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Intellectual Property Protection, Internalization,
and Technology Transfer

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Abstract:

I analyze the manner in which multinational enterprises facilitate technology transfer from the North to the South, and the role played by the protection of intellectual property. Different industries respond to changes in intellectual property protection (IPP) regimes differently, and will alter their mode of entry accordingly. Firms with complex but easily imitable products will tend to internalize production through foreign direct investment, but firms that face a lower risk of imitation will tend to license production to non-affiliated Southern firms. Changes in IPP alter the level and the composition of technology transfer, depending on the value of the firm's proprietary asset.

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1. Introduction

Technological advancements and access to technology are concentrated in the industrialized countries of the world. For example, the fifth of the population living in the wealthiest countries on the planet have 74% of the world's telephone lines and 93.3% of internet users, versus 1.5% and 0.1%, respectively, for the fifth in the poorest countries. Investment in research and development (RD), which provides the impetus for newly innovated goods in a national economy, is just as divergent. In 1993, ten countries hosted 85% of global RD expenditures, and over the past twenty years, these ten countries controlled 95% of U.S. patents. In addition, residents of industrialized countries controlled more than 80% of the patents granted to developing countries (United Nations 1999).

Multinational enterprises (MNEs) play an important role in the development and transfer of new technologies. MNEs invest a significant portion of the world's RD in research facilities generally located in the advanced economies. They realize commercial benefits to this investment by selling the innovated products in the developing world, which often requires a shift in their actual location of production. This shift in production represents a transfer of technology.

The extent of transfer, and manner in which it happens, depends on the level of intellectual property protection (IPP) in the developing world. This model shows that stronger IPP will preserve the monopoly rents of innovation and encourage MNEs to transfer technology to overseas subsidiaries. The response by MNEs to changes in IPP regimes depends on the firm's industry.

1.1 General framework

This paper analyzes the manner in which MNEs facilitate technology transfer from the industrialized countries (North) to the countries just removed from the world's technology frontier (South), and the role played by the level of intellectual property protection (IPP) in the South. I find that

the preferred mode of entry depends on industry-specific characteristics of the firm. Stronger protection of intellectual property leads to an overall increase in technology transfer, but changes its composition.

I define technology transfer in two ways. Firms that undertake foreign direct investment (FDI) by building affiliated overseas plants for the production of newly innovated goods are transferring the *location* of that technology. Firms may also directly license the *control* of technology to non-affiliated plants in the South.¹ These different types of transfer may affect the host economy in different ways. Mansfield (1994), as discussed below, shows that a firm's response to IPP, whether to license or internalize and whether to transfer the latest technology, depends on the industry of that firm.²

This paper addresses the mode of entry, the role of IPP, and the subsequent effects on technology transfer. Each firm begins with a monopoly on the latest quality innovation for its particular good and decides among three ways to service the Southern market - exporting, licensing, and FDI. The influence of IPP on this decision follows the market imperfections surrounding the new innovation. The firm's knowledge of this technical innovation is the proprietary asset that gives it an ownership advantage.³ This knowledge is non-rival, and if the firm cannot preserve the monopoly, others can use it in direct competition. Monopolistic power of the proprietary asset can only exist as long as the good is excludable, which relates directly to the level of IPP.

¹ Imitation of goods could be considered a transfer from location to control.

² The actual impact of FDI or licensing on a host country's growth and/or welfare is a huge question outside the scope of the present paper. I contend that the differences in technology transfer matter, and show the policy implications of IPP on the mode-of-entry decision. Aitken, Hanson, and Harrison (1997) offer a good example of a paper investigating the impact of spillovers from MNE activity. Haddad and Harrison (1993) describe how these effects may differ across industries. Grossman and Helpman (1991), chapter one, provide an excellent discussion of the importance of technology for a host country.

³ Dunning (1981) describes the OLI paradigm of MNE theory, which outlines the primary advantages necessary for a firm to engage in FDI as ownership, location, and internalization advantages.

Imperfect protection allows for this knowledge to leak to competing firms. Commonly, this dissipation of the proprietary asset is referred to as imitation. It could embody the direct copying of an existing good, or the development of a “knock-off” product. A wider scope, or breadth, of IPP prevents imitation. Weaker patent laws allow for closer substitutes to be marketed against the original commodity. An imitating firm must establish a larger distance from the original good in technology space.

Firms can protect the organizational advantage in two ways, either by keeping the knowledge secret, or by patenting and relying on legal means. I assume no reverse engineering of imported goods, so an exporting firm faces no risk of dissipation (although I do include an Appendix that discusses the implications of reverse engineering). Firms choose to shift production overseas if the Southern wage is low enough relative to the North. This relative wage is the location advantage. Firms that shift production to overseas affiliates patent their good to protect new technology. There exists the possibility that Southern firms will be able to develop a knock-off product that dissipates the proprietary asset. The level of IPP in the South affects the probability that this imitation will successfully infringe on the MNE’s ownership advantage.

Firms internalize production, rather than license, for various reasons. Often discussed in the literature are information asymmetries - a firm has a superior product, but cannot find a suitable contract for licensing due to its inability to successfully signal this quality.⁴ Another major factor for the internalization decision, and the one I use, is the fear of the defection of the licensee. Because of the non-rival nature of the technical knowledge, a licensee could defect with the proprietary asset in hand

⁴ Ethier (1986), Horstmann and Markusen (1987), Gallini and Wright (1990), Vishwasrao (1994), and Yang and Maskus (2000c) are all examples of models that use information asymmetries.

and compete with the licensor. Due to this threat, any licensing contract signed will be self-enforcing, wherein terms of the contract are such that the licensee will be better off not defecting. If a self-enforcing contract cannot be found, firms will undertake FDI.⁵ The level of IPP directly influences the conditions on which these contracts can arise.

1.2 Industry Differences

Both the location and the internalization decision by a firm are sensitive to the preservation of their intellectual property. Moreover, this sensitivity depends on the type of industry to which the firm belongs. Maskus (1998b) argues that the main effect of IPP on FDI is the extent to which the regime affects a firm's return on its proprietary asset, which will vary across sectors. Firms with complex but easily imitated technologies will be very sensitive to the level of IPP in the host country, but firms with older or less imitable products will not.

The impact of IPP on firm entry decisions differs considerably across industry, depending on inherent characteristics of the product itself. The greater the imitability of the product, the more important the non-exclusive imperfection. New pharmaceuticals, for example, embody considerable R&D efforts in the composition of each drug. This composition, however, can be mimicked fairly easily. Without adequate protection of the intellectual property embodied by the innovated good, competitors could produce and sell an imitated product and steal the market. A firm producing a good without this easy imitability, such as in metals or machinery, does not have this same fear of imitation and thus less of a dependence on IPP.

The dependence of a firm's decision to transfer technology on IPP differs across industries.

⁵ Ethier and Markusen (1996), Markusen (1999), and Yang and Maskus (2000a) are models that use this self-enforcing

Mansfield (1994) surveyed 100 U.S. firms in six manufacturing industries to compare the impact that the IPP levels of various developing countries have on the decision to transfer technology. He found very little correlation across industries for each country, but considerable positive correlation across countries for each industry. That is, within each country, there was no solid relationship between two different industries as to the importance of the IPP regime. Each industry, however, generally felt a similar dependence on IPP for all the countries. For example, the percentage of chemical firms that said IPP is too weak to permit licensing of their latest technology was highest or second-highest among the six industries for all 14 of the developing countries listed. In the same question, the percentage of metals firms were the lowest of the six for all but one country. Mansfield (1995), a follow-up survey, shows that these industry relationships also hold for German and Japanese firms.

The actual impact of IPP on activities such as research and development varies across industries as well. Levin, et al (1987) shows that, while many industries are greatly responsive to IPP regimes, some, such as the aircraft industry, are hardly affected. In a survey by the U.S. International Trade Commission (1988), 42% of firms (concentrated in the high-technology fields) said patents were “very important” to their business, while 27% of firms said patents were only of “moderate” importance. In many industries, IPP matters little, if at all.

In this paper I capture these cross-sectoral differences by distinguishing MNEs by the *type* of industry they represent. Although the motivation for shifting production to overseas affiliates, and the rents achieved through patent-induced monopolistic control of innovations, may be the same across industries, the relative role for technology transfer by MNEs is not. A firm’s decision to license or

contract mechanism.

internalize production depends on the ease with which their products can be imitated, which is also related to their dependence on protection of their intellectual property. My model shows how industry differentiation of MNEs affects the relevance of IPP policy in the South.

There are two types of firms in the model, differentiated by the relative ease with which their product may be imitated. Some products, such as pharmaceuticals, may embody great technical sophistication but can be easily replicated. I call firms that produce these goods P firms. On the other hand, M firms, such as metals or machinery industries, produce goods that cannot easily be replicated. In the model, different firms choose different modes of entry due to this relative imitability. The products of M firms are by nature difficult to imitate, no matter the legal backing of intellectual property.

Moreover, P and M firms differ in their reactions to IPP levels. Stronger IPP should encourage firms to prefer overseas production due to the expanded protection on their ownership advantage. M firms tend to choose licensing, and P firms to choose FDI, but stronger IPP may cause firms to substitute one for the other. Not only is there an increase in FDI and licensing with stronger IPP, but there is also a change in the composition of technology transfer, depending on parameters.

1.3 Literature review

Theoretical papers on MNEs and IPP generally assume a positive correlation between IPP and foreign direct investment (FDI) flows from the North to the South. Firms that engage in FDI face the risk of the diffusion of their proprietary asset via Southern imitation. In most existing models, IPP makes this imitation more costly, which increases the marginal benefits for FDI. Helpman (1993) models IPP as an explicit reduction in the rate of imitation, while Lai (1998) models it as a percent reduction in an existing rate of imitation. Glass and Saggi (1995) incorporate IPP as increasing the cost of imitation.

Ethier and Markusen (1996) present a model where firms choose between exporting, licensing,

or shifting production to an overseas affiliate. The model identifies the role played by various parameters that affect the arrangement chosen by the firm. Firms want to shift production overseas to avoid transport costs, and may choose to either license to non-affiliated subsidiary or pay the fixed cost of establishing their own subsidiary. In the absence of IPP, firms internalize to avoid the dissipation of their proprietary asset. This dissipation represents technology transfer.

Licensing models in one strand of internalization theory hold that firms face the risk of diffusion by defection of the licensee. Markusen (1999) models IPP under the rubric of contract enforcement. Rents are higher in licensing, but firms again face the risk of the diffusion of their proprietary asset, in this case through defection by the licensed agent. Contract enforcement, or IPP, imposes a cost for defection on the licensed agent, which thus affects the initial decision by the firm to export or license. As IPP increases, the penalty for defection by a licensee increases, and firm is more likely to license. Markusen finds that a developing country will set the level of IPP just high enough to induce entry by the firm.

Glass and Saggi (1997) also model a situation where MNEs face the prospect of defection in the host country. The dissipation of the proprietary asset in their model is not constrained by a level of IPP, but by an efficiency wage paid by the firm. The MNE offers a wage premium high enough to prevent dissipation. If no technology transfer occurs, the welfare benefits to the South of FDI come from higher wages rather than technology transfer. For Yang and Maskus (2000a), IPP affects the licensing decision through both the costs of licensing and the risk of imitation. As IPP increases, both of these features go down. The former leads to a direct increase in the incentive to license, while the latter indirectly increases the incentive by increasing the royalty rate received by the licensing firm. In McDaniel (2000), IPP affects the extent to which imitated products substitute for the original good, a

clear illumination of the breadth of protection.

The empirical literature generally supports this positive correlation between IPP and MNE activity, although studies in this field suffer from the inherent difficulties in assigning quantitative values to various countries' IPP levels.⁶ Ferrantino (1993) uses membership in international patent agreements as a proxy for IPP, and finds that stronger IPP leads to increased licensing royalties. Mansfield (1995) constructs a measure of IPP using the percentage of firms that felt patent protection affected their decision to engage in a joint venture or licensing arrangement with their latest technology. In a simple econometric study, he finds statistical support that stronger IPP, as represented by a lower percentage of firms affected by patent levels, leads to greater FDI outflows from the United States. Maskus (1998a), using the Ginarte-Park index, finds that IPP has a positive, and statistically significant, impact on various U.S. MNE activities in developing countries, including the stocks of sales, exports, and assets held by the affiliates.

Yang and Maskus (2000b) investigate the effects of IPP on both affiliated and unaffiliated licensing. They find that IPP has a significant and positive impact on arms-length royalties and licensing fees, but less significant impacts on intra-firm activities. This latter finding is consistent with internalization theory, which suggests that as IPP increases, firms would be more willing to license their technology to a third party. Smith (1999) performs an empirical analysis that separates the effects of IPP on the three components of the OLI framework. She finds that IPP does improve all forms of bilateral exchange, and also leads to a substitution from exporting to either licensing or production in overseas affiliates.

⁶ Maskus (2000), chapter four, describes in detail the difficulties in "measuring what we cannot see". Although various proxies of IPP have been used for various studies, the two indices that are generally best received are those

Despite the established notion that industries respond to IPP differently, none of the above studies, whether theoretical or empirical, differentiate according to industry characteristics that affect their responses to FDI.⁷ My model clearly distinguishes industries based on inherent characteristics directly related to intellectual property and its protection. The impact of IPP on different firms' entry decisions alters both the level and composition of technology transfer to the South.

2. The benchmark model

2.1 Basics

There are two regions in the world, a North and a South. The North houses all innovating firms, and the South houses all imitating firms. Goods are indexed j along a continuum from $(0,1)$, which means a fixed variety of goods exists, each of which can be improved in quality. For every good a corresponding firm in the North exists that can produce only that good. At the beginning of every time period t , each Northern firm realizes an exogenous innovation on the quality of the good it produces. This quality improves the utility gleaned from the good by the multiplicative value $q > 1$. That is, starting at quality level 1, the next improvement yields a quality q , the next improvement a quality level q^2 , and so on. For every vertical innovation, consumers are willing to pay q times the price of the most recent highest level of quality.

Firms have a monopoly on the innovation, but when the innovation is realized the knowledge of all previous quality levels are dissipated and produced/sold competitively. Thus, at the beginning of

developed by Rapp and Rozek (1990) and Park and Ginarte (1997).

⁷ Markusen (1999) includes an extension with firms that have large fixed costs, so that the optimal level of IPP may be set to induce the entry of the second firm, and Glass and Saggi (1998) model FDI in two states of nature, where the South may be one or two levels away from the technology frontier. Neither of these, however, capture the differences in the nature of the product produced that affect a firm's response to IPP levels.

every time period, firms own the rights to the latest quality level for their particular good, but every other firm in the world can produce and sell the q_{t-1} quality level of the good innovated in the previous time period $t-1$. As shown below, the innovating firms set prices to capture the entire market for each type of good.

2.2 Shifting production

Northern firms choose among three options for servicing the Southern market with the latest innovation, depending on the expected value for each. They can produce the good domestically and then export it, or they can choose to shift production to the South and take advantage of lower factor costs.⁸ For simplicity, I assume no transportation costs in the model.⁹

If the relative wage is attractive enough for firms to shift production, they can choose between licensing the new technology to a Southern firm, or by internalizing production within their own subsidiary. I call any firm that shifts production a multinational enterprise. If they do internalize production within an affiliated subsidiary, I call the activity FDI. Firms choose between licensing and FDI depending on characteristics of the Southern market and their own industry. If FDI is chosen, the firm must pay a fixed cost F to cover the establishment of a new plant and faces the possibility that imitation will lead to dissipation of the firm's proprietary asset.¹⁰ There can be no imitation of exported goods in this model.¹¹

⁸ In contrast to Hortsman and Markusen (1987), who use a "licensee cost advantage" for both licensing and FDI to occur in equilibrium, I assume symmetry of marginal cost for all Southern production.

⁹ Appendix A.1 works through the fundamental equations of the model with a parameter for trade costs. I show that this parameter adds complexity to the basic model without additional theoretical insights. Transportation costs can be understood simply as part of the wedge between relative wages.

¹⁰ Vishwasrao (1994) assumes firms that internalize cannot be imitated, while those that license face the possibility of imitation. I allow for the defection of a licensee, but such that it will not occur in the presence of a self-enforcing contract. Imitation of FDI allows the model to capture the influence of IPP on the exporting versus FDI decision.

¹¹ I show in Appendix A.2 the changes in the model if reverse engineering is possible.

If a firm chooses to license, it avoids any explicit fixed costs or risk of dissipation. These costs and risks are covered by the firm offering a self-enforcing contract to the licensee, so that remaining under contract is more attractive to the producing firm than defecting and starting a rival plant. The costs of this plant, and the risk of defection, are thus implicitly covered in the rent-sharing contract. Under licensing, the MNE receives the royalty rate r from its sales of the good, with the rate determined by outside parameters.

The benefits and costs for the three modes of entry are outlined in table 1. Exporting firms produce in their domestic plant, so they pay no fixed costs for production. With no reverse engineering, they also maintain secrecy of their technology and thus do not face any risk of dissipation of their proprietary asset. In addition, they earn the full rents from the sales of the good. These rents, however, are lower than if production were shifted, due to the higher marginal cost of production in the North.

Licensing firms benefit from the lower Southern wages and thus earn higher rents. They only earn the royalty rate r from the sales of their goods, which implicitly captures the fixed costs of production and the risk of defection by the licensee.¹² Firms that engage in FDI earn the full rents from Southern production, not having to split them with a licensee. The disincentives for FDI include the fixed cost F of establishing the overseas subsidiary and the risk of imitation by a Southern firm.

Table 1: The three modes of entry

Mode of Entry	Benefits	Costs
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¹² Markusen (1999) and McDaniel (2000) both assume fixed costs for both FDI and licensing, where the fixed cost of licensing is lower. This assumption makes sense, but there is no necessary relationship between these two fixed costs in my model.

Exporting	<ul style="list-style-type: none"> • Pay no fixed costs • Face no risk of dissipation • Earn full rents 	<ul style="list-style-type: none"> • Pay higher marginal cost $w > 1$
Licensing	<ul style="list-style-type: none"> • Pay lower marginal cost • No explicit fixed costs • No explicit risk of dissipation 	<ul style="list-style-type: none"> • Earn $r\%$ of rents, with implicit fixed costs and implicit risk of dissipation
FDI	<ul style="list-style-type: none"> • Pay lower marginal cost • Earn full rents 	<ul style="list-style-type: none"> • Pay fixed cost F • Face risk of dissipation m

The incentives for exporting decrease with the relative wage between the North and the South.

The higher this relative wage, the lower the rents achieved with Northern production, and the more likely for a firm to shift production overseas. The relative wage serves as the primary determinant for the location of production.

The decision between licensing and FDI depends on other variables, independent of the relative wage since both use the same costs of production. The incentives for licensing increase as r increases, and the incentives for FDI increase as F or m decrease. As shown below, the incentive for FDI relative to licensing also increases with the rents from overseas production.

Each time period breaks down into two stages. The first stage involves a two-part decision by the firm whether to export or shift production depending on the relative wage. If the firm decides to shift production, it chooses between licensing and FDI. In the second stage, a firm that has chosen overseas production faces the risk of dissipation. For a licensing firm, the rent-sharing contract is set so that this never occurs if the contract is accepted. For a firm that has internalized production, this imitation risk occurs at probability m , which is determined in part by the level of IPP.

Exporting yields rents E in each stage.¹³ Production overseas as a monopoly earns rents R , while production overseas after dissipation earns duopoly rents D . Licensing firms earn R in each stage, but receive only $r\%$ of the rents. MNEs earn the rents $(R-F)$ in the first stage, when the asset is protected, but earn R with probability $(1-m)$ and D with probability m in the second. I assume firms are risk-neutral, so they are indifferent between the expected returns and the actual returns. That is, a firm considers the expected return $(1-m)R + mD$ to be equivalent to the actual value $(1-m)R + mD$.

A firm will choose to shift production if the returns to exporting $2E$ are lower than either the returns to licensing and FDI. MNEs that engage in FDI earn first-stage rents $(R-F)$ and the second-stage rents $(1-m)R+mD$. Licensing firms earn total rents $r(2R)$. Thus, the firm will choose to shift production if the following two conditions hold

$$(1) \quad (R-F) + (1-m)R + mD > 2E$$

and

$$(2) \quad r[2R] > 2E.$$

If both inequalities for (1) and (2) hold, the firm will choose between licensing and FDI based on the expected returns from both. The firm will choose to license if:

$$(3) \quad r[2R] > (R-F) + (1-m)R + mD.$$

2.3 Profit Equations

Following Grossman and Helpman (1991), both the quantity and the quality of each good consumed provides utility for the time period t . Consider, across all goods, the instantaneous logarithmic utility function and budget constraint,

¹³ I assume no discounting occurs within time periods (i.e., between stages).

$$(4) \quad \log u(t) = \int_0^1 \log \left[\sum_k q_k(j) x_{kt}(j) \right] dj \quad s.t. \int_0^1 p_j x_j dj = w_s L_s,$$

where $q_k(j)$ is the quality level k of good j consumed, and $x_{kt}(j)$ is the amount of quality level k of good j consumed at time t . The innovations improve a good relative to itself, so without loss of generality the naught quality level can be normalized $q_0(j)=1$ leaving $q_k(j)=q^k$, where the last term is not a superscript but an exponent.

Goods perfectly substitute across type, which means consumers spread their purchases evenly along the product line. For each type of good j , they purchase only the quality level sold for the lowest price per unit of quality. In Bertrand competition, innovating firms are able to ensure this lowest price is always for the latest quality level, capturing the entire market.

Firms compete in price to differentiate the type of each good they are selling. The goods q_{-1} and below are produced and sold competitively by firms throughout the world. Since the lowest marginal cost is the Southern wage, these goods are priced w_s . For simplicity, normalize everything to this wage, so that $w_s = 1$. The advantage of having the innovated good is reflected in the premium consumers are willing to pay for the new good, which in this case is q times the price of the next quality level below it. Profit-maximizing firms thus charge $(q-\epsilon)w_s$, capturing the entire market. As $\epsilon \rightarrow 0$, this limit price is $q^*w_s = q$.

With symmetrical demand for all varieties of goods j , consumers split their income evenly along the continuum. Thus, the quantity sold depends only on the size of the Southern market L_s .

$$(5) \quad x_j = L_s / p_j.$$

Profits are given by the difference between price and cost times quantity.

$$(6) \quad \text{Profit} = (p_j - w_j) * \frac{L_s}{p_j} .$$

The only difference between exporting profits (E) and MNE profits (R) is the wage paid, since the price p_j does not change. Define the relative wage $w \equiv w_n/w_s = w_n$ so that

$$(7) \quad E = (q * w_s - w_n) \frac{L_s}{q * w_s} = (1 - \frac{w}{q}) L_s$$

$$(8) \quad R = (q * w_s - w_s) \frac{L_s}{q * w_s} = (1 - \frac{1}{q}) L_s .$$

With this Bertrand competition, a second competitor bids the price down to cost. In this case, duopoly profits following imitation go to zero. Note then,

$$(9) \quad D = 0$$

$$(10) \quad R - E = (w - 1) \frac{L_s}{q} .$$

From (1), firms choose FDI over exporting if $2(R-E) - F > m(R-D)$. Plugging in for (R-E) and (R-D) yields

$$(11) \quad 2(w - 1) \frac{L_s}{q} - F > m \frac{L_s}{q} (q - 1)$$

which simplifies to

$$(12) \quad w > 1 + F \frac{q}{2L_s} + \frac{m(q - 1)}{2} .$$

A firm will prefer FDI to exporting if the relative wage is high with respect to the right-hand side of (12). The value of the wage that determines this decision increases as F or m increase. When the disincentives for FDI are higher, a larger difference between Northern and Southern wages is necessary

to induce overseas production.

(12) can be simplified with division by $(q-1)$, without changing the relationship between the variables. Since there is no loss of generality, I will continue to refer to $w/(q-1)$ as the relative wage.

This division yields

$$(13) \quad \frac{w}{q-1} > \frac{1}{q-1} + \frac{F}{2R} + \frac{m}{2}.$$

Thus, an increase in the rents of overseas production R lowers the relative wage w necessary to induce FDI over exporting.

From (2), firms choose licensing over exporting if $rR > E$. Plugging in for R and E yields

$$(14) \quad r \frac{L_s}{q} (q-1) > \frac{L}{q} (q-w)$$

which simplifies to

$$(15) \quad w > q - r(q-1)$$

or

$$(16) \quad \frac{w}{q-1} > \frac{q}{q-1} - r.$$

A firm prefers licensing to exporting if the wage is high relative to the right-hand side of (16). This tendency towards licensing increases with r , since as a firm enjoys higher returns they will be more likely to license even at lower wages.

From (3), a firm prefers licensing to FDI if $r[2R] > 2R - mR - F$, which simplifies to

$$(17) \quad \frac{F}{2R} + \frac{m}{2} > 1 - r.$$

The preference of licensing over FDI increases with the fixed costs of FDI, the probability of imitation,

and the royalty rate, but decreases with the rents from overseas production.

If the relative wage is such that only one of (13) and (16) hold, the firm chooses the mode of entry determined by that wage. If (16) holds but (13) does not, the firm prefers licensing to exporting, and exporting to FDI. This suggests that

$$(18) \quad \frac{1}{q-1} + \frac{F}{2R} + \frac{p}{2} > \frac{w}{q-1} > \frac{q}{q-1} - r,$$

which can be rearranged to show that (17) also holds. That is, if licensing is preferred to exporting, and exporting to FDI, then licensing is preferred to FDI.

Similarly, if (13) holds but (16) does not, the firm prefers FDI to exporting, exporting to licensing, and thus FDI to licensing. The firm would choose FDI. If neither (13) nor (16) hold, the firm chooses to export. If both equations hold, the firm chooses to shift production, deciding between FDI and licensing depending on the relative values of (17). Notice that the relative wage does not affect this decision - in this case, the Southern wage is low enough relative to the North that the firm will not export at all, and only decides how to utilize Southern labor.

2.4 The royalty rate

The royalty rate r implicitly captures elements of the licensing contract. For licensing to occur, the firm must be able to set a self-enforcing contract so that the returns to it, based on the royalty rate, are greater than the returns to FDI or exporting. I set up a simple exposition of this contract, based on Markusen (1995, 1999).

I assume there is no cost to the contract, and that the royalty rate must be set at the same value of r for both periods. As part of the contract the licensee always pays the production cost G , earns the rents from production, but pays a percentage r to the licensor. In the first period, the licensee thus earns

$(1-r)R - G$.

If the licensee defects, it obtains new rents, but must pay the cost G for new production facilities. Suppose that it also must pay a defection cost d that enables the firm to circumvent existing laws on intellectual property.¹⁴ This cost may cover the R&D necessary to produce a good that is perfectly competitive with the MNE's good, using information only available in the licensing contract. I assume d rises with IPP levels.

The MNE cannot defect from the contract, and if the licensee defects the MNE receives no rents. This would be true if there were no lag time between stages for the MNE to find a new contract or build a new plant. Since there are no duopoly profits in the model, the MNE is left without an enforceable contract and without an ability to produce its product.

Thus, an MNE will only engage in licensing if there is no defection, which can only be prevented with a self-enforcing contract. With no defection, the licensee earns $(1-r)R$ in the second stage. With defection, the licensee earns $R-G-d$. To ensure no defection, the contract is set so that $(1-r)R \geq R-G-d$, or $r \leq (G+d)/R$. The MNE maximizes its return by setting $r = (G+d)/R$.

2.5 Relative wage and the probability of imitation

Firms choose among the three modes of entry depending on various parameters of the model. The relative wage determines whether firms will produce domestically or overseas, while the probability of imitation determines whether overseas production takes the form of licensing or FDI. The effects of these two factors are related to the parameters q , R , F , and r .

The likelihood for licensing depends on the probability of imitation, which lies between 0 and 1.

¹⁴ This is similar to Gallini and Wright (1990) and Yang and Maskus (2000c), where the licensee's ability to imitate depends on the level of IPP.

From (17), a clear relationship exists as to whether a firm will ever consider licensing or FDI in equilibrium. If

$$(19) \quad \frac{F}{2R} > 1 - r,$$

then a firm will always prefer licensing to FDI, even if the probability of imitation is zero. I refer to (19) as the “no-FDI” condition.

Similarly, if

$$(20) \quad \frac{F}{2R} + \frac{1}{2} < 1 - r,$$

then a firm will prefer FDI to licensing even if $m = 1$, when they are assured of imitation. I thus refer to (20) as the “no-licensing” condition. Notice that since $F/(2R) > 0$, then if $r > 1/2$ then this condition does not hold and licensing is a possibility.

Suppose F , R , and r are such that neither (19) nor (20) hold, which leads to the “split-decision” condition

$$(21) \quad 1 - r > \frac{F}{2R} > \frac{1}{2} - r.$$

Both FDI and licensing can take place in equilibrium if the inequalities in (21) hold.

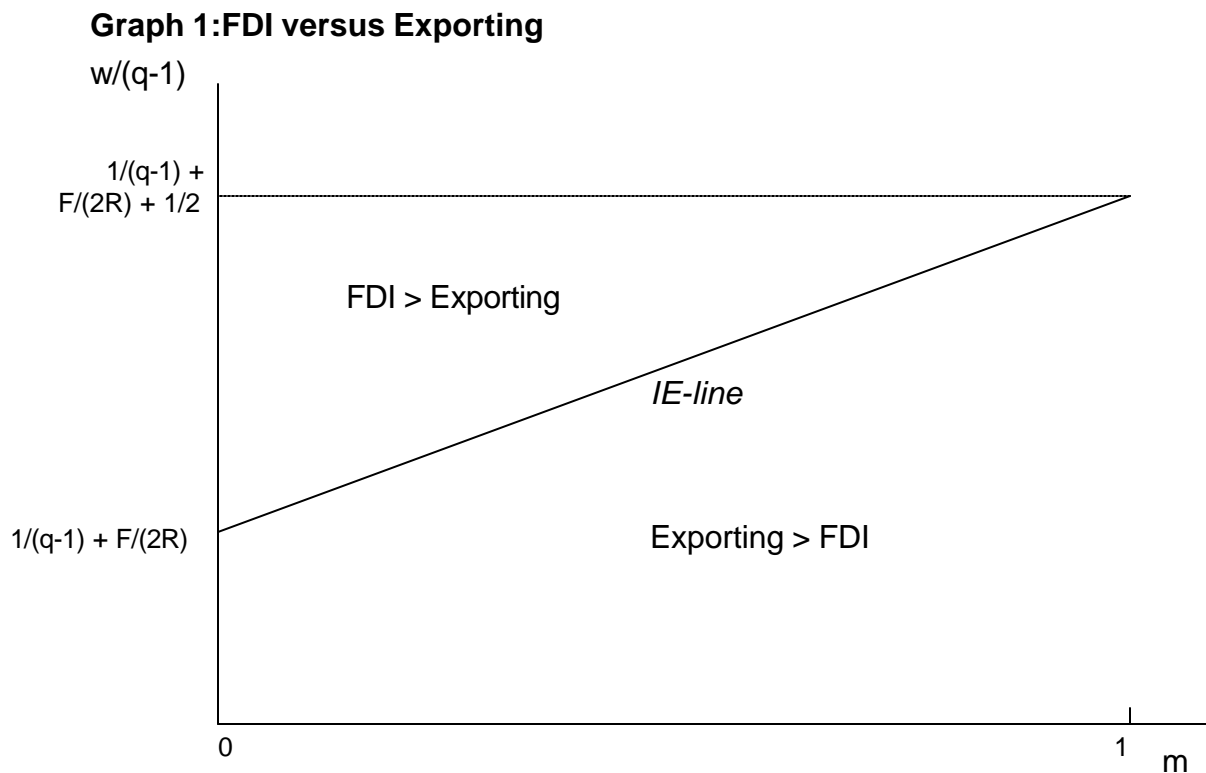
2.5.1 The IE decision

The regions of parameters that support exporting, FDI, and licensing as the preferred mode of entry can be graphed across the relative wage and the probability of imitation. A firm is indifferent between exporting and FDI if (13) holds with equality, that is

$$(22) \quad \frac{w}{q-1} = \frac{1}{q-1} + \frac{F}{2R} + \frac{m}{2}.$$

Graph 1 depicts this relationship, drawing $w/(q-1)$ on the vertical axis, and m on the horizontal axis.

The IE line (I for “internalize”) maps all the points at which a firm is indifferent between exporting and FDI. If the relative wage is below this line, the difference in factor costs between the two regions is not large enough to shift production, and the firm chooses to export. If the relative wage is above this line, the firm prefers FDI to exporting. The slope of the line is $1/2$.



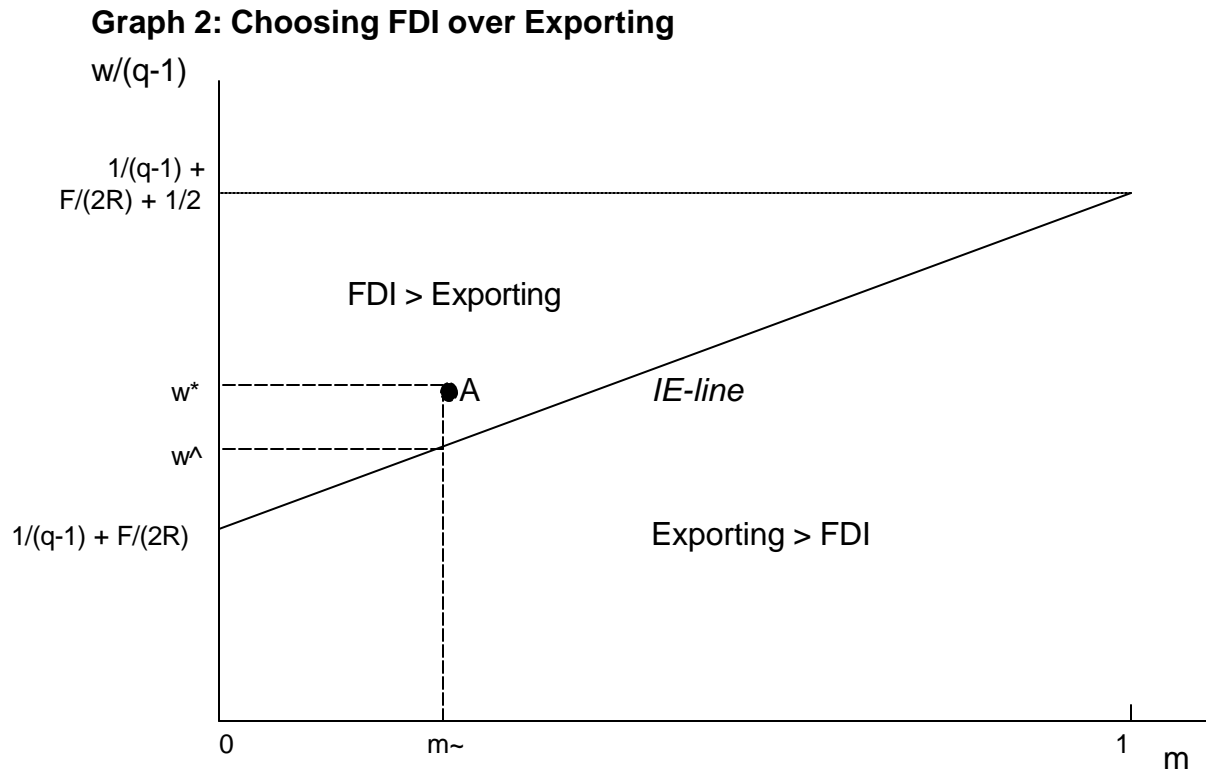
A firm knows the value of F , q , and R , in addition to m . Using this knowledge, it bases the IE decision on the relative wage prevailing in the economy. I call this the *actual wage* w^* , which the firm takes as given.

The parameters F , q , and R determine the IE-line in graph 1. For each value of m , there is a corresponding value of w that would make the firm indifferent between exporting and FDI. I call this

the *indifference wage* w^\wedge . The wage w^\wedge can be solved from (22), for a given set (F, q, R) and for any value of m . The IE-line plots the values for w^\wedge .

If $w^* > w^\wedge$, then the actual wage faced by the firm is greater than the wage which would make it indifferent between exporting and FDI at that probability m . This higher wage makes FDI attractive to the firm. The set of these wages are in the region of graph 1 where $FDI > Exporting$.

Suppose a firm faced the probability of imitation m^\sim , as shown in graph 2, with an actual wage w^* . The point of decision is point A. For this m^\sim , the relative wage that would make the firm indifferent between FDI and exporting is w^\wedge . Since as drawn $w^* > w^\wedge$, the firm will choose FDI.



If $w^\wedge > w^*$, then the actual wage is lower than the indifference wage, and the firm would choose to export. This set of points is in the Exporting > FDI region of graph 1. If $w^* = w^\wedge$, equation (22) holds, the firm is on the IE-line, and is thus indifferent between FDI and exporting.

The effects of parameter changes can be seen in graph (2). If the fixed cost increases, then the IE-line shifts upward. This raises w^\wedge - a higher wage is necessary to induce FDI. Firms are now more likely to export for a given w^* . If the shift in the IE-line moved w^\wedge above w^* , the firm would no longer engage in FDI in the presence of the higher fixed cost.

An increase in m also diminishes the tendency for a firm to choose FDI over exporting. If firms face a higher risk of imitation, a higher indifference wage is necessary for (22) to hold. Consider a shift to the right for m in graph (2). The indifference wage w^\wedge rises along the IE-line, and if the shift is large enough then the firm will eventually choose to export.

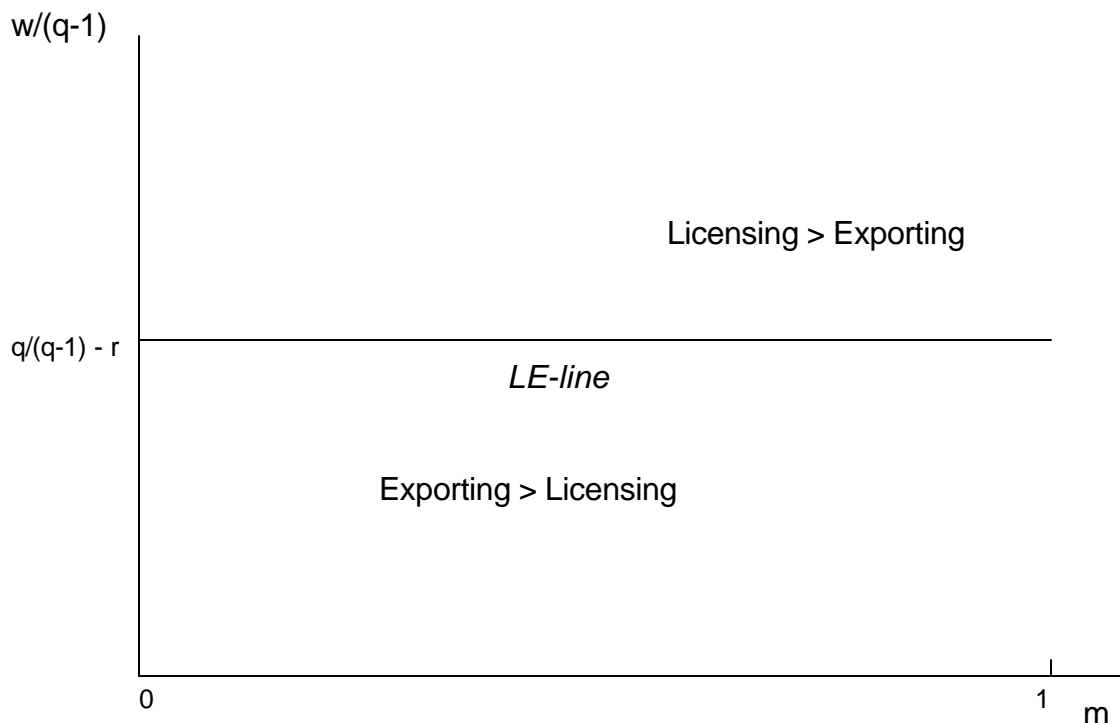
2.5.2 The LE decision

A firm is indifferent between exporting and licensing if (16) holds with equality, when

$$(23) \quad \frac{w}{q-1} = \frac{q}{q-1} - r$$

This relationship is independent of m , thus the LE-line is horizontal in graph 3. If the relative wage faced by the firm is above this line, the firm prefers licensing to exporting, and if the wage is below this line the firm prefers exporting.

Graph 3: Licensing versus Exporting



Since m does not affect the returns to licensing or exporting, it does not affect the LE decision.

For any given m , a firm will choose L or E based entirely on the relative wage. Thus, the licensing indifference wage is fixed at $q/(q-1) - r$.

An increase in the royalty rate improves the tendency towards licensing. If r increases, the $q/(q-1) - r$ decreases, and the LE-line shifts down. For a given equilibrium wage, the firm is more likely to choose licensing.

2.5.3 The IL decision

A firm chooses between FDI and licensing based on the probability of imitation, and is indifferent if equation (17) holds with equality,

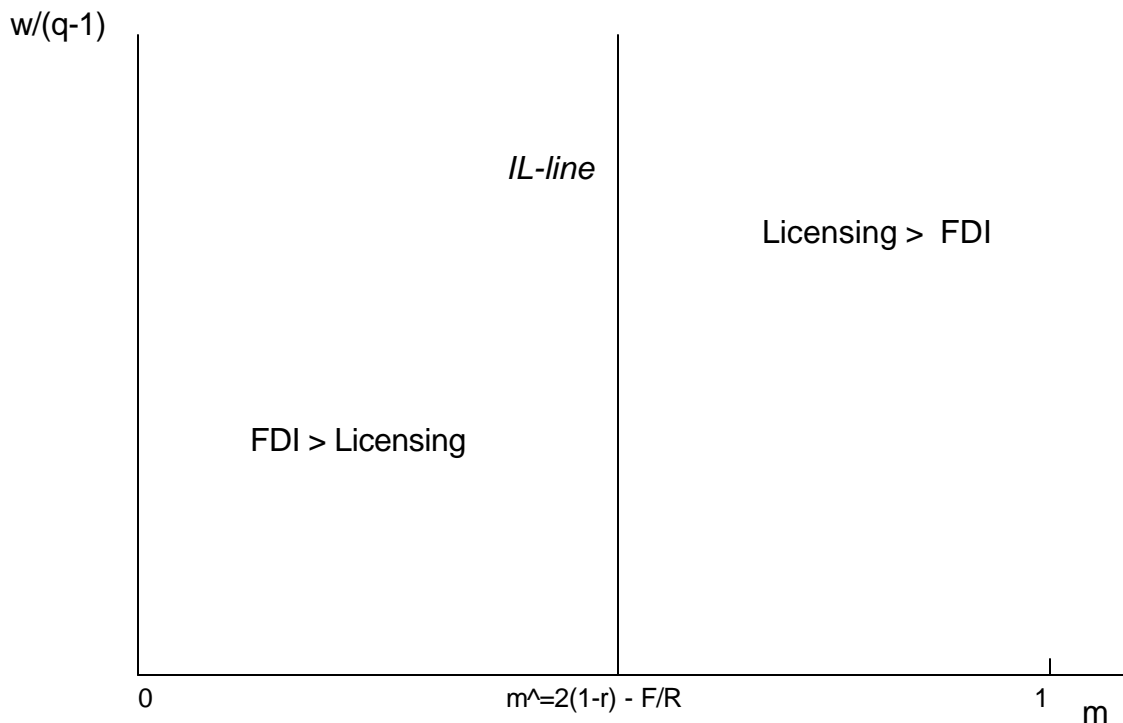
$$(24) \quad \frac{F}{2R} + \frac{m}{2} = 1 - r,$$

which gives the indifference probability

$$(25) \quad m^{\wedge} \equiv 2(1-r) - \frac{F}{R}$$

This relationship is independent of the relative wage, which graph 3 depicts as a vertical line. If the probability of imitation lies to the left of the IL line, a firm prefers to internalize its production. If m lies to the right, a firm will license. Notice that $0 < m^{\wedge} < 1$, or the decision is trivial. If $m^{\wedge} < 0$, then the “no-FDI” condition (19) holds, and if $m^{\wedge} > 1$ then the “no-licensing” condition (20) holds.

Graph 4: FDI versus Licensing



The IL decision only matters if a firm has already chosen overseas production, and is thus independent of the equilibrium wage. This decision depends entirely on the indifference probability m^{\wedge} . If the actual probability m^* faced by the firm is higher, then the firm chooses a licensing contract. If $m^* < m^{\wedge}$, the firm chooses FDI.

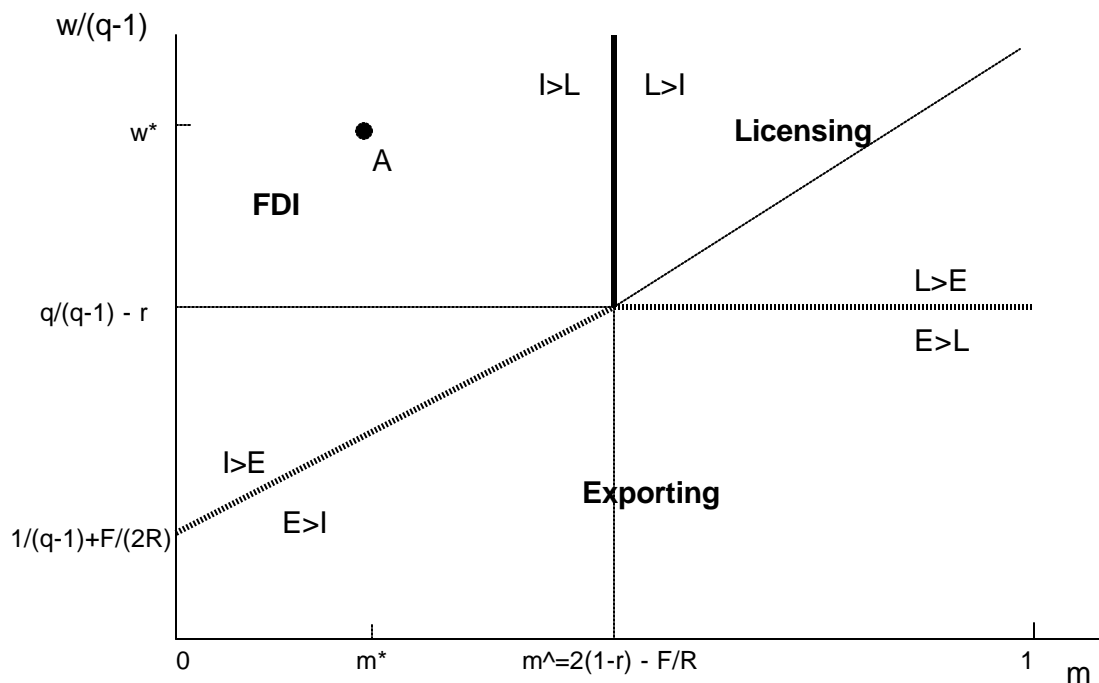
As before, an increase in F diminishes the tendency towards FDI, and an increase in r improves the tendency to license. For either of these changes, the IL-line shifts left, and for a given (w^*, m^*) the

firm will be more likely to license.

Tri-entry decision

The full decision for the firm includes all three of these relationships. Graph 5 shows the necessary relationships between w and m for a firm to license, export, or engage in FDI.

Graph 5: FDI, Licensing, and Exporting



Consider a firm that faces the actual wage w^* and the probability of imitation m^* , so that its point of decision - A clearly falls in FDI space. In this situation $w^* > w^\wedge$, so equation (13) holds and the firm prefers FDI to exporting, and $m^* < m^\wedge$, so equation (17) does not hold and the firm prefers FDI to licensing. The firm chooses to engage in FDI.

3. Industries

3.1 Differentiating industries

The model differentiates industries according to how easily a firm's innovation can be imitated by a competitor, which in turn affects their dependence on IPP. M firms are in industries that enjoy

natural barriers to imitation, and are thus relatively free from the threat of imitation, no matter the level of IPP. P firms, however, are in industries vulnerable to imitation of their latest quality innovations, and would require a higher level of IPP to protect the rents from innovation.

These industry differences affect both the licensing and the FDI decision. For FDI, the primary effect is a higher fixed cost F . Higher costs indicate natural barriers for protection, so as F rises then the risk of imitation should fall. Thus, the secondary effects on m follows the fixed costs F , where $m=m(F)$ and $m'(F)<0$.¹⁵ For the same reasons I assume $F_M>F_P$, I set $G_M>G_P$, and thus $r_M>r_P$. M industries have a lesser fear of defections, so they can set contracts for a higher r .

Industries that differ according to their fixed cost F , and in turn their probability of imitation m , face different relative wages that would make them indifferent between FDI and exporting. Industries that differ according to their cost G , and in turn their royalty rate r , face different relative wages that would make them indifferent between licensing and exporting. These changes also influence the decision between FDI and licensing by shifting the imitation level which leaves the firm indifferent. For M industries, the IE line shifts up, the LE line shifts down, and the IL line shifts left, with the opposite shifts for P industries. Moreover, the actual risk of imitation m^* faced by the firm would change. Not only are the regions changing, but the point of decision is changing. The tendencies towards each of the modes of entry depend on which effect dominates - the increased fixed cost, the decreased probability of imitation, or the royalty rate.

3.2 Changes in the firm's decision

3.2.1 IE changes

¹⁵ Teece (1976), chapter three, investigates the costs of technology transfer. Summary statistics of his survey data indicate that the costs for chemicals and petroleum industries, which are closer to my P industries, are lower than for

As industries differ according to the fixed cost F they realize different relative wages that would make them indifferent between FDI and exporting. The indifference wage w^* depends on industry-specific parameters. Whether this wage is higher in the M or the P industry depends on the magnitude of dm/dF .

The IE indifference wage, as shown in (22) above, depends on (F, q, R) as well as m . That is, $w = w(F, m, q, R)$. Since the parameters of interest are F and m , this can be rewritten

$$(26) \quad w = w(F, m(F); q, R).$$

Differentiating w with respect to F gives

$$(27) \quad dw/dF = \partial w/\partial F + \partial w/\partial m * dm/dF.$$

From (22) it is obvious that $\partial w/\partial F > 0$ and $\partial w/\partial m > 0$. The assumption that $dm/dF < 0$, however, suggests that the sign on (27) is ambiguous, depending on the magnitude of dm/dF .

Differentiating equation (22) provides a specific representation of (27):

$$(28) \quad dw/dF = (q-1) \left[\frac{1}{2R} + \frac{1}{2} (dm/dF) \right].$$

If (28) equals zero, there is no difference in the relative wage across industries and the changes in F and m offset each other. In this situation,

$$(29) \quad \frac{1}{2R} = -\frac{1}{2} (dm/dF) = \frac{1}{2} |dm/dF|.$$

Rewriting this,

$$(30) \quad |dm/dF| = \frac{1}{R}.$$

machinery industries.

Thus, the sign on dw/dF depends on the magnitude of dm/dF relative to $1/R$. This gives the following three cases:

Case (i): $dw/dF > 0$ if $|dm/dF| < 1/R$

Case (ii): $dw/dF = 0$ if $|dm/dF| = 1/R$

Case (iii): $dw/dF < 0$ if $|dm/dF| > 1/R$.

In case (i), the higher fixed cost dominates the lower probability of imitation, so that M firms will need a higher relative wage to engage in FDI. In case (iii), the effect on the probability dominates, so that firms will engage in FDI at a lower relative wage. For P firms, the opposite is true. Firms that are more imitable, but with lower fixed costs, will tend to engage in FDI in case (i) and export in case (iii). In case (ii), the direct and indirect effects offset each other, and the industry differences do not affect the IE decision.

The expression R , for monopoly rents, plays an important role in a firm's decision-making. Here, it affects how the IE decision responds to industry differentiation, while above it was shown to affect the general IL decision. Essentially, R captures the value of the proprietary asset, and thus the extent of its loss by imitation. If this value is large, the effect of m would tend to dominate all expressions, such as in case (iii).

The effects of industry differentiation can best be seen in the shifts away from a point of indifference. Consider two firms that are both indifferent between FDI and exporting, and realize a shift in their industry complexities. One firm increases in complexity, becoming an M firm with a higher F and a lower m , and the other firm becomes a P firm. Applying subscripts to these changes yields $F_M > F_P$ and $m_M < m_P$.

Since both firms were originally on the IE-line, then for both the actual wage w^* was equal to

their indifference wage before the shift. That is,

$$(31) \quad \frac{w^*}{q-1} = \frac{\hat{w}}{q-1} = \frac{1}{q-1} + \frac{F}{2R} + \frac{m}{2}$$

for both industries.

Both firms, formerly indifferent between FDI and exporting, now realize a preference for one over the other. Whether the decision is exporting or FDI depends on the magnitude of dm/dF . In case (i), an increase in F leads to an increase in the indifference wage. Thus, for M firms,

$$(32) \quad \frac{w_M}{q-1} = \frac{1}{q-1} + \frac{F_M}{2R} + \frac{m_M}{2} > \frac{w^*}{q-1}$$

Notice that since F increases for M firms and decreases for P firms, each will have an opposing tendency towards each activity. For P firms in case (i),

$$(33) \quad \frac{w_P}{q-1} = \frac{1}{q-1} + \frac{F_P}{2R} + \frac{m_P}{2} < \frac{w^*}{q-1}$$

Graphically, changing F from a point of indifference means shifting the IE-line. For P firms, the line shifts right, and for M firms it shift left. On this new graph, however, the probability of imitation m also moves, since it depends on F . The actual decision of each firm – whether to export or engage in FDI – depends on which changes more, m or F .

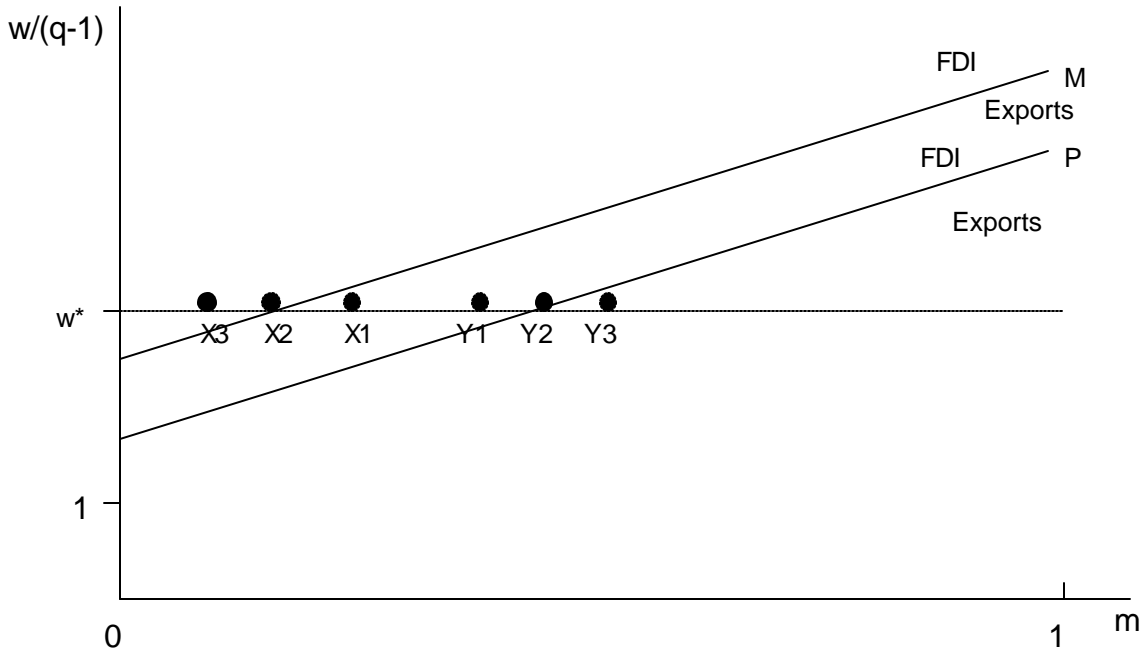
In case (i), $|dm/dF| < 1/R$, and an increase in F leads to an increase in the indifference wages. For M firms, this means the indifference wage is now *higher* than the relative wage, and they will choose to export. The point of decision for M firms in case (i) is X^1 . As can be seen in graph 6, it is a point where m_M does not change as much as F_M when shifting from indifference.

For P firms, the opposite is true. In case (i), although m_P does not shift as much as F_P , the

indifference wage is *lower* than the relative wage, and the point of decision Y^1 clearly lies in FDI space.

P firms choose to engage in FDI.

Graph 6: The IE decision with industry differentiation

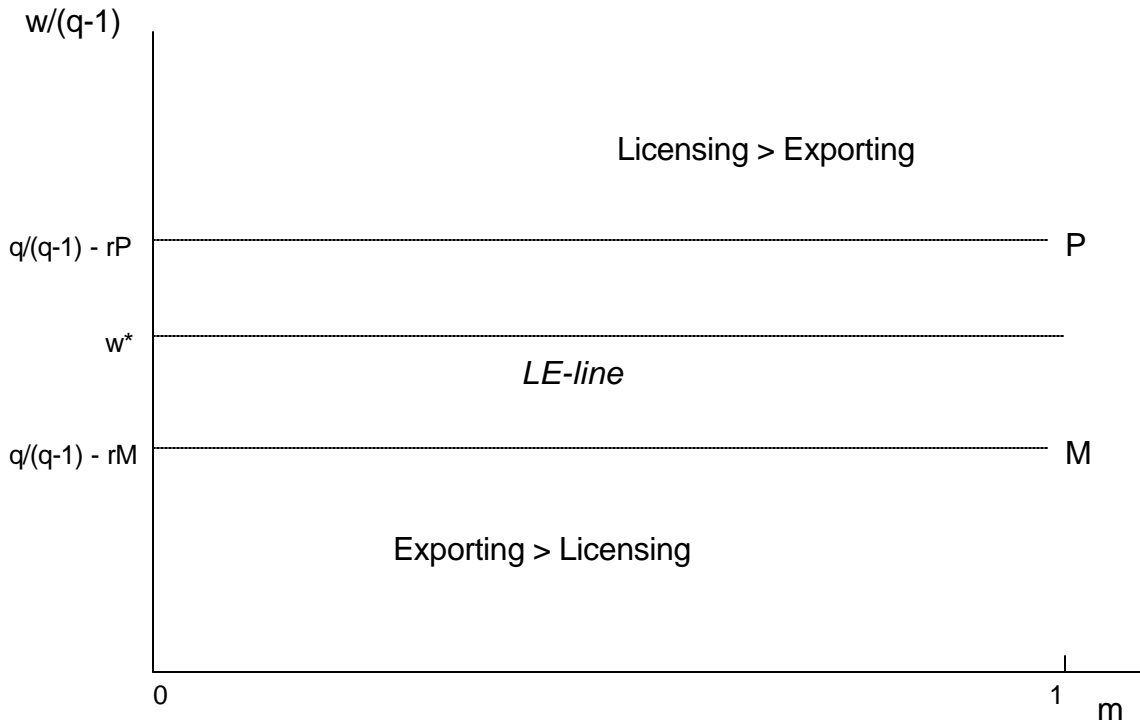


In case (ii), the changes in F and m are perfectly offsetting, and both firms remain indifferent, as shown by points X^2 and Y^2 . In case (iii), m shifts *more* than F , yielding points X^3 and Y^3 . Clearly, in this case M firms engage in FDI and P firms choose to export.

3.2.2 EL decision

A similar analysis determines how industry differentiation affects the decision between exporting and licensing. Consider starting from indifference, where the firm faces the relative wage indicated by (23). Differentiating industries raises the royalty rate for M firms, and lowers it for P firms. Thus, the LE-line shifts up for P firms and down for M firms, as depicted in graph 8. Since the actual wage w^* does not change, P firms will choose exporting over licensing, and M firms will choose licensing over exporting.

Graph 7: The LE decision with industry differentiation



3.2.3 IL changes

The effects of industry differentiation on the decision between FDI and licensing is slightly more complicated, due to the effects on both modes of entry. Again, start with two firms that are both on their indifference line. That is, for both firms, the probability of imitation they face is the same as the indifference probability,

$$(34) \quad m^* = 2(1 - r) - \frac{F}{R} .$$

Notice that the term on the right-hand side of (34) has been defined as m^\wedge in (25) above. The firm actually faces probability m^* , which in general can be higher or lower than the probability m^\wedge that makes it indifferent between FDI and licensing. Industry differentiation changes both m^* and m^\wedge , with the effects on the decision of the firm depending on which changes more. As discussed, these decisions are affected both by the change in F , which changes m , and the change in G , which changes r . I discuss

each of these effects in turn.

Consider first the effects of industry-specific changes in F from the point of indifference along the IL-line, leaving r constant. Like the IE case above, the underlying factor is the magnitude of dm/dF relative to the monopoly rents R . Fully differentiating (34) with respect to F yields

$$(35) \quad dm / dF = -\frac{1}{R}$$

or

$$(36) \quad \frac{1}{R} - |dm / dF| = 0$$

In case (i), (36) is positive, so that an increase in F leads to a larger increase in the left-hand side of (34) than the right-hand side. The rising fixed costs dominate the lowered probability. The indifference probability for M industries grows larger than the actual risk of imitation they face. Thus, $m^* > m^\wedge$ and licensing is preferred to FDI, as given by

$$(37) \quad m_M^* > m_M^\wedge = 2(1-r) - \frac{F_M}{R}$$

M firms are affected more by the increased fixed cost than the lowered probability.

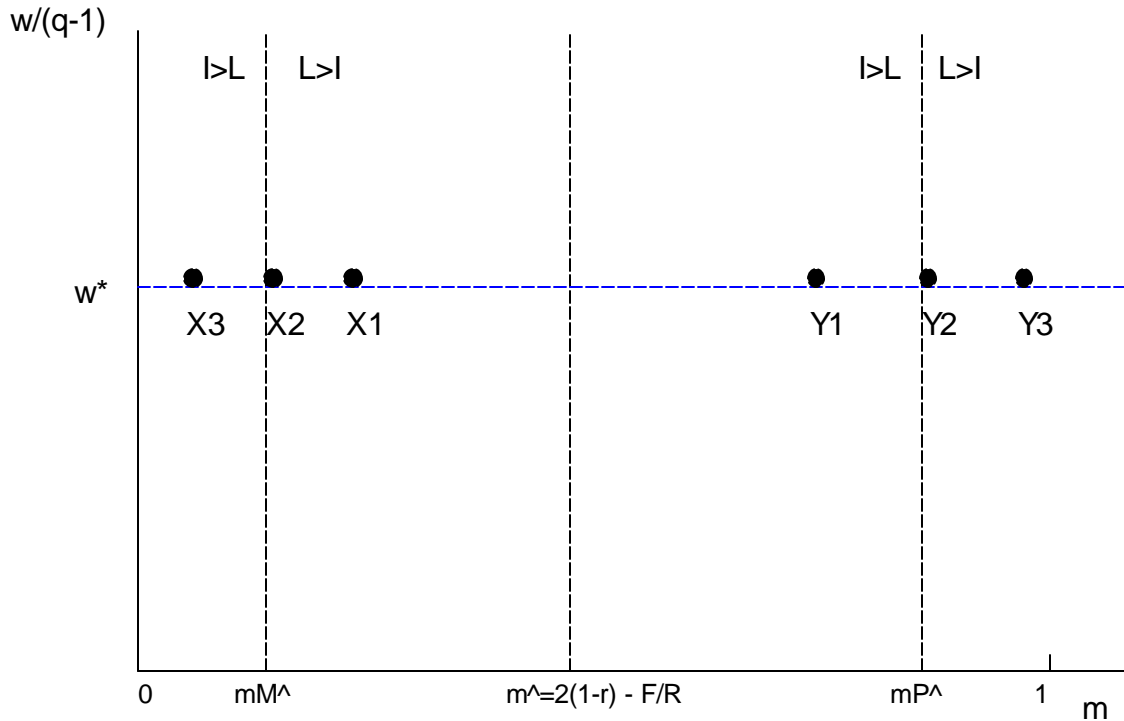
For P firms, however, in case (i) a lowered fixed cost means the indifference probability drops more than the actual risk of imitation, and they are more likely to choose FDI, as given by

$$(38) \quad m_P^* < m_P^\wedge = 2(1-r) - \frac{F_P}{R}$$

In case (iii), the opposite is true. If $|dm/dF| > 1/R$, M firms realize a higher *indifference* probability and choose to engage in FDI. P firms realize a higher *actual* probability and choose to license. In case (ii), the changes offset, and firms remain indifferent. Graph 8 depicts the IL decision

with industry differentiation when r is held constant. Notice that after industry differentiation, both firms face different indifferent probabilities m^\wedge as well as different actual probabilities m^* . This differs from the IE decision, in which industry differentiation leads to changes in the indifference wages w^\wedge but does not affect the equilibrium wage w^* .

Graph 8: The IL decision with Industry Differentiation



Now consider the effects of changes in r . Industry differentiation raises r for M firms, and lowers r for P firms. This does not affect the actual probability of imitation m^* for either firm, but lowers the indifferent probability m^\wedge for M firms and raises m^\wedge for P firms. In graph 8, the full lines shift outward, further from the original m^\wedge .

In case (i), the changes on the royalty rate only exacerbate the influence of industry differentiation already taking place in the shifts in F . For M firms, m^\wedge drops further beyond X^1 , and for P firms m^\wedge rises even further past Y^1 . In case (ii), the changes in the royalty rate, however, make

licensing more attractive to M firms and FDI more attractive to P firms. The shift in the full lines in graph 8 put X^2 in licensing space, and Y^2 in FDI space.

In case (iii), the changes in the royalty rate work contrary to the influences of the changes in F. In graph 8, the m^{\wedge} lines for both the M firms and the P firms move closer to the points X^3 and Y^3 . At some point the effects of the royalty rate will dominate.¹⁶ Under this condition, M firms will *always* prefer licensing to FDI, and P firms will *always* prefer to internalize. I call this the “internalization effect”.

3.2.4 Full Effects of Industry Differentiation

The full effects of industry differentiation for the three cases are shown in table 2, with the ultimate decision of the firm shown in the bottom row. In case (i), licensing dominates for M firms and FDI dominates for P firms. In case (ii), licensing again dominates for M firms. For P firms starting from a point of indifference, a lowered fixed cost and raised royalty rate will still leave them indifferent between exporting and FDI. This divergence follows the special property of case (ii), where the effects on the fixed cost and the relative wage are off-setting, leaving firms on the EI-line.

Table 2: The different cases of industry differentiation

	Case (i)		Case (ii)		Case (iii)	
<u>Decision</u>	M firms	P firms	M firms	P firms	M firms	P firms
EI	exports	FDI	indifferent	indifferent	FDI	exports
EL	licenses	exports	licenses	exports	licenses	exports
IL	licenses	FDI	licenses	FDI	FDI/license*	licenses
Prefers:	Licenses	FDI	Licenses	Export/FDI indifferent	I vs L*	Exports

¹⁶This exact point cannot be found without assuming a relationship between F and G.

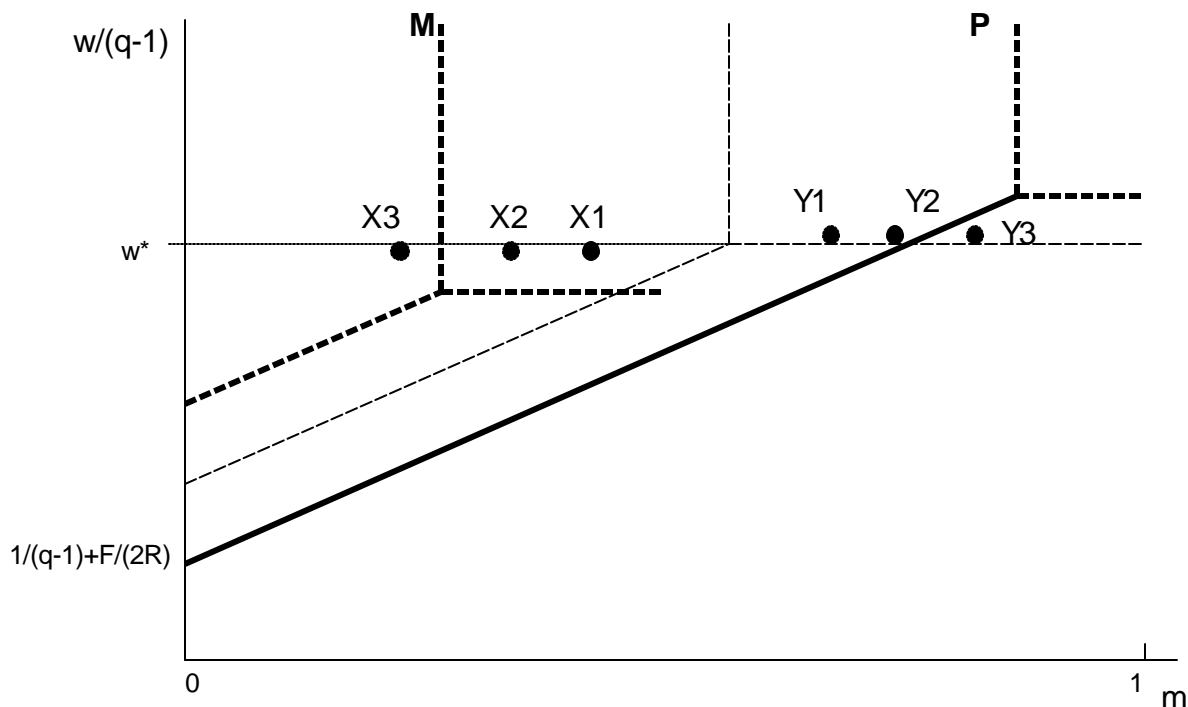
* Depends on the “internalization effect”

– In case (iii), exporting dominates for P firms, but M firms will prefer FDI or licensing depending on the internalize effect. If the only effects considered are on the fixed costs, M firms will choose FDI over licensing and thus engage in FDI. As discussed above, however, for a large enough royalty rate, M firms will shift their preference to licensing. This changes their ultimate decision, since both FDI and licensing are preferred to exporting for M firms in case (iii). For P firms, exporting is preferred, no matter the position of m^* .

Graph (9) shows the combined effects of industry differentiation in cases (i) - (iii). The only significant difference among the graphs is the position of the industry-specific m^* , since the actual dimensions are the same in all three cases. For M firms, the licensing and exporting spaces grow at the expense of FDI space, and for P firms the FDI space grows at the expense of both licensing and exporting. I indicate the original dimensions of graph 5 with a dashed line.

In case (i), the probabilities do not shift as much as the IL-line, leading to the points of decision X^1 and Y^1 for M and P firms, respectively. Based on the actual wage, M firms thus decide to license and P firms to engage in FDI. In case (ii), the probabilities shift along the IL-line, leaving P firms indifferent between exporting and licensing when facing the actual wage w^* . M firms are clearly in licensing space, due to the shift down in the EL-line.

Graph 11: Full effects of industry differentiation



In case (iii), P firms clearly find themselves in exporting space no matter the position of their IL-line (the m^* that depends on the royalty rate). As drawn, M firms find themselves to the left of the IL-line, and would choose to internalize. The actual result, however, depends on the “internalization effect”. If the line were shifted to the left, it would eventually reach the point where M firms would ultimately choose to license.

4. Intellectual property protection and technology transfer

4.1 The relative wage and mode of entry

The bottom row of table 2 shows the mode of entry a firm will choose when the actual wage faced by the firm takes the value w^* . Under these conditions, M firms will never export, and will only engage in FDI if the “internalization condition” is not met. P firms will never license, and decide between exporting and FDI depending on the value of $|dm/dF|-1/R$.

I have defined two aspects of technology transfer. The shifting of production via FDI is a change in the *location* of technology, while the direct licensing of a product is a shift in *control*.¹⁷ In this model, the M industries are more likely to license their technology, and P industries are more likely to engage in FDI. Note that these tendencies do not depend on the relative wage, as shown in table 3. As w changes, the decision to export or shift production changes, but the manner of shifting production does not change. The decision to license or engage in FDI is independent of the relative wage.

Table 3: Different relative wages

	M firms			P firms		
	<u>case (i)</u>	<u>case (ii)</u>	<u>case (iii)</u>	<u>case (i)</u>	<u>case (ii)</u>	<u>case (iii)</u>
High w	license	license	license	FDI	FDI	FDI
$w=w^*$	license	license	license/FDI*	FDI	Export~FDI	Export
Low w	export	export	export	export	export	Export

* Depends on “internalization” effect

4.2 Intellectual property protection

The Southern government can influence technology transfer through its IPP regime. Two methods exist in the model: 1) altering the ability to imitate products after FDI, and 2) changing the costs to defection from a licensing contract. Both of these methods represent the scope, or breadth, of patent protection. With a small scope for protection, imitating or defecting firms can easily introduce a competing product that closely substitutes for the existing good. As the scope of protection increases,

¹⁷ The imitation of a product could also be considered a shift in control, but as mentioned above I do not consider it in the present analysis.

further costs of imitation are involved. In the model, this means that stronger IPP yields a lower m^* and a higher r (from the higher d) for both firm types.

Considered independently, any lowering of the imitation rate m^* shifts the firm's decision point further into FDI space. For firms already engaging in FDI, such as P firms in case (i), the change in IPP does not affect their entry decision. For other firms, such as M firms in case (i), a low enough m^* may induce a change from licensing to FDI.

A shift in r (through d) does not change the point of decision, but shifts the lines that define the decision space for the firm. The LE-line shifts down as r increases, and the IL-line shifts left. There is no change along the IE-line, since r plays no role in the direct FDI versus exporting decision. This results in an expansion of the licensing space at the expense of both FDI and exporting space. For firms that already license, this has no effect, but for firms that either export or engage in FDI, this could induce a change to licensing.

The two elements of IPP both lead to higher levels of technology transfer, but have different influences on the composition of technology transfer. If m goes down or r goes up, then both M firms and P firms will be more likely to shift production overseas. M firms generally demonstrate a propensity to license, and P firms to engage in FDI. Whether these tendencies change with IPP depends on parameters of the model.

Consider the situation of case (i) when the relative wage is w^* , as depicted in graph 11. Stronger IPP shifts m^* left for both types of firms, which increases the tendency towards FDI, but also expands the licensing space for each firm. Before any IPP changes, P firms prefer FDI to licensing because

$$(39) \quad 2(1 - r_p) - \frac{F_p}{R} > m_p^*.$$

A strengthening of IPP increases r and lowers m^* , so that both sides of (39) decrease. For the tendency towards licensing to increase with a change in IPP, the change in the right-hand side of (39) must grow relative to the change in the left-hand side. Fully differentiating (39) so that the change for the right-hand side is larger yields

$$(40) \quad -2dr_p > dm_p,$$

which can be rearranged to show

$$(41) \quad dm/dr < -2,$$

where the subscripts are dropped since this is a general relationship.

To get an explicit representation of the effects of IPP changes, consider the conjecture $r = (G + \delta)/R$. Fully differentiating (39) again yields

$$(42) \quad -\frac{2}{R} d\mathbf{d} > dm,$$

or

$$(43) \quad \left| \frac{dm}{d\mathbf{d}} \right| > \frac{2}{R}.$$

If (43) holds, then an increase in IPP increases a firm's tendency towards licensing. If it does not hold, then an increase in IPP increases a firm's tendency towards FDI. Note that the latter is more likely for a large R , which follows from the previous result that greater monopoly rents increases a firm's tendency to choose FDI over licensing.

5. Conclusion

This model shows the effects of intellectual property protection on technology transfer, when

multinationals can choose between FDI and licensing. I extend the present literature to include industry-specific characteristics of the good produced, which affect both the entry decision and the response to varied IPP regimes.

Industries with large fixed costs but a low risk of imitation, such as metals, are more likely to enter a market through licensing, while industries with a high risk of imitation, such as pharmaceuticals, are more likely to enter a market through FDI. Policy changes that affect the scope of intellectual property tend to increase the overall level of technology transfer through FDI and licensing. Moreover, different IPP regimes alter the composition of technology transfer, depending on the monopoly rents of new innovations.

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Appendix A

Appendix A.1 Transportation costs and non-traded goods

For simplicity, I have assumed zero transportation costs in the main model. In this section, I show that including these costs simply adds a nuisance parameter to the model. Reproduce the fundamental equations (1) – (3) as

$$(A1) \quad (R-F) + (1-m)R + mD > 2E$$

$$(A2) \quad r[2R] > 2E.$$

$$(A3) \quad r[2R] > (R-F) + (1-m)R + mD.$$

Suppose exporting firms had to pay a transportation cost τ for each good sold. The marginal cost for Northern production becomes $w_n\tau$, with a relative cost difference $w_n\tau/w_s = w\tau$. Rewriting the profit equations (7) and (8)

$$(A4) \quad E = (1 - \frac{w}{q}\mathbf{t})L_s$$

$$(A5) \quad R = (1 - \frac{1}{q})L_s.$$

Thus, (10) becomes

$$(A6) \quad R - E = (w\mathbf{t} - 1)\frac{L_s}{q}.$$

Plugging this into the IE-line (A1) and the LE-line (A2) yields

$$(A7) \quad \frac{w}{q-1}\mathbf{t} > \frac{1}{q-1} + \frac{F}{2R} + \frac{m}{2}$$

$$(A8) \quad \frac{w}{q-1}\mathbf{t} > \frac{q}{q-1} - r.$$

The IL-line does not change. Transportation costs simply scale the relative wage upward.

Notice that some values of τ lead to the presence of non-traded goods in the model. This occurs if exporting is preferred to FDI and licensing (neither A7 nor A8 hold) but exporting yields negative rents due to the high transportation costs. If exporting yields negative rents, then

$$(A11) \quad \left(1 - \frac{w}{q}\tau\right)L_s < 0;$$

thus, goods are non-traded if $\tau > q/w$.

Appendix A.2 Reverse engineering

In the main paper, I have assumed that exporting firms are free from the risk of imitation. This assumption, common in the literature, greatly simplifies the overall equations without reducing the model's explanatory power. In this section, I show the results when considering the possibility of reverse engineering.

Suppose exporting firms face the risk of imitation μ . The expected rents from exporting, formerly 2E, are now

$$(A12) \quad E + (1-\mu)E + \mu D,$$

$$= 2E - \mu E$$

The IE-line from (1) can be rewritten

$$(A13) \quad 2(R-E) - F > mR - \mu E.$$

Plugging in the profit equations (7) and (8) yields

$$(A14) \quad \frac{w}{q-1} > \frac{1}{q-1} + \frac{F}{2R} + \frac{m}{2} - \frac{\mu}{2} \left(\frac{q-w}{q-1}\right).$$

The IE-line shifts down, making firms more likely to prefer FDI to exporting.

Similarly, the LE-line from (2) can be rewritten

$$(A15) \quad r[2R] > 2E - \mu E.$$

Plugging in for the profit equations yields

$$(A16) \quad \frac{w}{q-1} > \frac{q}{q-1} - \frac{2}{2-m} r.$$

The LE-line shifts down, making firms more likely to prefer licensing to exporting.

As would be expected, the possibility for reverse engineering that lowers the returns to exporting decreases the regions in (w, m) space that firms would be likely to export. An interesting addendum to this discussion considers the possibility that reverse engineering and imitation after FDI occur at the same rate, if $\mu = m$. In this scenario, the IE-line can be written

$$(A17) \quad \frac{w}{q-1} > \frac{1}{q-1} + \frac{F}{(2-m)R}$$

and the LE-line can be written

$$(A18) \quad \frac{w}{q-1} > \frac{q}{q-1} - \frac{2}{2-m} r.$$

The presence of m as a variable in the denominator of the equations of these two lines makes graph 5 considerably more complicated. The IE-line is now increasing and convex, with the IL-line decreasing and concave. The firm's decision-making process, however, does not change.