, the value of an innovation, the value of an imitation, and resource demand in each country rise (through increased resource demand in innovation and imitation) owing to the faster pace of product cycles as FDI flows accelerate.

These expressions for the causal forces help to clarify why the dynamic effects disappear (as the discount rate becomes trivial) when imitation can transfer technology to the South. The commonly advanced argument that FDI contributes to technology transfer applies only when imitation of Northern products is prohibitively costly, so that alternative channels of ITT are absent. When both FDI and imitation transfer technology, an increase in FDI flows merely reorients imitative efforts without affecting the rate at which the Southern technology frontier advances.

As illustrated in figure 2, when ITT through FDI ($\Phi \equiv \iota_F n_N = \iota_{SF} n_F$) increases, ITT through imitation ($\iota_{SN} n_N$) declines in proportion. Therefore, hopes of some (more developed) developing countries that expanded FDI will bring in technology and thus lead to an expansion of their own imitative abilities may be confounded. FDI essentially will cease to fulfil such hopes once the South has developed enough that Southern firms can imitate Northern products, even when Northern firms keep production in the North, where knowledge spillovers to the South are smaller. With

10 We add a term equal to $VN/\Phi = 0$ to c_3, where $VN = 0$ is the innovation valuation condition (34).

11 Specifically, we add a term equal to $vn/\Phi = 0$ to c_3, where $vn = 0$ is the innovation valuation condition (39).

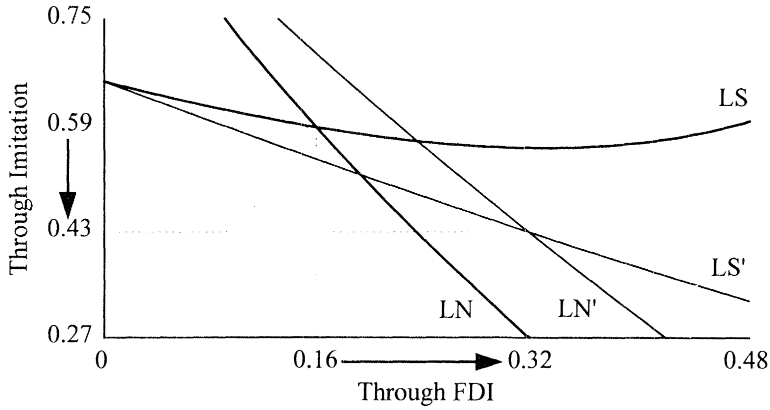

FIGURE 2 Composition of technology transfer

more FDI, a sufficiently developed lagging country will discover that its technology frontier advances no faster, since FDI merely displaces imitation as a channel of ITT. Next we examine the impact of FDI flows on relative wages and aggregate expenditure to determine the static effects of FDI.

4.3. Relative wage and aggregate expenditure

For the upper range of γ, the equilibrium relative wage (26) is determined exclusively by the valuation conditions for imitation targeting multinationals and Northern firms. Clearly, the relative wage is exactly independent of FDI flows Φ regardless of the discount rate ρ. The relative wage does increase with the cost disadvantage suffered by multinationals relative to Southern firms ζ. A higher ζ makes imitation of multinationals more attractive; hence, the relative wage must rise to restore the relative attractiveness of imitating Northern firms.

Additionally, the relative wage increases with the extent of spillovers from FDI relative to international trade (smaller γ). The greater the knowledge spillovers from FDI relative to international trade, the easier it is for Southern firms to imitate a multinational compared with imitating a Northern firm. A lower γ (larger relative spillovers) is accompanied by a rise in the relative wage to restore the relative attractiveness of imitating Northern firms (by providing a larger markup).

Even though the relative wage is unaffected by the magnitude of FDI flows when FDI is not the sole channel of ITT, the North may incur some negative repercussions from the mere presence of FDI if the two different economic environments converge over time. If, over time, multinationals become better adapted to the Southern economic environment (so ζ falls) or Southern firms become more adept at imitation without the assistance of FDI (so γ rises), each of these effects will cause the relative wage to fall, depleting the standard of living advantage in the North relative to the South.

However, faster flows of FDI (Φ) do not alter the relative wage or aggregate spending when both channels of ITT are active. Failure to decrease aggregate spending implies failure to increase the Southern wage, which serves as numeraire.

PROPOSITION 3. *When imitation targets both multinationals and Northern firms, an increase in the flow of FDI does not affect the relative wage or aggregate expenditure. When imitation of Northern firms is prohibitively costly, an increase in the flow of FDI decreases the relative wage and aggregate expenditure.*

In the lower range of γ, where FDI is the sole channel of ITT, greater flows of FDI to the South do decrease the relative wage, thus reducing Northern income. The reduction in real aggregate expenditure implies a rise in the Southern wage, since the Southern wage serves as numeraire.

The decline in the Northern wage due to greater flows of FDI may explain the opposition of Northern workers to FDI outflows. It is interesting to note that such a decline does not always occur, not if FDI merely displaces imitation as a channel of ITT. This contrast is consistent with workers objecting most to FDI in the least developed countries. Next, we examine the impact of FDI flows on welfare and draw an interesting distinction between the type of FDI benefits generated in these two scenarios based on whether multiple channels of ITT coexist.

4.4. Welfare

Having determined the effect of FDI flows on the relevant endogenous variables, we are now prepared to address welfare. Instantaneous utility (2) is given by

$$\log u_i(t) = \log E_i + \bar{m} \log \lambda - \log \bar{p}, \tag{46}$$

where the expected number of innovations arriving in time period t is $\bar{m} = \iota t$ and the average price paid by consumers is

$$\bar{p} = \lambda(1 - n_S) + w n_{SN} + \zeta n_{SF}. \tag{47}$$

Lifetime utility (1) is then

$$U_i = \frac{\log E_i + \frac{\iota}{\rho} \log \lambda - \log \bar{p}}{\rho}. \tag{48}$$

Lifetime utility balances the effects of expenditure, innovation, and the average price level.

How does FDI affect the average price paid by consumers? FDI has no effect on prices charged by Northern firms (including multinationals) because Northern firms innovate over Southern firms and charge limit prices reflecting their quality advantage λ. Even though FDI lowers the marginal cost of production of Northern firms, they charge the same price when they produce in the South as they did when still producing in the North.

In the upper range of γ, however, an increase in FDI flows does cause the average price level to fall, owing to lower prices charged by Southern firms. An increase in FDI flows causes more of the successful imitators to have multinationals rather than Northern firms as rivals (with the measure of Southern production essentially constant). This rearrangement of Southern production occurs in the direction of lower-priced products, since more Southern firms have lower-cost firms (multinationals) as rivals, so the average price charged by Southern firms falls. Consequently, the average price of an imitated product falls.

The benefits of FDI are essentially only the static benefit from a lower price level in this upper range of γ. Owing to the substitution of ITT through FDI for ITT through imitation, FDI neither accelerates technology transfer from the North to the South nor accelerates the rate of innovation. Since an increase in FDI flows Φ lowers the average price level without affecting the rate of innovation and aggregate spending, welfare unambiguously rises. Owing to the absence of any growth benefits, FDI – while still attractive – fails to be as attractive as static gains reinforced by positive growth effects.

PROPOSITION 4. *When imitation targets both multinationals and Northern firms, an increase in the flow of FDI increases welfare in each country by decreasing the average price level. When imitation of Northern firms is prohibitively costly, an increase in the flow of FDI increases welfare in each country, if discounting is sufficiently slight, by increasing the rate of innovation.*

In the lower range of γ, FDI is the sole channel of ITT and the positive growth effects do emerge, but the level effects may be negative for the North, owing to declining wages. None the less, if discounting is sufficiently slight, FDI will prove beneficial for even the North, owing to the faster arrival of innovations (FDI is always beneficial for the South). The demarcation point for whether FDI is the sole channel of ITT also serves as the demarcation point for whether the benefits of FDI are mostly dynamic (through faster innovation) or mostly static (through lower prices).

5. Conclusion

This paper examines the effect of FDI on the rates of innovation, imitation, and ITT. The dynamic benefits of FDI have been pursued by host countries expecting FDI to accelerate inflows of technology from abroad and imitation by indigenous firms. Our model supports the potential for dynamic gains from FDI but we caution that these gains are not significant if its firms can imitate technologies from abroad. The dynamic gains from FDI are muted, because FDI displaces imitation as a channel of ITT.

Even though FDI makes imitation easier for Southern firms, a faster arrival of FDI opportunities does not accelerate the advancement of the Southern technology frontier when both FDI and imitation transfer technology across borders. Southern firms respond to the faster formation of multinationals by shifting their imitation efforts towards products produced by multinationals, leaving products produced in the North safer from attack. The faster imitation of multinationals is offset by the slower imitation of Northern firms, so the rate of imitation remains unchanged when the discount rate is trivial.

Even though FDI lowers the costs of Northern firms, a faster arrival of FDI opportunities does not accelerate innovation. The faster increase in profits for Northern firms when they become multinationals is offset by a faster termination of those profits, leaving the reward to innovation unchanged. The major insight of our model is that expanded ITT through FDI can be offset substantially by reduced ITT through imitation of Northern firms. Even when such offsetting is complete (and thus dynamic benefits are absent), FDI lowers the markups charged by Southern firms while leaving the markups of Northern producers unaffected, so a faster flow of FDI does lower the overall price level.

We relate the property of whether FDI is the sole channel of ITT to the cost of imitating multinationals relative to Northern firms. The developing world could be segmented into two groups, one even less developed than the other. For the *least* developed countries, FDI is the sole channel of ITT and thus does expand ITT, imitation, and innovation and generate dynamic gains. For the *less* developed countries, however, FDI merely displaces imitation, shutting down the dynamic gains but leaving static gains from lower prices. Thus we caution countries as they develop not to count on sizable dynamic gains from FDI continuing forever. Our model predicts a key shift in the form of benefits of FDI from dynamic to static as alternative channels of ITT develop.

While we distinguish here between two groups of developing countries based on level of development, at least one more group exists below the lower group considered here. Many less developed countries are so far behind the technology frontier that they remain unable to imitate the state-of–the-art even when produced in the South by a multinational. These severely lagging countries are able to imitate only those quality levels below the state-of-the-art. In such a setting, FDI and imitation may generate bidirectional spillovers: FDI makes imitation easier, but imitation of a low quality level makes high quality FDI easier, since Southern firms create a technology base capable of supporting better technologies. Glass and Saggi (1998) examine policies the government in such a country can pursue to encourage FDI at the high-quality level.

FDI could be made endogenous and increased through decreasing the cost of adapting technologies for the Southern environment, increasing Southern resources, increasing Southern imitation efficiency or other forces (see Glass and Saggi 1995, 1999). Here, we do not want to introduce any force that would generate its own direct effect on the rate of innovation. Instead, we focus on the impact of different exogenous flows of FDI due to different speeds of standardization.[12]

12 One of the values for the arrival rate of FDI opportunities would be the optimal intensity for Northern firms to attempt to adapt their technologies for the Southern economic environment.

While increased flows of FDI are often correlated with accumulation of Southern resources or improved Southern efficiency, we feel it is vital to understand the role of FDI separate from these other causal forces. Otherwise, credit for increases in innovation stemming from resource accumulation might wrongly be attributed to FDI instead. FDI may serve as a barometer of such causal forces, but whether FDI has any independent role of its own in promoting innovation needs to be determined.

Appendix A: Imitation of multinationals and Northern firms

Totally differentiate the system with respect to FDI flows Φ to find the effects on the endogenous variables (except for the relative wage)

$$\begin{bmatrix} a_N & E\delta & 0 & n_N\delta \\ b_{21} & -E\delta\iota & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ -\zeta a_S & 0 & E(\zeta-1)-\rho\zeta a_S & n_S(\zeta-1) \end{bmatrix} \begin{bmatrix} \partial\iota \\ \partial n_N \\ \partial n_S \\ \partial E \end{bmatrix} = \begin{bmatrix} 0 \\ c_2\partial\Phi \\ c_3\partial\Phi \\ 0 \end{bmatrix},$$

where

$$b_{21} = 2a_S\iota + E(1-n_N)\delta + En_S(1-\delta) - L_S - a_S(1-\gamma)\Phi$$

$$b_{23} = E\left[(1-\delta)\iota + \left(\frac{w-\zeta}{w\zeta}\right)\Phi\right]$$

$$b_{24} = [(1-n_N)\delta + n_S(1-\delta)]\iota + n_S\left(\frac{w-\zeta}{w\zeta}\right)\Phi$$

$$b_{31} = -wa_N[\rho(1-n_N-n_S)+\Phi]$$

$$b_{32} = -E(1-\zeta\delta)\Phi - \rho[E(1-w\delta)n_N - wa_N(\rho n_N+\iota)] + [E(1-w\delta) - wa_N\rho][\rho(1-n_N-n_S)+\Phi]$$

$$b_{33} = -\rho[E(1-w\delta)n_N - wa_N(\rho n_N+\iota)] - E(1-\zeta\delta)\Phi$$

$$b_{34} = (1-w\delta)n_N[\rho(1-n_N-n_S)+\Phi] + (1-\zeta\delta)(1-n_N-n_S)\Phi$$

and

$$c_2 = -a_S\iota(1-\gamma) + En_S\left(\frac{w-\zeta}{w\zeta}\right)$$

$$c_3 = E(1-w\delta)n_N - wa_N(\rho n_N+\iota) + E(1-\zeta\delta)(1-n_N-n_S).$$

Since the relative wage depends only on parameters of the model other than Φ, inserting the expression for w is not necessary prior to calculating the derivatives.

Take the limit of the expressions for the derivatives in the limit as the discount rate goes to zero $\rho \longrightarrow 0$, since terms involving the discount rate should be trivial. Simplify the expressions for the derivatives by solving the resource constraints and valuation conditions for L_N, L_S, a_N, and a_S, then assigning these values to impose an initial equilibrium. According to results simplified using MAPLE, an increased flow of FDI to the South has (virtually) no effect on the rate of innovation, the measure of Northern production, the measure of Southern production, or real aggregate expenditure:

$$\frac{\partial \iota}{\partial \Phi} = \frac{\partial n_N}{\partial \Phi} = \frac{\partial n_S}{\partial \Phi} = \frac{\partial E}{\partial \Phi} = 0.$$

These non-effects imply non-effects on the measure of multinational production $n_F = 1 - n_N - n_S$ and innovation intensity $\iota_N = \iota / n_S$. Owing purely to the direct increase in Φ, imitation shifts from targeting Northern firms ($\iota_{SN} = (\iota - \Phi)/n_N$ falls) toward targeting multinationals ($\iota_{SF} = \Phi / n_F$ rises). Consequently, more Southern firms have multinational rivals and fewer have Northern rivals ($n_{SF} = (\Phi/\iota) n_S$ rises while $n_{SN} = (1 - \Phi/\iota) n_S$ falls). Meanwhile, the relative wage is also unaffected by flows of FDI to the South (exactly even for $\rho > 0$) as seen from the equilibrium relative wage (26):

$$\frac{\partial w}{\partial \Phi} = 0.$$

The derivative of the price level for imitated goods with respect to Φ is

$$\frac{\partial \bar{p}_S}{\partial \Phi} = \zeta \left[\frac{\partial n_{SF}}{\partial \Phi} \right] + w \left[\frac{\partial n_{SN}}{\partial \Phi} \right] + n_{SN} \left[\frac{\partial w}{\partial \Phi} \right].$$

As $\partial w / \partial \Phi = 0$ and $\partial n_{SN} / \partial \Phi = -\partial n_{SF} / \partial \Phi < 0$, the effect simplifies to

$$\frac{\partial \bar{p}_S}{\partial \Phi} = -(w - \zeta) \left[\frac{\partial n_{SF}}{\partial \Phi} \right] = -(w - \zeta) \frac{n_S}{\iota} < 0.$$

As $\partial n_S / \partial \Phi = 0$, the overall price level reflects only the change in the price level for imitated goods:

$$\frac{\partial \bar{p}}{\partial \Phi} = (P_S - \lambda) \left[\frac{\partial n_S}{\partial \Phi} \right] + n_S \left[\frac{\partial \bar{p}_S}{\partial \Phi} \right] = n_S \left[\frac{\partial \bar{p}_S}{\partial \Phi} \right] = -(w - \zeta) \frac{n_S^2}{\iota} < 0.$$

As FDI flows have no other effects on utility ($\partial E / \partial \Phi = \partial w / \partial \Phi = \partial \iota / \partial \Phi = 0$), the only effect on instantaneous utility is the benefit from a lower average price level:

$$\frac{\partial \log u_i}{\partial \Phi} = -\frac{1}{\bar{p}} \frac{\partial \bar{p}}{\partial \Phi} > 0.$$

Thus, FDI flows raise utility, owing to the positive level effect of lower prices. An example confirms that terms involving ρ are indeed apt to be trivial. For $\rho = 1/12$, $a_S = 2$, $\gamma = 1/2$, $a_N = 3$, $\lambda = 4$, $\zeta = 6/5$, $L_N = 3$, $L_S = 5$, and a doubling of FDI flows from $\Phi = 1/4$ to $\Phi' = 1/2$, the rate of innovation and Southern production very slightly rise ($\%\Delta\iota = 0.02\%$ and $\%\Delta n_S = 0.06\%$), while aggregate expenditure very slightly falls ($\%\Delta E = -0.61\%$); meanwhile, the shift within Southern production is massive ($\%\Delta n_{SN} = -52.55\%$ and $\%\Delta n_{SF} = 101.28\%$).

Appendix B: No imitation of Northern firms

Totally differentiate the system with respect to FDI flows to find the effects on the other endogenous variables (this time including w but excluding ι).

$$\begin{bmatrix} 0 & E\delta & 0 & n_N\delta \\ 0 & -E\delta & E\left(\frac{1}{\zeta}-\delta\right) & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ 0 & 0 & E(\zeta-1)-\rho\zeta a_S & n_S(\zeta-1) \end{bmatrix} \begin{bmatrix} \partial w \\ \partial n_N \\ \partial n_S \\ \partial E \end{bmatrix} = \begin{bmatrix} -a_N\partial\Phi \\ -\gamma a_S\partial\Phi \\ c_3\partial\Phi \\ \gamma\zeta a_S\partial\Phi \end{bmatrix},$$

where

$$b_{24} = (1-n_N)\delta + n_S\left(\frac{1}{\zeta}-\delta\right)$$

$$b_{31} = [En_N\delta - a_N(\rho n_N + \Phi)](\rho(1-n_N-n_S)+\Phi)$$

$$b_{32} = [E(1-w\delta) - wa_N\rho](\rho(1-n_N-n_S)+\Phi) \\ - \rho[En_N(1-w\delta) - wa_N(\rho n_N+\Phi)] - \Phi E(1-\zeta\delta)$$

$$b_{33} = -\rho[En_N(1-w\delta) - wa_N(\rho n_N+\Phi)] - \Phi E(1-\zeta\delta)$$

$$b_{34} = [n_N(1-w\delta)](\rho(1-n_N-n_S)+\Phi) + (1-\zeta\delta)(1-n_N-n_S)\Phi$$

and

$$c_3 = \rho(1-n_N-n_S) + \Phi - wa_N(\rho n_N+\Phi) \\ + E[n_N(1-w\delta) + (1-n_N-n_S)(1-\zeta\delta)],$$

where

$$\lim_{\rho\to 0} c_3 = \lim_{\rho\to 0}\left(c_3 + \frac{vn}{\Phi}\right) = wa_N\Phi.$$

Take the limit of the expressions for the derivatives in the limit as the discount rate goes to zero $\rho \to 0$. According to results simplified using MAPLE, an increased flow of FDI to the South decreases the relative wage,

$$\frac{\partial w}{\partial\Phi} = -\frac{L_N(1-w\delta) + L_S(1-\zeta\delta)}{L_N\delta\Phi} < 0,$$

increases the measure of Southern production,

$$\frac{\partial n_S}{\partial \Phi} = \frac{n_S a_N\left(1-\frac{1}{\zeta}\right) + \gamma a_S[n_S(1-\delta)+\delta]}{\delta E\left(1-\frac{1}{\zeta}\right)} > 0,$$

and decreases real aggregate expenditure,

$$\frac{\partial E}{\partial \Phi} = -\frac{a_N\left(1-\frac{1}{\zeta}\right) + \gamma a_S(1-\delta)}{\delta\left(1-\frac{1}{\zeta}\right)} < 0.$$

Meanwhile, the rate of innovation clearly rises with faster flows of FDI, since the rate of innovation and the flows of FDI must be the same, $\iota = \Phi$:

$$\frac{\partial \iota}{\partial \Phi} = 1 > 0.$$

These results can also be generated by assuming any exogenous imitation intensity targeting Northern firms. The key attribute of our model is whether Southern firms decide whether their imitation activity should target multinationals or Northern firms. As long as Southern firms can adjust the target of their imitation, FDI can crowd out imitation as a channel of ITT.

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