

Incomplete Contracts and the Product Cycle

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Abstract

The incomplete nature of contracts governing international transactions limits the extent to which the production process can be fragmented across borders. In a dynamic, general-equilibrium Ricardian model of North-South trade, contract incompleteness is shown to lead to the emergence of product cycles. Goods are initially manufactured in the North, where product development takes place. As the good matures and becomes more standardized, manufacturing is shifted to the South to benefit from lower wages. Following the property-rights approach to the theory of the firm, the same force that creates product cycles, i.e. incomplete contracts, opens the door to a parallel analysis of the determinants of the mode of organization. As a result, a new version of the product cycle emerges, in which manufacturing is shifted to the South first within firm boundaries, and only at a later stage to independent firms in the South. Relative to a world with only arm's length transacting, allowing for intrafirm production transfer by multinational firms is shown to accelerate the shift of production towards the South, while having an ambiguous effect on relative wages. The model delivers macroeconomic implications that complement the work of Krugman (1979). I also discuss several microeconomic implications of the model and relate them to the empirical literature on the product cycle.

Keywords International Trade, Product Cycle, Property-rights theory, Multinational Firms.

JEL Classification Numbers D23, F12, F14, F21, F23, L22, L33

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1 Introduction

In an enormously influential article, Vernon (1966) described a natural life cycle for the typical commodity. Most new goods, he argued, are initially manufactured in the country where they are first developed, with the bulk of innovations occurring in the industrialized, high-wage North. Only when the appropriate designs have been worked out and the production techniques have been standardized is the locus of production shifted to the less developed South, where wages are lower. Vernon emphasized the role of multinational firms in the international transfer of technology. In his formulation of a product's life cycle, the shift of production to the South is a profit-maximizing decision from the point of view of the innovating firm.

The "product cycle hypothesis" soon gave rise to an extensive empirical literature that searched for evidence of the patterns suggested by Vernon.¹ The picture that has emerged from this literature has turned out to be much richer than originally envisioned by Vernon. The evidence indeed supports the existence of product cycles, but it has become clear that foreign direct investment by multinational firms is not the only vehicle of production transfer to the South. In particular, the literature has identified several instances in which technologies have been transferred to the South through licensing, subcontracting, and other similar arm's length arrangements. More interestingly, several studies have pointed out that the choice between intrafirm and market transactions is significantly affected by both the degree of standardization of the technology and the transferor's resources devoted to product development.² In particular, overseas assembly of relatively new and unstandardized products tends to be undertaken within firm boundaries, i.e. through foreign direct investment, while innovators seem more willing to resort to licensing and subcontracting in standardized goods with little product development requirements.

The product cycle hypothesis has also attracted considerable attention among international trade theorists eager to explore the macroeconomic and trade implications of Vernon's insights. Krugman (1979) developed a simple model of trade in which new goods are produced in the industrialized North and exchanged for old goods produced in the South. In order to concentrate on the effects of the product cycle on trade flows and relative wages, Krugman (1979) specified a very simple form of technological transfer, with new goods becoming old goods at an exogenously given Poisson rate. This "imitation lag," as he called

¹See Gruber et al. (1967), Hirsch (1967), Wells (1969), and Parry (1975) for early tests of the theory.

²See, for instance, Davidson and McFetridge (1984, 1985), Mansfield et al. (1979), Mansfield and Romeo (1980), Vernon and Davidson (1979), and Wilson (1977). These studies will be discussed in more detail later in the paper.

it, was later endogenized by Grossman and Helpman (1991a,b) using the machinery developed by the endogenous growth literature. In particular, Grossman and Helpman (1991a,b) developed a model in which purposeful innovation and imitation gave rise to endogenous product cycles, with the timing of production transfer being a function of the imitation effort exerted by firms in the South. As the empirical literature on the product cycle suggests, however, the bulk of technology transfer is driven by voluntary decisions of Northern firms, which choose to undertake offshore production within firm boundaries or transact with independent subcontractors or licensees.³

In this paper, I provide a theory of the product cycle that is much more akin to Vernon's (1966) original formulation and that delivers implications that are very much in line with the findings of the empirical literature discussed above. In the model, goods are produced combining a hi-tech input, which I associate with product development, and a low-tech input, which is meant to capture the simple assembly or manufacturing of the good. As in Grossman and Helpman (1991a,b), the North is assumed to have a high enough comparative advantage in product development so as to ensure that this activity is always undertaken there. My specification of technology differs, however, in one important respect from that in Grossman and Helpman (1991a,b). In particular, I treat product development as a continuously active sector along the life cycle of a good. The concept of product development used here is therefore quite broad and is meant to include, among others, the development of ideas for improving existing products, marketing and advertising. Following Vernon (1966), this specification of technology enables me to capture the standardization process of a good along its life cycle. More specifically, I assume that the contribution of product development to output (as measured by the output elasticity of the hi-tech input) is inversely related to the age or maturity of the good. Intuitively, the initial phases of a product life cycle entail substantial testing and re-testing of prototypes as well as considerable marketing efforts to make consumers aware of the existence of the good. As the good matures and production techniques become standardized, however, the mere assembly of the product becomes a much more significant input in production.

Following Vernon (1966) and contrary to Grossman and Helpman (1991a,b), I allow

³Grossman and Helpman (1991b) claimed that their model generated realistic predictions about the evolution of market shares and the pattern of trade in a given industry. Indeed, as they point out, purposeful imitation by low-wage countries has been an important driving force in the transfer of production of micro-processors from the United States and Japan to Taiwan and Korea. Based on recent studies, I will argue below, however, that even in the case of the electronics industry, the spectacular increase in the market share of Korean exports is better explained by technology transfer by foreign-based firms than by simple imitation by domestic Korean firms.

Northern firms to split the production process internationally and transact with manufacturing plants in the South.⁴ With no frictions to the international fragmentation of the production process, I show that the model fails to deliver a product cycle. Intuitively, provided that labor is paid a lower wage in the South than in the North, manufacturing will be shifted to the South even for the most unstandardized, *product-development intensive* goods. Vernon (1966) was well aware that his theory required some type of friction that limited offshore assembly. In fact, he argued that in the initial phase of a product's life cycle, overseas production would be discouraged by a low price elasticity of demand, the need for a thick market for inputs, and the need for swift and effective communication between producers and suppliers.

This paper will instead push the view that what limits the international fragmentation of the production process is the incomplete nature of contracts governing international transactions. Building on the seminal work of Williamson (1985) and Grossman and Hart (1986), I show that the presence of incomplete contracts creates a hold-up problem, which in turn gives rise to suboptimal relationship-specific investments by the parties involved in a transaction. The product development manager of a Northern firm can alleviate this type of distortions by keeping the manufacturing process in the North, where contracts can be better enforced. In choosing between domestic or overseas manufacturing, the product development manager therefore faces a trade-off between the lower costs of Southern manufacturing and the distortions coming from incomplete contracting, which are shown to affect both the manufacturing *and* the product development inputs in production. This trade-off is shown to lead naturally to the emergence of product cycles: when the good is new and unstandardized, Southern production is very unattractive because it bears the full cost of incomplete contracting with little benefit from the lower wage in the South. Conversely, when the good is mature and requires very little product development, the benefits from lower wages in the South fare much better against the distortions from incomplete contracting, and the good is produced in the South.

The model focuses first on the profit-maximizing choice of location by a single Northern product development manager. I then embed this choice in a general-equilibrium, dynamic

⁴There is a recent literature in international trade documenting an increasing international disintegration of the production process. A variety of terms have been used to refer to this phenomenon: the "slicing of the value chain", "international outsourcing", "vertical specialization", "global production sharing", and many more. Feenstra (1998) discusses the widely cited example of Nike. In 1994, Nike employed around 2,500 U.S. workers in management, design, sales, and promotion, while leaving manufacturing in the hands of some 75,000 workers in Asia. Interestingly, Nike subcontracts most parts of its production process, so that the production plants in Asia are not Nike affiliates and their 75,000 workers are not Nike employees.

Ricardian model of North-South trade with a continuum of industries that standardize at different rates. The model solves for the timing of production transfer for any given industry, as well as for the time path of the relative wage in the two countries. In spite of the rich heterogeneity in industry product-cycle dynamics, the cross-sectional picture that emerges from the model is very similar to that in the Ricardian model with a continuum of goods of Dornbusch, Fischer and Samuelson (1977). In contrast to the exogenous cross-industry and cross-country productivity differences in their model, comparative advantage arises here from a combination of the Northern productivity advantage in product development, the continuous standardization of goods, and the fact that contracts are incomplete.

Following the lead of Krugman (1979), I study the effect of an acceleration of technological change in the North on the world distribution of income. I show that his result that increased technological change widens the wage differential greatly depends on technological change taking the form of the introduction of new products into the economy. If, instead, technological change takes the form of an increase in the rate at which goods standardize, I show that the converse result is true and relative wages move in favor of the South. I next analyze the welfare implications of a shift from a steady-state equilibrium with incomplete contracts to a steady-state equilibrium with complete contracts. This improvement in the contracting environment in international transactions is shown to unambiguously increase welfare in the South, while having an ambiguous effect on Northern welfare.

Following the property-rights approach to the theory of the firm (Grossman and Hart, 1986, Hart and Moore, 1990), the same force that creates product cycles, i.e. incomplete contracts, opens the door to a parallel analysis of the determinants of ownership structure. As in Grossman and Hart (1986), I associate ownership with the entitlement of some residual rights of control. When parties undertake noncontractible, relationship-specific investments, the allocation of residual rights has a critical effect on each party's *ex-post* outside option, which in turn determines each party's *ex-ante* incentives to invest. Ex-ante efficiency (i.e., transaction-cost minimization) then dictates that residual rights should be controlled by the party whose investment contributes most to the value of the relationship. As a result, a new version of the product cycle emerges. If the threshold *product-development intensity* at which manufacturing is shifted to the South is high enough, production transfer will occur within the boundaries of the Northern firm by establishing a wholly-owned foreign affiliate. In such case, at a later stage in the product cycle, the product development manager finds it optimal to give away these residual rights of control, and the assembly will be assigned to an independent subcontractor in the South, an arrangement which is analogous to the

Northern firm licensing its technology (hi-tech input). For a lower *product-development intensity* threshold, i.e., for a higher maturity of the good at the time of the transfer, the model predicts that the transfer to the South will occur directly at arm's length, and multinationals will not arise.

Solving for the general equilibrium with multinational firms, I show that, relative to a world in which only arm's length or licensing transactions are allowed, the introduction of intrafirm production transfer by multinational firms accelerates the shift of production towards the South, while having an ambiguous effect on relative wages. Furthermore, provided that its effect on relative wages is small enough, the emergence of multinational firms is shown to be welfare improving for both countries. I finally discuss how the equilibrium timing of production transfer, as well as the choice between intrafirm and arm's length production transfer, are affected by several parameters in the model and discuss the empirical validity of these predictions.

The model is useful for understanding the evolution of the Korean electronics industry after the Korean War.⁵ In the early 1960s, Korean electronic firms were producing mostly low-quality consumer electronics for their domestic market. The industry took off in the late 1960s with the establishment of a few large U.S. assembly plants, almost all wholly owned, followed in the early 1970s by substantial Japanese investments. These foreign subsidiaries tended to assemble components exclusively for export using imported parts.⁶ In this initial phase, foreign affiliates were responsible for 71% of exports in electronics, with the percentage reaching 97% for the case of exports of integrated circuits and transistors, and 100% for memory planes and magnetic heads. In the 1970s and 1980s domestic Korean firms progressively gained a much larger market share, but the strengthening of domestic electronic companies was accompanied by a considerable expansion of technology licensing from foreign firms. Indeed, as late as 1988, 60% of Korean electronic exports were recorded as part of an Original Equipment Manufacturing (OEM) transaction.⁷ The percentage approached 100% in the case of exports of computer terminals and telecommunications equipment. Korean giants such as Samsung or Goldstar were heavily dependent on foreign licenses and OEM agreements even up to the late 1980s.

There is also some evidence that Northern firms did not license their leading edge tech-

⁵The following discussion is based on Bloom (1992), UNCTAD (1995, pp. 251-253), and Cyhn (2002).

⁶Motorola established a production plant in Korea in 1968. Other U.S.-based multinationals establishing subsidiaries in Korea during this period include Signetics, Fairchild and Control Data.

⁷OEM is a form of subcontracting which as Cyhn's (2002) writes "occurs when a company arranges for an item to be produced with its logo or brand name on it, even though that company is not the producer".

nologies to their Korean licensees. For instance, in 1986, Hitachi licensed to Goldstar the technology to produce the 1-megabyte Dynamic Random Access Memory (DRAM) chip, when at the same time it was shifting to the 4-megabyte DRAM chip. Similarly, Phillips licensed the production of compact disk players to ten Korean producers, while keeping within firm boundaries the assembly of their deck mechanisms.

The rest of the paper is structured as follows. Section 2 focuses on a simple dynamic model that shows how the presence of incomplete contracts gives rise to product cycles. For simplicity, I initially abstract from the choice of ownership structure by allowing only arm's length production transfer to the South. In section 3, I embed this simple model in a general-equilibrium model of North-South trade and study the effects of incomplete contracting on relative wages and the speed of technology transfer. In section 4, I allow for intrafirm technology transfer and describe the richer product life cycle that emerges from it, both in partial and in general equilibrium. I discuss several implications of the model and relate them to the empirical literature on the product cycle. Section 5 concludes. The proofs of the main results are relegated to the Appendix.

2 Incomplete Contracts and the Life Cycle of a Product

This section describes a situation in which a product development manager has to decide how to organize production of a particular good, taking the behavior of other producers as well as wages as given. I will first analyze the static problem, and then show how a product cycle emerges in a dynamic extension in which the good gets standardized over time.

2.1 Set-up

Environment There are two countries, the North and the South, and a single good y produced only with labor. I denote the wage rate in the North by w^N and that in the South by w^S . Consumer preferences are such that the unique producer of good y faces the following iso-elastic demand function:

$$y = \lambda p^{-1/(1-\alpha)}, \quad 0 < \alpha < 1 \quad (1)$$

where p is the price of the good and λ is a parameter that the producer takes as given.⁸

Production of good y requires the development of a special and distinct hi-tech input x_h , as well as the production of a special and distinct low-tech input x_l . As discussed in the introduction, the hi-tech input is meant to comprise research and product development,

⁸This demand function will be derived from preferences in the general-equilibrium model.

marketing, and other similar skill-demanding tasks. The low-tech input is instead meant to capture the mere manufacturing or assembly of the good. The specialized inputs can be of good or bad quality. If any of the two inputs is of bad quality, the output of the final good is zero. If both inputs are of good quality, production of the final good requires no additional inputs and output is given by:

$$y = \zeta_z x_h^{1-z} x_l^z, \quad 0 \leq z \leq 1, \quad (2)$$

where $\zeta_z = z^{-z} (1-z)^{-(1-z)}$.

The unit cost function for producing the hi-tech input varies by country. In the North, production of each unit of a good-quality, hi-tech input requires the employment of one unit of Northern labor. The South is much less efficient at producing the hi-tech input. In fact, the productivity advantage of the North is assumed large enough to ensure that x_h is only produced in the North. Meanwhile, production of one unit of low-tech input also requires labor, but the unit input requirement is assumed to be equal to 1 for both countries. Finally, production of any type of bad-quality input can be undertaken at a positive but negligible cost.

Both the hi-tech and the low-tech inputs are freely tradable.

Firm Structure: There are two types of producers: a research center and a manufacturing or assembly plant. A research center is defined as the producer of the hi-tech input. It follows that the research center will always locate in the North. The research center needs to contract with an independent manufacturing plant for the provision of the low-tech input. I allow for an international fragmentation of the production process, so that the research center can choose to transact with an independent assembly plant in the North or with one in the South. The timing of events is as follows. Before any investment is made, a research center decides whether to produce a hi-tech input, and if so, whether to match with an assembly plant in the North, or match with an assembly plant in the South. The manufacturer makes, upon entry, a lump-sum transfer T to the research center.⁹ I assume that ex-ante there is large number of identical, potential manufacturers of the good, so that competition among them makes T adjust so as to make the chosen manufacturer break even. The research center chooses the location of manufacturing to maximize its ex-ante profits.

⁹If the final good is produced by the manufacturing plant, this transfer T can be interpreted as licensing fee for the use of the hi-tech input.

Investments are assumed to be relationship-specific. The research center tailors the hi-tech input specifically to the assembly plant, while the low-tech input is customized according to the specific needs of the research center. In sum, the investments in labor needed to produce x_h and x_l are incurred upon entry and are useless outside the relationship.

Contracting environment: The setting is one of incomplete contracts in situations of international production sharing. In particular, it is assumed that only when both inputs are produced in the same country can an outside party distinguish between a good-quality and a bad-quality intermediate input.¹⁰ Hence, the manager of the research center and that of a Southern assembly plant cannot sign an enforceable contract specifying the purchase of a certain type of intermediate input for a certain price. If they did, the party receiving a positive payment would have an incentive to produce the bad-quality input at the lower cost.

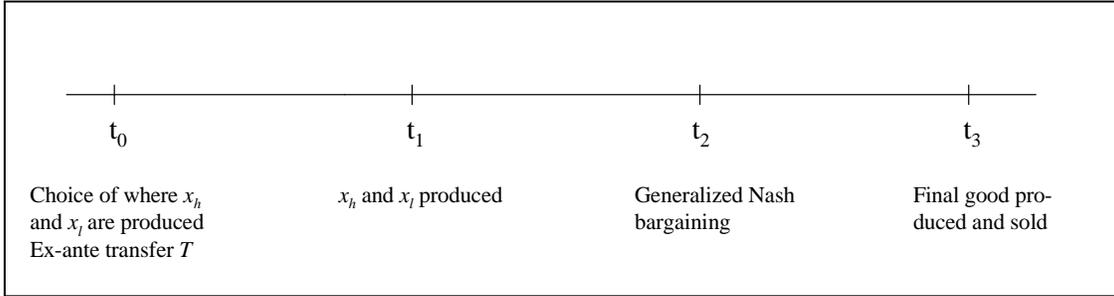
It is equally assumed that no outside party can verify the amount of ex-ante investments in labor. If these were verifiable, the managers could contract on them, and the cost-reducing benefit of producing a bad-quality input would disappear. For the same reason, it is assumed that the parties cannot write contracts contingent on the volume of sale revenues obtained when the final good is sold. The only contractible ex-ante is the transfer T between the parties.¹¹

When the research center chooses to transact with an assembly plant in the North, the fact that labor investments are not contractible is irrelevant because the parties can always appeal to an outside party to enforce quality-contingent contracts. In contrast, when manufacturing is done by a plant in the South, no enforceable contract will be signed ex-ante and the two parties will bargain over the surplus of the relationship after the inputs have been produced. At this point, the quality of the inputs (and therefore also the ex-ante investments) are observable to both parties and thus the costless bargaining will yield an ex-post efficient outcome. I assume that Generalized Nash Bargaining leaves the research

¹⁰This can be interpreted as a physical constraint imposed on the outside party if, for instance, in order to observe the quality of the input, the outside party needs to supervise its actual production process. More generally, this assumption is meant to capture broader contractual difficulties in international transactions, such as ambiguous jurisdiction, language conflicts, or, more simply, weak protection of property rights in low-wage countries.

¹¹I take the fact that contracts are incomplete as given. From the work of Aghion, Dewatripont and Rey (1994), Nöldeke and Schmidt (1995) and others, it is well known that allowing for specific-performance contracts can lead, under certain circumstances, to efficient ex-ante relationship-specific investments. Che and Hausch (1997) have shown, however, that when ex-ante investments are cooperative (in the sense, that one party's investment benefits the other party), specific-performance contracts may not lead to first-best investment levels and may actually have no value.

Figure 1: Timing of Events



center with a fraction $\phi \in (0, 1)$ of the surplus. Since the inputs are tailored specifically to the other party in the transaction, if the two parties fail to agree on a division of the surplus, both are left with nothing.

As I will show below, the fact that contracts are incomplete will lead to underinvestment in both product development and manufacturing when the production process is fragmented internationally. Furthermore, the underprovision of product development will be more severe the lower is ϕ , i.e., the lower the bargaining power of the research center manager. For some of the results below, it is important that product development is sufficiently distorted. This is ensured by the following assumption:

Assumption 1: $\phi \leq 3/4$.

If the transaction between the research center and the manufacturing plant is interpreted as a licensing arrangement, this assumption is consistent with available evidence. As Caves (1996) writes, “*the empirical evidence on licensing convincingly shows that licensors on average can appropriate less than half of the surplus associated with the license transaction*” (p. 167).

This completes the description of the model. The timing of events is summarized in Figure 1.

2.2 Firm Behavior

As discussed above, the North has a sufficiently high productivity advantage in producing the hi-tech input to ensure that x_h is produced there. On the other hand, the decision of where to produce the low-tech input is nontrivial. In his choice, the manager of the research center compares ex-ante profits from two options, which I analyze in turn.

A. Assembly in the North by an Independent Manufacturing Plant

Consider first the case of a research center who decides to deal with an independent manufacturing plant in the North. In such case, the two parties can write an ex-ante quality-contingent contract that will not be renegotiated ex-post. The initial contract stipulates production of good-quality inputs in an amount that maximizes the research center's ex-ante profits, which from equations (1) and (2), and taking account of the transfer T , are given by $\pi^N = \lambda^{1-\alpha} \zeta_z^\alpha x_h^{\alpha(1-z)} x_l^{\alpha z} - w^N x_h - w^N x_l$. It is straightforward to check that this program yields an optimal price of

$$p^N(z) = \frac{w^N}{\alpha}. \quad (3)$$

Since the research center faces a constant elasticity of demand, the optimal price is equal to a constant mark-up over marginal cost. Ex-ante profits for the research center are equal to

$$\pi^N(z) = (1 - \alpha) \lambda \left(\frac{w^N}{\alpha} \right)^{-\alpha/(1-\alpha)}. \quad (4)$$

B. Assembly in the South by an Independent Manufacturing Plant

Consider next the problem faced by a research center that decides to transact with an assembly plant in the South. As discussed above, in this case the initial contract stipulates only the transfer T . The game played by the manager of the research center and that of the assembly plant is solved by starting at t_3 and moving backwards. If both producers make good-quality intermediate inputs and the firms agree in the bargaining, the potential revenues from the sale of the final good at t_3 are $R = \lambda^{1-\alpha} \zeta_z^\alpha x_h^{\alpha(1-z)} x_l^{\alpha z}$. In contrast, if the parties fail to agree in the bargaining, both are left with nothing. The quasi-rents of the relationship are therefore equal to sale revenues, i.e., R .

The contract incompleteness will give rise to renegotiation at t_2 . In the bargaining, Generalized Nash bargaining leaves the research center manager with a fraction ϕ of the quasi-rents, while the assembly plant manager in the South receives the remaining fraction $1 - \phi$ of the quasi-rents. Since ϕ is assumed to be in $(0, 1)$, both parties' ex-post revenues from producing a good-quality input are always strictly positive. Bad-quality inputs will therefore never be produced.

Rolling back to t_1 , the research center manager will therefore set x_h to maximize $\phi R - w^N x_h$. The assembly plant will simultaneously choose x_l to maximize $(1 - \phi) R - w^S x_l$. Combining the first-order conditions of these two programs yields the following optimal

price for the final good:

$$p^S(z) = \frac{(w^N)^{1-z} (w^S)^z}{\alpha \phi^{1-z} (1-\phi)^z}. \quad (5)$$

It is straightforward to show that if contracts were also complete for international transactions, the research center would instead set a price equal to $(w^N)^{1-z} (w^S)^z / \alpha$. Incomplete contracting therefore inflates the optimal mark-up by a factor that is inversely related to $\phi^{1-z} (1-\phi)^z$. If z is low, the distortion is relatively higher, the lower is ϕ . Conversely, if production of y requires mostly the low-tech input (z high), the distortion is relatively higher, the higher is ϕ .

Setting T so as to make the assembly plant break even leads to the following expression for the research center's ex-ante profits:

$$\pi^S(z) = (1 - \alpha (\phi(1-z) + (1-\phi)z)) \lambda \left(\frac{(w^N)^{1-z} (w^S)^z}{\alpha \phi^{1-z} (1-\phi)^z} \right)^{-\alpha/(1-\alpha)}. \quad (6)$$

Comparing equations (4) and (6), it is possible to show that the low-tech input will be produced in the South only if $\omega \equiv w^N/w^S > 1$. Intuitively, Southern assembly becomes profitable only when wages in the South are low enough to offset the distortions coming from incomplete contracting. By a continuity argument, if ω is close enough to one, it is also necessarily the case that $\pi^N(z) > \pi^S(z)$ for all $z \in [0, 1]$, and production in the South would never be chosen either. To make matters more interesting, I assume that ω is high enough so that $\pi^N(z_c) < \pi^S(z_c)$ for some $z_c \in (0, 1)$. Comparing equations (4) and (6) this condition can be rewritten as:

Condition 1: There exists a $z_c \in (0, 1)$ such that $A(z_c) < \omega$, where

$$A(z) \equiv \left(\frac{1 - \alpha}{1 - \alpha (\phi(1-z) + (1-\phi)z)} \right)^{(1-\alpha)/\alpha z} \frac{\phi^{-(1-z)/z}}{1 - \phi}. \quad (7)$$

This condition will in fact be shown to necessarily hold in the general-equilibrium model and this is why I avoid labelling it as an assumption. The intuition for why Condition 1 will hold true in the general equilibrium is that the relative wage in the North will necessarily adjust to ensure positive labor demand in the South.

2.3 The Equilibrium Choice

The main result from this section will be that production of the low-tech input (i.e., manufacturing) will be kept in the North if and only if production of the final-good is sufficiently *product-development intensive*. To gain intuition on the result, consider first the case in

which the mode of organization were chosen to minimize the optimal price (notice that revenues $py = \lambda p^{-\alpha/(1-\alpha)}$ are decreasing in p). In such case, assembly would be done by the research center in the North if $p^N(z) < p^S(z)$, a condition that can be rewritten as

$$(\omega(1-\phi))^z < \left(\frac{1}{\phi}\right)^{1-z}. \quad (8)$$

The left-hand side of the inequality corresponds to the benefits of locating assembly in the South. These benefits are higher, the higher the relative wage in the North and the lower is ϕ . Intuitively, the higher is ω , the larger will the cost reduction of manufacturing in the South be, while the lower is ϕ , the larger will the Southern manager's bargaining power be, and therefore the less severe will his underinvestment in x_l be. The right-hand side of the inequality captures instead the costs of Southern assembly and correspond to the distortions caused by incomplete contracting on the production of the hi-tech input in the North. Because the hold-up problem is two-sided, the research center will also underinvest in product development (x_h), with the degree of underinvestment decreasing in the Northern manager's bargaining power (ϕ).

It is clear from equation (8) that if $\omega(1-\phi) < 1$, then $p^N(z) < p^S(z)$ will hold for all $z \in [0, 1]$ and production in the South will never be chosen. This is the type of situations that Condition 1 rules out. On the other hand, if $\omega(1-\phi) > 1$, the benefits from Southern assembly are increasing in z , while the costs are decreasing in z . Intuitively, the more important is the hi-tech input in the production process (the lower z), the more costly are distortions in product development, and the less weight is carried by the lower assembly wages in the South. Furthermore, for $z = 0$, the costs necessarily outweigh the benefits, and conversely for $z = 1$. It follows that there exists a unique z_p for which $p^N(z_p) = p^S(z_p)$, and such that $p^N(z) < p^S(z)$ if and only if $z < z_p$.

When the mode of organization is chosen to maximize profits rather than to minimize the price set (or maximize revenues), the analysis is complicated by the fact that incomplete contracting not only distorts the mark-up over marginal cost, but also the fraction of revenues that producers are able to capture as operating profits. Provided that Assumption 1 ($\phi \leq 3/4$) holds, however, a result analogous to that under price minimization applies:

Lemma 1 *Under Assumption 1 and Condition 1, there exists a unique threshold $\bar{z} \in (0, 1)$ such that the low-tech input is produced in the North if $z < \bar{z} \equiv A^{-1}(\omega)$, while it is produced in the South if $z > \bar{z} \equiv A^{-1}(\omega)$, where $A(z)$ is given by equation (7) and ω is the relative wage in the North.*

Proof. See Appendix A.1. ■

Figure 2: The Choice of Location

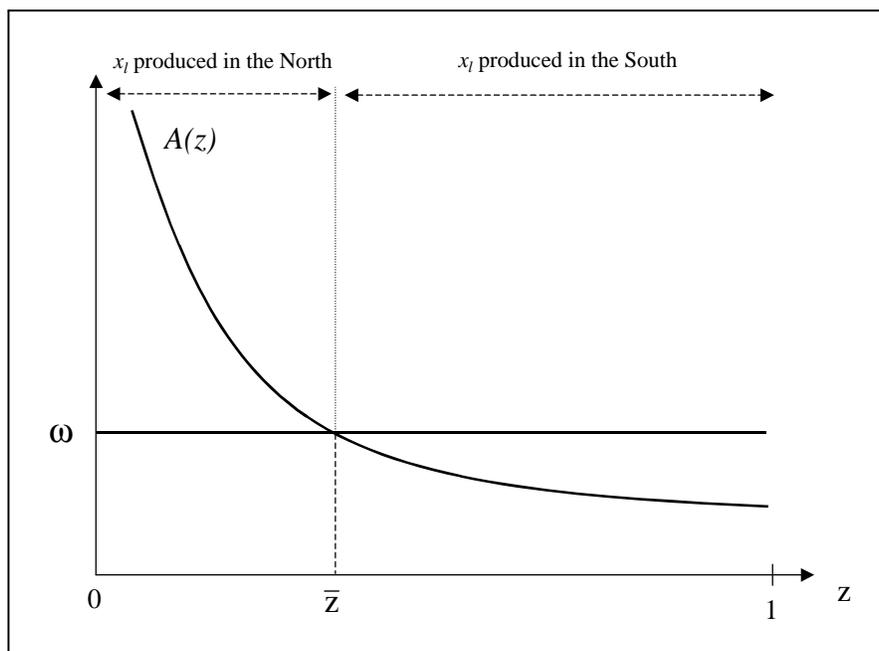


Figure 2 depicts the profit-maximizing choice of location as a function of z . Under Assumption 1, the $A(z)$ curve is decreasing in z for all $z \in [0, 1]$, while by Condition 1, $A(1) < \omega$. Therefore there exists a unique \bar{z} such that $A(z) > \omega$ for $z < \bar{z}$, and $A(z) < \omega$ for $z > \bar{z}$. As shown in Figure 2, x_l is produced in the North for $z < \bar{z}$, while it is produced in the South for $z > \bar{z}$.

From direct inspection of Figure 2, it is clear that an increase in the relative wage in the North reduces the threshold \bar{z} . Intuitively, an increase in ω makes Southern manufacturing relatively more profitable, and this leads to a reduction in the measure of hi-tech intensities for which the whole production process stays in the North.

An increase in the relative bargaining power of the research center can be shown to rotate the $A(z)$ curve in a counterclockwise direction about some $z_\phi \in (0, 1)$. It follows that for a high enough ω , an increase in ϕ leads to a fall in \bar{z} , with the converse result applying for low enough ω . The intuition behind this result will be discussed at length in section 4, when I introduce multinational firms.

2.4 Dynamics: The Product Cycle

As discussed in the introduction, one of the premises of Vernon's (1966) original product-cycle hypothesis is that as a good matures throughout its life cycle, it becomes more and more standardized.¹² Vernon believed that the unstandardized nature of new goods was crucial for understanding that they would first be produced in a high-wage country, such as the United States. To capture this standardization process in a simple way, consider the following simple dynamic extension of the static model developed above. Time is continuous, index by t , with $t \in [0, \infty)$. Consumers are infinitely lived and, at any $t \in [0, \infty)$, their preferences for good y are captured by the demand function (1).

On the technology and contracting sides, the parameters α and ϕ , as well as the relative wage ω , are assumed to be time-invariant.¹³ The output elasticity of the low-tech input is instead assumed to increase through time. In particular, this elasticity is given by

$$z(t) = h(t), \text{ with } h'(t) > 0, h(0) = 0, \text{ and } \lim_{t \rightarrow \infty} h(t) = 1. \quad (9)$$

I therefore assume that the product-development intensity of the good is inversely related to its maturity. This is meant to capture the above discussion indicating that most goods require a lot of R&D and product development in the early stages of their life cycle, whereas the mere assembling or manufacturing becomes a much more significant input in production as the good matures. I will take these dynamics as given, but it can be shown that, under Assumption 1 and Condition 1, profits for the Northern research center are weakly increasing in z . It follows that the smooth process of standardization specified here could, in principle, be derived endogenously in a richer framework that incorporated some costs of standardization.¹⁴

Finally, I assume that the firm structure is such that when Southern assembly is chosen, the game played by the two managers can be treated as a static one and we can abstract from an analysis of reputational equilibria. This is a warranted assumption when the separation rate for managers is high enough or when they discount enough future profit streams.¹⁵

¹²In discussing some previous empirical studies on the location of industry, Vernon wrote: "in the early stages of introduction of a new good, producers were usually confronted with a number of critical, albeit transitory, conditions. For one thing, the product itself may be quite unstandardized for a time; its inputs, its processing, and its final specifications may cover a wide range. Contrast the great variety of automobiles produced and marketed before 1910 with the thoroughly standardized product of the 1930's, or the variegated radio designs of the 1920's with the uniform models of the 1930's." (Vernon, 1966, p.197).

¹³The latter assumption will be relaxed in the general-equilibrium model, where ω will be endogenized.

¹⁴For instance, if such costs were increasing in dz/dt , then the cost of a discrete increase in z would be infinite.

¹⁵The general-equilibrium model developed below will in fact incorporate positive, endogenous separation rates.

With this simplified, dynamic set-up, the cut-off level $\bar{z} \equiv A^{-1}(\omega)$ is time-invariant, and the following result is a straightforward implication of Lemma 1:

Proposition 1 *The model displays a product cycle. When the industry is young, i.e. $t < h^{-1}(\bar{z})$, the low-tech input is produced in the North. When the good is mature or standardized, i.e. $t \geq h^{-1}(\bar{z})$, manufacturing is shifted to the South.*

Consider, for instance, the following specification of the standardization process:

$$z(t) = h(t) = 1 - e^{-t/\theta},$$

where $1/\theta$ measures the rate at which $1-z$ falls towards zero, i.e. the rate of standardization. With this functional form, the whole production process remains in the North until the product reaches an age equal to $\theta \ln\left(\frac{1}{1-\bar{z}}\right)$, at which point manufacturing is shifted to the South. Naturally, production of the low-tech input is transferred to the South earlier, the higher is the speed of standardization, $1/\theta$, and the lower is the threshold intensity \bar{z} . Furthermore, I showed above that \bar{z} is itself a decreasing function of ω , from which it follows that the higher is the relative wage in the North, the earlier will production transfer occur.¹⁶

Comparison with the Case of Complete Contracts So far I have shown that the model delivers a product cycle. I now briefly demonstrate my claim in the introduction that contract incompleteness is in fact necessary for the product cycle to emerge. For this purpose, consider the case in which the quality of intermediate inputs was also verifiable by an outside court in international transactions, so that the manager of the research center and that of the Southern assembly plant could write enforceable contracts. It is straightforward to check that, in such case, profits for the research center would be:

$$\pi^S(z) = (1 - \alpha) \lambda \left(\frac{(w^N)^{1-z} (w^S)^z}{\alpha} \right)^{-\alpha/(1-\alpha)}$$

Comparing this expression with equation (4), it follows that labor demand in the South could be positive if and only if $\omega \geq 1$ (this is the analog of Condition 1 above). Next,

¹⁶Vernon (1966) hypothesized instead that before being transferred to low-wage countries, production would first be located in middle-income countries for a period of time. An important point to notice is that in doing the comparative statics with respect to ω , I have held the contracting environment constant. In the real world, a country's degree of contract incompleteness seems to be negatively correlated with its wage rate. The empirical growth literature consistently finds that countries with better legal systems grow faster (Mauro, 1995, Knack and Keefer, 1995) and have higher per-capita income (Hall and Jones, 1999, Acemoglu et al. 2001). If I allowed for this type of correlation in the model, production would not necessarily be transferred earlier the higher ω .

notice that as long as $\omega > 1$, it will necessarily be the case that $\pi^N(z) \leq \pi^S(z)$ for all $z \in [0, 1]$, with strict inequality for $z > 0$. It follows that the low tech-input will never be produced in the North, and the production process will be broken up from time 0. A product cycle therefore does not arise if $\omega > 1$. On the other hand, if $\omega = 1$, then it follows that $\pi^N(z) = \pi^S(z)$ for all $z \in [0, 1]$ and the location of assembly remains indeterminate. In such case, product cycles emerge with probability zero.¹⁷

3 Incomplete Contracts and the Product Cycle in General Equilibrium

In this section, the partial-equilibrium model developed above is embedded in a dynamic, general-equilibrium framework with varieties in different sectors standardizing at different rates. I will first solve for the time-path of the relative wage in the two countries and show that the equilibrium wage in the North is necessarily higher than that in the South. Next, I will study some macroeconomic and welfare implications of this new view of the product cycle.

3.1 Set-up

The North is endowed with L^N units of labor at any $t \in (0, \infty)$, while the Southern endowment is also constant and equal to L^S . At each period t , there is a measure $N(t)$ of industries indexed by j , each producing an endogenously determined measure $n_j(t)$ of differentiated goods. Preferences of the infinitely-lived representative consumer in each country are given by:

$$U = \int_0^\infty e^{-\rho t} \int_0^{N(t)} \log \left(\int_0^{n_j(t)} y_j(i, t)^\alpha di \right)^{1/\alpha} dj dt, \quad (10)$$

where ρ is the rate at which the consumer discounts future utility streams. Notice that all industries are viewed as symmetric with a unitary elasticity of substitution between them. The varieties of differentiated goods also enter symmetrically into (10), but with an elasticity of substitution equal to $1/(1 - \alpha) > 1$. Because the economy has no means of saving and preferences are time-separable, the consumer maximizes utility period by period and the

¹⁷This shows that, in the otherwise frictionless framework I developed, incomplete contracts are necessary for product cycles to emerge. This is not to say that incomplete contracting is the crucial driving force behind product cycles in the model. Arguably, the process of standardization is more important for obtaining the results. Incomplete contracting is just one of the many potential frictions that would make manufacturing stay in the North for a period of time. I choose to emphasize here the role of incomplete contracts because I believe that they are an important source of frictions in the real world and, more importantly, because they are a very useful theoretical tool for understanding firm boundaries, which are the focus of section 4 below.

discount rate plays no role in the model (other than to make the problem bounded). As is well known, the instantaneous utility function in (10) gives rise to a constant price-elasticity of demand for any variety i in any industry j :

$$y_j(i, t) = \lambda_j(t) p_j(i, t)^{-1/(1-\alpha)}, \quad (11)$$

where

$$\lambda_j(t) = \frac{1}{N(t)} \frac{E(t)}{\int_0^{n_j(t)} p_j(i', t)^{-\alpha/(1-\alpha)} di'} \quad (12)$$

and $E(t)$ is total world spending in period t . Because firms take $\lambda_j(t)$ as given, each producer of a final-good variety faces a demand function analogous to that in equation (1) above.

At each point in time, production of each final-good variety is also as described in the partial-equilibrium model above, with the additional assumption that, at every period t , production of each variety also requires a fixed cost of f units of labor in the country where the hi-tech input is produced (i.e., the North). It is assumed that all producers in a given industry share the same technology as specified in (2), with a common time-varying elasticity $z_j(t - t_{0j})$, where t_{0j} is the date at which industry j was born. As before, I assume $z'_j(\cdot) > 0$, $z_j(0) = 0$, and $\lim_{t-t_{0j} \rightarrow \infty} z_j(t - t_{0j}) = 1$. In words, varieties in a given industry j are produced for the first time at t_{0j} using only the hi-tech input, and then all standardize at a common rate.

Notice that industries may vary not only in their birth dates, but also in the shape of their specific $z_j(\cdot)$ functions. To isolate the effect of cross-industry differences in maturity and in standardization rates, I assume that the technology for producing intermediate inputs, as well as fixed costs, are identical across industries and varieties.

Firm structure is as described above, with the additional assumption that there is free entry at every period t , so that the measure $n_j(t)$ of varieties in each industry always adjusts so as to make research centers break even. The lack of profits in equilibrium is implied by the fact that technology is a function of the industry's age and not of the age of the producer of a particular variety. Furthermore, as in section 2.4, I assume that firm structure is such that when Southern procurement is chosen, the game played by the two managers can be treated as a static one and we can abstract from an analysis of reputational equilibria. This assumption, coupled with the absence of means of saving in the model, permits a period-by-period analysis of the dynamic, general-equilibrium model.

The contracting environment is also analogous to that of the partial-equilibrium model and, in particular, the parameter ϕ is time-invariant and common for all varieties and

industries.

I consider an economy in which exogenous inventions continuously adds to the stock of existing industries. In particular, I let $\dot{N}(t) = gN(t)$ and $N(0) = N_0 > 0$. Hence, in any period t there are $N(t) = N_0 e^{gt}$ industries producing varieties of final goods.

3.2 Industry Equilibrium

Consider now the industry equilibrium at any $t \in [0, \infty)$. The unit elasticity of substitution between varieties in different industries implies that we can analyze firm behavior in each industry independently. Consider then any industry j . Facing the same technology and contracting environment, all research centers in the same industry will necessarily set the same price and therefore will earn the same profits. It follows that letting again $\bar{z}(t) \equiv A^{-1}(\omega(t))$, the low-tech input will be produced in the North if $z_j(t - t_{0j}) < \bar{z}(t)$, and in the South $z_j(t - t_{0j}) > \bar{z}(t)$, with the choice remaining indeterminate for $z_j(t - t_{0j}) = \bar{z}(t)$.

In order to characterize the industry equilibrium, notice first that since all firms in a given industry j will charge an identical optimal price $p(z_j(\cdot))$, equation (12) simplifies to:

$$\lambda_j(t) = \begin{cases} \frac{E(t)}{N(t)n_j(t)} \left(\frac{w^N(t)}{\alpha} \right)^{\alpha/(1-\alpha)} & \text{if } z_j(t - t_{0j}) < \bar{z}(t) \\ \frac{E(t)}{N(t)n_j(t)} \left(\frac{(w^N(t))^{1-z_j(t-t_{0j})} (w^S(t))^{z_j(t-t_{0j})}}{\alpha \phi^{1-z_j(t-t_{0j})} (1-\phi)^{z_j(t-t_{0j})}} \right)^{\alpha/(1-\alpha)} & \text{if } z_j(t - t_{0j}) > \bar{z}(t) \end{cases} . \quad (13)$$

The equilibrium number of varieties produced in industry j at time t is computed by plugging equation (13) in the profit functions (4) and (6), and setting operating profits equal to fixed costs, as dictated by free entry. This yields:

$$n_j(t) = \begin{cases} \frac{(1-\alpha)E(t)}{N(t)w^N(t)f} & \text{if } z_j(t - t_{0j}) < \bar{z}(t) \\ \frac{(1-\alpha(\phi(1-z_j(t-t_{0j}))+(1-\phi)z_j(t-t_{0j})))E(t)}{N(t)w^N(t)f} & \text{if } z_j(t - t_{0j}) > \bar{z}(t) \end{cases} . \quad (14)$$

Notice that in a stationary equilibrium in which both $E(t)$ and $w^N(t)$ are constant through time and $N(t)$ grows at rate g , the measure of varieties in a given industry falls at rate g for $z_j(t - t_{0j}) < \bar{z}(t)$. The evolution of the number of varieties when $z_j(t - t_{0j}) > \bar{z}(t)$ is more complicated and depends on the relative growth rates of $z_j(t - t_{0j})$ and $N(t)$, as well as on whether ϕ is greater or lower than $1/2$.

3.3 General Equilibrium

Having described the equilibrium for a particular industry at time t , we can now move to the general equilibrium, in which income equals spending

$$w^N(t)L^N + w^S(t)L^S = E(t) \quad (15)$$

and the labor market in each country clears. By Walras' law, we can focus on the equilibrium of the labor market in the South. Southern labor will only be demanded by those assembly plants belonging to an industry with $z_j(t - t_{0j}) > \bar{z}(t)$. Labor demand by each assembly plant in the South can be shown to equal $L_l^S = \alpha(1 - \phi) z_j(\cdot) \lambda_j(t) p_j^S(t)^{-\alpha/(1-\alpha)} / w^S(t)$, which simplifies to $L_l^S = \alpha(1 - \phi) z_j(\cdot) E(t) / (w^S(t) N(t) n_j(t))$. Denote by $F_{z,t}(z)$ the *fraction* of industries with $z_j(t - t_{0j}) < \bar{z}(t)$ at time t . Letting $f_{z,t}(z)$ be the corresponding probability density function, the Southern labor-market clearing condition can be expressed as:

$$\int_{\bar{z}(t)}^1 \alpha(1 - \phi) z E(t) f_{z,t}(z) dz = w^S(t) L^S. \quad (16)$$

Defining $\xi_t(a, b) \equiv \int_a^b z f_{z,t}(z) dz$ and using (15), equation (16) can be then rewritten as:

$$\omega(t) = B_t(\bar{z}(t)) \equiv \frac{1 - \alpha(1 - \phi) \xi_t(\bar{z}(t), 1) L^S}{\alpha(1 - \phi) \xi_t(\bar{z}(t), 1) L^N}. \quad (17)$$

$B_t(\bar{z}(t))$ is an increasing function of $\bar{z}(t)$ satisfying $B_t(0) > 0$ and $\lim_{\bar{z}(t) \rightarrow 1} B_t(\bar{z}(t)) = +\infty$. Intuitively, the higher is $\bar{z}(t)$, the lower is labor demand in the South for a given $\omega(t)$. An increase in $\omega(t)$ is necessary to bring us back to equilibrium. When $\bar{z}(t)$ goes to 1, labor demand in the South goes to 0, and the required relative wage goes to $+\infty$. On the other hand, since the North always produces the hi-tech input, even when $\bar{z}(t)$ goes to 0 labor demand in the North is positive and $B_t(0)$ is greater than 0. Figure 3 depicts the curve $B_t(\cdot)$ in the (z, ω) space.

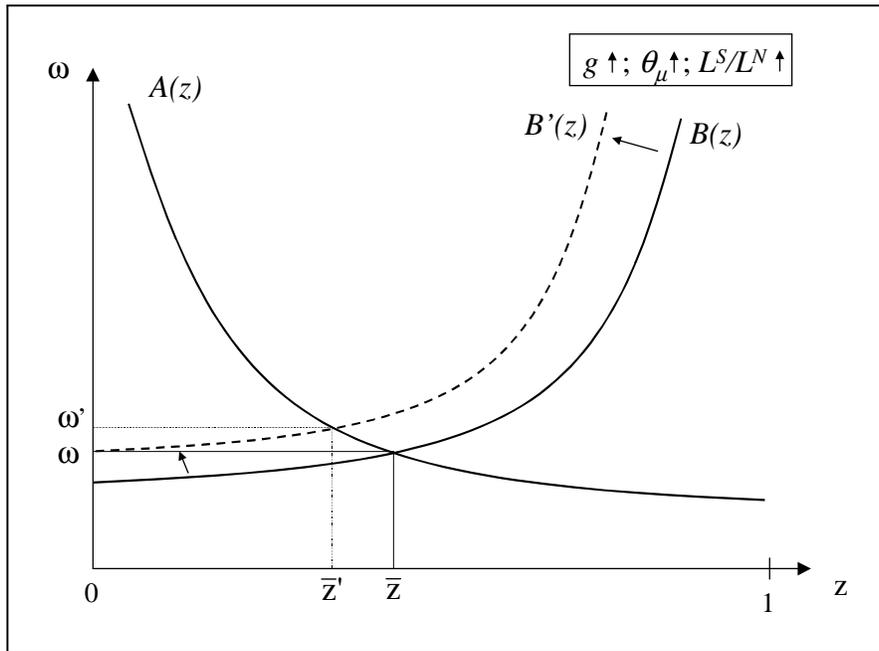
The other equilibrium condition that pins down $\bar{z}(t)$ and $\omega(t)$ comes from the partial equilibrium. In particular, since α and ϕ are common across industries, $\bar{z}(t)$ is also implicitly defined by

$$\omega(t) = A(\bar{z}(t)) \equiv \left(\frac{1 - \alpha}{1 - \alpha(\phi(1 - \bar{z}(t)) + (1 - \phi)\bar{z}(t))} \right)^{(1-\alpha)/\alpha\bar{z}(t)} \frac{\phi^{-(1-\bar{z}(t))/\bar{z}(t)}}{1 - \phi}. \quad (18)$$

As discussed above, under Assumption 1, $A(\bar{z}(t))$ is a decreasing function of $\bar{z}(t)$ satisfying $\lim_{\bar{z}(t) \rightarrow 0} A(\bar{z}(t)) = +\infty$ and $A(1) > 1$.¹⁸ The function $A(\cdot)$ is also depicted in Figure 3.

¹⁸In particular, $A(1) = \left(\frac{1-\alpha}{1-\alpha(1-\phi)} (1-\phi)^{-\alpha/(1-\alpha)} \right)^{(1-\alpha)/\alpha}$ which is greater than one because $(1 - \alpha x) x^{\alpha/(1-\alpha)}$ is increasing in x for $\alpha \in (0, 1)$ and $x \in (0, 1)$.

Figure 3: General Equilibrium



As it appears in Figure 3, there exists a unique equilibrium pair $(\bar{z}(t), \omega(t))$ for each t . Furthermore, the fact that $A(1)$ is greater than 1, ensures that in equilibrium the wage in the North is higher than that in the South, or $\omega(t) > 1$.

The general equilibrium of the dynamic model is simply the sequence of period-by-period general equilibria. In addition, if the distribution function $F_{z,t}(z)$ is (or converges to) a time-invariant distribution, the equilibrium values for $\bar{z}(t)$ and $\omega(t)$ will also be time-invariant. In such case, all industries will necessarily follow product cycles, with varieties in those industries being manufactured first in the North and then later in the South.¹⁹

Consider again the particular functional form:

$$z_j(t, t_{0j}) = 1 - e^{-(t-t_{0j})/\theta_j}, \quad (19)$$

so that the elasticity of output with respect to x_h falls at a constant rate $1/\theta_j$. As before, I will refer to $1/\theta_j$ as industry j 's specific rate of standardization. From the discussion in section 2.4, and given that the threshold $\bar{z}(t)$ is common across industries, the model predicts that industries with a higher rates of standardization will transfer manufacturing earlier to the South. In the general equilibrium, however, the cross-industry distribution

¹⁹In fact, a much weaker assumption is need for product cycles to emerge, namely, that the growth rate of $\bar{z}(t)$ be lower than that of $z_j(t - t_{0j})$ for all industries j .

of standardization rates will have an additional effect on the timing of production transfer, through its impact on the overall distribution of hi-tech intensities as given by $F_{z,t}(z)$. To see this, assume that θ_j is independent from t_{0j} and is exponentially distributed with mean θ_μ , i.e., $F_\theta(\theta_j) = 1 - e^{-\theta_j/\theta_\mu}$. Notice that since $N(t)$ grows at constant rate g , the distribution of birth dates in the economy converges to the c.d.f. $F_{t_0}(t_0, t) \equiv N(t_0)/N(t) = e^{-g(t-t_0)}$. Under these assumptions, Appendix A.2 shows that $F_{z,t}(z)$ converges to a time-invariant distribution function characterized by:

$$F_z(z) = \frac{g\theta_\mu \ln\left(\frac{1}{1-z}\right)}{1 + g\theta_\mu \ln\left(\frac{1}{1-z}\right)}. \quad (20)$$

Computing the corresponding density function, it follows that $\xi_t(a, b)$ converges to

$$\xi(a, b) \equiv \int_a^b z f_z(z) dz = \int_a^b \frac{zg\theta_\mu}{\left(1 + g\theta_\mu \ln\left(\frac{1}{1-z}\right)\right)^2 (1-z)} dz. \quad (21)$$

In light of equations (17) and (21), the economy converges to a steady state in which the $B_t(\bar{z}(t))$ curve is time-invariant and increasing in $\bar{z}(t)$. In such a steady state, the general equilibrium values of \bar{z} and ω are unique and time-invariant.

It is interesting to notice that in spite of the rich heterogeneity in industry product-cycle dynamics, the cross-sectional picture that emerges from the model is very similar to that in the classical Ricardian model with a continuum of goods of Dornbusch, Fischer and Samuelson (1977). In contrast to their model, however, comparative advantage arises here from a combination of the Northern productivity advantage in product development, the continuous standardization of goods, and the fact that contracts are incomplete.

3.4 Comparative Statics

Consider first an increase in the relative size of the South, i.e. an increase in L^S/L^N (see Figure 3). As in Dornbusch, Fischer and Samuelson (1977), this shifts the $B(\cdot)$ curve up and to the left leading to an increase in the relative wage in the North and a fall in \bar{z} , which in turn implies that all industries will shift manufacturing to the South at an earlier phase of their life cycle. The intuition behind this result is as follows. At the initial relative wage, the increase in the Southern relative labor creates an excess supply of labor in the South and excess demand for labor in the North. An increase in ω and a fall in the measure of hi-tech intensities for which manufacturing is done in the North are necessary to restore equilibrium.

With the particular functional form in equation (19), an increase in the exogenous rate of invention (g) or a fall in the rate of standardization ($1/\theta_\mu$) also shift the $B(\cdot)$ curve up and to the left and thus have completely analogous effects on the equilibrium values of ω and \bar{z} .²⁰ As it is apparent from equation (20), an increase in g or θ_μ tends to transfer probability mass from high z 's to low z 's, which tends to create again an excess supply (demand) of labor in the South (North) at the initial ω and \bar{z} . In sum,

Proposition 2 *Holding θ_j and t_{0j} constant, the relative wage in the North is higher and the shift to Southern assembly occur earlier: (i) the higher the rate of invention g , (ii) the lower the average rate of standardization $1/\theta_\mu$, (iii) the larger the relative population size of the South L^S/L^N .*

The comparative statics on the relative wage are related to those obtained by Krugman (1979) in the first paper to explore the macroeconomic implications of the product cycle hypothesis. Krugman (1979) developed a simple model with two types of goods: new goods and old goods. In his model, exogenous innovation adds to the stock of new goods which, by assumption, can only be produced in the North. New goods become old goods at an exogenous “imitation” rate, at which point they start being manufactured in the low-wage South. As in Proposition 2 above, in his model too an increase in the rate at which new goods appear in the North or an increase in the relative size of the South lead an excess demand for Northern labor which needs to be matched by an increase in the relative wage in the North to restore equilibrium. Krugman (1979) concluded from his comparative static results that increased technological change in the North redistributed income from the South to the North. Proposition 2 demonstrates that the validity of this claim depends very much on the assumption that technological change takes the form of adding new products to the economy. If instead it takes the form of an increase in the rate at which goods standardize (an increase in $1/\theta_\mu$ in the model) the converse result applies.

By endogenizing the timing of technology transfer, the present model delivers additional implications of a shift in the parameters g and θ_μ . For instance, an increase in the rate of invention also leads to a reduction in the time it takes for manufacturing of a particular good to be shifted to the South, which in Krugman’s (1979) model depends only on the exogenous rate of imitation.

Furthermore, in light of Proposition 2, the industry-specific and the average rates of standardization have opposite effects on the timing of technology transfer. Although, the

²⁰In Appendix A.2, I show that both $\partial\xi(\cdot)/\partial g < 0$ and $\partial\xi(\cdot)/\partial\theta_\mu < 0$.

manufacturing of those goods that become standardized relatively faster will be transferred to the South relatively earlier, the model predicts that for a given θ_j , an increase in the average rate of standardization will in fact slow production transfer of varieties in industry j . This result may help shed light on the evidence of a fall in the interval of time between the introduction of a new product in the United States and its first production in a foreign location (c.f., Vernon, 1979). The partial equilibrium model would suggest a simple explanation for this pattern: the technologies transferred in the recent past (e.g., computer parts) get standardized much faster than those transferred in the 1950s and 1960s (e.g. television sets). Nevertheless, Proposition 2 indicates that an *average* decline in the transfer of technologies does not necessarily follow from an *average* increase in the speed of standardization. Moreover, Proposition 2 suggests two alternatives for explaining this fact: an increase in the rate of invention or an increase in the relative population size of the South.

3.5 Welfare: Comparison with the Case of Complete Contracts

At the end of section 2, I showed that in the one-good model, incomplete contracts were necessary for a product cycle to emerge. This remains valid in the general-equilibrium model. From the analysis of firm behavior, if contracts are complete, Northern and Southern assembly are equally profitable if and only if $\omega = 1$, from which it follows that the $A(\cdot)$ curve becomes flat at one. Solving for Southern labor demand under complete contracts, the analogous of the $B(\cdot)$ curve is given by:

$$\omega(t) = B_C(\bar{z}(t)) = \frac{1 - \alpha\xi_t(\bar{z}, 1)}{\alpha\xi_t(\bar{z}, 1)} \frac{L^S}{L^N}.$$

Relative to a world with incomplete contracts, the introduction of complete contracts shifts the $B(\bar{z})$ down and to the right (since $\alpha(1 - \phi) < 1$).

The general equilibrium under complete contracts is as follows. If $B_C(0) > 1$, then the relative wage in the North is necessarily greater than one and assembly is always done in the South. As before, production transfer occurs instantly and no product cycles emerge. If instead $B_C(0) < 1$, then the relative wage in the North will be equal to one in equilibrium and the location of production of low-tech inputs will be indeterminate. Labor market clearing in the South will only require that the set of industries $\mathcal{Z} \subset [0, 1]$ that choose to manufacture in the South satisfy $L^S \left(1 - \int_{z \in \mathcal{Z}} z f_{z,t}(z) dz\right) = L^N \int_{z \in \mathcal{Z}} z f_{z,t}(z) dz$. Clearly, in such case product cycles emerge with probability zero.

Consider next the welfare implications for each country of a shift from incomplete con-

tracting to complete contracting.²¹ It is useful to decompose the welfare change into three items: (a) terms of trade, (b) production efficiency, and (c) available products. The terms of trade effect relates to the fact that such a move towards complete contracts necessarily depresses the relative wage in the North. Intuitively, Northern wages include a rent on its comparative advantage stemming in part from incomplete contracting. In a world of complete contracts, this rent disappears and the relative wage in the North is lower. On account of this terms of trade effect, the South benefits from complete contracting, while the North is worse off.²²

Second, the shift to complete contracts improves production efficiency on two accounts. On the one hand, it eliminates the direct distortions coming from incomplete contracting (e.g., inflation of mark-ups). On the other hand, there is also a production composition effect related to the fact that complete contracts lead to a shift of production towards the lower-wage country. On this account, both countries gain from a move to complete contracts.

The third effect relates to the effect on the endogenously determined measure of varieties in each industry. Because preferences of the representative consumer feature a love for variety, welfare is increasing in this measure. In a steady-state equilibrium with complete contracts, this measure would be given by $n^j = (1 - \alpha) (L^N + L^S / \omega_C) / Nf$, where ω_C is the equilibrium relative wage in such case. Comparing this expression with equation (14), it becomes clear that the overall effect of complete contracting on n^j is only unambiguous for those industries with $z(j) < \bar{z}$. On the one hand, the fall in the relative wage ($\omega_C < \omega$) increases the measure of varieties because fixed costs in the North become relatively cheaper. On the other hand, the fraction of revenues that producers are able to capture as operating profits falls ($1 - \alpha < 1 - \alpha(\phi(1 - z) + (1 - \phi)z)$), which translates into a lower n^j for a given relative wage.

It follows that the first and second effects work in favor of the South, while the North also benefits from the second, but loses from the first. Although the third effect is in general ambiguous, it can be shown that it is always dominated by the production efficiency effect, in the sense that, on account of the second and third effects combined, both the South and

²¹To be more accurate, I will compare welfare in a steady-state equilibrium with incomplete contracts to that in a steady-state equilibrium with complete contracts.

²²The terms of trade move in favor of the South for an additional reason which is related to the assumption that fixed costs are incurred in the North. In the model, incomplete contracts shift rents from the variable to the fixed cost sector, i.e., from the South to the North. A move to complete contracting eliminates this rent-shifting effect thereby reducing the relative wage in the North. Graphically, this corresponds to the $B(\cdot)$ curve shifting down and to the right.

the North are better off under complete contracts (see Appendix A.3). From this result, it follows that:

Proposition 3 *Relative to a world with incomplete contracting, a shift to complete contracts unambiguously increases welfare in the South, while having an ambiguous effect on welfare in the North.*

Proof. See Appendix A.3. ■

If we interpret the shift towards better enforcement of international contracts as a tightening of intellectual property rights (IPRs) in the South, then Proposition 3 gives a result diametrically opposed to that in Helpman (1993).²³ He analyzed the welfare implications of a shift to better enforcement of IPRs in models with both exogenous and endogenous innovation and imitation. As he wrote in his concluding remarks:

“Who benefits from tight intellectual property rights in less developed countries? My analysis suggests that if anyone benefits, it is not the South” (Helpman, 1993, p. 1274)

My analysis suggests instead that if anyone loses out, it is not the South. Our different conclusions stem from our different modelling of the vehicle of production transfer.²⁴ When the South gains market share mostly by imitating, a tightening of IPRs will naturally hinder production transfer, reduce labor demand in the South, and make the South worse off. If production transfer is instead driven by voluntary decisions of Northern firms choosing to transact with offshore independent subcontractors or licensees, then a tightening of IPRs, to the extent that it alleviates contractual distortions in those international transactions, will increase relative labor demand in the South and improve welfare there.

4 Firm Boundaries and the Product Cycle

The purpose of this paper has been so far to develop a new theory of the product cycle based on the existence of incomplete contracts, and to analyze its macroeconomic implications.

²³Admittedly, in the set-up described in section 2.1, an improvement in the contracting environment is more closely related to a tightening of trade-related intellectual property rights (TRIPS). Nevertheless, an alternative set-up in which contract incompleteness originated from a weak legal system in the South would yield similar results. In such a framework, the comparison between Proposition 3 and the results in Helpman (1993) would be more transparent.

²⁴Lai (1998) makes a similar point in comparing the welfare implications of a tightening of IPRs in an endogenous-growth model with both foreign direct investment and imitation as vehicles of technology transfer.

The recent literature on the theory of the firm has shown that incomplete contracts are also a useful vehicle to understand the determinants of ownership structure. I will build on this literature to draw firm boundaries in a simple extension of the model developed above. As a result, a much richer product cycle will emerge in which the transfer of production to the South may occur within firm boundaries or at arm's length.

The set-up of the model is the same as before with just one new feature: I allow the research center to vertically integrate the assembly plant and become a multinational firm. Following the property-rights approach of the theory of firm, vertical integration has the benefit of strengthening the ex-post bargaining power of the integrating party (the research center), but the cost of reducing the ex-post bargaining power of the integrated party (the assembly plant).

In particular, by integrating the production of the low-tech input, the manager of the assembly plant becomes an employee of the manager in the research center. This implies that if the assembly plant manager refuses to trade after the sunk costs have been incurred, the research center manager now has the option of firing him and seize the amount of x_l produced. As in Grossman and Hart (1986), ownership is identified with the residual rights of control over certain assets. In this case, the low-tech input plays the role of this asset.²⁵

If there were no costs associated with firing the assembly plant manager, there would be no surplus to bargain over after production, and the assembly plant manager would ex-ante optimally set $x_l = 0$ (which of course would imply $y = 0$). In such case, integration would never be chosen. To make things more interesting, I assume that firing the assembly plant manager results in a negative productivity shock so that a fraction $1 - \delta$ of final-good production is lost. Under this assumption, the surplus of the relationship remains positive even under integration.²⁶ I take the fact that δ is strictly less than one as given, but this assumption could be rationalized in a richer framework.

For reasons analogous to those that make Assumption 1 necessary, I now assume that:

Assumption 2: $\delta \leq \left(\frac{3/4 - \phi}{1 - \phi} \right)^{1/\alpha}$.

The rest of this section is structured as follows. I will first revisit the static, partial-equilibrium model developed in section 2. Next, I will analyze the dynamics of the model and discuss the implications of vertical integration for this new view of the product cycle. Finally, I will solve for the general-equilibrium model with multinational firms.

²⁵See Antràs (2002) for a related set-up.

²⁶The fact that the fraction of final-good production lost is independent of z greatly simplifies the analysis, but is not necessary for the qualitative results discussed below.

4.1 Firm Behavior

In section 2.2, I computed ex-ante profits for the research center under two possible modes of organization: (A) assembly in the North by an independent manufacturing plant; and (B) assembly in the South by an independent manufacturing plant. The possibility of vertical integration introduces two additional options: assembly in the North by a vertically integrated manufacturing plant and assembly in the South by a vertically integrated manufacturing plant. Because contracts are assumed to be perfectly enforceable in transactions involving two firms located in the same country, it is straightforward to show that the first of these new options yields ex-ante profits identical to those in case (A). As is well known from the property-rights literature, in a world of complete contracts, ownership structure is both indeterminate and irrelevant. In contrast, when Southern assembly is chosen, the assignment of residual rights is much more interesting.

C. Assembly in the South by a Vertically-Integrated Manufacturing Plant

Consider the problem faced by a research center and its integrated assembly plant in the South. If both managers decide to make good-quality intermediate inputs and they agree in the bargaining, the potential revenues from the sale of the final good are again $R = \lambda^{1-\alpha} \zeta_z^\alpha x_h^{\alpha(1-z)} x_l^{\alpha z}$. In contrast, if the parties fail to agree in the bargaining, the product-development manager will fire the assembly plant manager, who will be left with nothing. The research center will instead be able to sell an amount $\delta y(i)$ of output, which using equation (1) will translate into sale revenues of $\delta^\alpha R$. The quasi-rents of the relationship are therefore given by $(1 - \delta^\alpha) R$.

The contract incompleteness will give rise to renegotiation at t_2 . In the bargaining, Generalized Nash bargaining leaves the research center with its default option plus a fraction ϕ of the quasi-rents. The manager of the integrated assembly plant receives the remaining fraction $1 - \phi$ of the quasi-rents. Since both ϕ and δ are assumed to be strictly less than one, ex-post revenues from producing a good-quality input are always strictly positive. Bad-quality inputs will therefore never be produced.

Rolling back to t_1 , the research center will therefore set x_h to maximize $\bar{\phi} R - w^N x_h$, where

$$\bar{\phi} = \delta^\alpha + \phi(1 - \delta^\alpha) > \phi.$$

On the other hand, the Southern assembly plant will simultaneously choose x_l to maximize $(1 - \bar{\phi}) R - w^S x_l$. Combining the first-order conditions of these two programs yields the

following optimal price for the final good:

$$p_M^S(z) = \frac{(w^N)^{1-z} (w^S)^z}{\alpha \bar{\phi}^{1-z} (1 - \bar{\phi})^z}.$$

Setting T so as to make the integrated assembly plant break even leads to the following expression for the research center's ex-ante profits:

$$\pi_M^S(z) = (1 - \alpha (\bar{\phi} (1 - z) + (1 - \bar{\phi}) z)) \lambda \left(\frac{(w^N)^{1-z} (w^S)^z}{\alpha \bar{\phi}^{1-z} (1 - \bar{\phi})^z} \right)^{-\alpha/(1-\alpha)}, \quad (22)$$

which is identical to (6) with $\bar{\phi}$ replacing ϕ , and where the subscript M reflects the fact that the research center becomes a multinational firm under this arrangement.

The Equilibrium Choice Revisited

The product manager will now choose the manufacturing location *and* ownership structure that maximize profits for a given z . Consider first the choice between Northern assembly and Southern assembly by an independent firm. This was analyzed in section 2.3, where I showed that under Assumption 1 and Condition 1, there exists a unique \bar{z} such that $\pi^N(z) > \pi^S(z)$ for $z < \bar{z}$, and $\pi^N(z) < \pi^S(z)$ for $z > \bar{z}$. Again, the cut-off level \bar{z} is implicitly defined by $\bar{z} = A^{-1}(\omega)$, where $A(z)$ is given in equation (7).

Consider next the choice between Northern assembly and Southern assembly by an integrated firm. Comparing equations (4) and (22), it follows that $\pi^N(z) > \pi_M^S(z)$ if and only if

$$\omega < \bar{A}(z) \equiv \left(\frac{1 - \alpha}{1 - \alpha (\bar{\phi} (1 - z) + (1 - \bar{\phi}) z)} \right)^{(1-\alpha)/\alpha z} \frac{\bar{\phi}^{-z/(1-z)}}{1 - \bar{\phi}}. \quad (23)$$

Under Assumption 2, $\bar{\phi}$ is less or equal to $3/4$ and it can be shown that $\bar{A}'(z) < 0$ (see Appendix A.1). Furthermore, when z goes to zero, $\bar{A}(z)$ goes to $+\infty$, while when z goes to 1, $\bar{A}(1) > 1$.²⁷ If the relative wage is high enough, namely, $\omega > \bar{A}(1)$, then there exists a unique cutoff $\bar{z}_{MN} = \bar{A}^{-1}(\omega) \in (0, 1)$ such that $\pi^N(z) > \pi_M^S(z)$ for $z < \bar{z}_{MN}$, and $\pi^N(z) < \pi_M^S(z)$ for $z > \bar{z}_{MN}$.²⁸ The intuition for this result is essentially the same as the one discussed above. When the low-tech input is not very important in the production process, the cost-saving benefit of producing it in the South is outweighed by the costs of incomplete contracts, which distort the marginal cost of production of both the hi-tech and the low-tech inputs. On the other hand, when very little product development is needed for

²⁷This follows again from $(1 - \alpha x) x^{\alpha/(1-\alpha)}$ being an increasing function of x for $\alpha \in (0, 1)$ and $x \in (0, 1)$.

²⁸In contrast, if $\omega < \bar{A}(1)$, then $\pi^N(z) > \pi_M^S(z)$ for all z and vertical integration is never chosen in equilibrium.

production, then lower wages in the South are much more profit enhancing, and Southern assembly is more profitable. Crucial for this result is the fact that, following Grossman and Hart (1986), and contrary to the older transaction-cost literature, vertical integration does not eliminate the opportunistic behavior at the heart of the hold-up problem. Ownership, however, crucially affects the distribution of ex-post surplus through its effect on each party's outside option, and this explains that \bar{z} and \bar{z}_{MN} are not identical.

Finally, we need to compare profits under Southern assembly by an independent firm with those under Southern assembly by an integrated firm. Comparing equations (6) and (22), it follows that $\pi_M^S(z) > \pi^S(z)$ if and only if

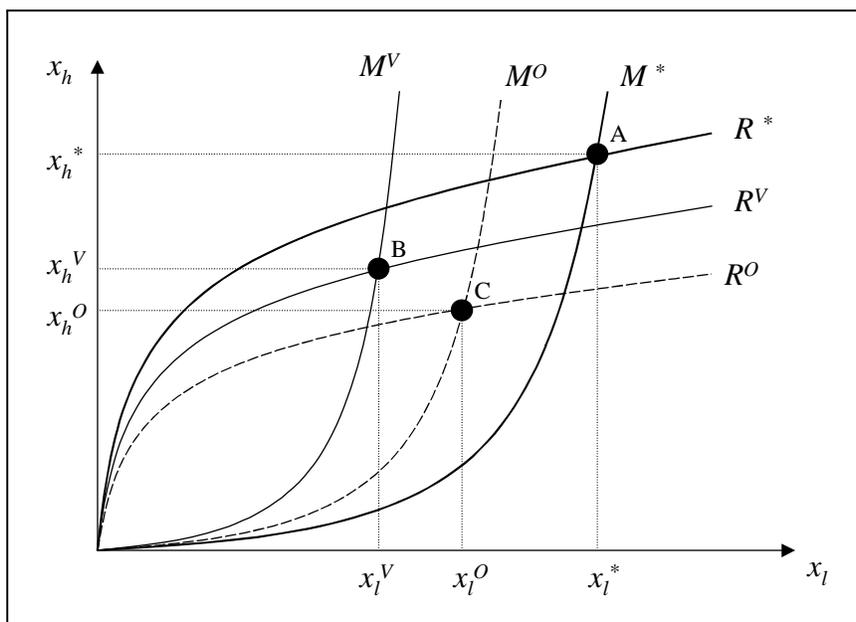
$$1 < \Theta(z) \equiv \frac{1 - \alpha(\bar{\phi}(1-z) + (1-\bar{\phi})z)}{1 - \alpha(\phi(1-z) + (1-\phi)z)} \left(\left(\frac{\bar{\phi}}{\phi} \right)^{1-z} \left(\frac{1-\bar{\phi}}{1-\phi} \right)^z \right)^{\frac{\alpha}{1-\alpha}} \quad (24)$$

Appendix A.4 demonstrates that $\Theta(z)$ is a decreasing function of z , and that both $\Theta(0) > 1$ and $\Theta(1) < 1$. This implies that there is unique cutoff $\bar{z}_{MS} = \Theta^{-1}(1)$ such that $\pi_M^S(z) > \pi^S(z)$ for $z < \bar{z}_{MS}$, and $\pi_M^S(z) < \pi^S(z)$ for $z > \bar{z}_{MS}$. The logic of this result also lies at the heart of Grossman and Hart's (1986) seminal contribution. Ex-ante efficiency dictates that residual rights should be controlled by the party undertaking a relatively more important investment. If production of the final good requires mostly product development (i.e., z is low), then the investment made by the assembly plant manager will be relatively small, and thus it will be optimal to assign the residual rights of control to the research center. Conversely, when the low-tech input is important in production, the research center will optimally choose to tilt the bargaining power in favor of the assembly plant by giving away these same residual rights.

Figure 4 illustrates this point by depicting the amounts of inputs produced under each organizational mode, as well as those prevailing under complete contracts. Incomplete contracts leads to underproduction of both x_h and x_l . The curves M^* and R^* represent the reaction functions $x_h^*(x_l)$ and $x_l^*(x_h)$ under complete contracts, with the corresponding equilibrium in point A. Similarly, B and C depict the incomplete-contract equilibria corresponding to vertical integration and arm's length transacting, respectively. The crucial point to notice from Figure 4 is that the underproduction in x_l is relatively higher under integration than under outsourcing. The more important is the low-tech input in production, the more value-reducing will the underinvestment in x_l be. It thus follows that profits under integration relative to those under arm's length transacting will tend to be lower, the more important is the low-tech input in production (i.e., the higher z).

So far I have only discussed the existence of the three cut-off levels: \bar{z} , \bar{z}_{MN} , and \bar{z}_{MS} .

Figure 4: Underproduction and Ownership Structure



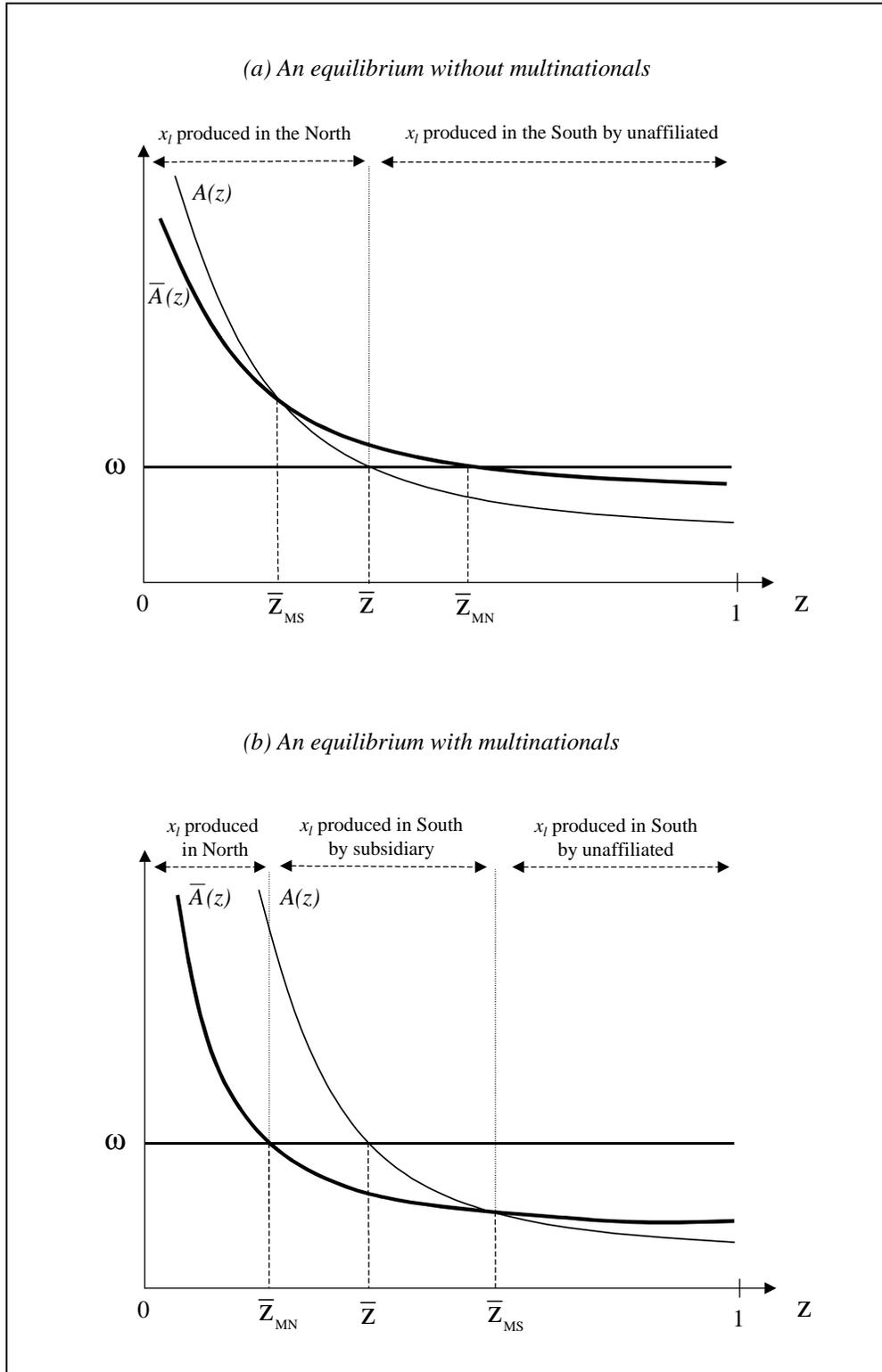
Notice, however, that $\Theta(z) = (A(z)/\bar{A}(z))^{\alpha z/(1-z)}$. This can be shown to imply that \bar{z} , \bar{z}_{MN} , and \bar{z}_{MS} must satisfy one of these three: (i) $\bar{z}_{MS} = \bar{z} = \bar{z}_{MN}$, (ii) $\bar{z}_{MS} < \bar{z} < \bar{z}_{MN}$, or (iii) $\bar{z}_{MN} < \bar{z} < \bar{z}_{MS}$.²⁹ Figure 5 is instructive in understanding this result. The figure depicts the curves $A(z)$ and $\bar{A}(z)$, the latter being the thicker curve. Under Assumptions 1 and 2, both $A(z)$ and $\bar{A}(z)$ are decreasing in z . That these curves intersect just once is ensured by the fact that $A(z') = \bar{A}(z')$ is only consistent with $\Theta(z') = 1$, which necessarily implies $z' = \bar{z}_{MS}$. Furthermore, it is easy to show that $A(z) > \bar{A}(z)$ for low enough z , while $A(1) < \bar{A}(1)$.³⁰ For any relative wage ω , it is clear that either $\bar{z}_{MS} < \bar{z} < \bar{z}_{MN}$ (top panel) or $\bar{z}_{MN} < \bar{z} < \bar{z}_{MS}$ (bottom panel). The case $\bar{z}_{MS} = \bar{z} = \bar{z}_{MN}$ will occur with probability zero and will be ignored hereafter.

As indicated in both panels in Figure 5, for a low enough value for z , the benefits from Southern assembly are too low relative to the distortions from incomplete contracting, and x_l is produced in the North. Furthermore, for a sufficiently high value of z , a profit-maximizing research center will decide to outsource the manufacturing input to an independent assembly plant in the South. Whether, for intermediate values of z , the research center becomes a

²⁹To see this, notice for instance that $\bar{z}_{MS} < \bar{z}$ if and only if both $A(\bar{z}_{MS}) > \omega$ and $\Theta(\bar{z}) < 1$. But the latter can only be true if $A(\bar{z})/\bar{A}(\bar{z}) = \omega/\bar{A}(\bar{z}) < 1$, which implies $\bar{z} < \bar{z}_{MN}$.

³⁰Notice the similarities between the curves $A(z)$ and $\bar{A}(z)$, and the comparative static exercise of increasing ϕ at the end of section 2.3.

Figure 5: Partial Equilibrium and Firm Boundaries



multinational firm or not depends on parameter values. If $\bar{z}_{MS} < \bar{z} < \bar{z}_{MN}$, then there exists no $z \in [0, 1]$ for which $\pi_M^S > \max\{\pi^N, \pi^S\}$, and multinational firms do not arise in equilibrium. Conversely, if $\bar{z}_{MN} < \bar{z} < \bar{z}_{MS}$, multinational firms can arise provided that $z \in [\bar{z}_{MN}, \bar{z}_{MS}]$. To summarize the results of this section,

Lemma 2 *If $\bar{z}_{MS} < \min\{\bar{z}, \bar{z}_{MN}\}$, the research center chooses to produce the low-tech input in the North for $z < \bar{z}$, and in the South by an unaffiliated party for $z > \bar{z}$. On the other hand, if $\bar{z}_{MS} > \min\{\bar{z}, \bar{z}_{MN}\}$, the low-tech input is produced in the North for $z < \bar{z}_{MN}$, in the South by an affiliated party if $\bar{z}_{MN} < z < \bar{z}_{MS}$, and in the South by an unaffiliated party if $\bar{z} > \bar{z}_{MS}$.*

Proof. See Appendix A.4. ■

An equilibrium with multinational firms is more likely the higher is \bar{z}_{MS} relative to the other two thresholds \bar{z} and \bar{z}_{MN} . In section 2.3, I showed that \bar{z} is a decreasing function of the relative wage ω . By way of implicit differentiation, and making use of the fact that $\bar{A}'(z) < 0$ whenever $\bar{\phi} \leq 3/4$, it follows that \bar{z}_{MN} is also decreasing in ω . The choice between an independent and an integrated Southern supplier, as captured by the threshold \bar{z}_{MS} is instead unaffected by the relative wage in the North.³¹ From this it follows that the measure of hi-tech intensities for which multinationals exist, i.e., $\min\{\bar{z}_{MS} - \bar{z}_{MN}, 0\}$, is non-decreasing in the relative wage ω in the North.

4.2 Dynamics: The Product Cycle

Consider a dynamic set-up analogous to that in section 2.4. As before, assume that the output elasticity of the low-tech input evolves according to $z(t) = h(t)$, with $h'(t) > 0$, $h(0) = 0$, and $\lim_{t \rightarrow \infty} h(t) = 1$. The parameters ϕ , α , ω , and δ are instead assumed to be time-invariant, implying that \bar{z} , \bar{z}_{MN} , and \bar{z}_{MS} are also constant through time. The following is a straightforward corollary of Lemma 2:

Proposition 4 *The model displays a product cycle. If $\bar{z}_{MS} < \min\{\bar{z}, \bar{z}_{MN}\}$, the product cycle is as described in Proposition 1. If instead $\bar{z}_{MS} > \min\{\bar{z}, \bar{z}_{MN}\}$, the following product cycle emerges. When the industry is young, i.e. $t < h^{-1}(\bar{z}_{MN})$, the low-tech input is produced in the North. For an intermediate maturity of the industry, $h^{-1}(\bar{z}_{MN}) < t <$*

³¹This follows directly from the assumption of Cobb-Douglas technology and isolates the partial-equilibrium decision to integrate or outsource from any potential general-equilibrium feedbacks. This implied block-recursiveness is a useful property for solving the model sequentially, but the main results should be robust to more general specifications for technology.

$h^{-1}(\bar{z}_{MS})$, production of the low-tech input is shifted to the South but is undertaken within firm boundaries. When the good is highly standardized, i.e. $t > h^{-1}(\bar{z}_{MS})$, production is shifted to an unaffiliated party in the South.

This is an important result of the paper. In words, it states that if the threshold product-development intensity at which manufacturing is shifted to the South is low enough, then production transfer will occur at arm's length and multinationals will not emerge in equilibrium. Conversely, if this threshold product-development intensity is high enough, manufacturing will be shifted to the South within the boundaries of the Northern firm by establishing a wholly-owned foreign affiliate. In such case, arm's length assembly in the South will only be observed at a later stage in the life cycle of the good.

As argued in the introduction, Proposition 4 is consistent with the evolution of the Korean electronics industry from the early 1960s to the late 1980s. The industry took off with the establishment of a few foreign affiliates of U.S. and Japanese-based corporations. These foreign affiliates were manufacturing goods that were relatively new for Korean standards and their exports constituted a very large percentage of Korean exports in electronics at that time. Then in the 1970s and 1980s, when the industry had matured, Northern corporations changed their strategies and started resorting much more to OEM and similar licensing arrangement. Within the industry, the evidence also seems to suggest that the probability of internalization of the technology transfer was higher for relatively new goods.

At a more micro level, several cross-sectional implications of the model are consistent with the findings of the empirical literature on the product cycle. Mansfield and Romeo (1980) analyzed 65 technology transfers by 31 U.S.-based firms in a variety of industries. They found that, on average, U.S.-based firms tended to transfer technologies internally to their subsidiaries within 6 years of their introduction in the United States. The average lag for technologies that were transferred through licensing or through a joint venture was instead 13 years.³² Similarly, after surveying R&D executives of 30 U.S.-based multinational firms, Mansfield, Romeo, and Wagner (1979) concluded that for young technologies (less than 5 years old), internal technology transfer tended to be preferred to licensing, whereas for more mature technologies (between 5 and 10 years), licensing became a much more attractive choice.

In much more detailed studies, Davidson and McFetridge (1984, 1985) looked at 1,376 internal and arm's-length transactions involving high-technology products carried out by 32 U.S.-based multinational enterprises between 1945 and 1975. Their logit estimates indicated

³²Their sample consisted of 39 internal transfer and 26 arm's length transfers.

that the probability of internalization was higher: (i) the newer and more radical was a technology; (ii) the fewer was the number of previous transfers of the same technology; and (iii) the larger was the fraction of the transferor's resources devoted to scientific R&D.

Considering again the specific functional form $z(t) = 1 - e^{-\frac{t}{\theta}}$, it is straightforward to check that another cross-sectional implication of the model is that an increase in the rate of standardization $1/\theta$ anticipates the shift of production towards the South but (weakly) reduces the length of time that the good is produced by a wholly-owned affiliate in the South. Using a sample of 350 US firms, Wilson (1977) indeed concluded that licensing was more attractive the less complex was the good involved, with his measure of complexity being positively correlated with the amount of R&D undertaken for its production. In their study of the transfer of 35 Swedish innovations, Kogut and Zander (1993) similarly found that the probability of internalization was lower the more codifiable and teachable and the less complex was the technology.

As mentioned at the end section 4.1, another implication of the model is that an increase in ω not only makes the shift to Southern production earlier (as in section 2.4), but also increases the probability that this transfer will occur within firm boundaries. This is also consistent with the cross-sectional results of at least two contributions to the empirical literature on the product cycle. In their sample of 1,376 transfers, Davidson and McFetridge (1985) found that controlling for several characteristics of the recipient country, a higher GNP per capita of the recipient country (in the model a lower ω) was associated with a lower probability of internalization. Using aggregate industry data from the U.S. Department of Commerce, Contractor (1984) found similar results.

4.3 General Equilibrium

In this section, I will adopt again the general-equilibrium framework in section 3 and solve for the equilibrium relative wage in the North in the model with multinational firms. By doing so, we can study the effect of some additional factors on the choice between foreign direct investment and arm's length arrangements, as well as the welfare implications of the emergence of multinational firms.

Consider first the industry equilibrium. As before, the unit elasticity of substitution between varieties in different industries allows an independent analysis of each industry. Furthermore, since all research centers share the same technology and contracting environment, they all behave in an identical manner. If $\bar{z}_{MS} < \min\{\bar{z}(t), \bar{z}_{MN}(t)\}$, there will be no active multinationals and the equilibrium number of varieties in any industry j is again

given by equation (14).³³ If instead $\bar{z}_{MS} > \min\{\bar{z}(t), \bar{z}_{MN}(t)\}$, then it can be shown that $n_j(t)$ is given by:

$$n_j(t) = \begin{cases} \frac{(1-\alpha)E(t)}{N(t)w^N(t)f} & \text{if } z_j(t-t_{0j}) < \bar{z}_{MN}(t) \\ \frac{(1-\alpha(\bar{\phi}(1-z_j(t-t_{0j}))+(1-\bar{\phi})z_j(t-t_{0j})))E(t)}{N(t)w^N(t)f} & \text{if } \bar{z}_{MN}(t) < z_j(t-t_{0j}) < \bar{z}_{MS} \\ \frac{(1-\alpha(\phi(1-z_j(t-t_{0j}))+(1-\phi)z_j(t-t_{0j})))E(t)}{N(t)w^N(t)f} & \text{if } z_j(t-t_{0j}) > \bar{z}_{MS} \end{cases} \quad (25)$$

In order to solve for the equilibrium relative wage, we will focus again on labor-market clearing in the South. It is useful to define $\tilde{z}(t) = \min\{\bar{z}_{MN}(t), \bar{z}(t)\}$, which according to Lemma 2 constitutes the threshold z above which production is shifted to the South regardless of ownership structure. Notice that this is the only variable apart from $\omega(t)$ that we need to pin down in the general equilibrium. This is because \bar{z}_{MS} does not depend on $\omega(t)$ and because the threshold $\bar{z}_{MN}(t)$ is only relevant when $\bar{z}_{MN}(t) < \bar{z}(t)$ (in which case $\bar{z}(t)$ is irrelevant). Computing labor demand by the Southern assembly plant yields a labor market clearing condition analogous to equation (16) above:

$$\int_{\tilde{z}(t)}^1 \alpha(1-\phi_z)zE(t)f_{z,t}(z)dz = w^S(t)L^S, \quad (26)$$

where $\phi_z = \bar{\phi}$ if $\bar{z}_{MN}(t) < z < \bar{z}_{MS}(t)$, and $\phi_z = \phi$ otherwise.

To save on notation, let the distribution function $F_{z,t}(z)$ converges to a time-invariant distribution, so that we can focus on the steady-state general equilibrium and safely drop time subscripts. Notice then that multinationals are active only if $\tilde{z} \leq \bar{z}_{MS}$. Plugging equation (15) into (26), and defining again $\xi(a, b) \equiv \int_a^b z f_z(z) dz$, we find the following equilibrium condition relating ω and \tilde{z} :

$$\omega = B_M(\tilde{z}) \equiv \begin{cases} \frac{1-\alpha(1-\bar{\phi})\xi(\tilde{z}, \bar{z}_{MS}) - \alpha(1-\phi)\xi(\bar{z}_{MS}, 1)}{\alpha(1-\bar{\phi})\xi(\tilde{z}, \bar{z}_{MS}) + \alpha(1-\phi)\xi(\bar{z}_{MS}, 1)} \frac{L^S}{L^N} & \text{if } \tilde{z} < \bar{z}_{MS} \\ \frac{1-\alpha(1-\phi)\xi(\tilde{z}, 1)}{\alpha(1-\phi)\xi(\tilde{z}, 1)} \frac{L^S}{L^N} & \text{if } \tilde{z} > \bar{z}_{MS} \end{cases} \quad (27)$$

Notice that if $\tilde{z} > \bar{z}_{MS}$ the equilibrium is one without multinationals and therefore the equilibrium condition collapses back to the one in the previous model, i.e. $B_M(\tilde{z}) = B(\tilde{z})$. If instead $\tilde{z} < \bar{z}_{MS}$, multinationals will arise in equilibrium. Furthermore, from the standard logic in Grossman and Hart (1986), an integrated assembly plant manager will tend to underinvest relative to a non-integrated one. Hence, for a given z , Southern labor demand is

³³Notice that if ϕ , α , and δ are time-invariant, so will \bar{z}_{MS} . The other two thresholds will only be constant through time in a steady-state equilibrium with a constant relative wage.

relatively lower for vertically-integrated manufacturing plants. It follows that for $\tilde{z} < \bar{z}_{MS}$, $B_M(\tilde{z}) > B(\tilde{z})$. This is depicted in Figure 6, where for comparison the curve $B(\tilde{z})$ is plotted as a dotted curve. Note also that $B_M(\tilde{z})$ is continuous and increasing function of \tilde{z} . Furthermore it satisfies $B_M(0) > B(0) > 0$ and $\lim_{\tilde{z} \rightarrow 1} B_M(\tilde{z}) = +\infty$.

The other equilibrium condition that pins down \tilde{z} and ω comes from firm behavior. In particular, since \bar{z} is implicitly defined by $\omega = A(\bar{z})$, and \bar{z}_{MN} is implicitly defined by $\omega = \bar{A}(\bar{z}_{MN})$, it follows that $\tilde{z} = \min\{\bar{z}_{MN}, \bar{z}\}$ is implicitly defined by:

$$\omega = A_M(\tilde{z}) \equiv \begin{cases} \left(\frac{1-\alpha}{1-\alpha(\bar{\phi}(1-\tilde{z})+(1-\bar{\phi})\tilde{z})} \right)^{(1-\alpha)/\alpha\tilde{z}} \frac{\bar{\phi}^{-(1-\tilde{z})/\tilde{z}}}{1-\bar{\phi}} & \text{if } \tilde{z} < \bar{z}_{MS} \\ \left(\frac{1-\alpha}{1-\alpha(\phi(1-\tilde{z})+(1-\phi)\tilde{z})} \right)^{(1-\alpha)/\alpha\tilde{z}} \frac{\phi^{-(1-\tilde{z})/\tilde{z}}}{1-\phi} & \text{if } \tilde{z} > \bar{z}_{MS} \end{cases}. \quad (28)$$

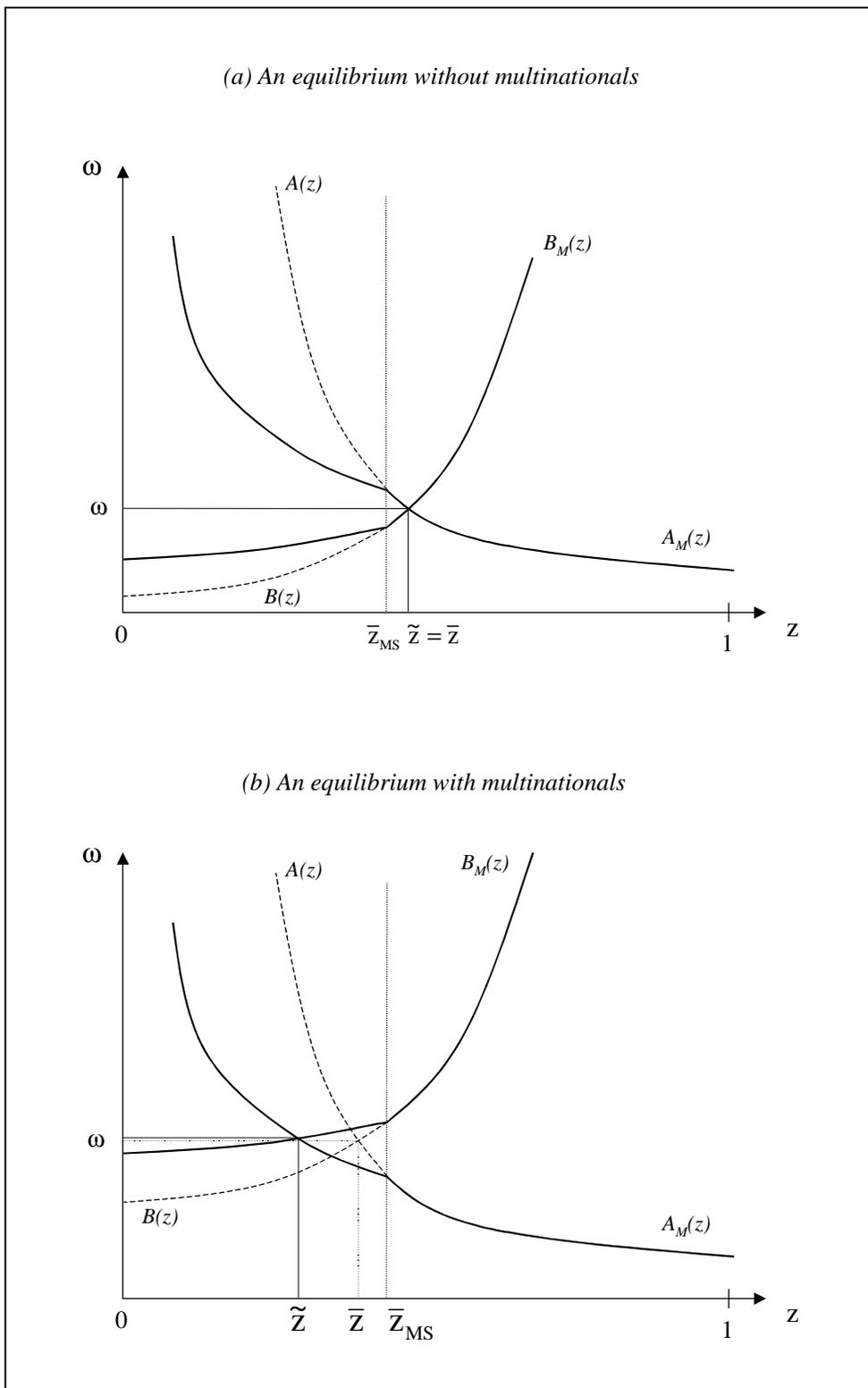
Again, if $\tilde{z} > \bar{z}_{MS}$, multinationals are not active in equilibrium and $A_M(\tilde{z}) = A(\tilde{z})$. On the other hand, if $\tilde{z} < \bar{z}_{MS}$, then it must be the case that $\Theta(\tilde{z}) > 1$, which of course implies $A_M(\tilde{z}) = \bar{A}(\tilde{z}) < A(\tilde{z})$. Research centers choose to vertically integrate the Southern manufacturing plant only when, by doing so, they manage to alleviate the distortions stemming from incomplete contracting. It should therefore not be surprising that to match the profitability of Northern assembly, an integrated manufacturing plant requires a lower relative wage than an independent one, This is again depicted in Figure 6, where the curve $A(\tilde{z})$ is the dotted one. Notice that $A_M(\tilde{z})$ is continuous and, under Assumptions 1 and 2, decreasing in \tilde{z} . Furthermore, $\lim_{\tilde{z} \rightarrow 0} A_M(\tilde{z}) = +\infty$ and $A_M(1) > 1$.

As illustrated in Figure 6, there exists a unique general-equilibrium (\tilde{z}, ω) pair. Depending on parameter values, the equilibrium is one with no multinational firms (top panel) or one with multinational firms (bottom panel). In the first case, the equilibrium is identical to that in the world with only arm's length transacting. As before, in the steady state, the general-equilibrium values of \tilde{z} and ω are time-invariant, and all industries will necessarily follow product cycles, with varieties in those industries first being manufactured in the North and then later in the South. On top of this endogenous product cycles, the model may feature endogenous organizational cycles, with technologies first shifted to the South within firm boundaries and only later licensed to independent firms in the South.

The following interesting result follows from direct inspection of Figure 6:

Proposition 5 *Relative to a world with only arm's length transacting, allowing for intrafirm technology transfer by multinational firms weakly accelerates the transfer of production to the South (lowers \tilde{z}), while having an ambiguous effect on the relative wage ω .*

Figure 6: General Equilibrium and Firm Boundaries



The intuition for this result is the following. The introduction of multinational firms in a world with only arm's length transacting (weakly) alleviates contract incompleteness. This is because the research center is now given the possibility to have the low-tech input produced in the South, while facing less of a hold-up problem in their production of the hi-tech input. When this option is chosen, the threshold z above which x_l is produced in the South necessarily falls (\tilde{z} falls). Alternatively, the relative Northern wage above which x_l is produced in the South necessarily falls (remember that this is the reason why $\bar{A}(\tilde{z}) < A(\tilde{z})$ to the left of \bar{z}_{MS}). On top of this partial-equilibrium effect, there is a general-equilibrium effect. As discussed above, integrated manufacturing plants demand relatively less Southern labor. To clear the Southern labor market requires either an increase in the measure of z 's for which production is done in the South (again a fall in \tilde{z}) or a fall in the relative wage in the South (a higher ω). In sum, both the partial and general-equilibrium effects work to reduce \tilde{z} , while they have opposite effects on the equilibrium relative wage.

The result in Proposition 5 fits well Moran's (2001) recent study of the effects of domestic-content, joint-venture, and technology-sharing mandates on production transfer to developing countries. Plants in host countries that impose such restrictions, he writes, "*utilize older technology, and suffer lags in the introduction of newer processes and products in comparison to wholly owned subsidiaries without such requirements*" (p. 32). He also describes an interesting case study. In 1998, Eastman Kodak agreed to set up joint ventures with three designated Chinese partners. These joint ventures specialized in producing conventional films under the Kodak name. When the Chinese government allowed Kodak to establish a parallel wholly owned plant, Kodak shifted to this affiliate the manufacturing of the latest digitalized film and camera products (Moran, 2001, p. 36).

4.4 Comparative Statics

Let us now return to the particular case analyzed before, so that $\xi_t(a, b)$ converges to

$$\xi(a, b) \equiv \int_a^b z f_{z,t}(z) dz = \int_a^b \frac{z g \theta_\mu}{\left(1 + g \theta_\mu \ln\left(\frac{1}{1-z}\right)\right)^2 (1-z)} dz$$

As before, an increase in g , θ_μ or L^S/L^N shifts the $B_M(\tilde{z})$ curve up and to the left (see Appendix A.2). This tends to increase the relative wage in the North and reduce \tilde{z} , so that production is shifted to the South earlier. Hence, introducing multinational firms does not undermine the validity of the comparative static results in Proposition 2.

More interestingly, an increase in the rate of invention, a slowdown in the rate of standardization, and an increase in the relative size of the South all tend to (weakly) increase

the measure of product-development intensities for which multinational firms exist:

Proposition 6 *The measure of product-development intensities for which multinationals exist, i.e., $\min\{\bar{z}_{MS} - \bar{z}_{MN}, 0\}$, is non-decreasing in g , θ_μ , and L^S/L^N .*

Intuitively, by creating an excess supply of Northern labor, an increase in g , θ_μ , and L^S/L^N , lead to an increase in the relative wage and an increase in the threshold product-development intensity $(1 - \tilde{z})$ below which manufacturing is transferred to the South. From the standard Grossman-Hart logic, it then becomes more likely that the Northern research center will decide to keep this transfer within firm boundaries.

Several authors have identified a recent surge in foreign direct investment flows to less developed countries (e.g., Feenstra, 1999). According to Proposition 6, this fact can be explained by the same forces that would have led to a fall in the interval of time between the introduction of a new product in the North and its first production in a less developed country (see the discussion following Proposition 2).

4.5 Welfare

According to Proposition 5, a shift towards an equilibrium in which foreign direct investment flows are positive accelerates the transfer of production to the South, while having an ambiguous effect on the relative wages. I now analyze the welfare implications of such a shift. To do so, it is useful to decompose again the change in welfare into the following three components: (a) terms of trade, (b) production efficiency, and (c) available products.

The fact that the introduction of multinational firms has an ambiguous effect on relative wages implies an equally ambiguous welfare change on account of both the terms-of-trade and the available-products components. In contrast, it is easy to show that the production efficiency effect works to increase welfare in both countries. On the one hand, multinationals will only be active to the extent that they alleviate the distortions coming from incomplete contracting. On the other hand, when active, multinationals lead to a shift of production to the lower-wage country.

In general, the net effect on each country's welfare is ambiguous. It can be shown, however, that the available-products effect is again dominated by the production efficiency component. It thus follows that:

Proposition 7 *Provided that its effect on relative wages is small enough, allowing for intrafirm production transfer by multinational firms is welfare improving for both countries.*

If the terms-of-trade effect is negligible, then the introduction of multinational firms has a net positive effect on each country's welfare. This result provides some support for the view pushed by Moran (2001), that the domestic-content, joint-venture, and technology-sharing requirements that certain host countries impose on foreign firms have a negative net contribution to welfare.

5 Conclusions

This paper presented a dynamic, general-equilibrium model featuring both endogenous product cycles and endogenous organizational cycles. It has been argued that the same forces that make firms choose to manufacture their new goods in high-wage countries can explain why, when they decide to transfer production to low-wage countries, they might choose to do so inside their firm boundaries. The model delivered a few macroeconomic implications that complement the work of Krugman (1979). For instance, I showed that increased technological change in rich countries will widen the world distribution of income only to the extent that technological change takes the form of an addition of new goods to the economy. When technological change takes the form of a continuous standardization of products, then an acceleration of technological change leads instead to a narrowing of the world distribution of income. Furthermore, it was shown that an improvement in the contractual environment in international transactions would necessarily benefit low-wage countries, with the net welfare effect being in generally ambiguous for high-wage countries.

In contrast to previous general-equilibrium theories of the multinational firm, firm boundaries were not drawn appealing to technological considerations, such as economies of scale or transport costs.³⁴ As in Antràs (2002), I instead set forth a purely organizational, property-rights model of the multinational firm.³⁵ Multinational firms emerged in equilibrium whenever transaction-cost minimization dictated that certain goods would be transacted more efficiently within firm boundaries than at arm's length. Relative to a world with only arm's length transacting, I showed that multinational firms, by alleviating contract incompleteness, anticipated the transfer of production to low-wage countries and,

³⁴This previous literature builds on the seminal work of Helpman (1984) and Markusen (1984). An exception is the work of Ethier (1986), who also dealt with the crucial issue of internalization, although in a very different framework. For an extensive review of previous theories of the multinational firm see Caves (1996).

³⁵This paper is related to an emerging literature on general-equilibrium models of ownership structure (c.f., McLaren, 2000, Grossman and Helpman, 2002a, Antràs, 2002). In Antràs (2002), I unveiled two systematic patterns in the volume of intrafirm trade, which I then rationalized in a theoretical framework that combined a Grossman-Hart-Moore view of the firm with a Helpman-Krugman view of international trade.

under certain conditions, increased welfare in both rich and poor countries.

The simple model developed here has proven to be a useful lens through which to interpret several findings in the international business literature. Nevertheless, much remains to be done. For instance, the present framework has abstracted from at least one important channel of production transfer, namely, imitation. Future efforts should also be directed at incorporating elements of alternative theories of the firm to the study of international patterns of specialization. Holmström and Milgrom (1994) have emphasized that, in many situations, issues related to job design and the cost of measuring performance are more relevant when choosing between inside or outside procurement. It would be interesting to investigate the implications of such a view of the firm for the way in which multinational firms organize their operations worldwide.

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A Appendix

A.1 Proof of Lemma 1

I will first show that under Assumption 1, $A'(z) < 0$ for all $z \in [0, 1]$.

Lemma 3 *If $\phi \leq 3/4$, then $A'(z) < 0$ for all $z \in [0, 1]$.*

Proof. *Straightforward differentiation yields $A'(z) < 0$ if and only if*

$$r(z, \phi, \alpha) = \ln \left(\frac{1 - \alpha(\phi(1-z) + (1-\phi)z)}{1-\alpha} \phi^{\alpha/(1-\alpha)} \right) - \frac{(2\phi-1)\alpha z}{(1-\alpha(\phi(1-z) + (1-\phi)z))} < 0$$

It can be shown that both $\partial r(\cdot)/\partial z \geq 0$ for all $z \in [0, 1]$ (with strict inequality for $z > 0$), and $\partial r(\cdot)/\partial \phi \geq 0$ all $\phi \in (0, 1)$. We hence need only show that $r(1, 3/4, \alpha) < 0$. But this is true because $\partial r(1, 3/4, \alpha)/\partial \alpha < 0$ for $\alpha \in (0, 1)$ and $r(1, 3/4, 0) = 0$. QED.³⁶ ■

Notice next that $\omega < \lim_{z \rightarrow 0} A(z) = \infty$, where in computing the limit I make use of the fact that $(1 - \alpha x) x^{\alpha/(1-\alpha)}$ is increasing in x for $\alpha \in (0, 1)$ and $x \in (0, 1)$. Finally, by Condition 1, there exists a $z_c \in [0, 1]$ such that $A(z_c) < \omega$. Since $A(z)$ is a continuous function of z for $z \in [0, 1]$, and by Lemma 3 $A'(z) < 0$, it follows that there is a unique \bar{z} such that $\omega = A(\bar{z})$. Furthermore, for all $z < \bar{z}$, $A(z) > \omega$, and for all $z > \bar{z}$, $A(z) < \omega$. QED.

A.2 Algebra of the Particular Case

I will first show that the distribution of z converges to a c.d.f. characterized by equation (20). Note that from equation (19), $t_{0j} = t + \theta_j \ln(1 - z_j(t, t_{0j}))$. For a given θ_j , the fraction of industries with $z_j(t - t_{0j}) < z$ converges to

$$F_z(z|\theta_j) = 1 - F_{t_0}(t + \theta_j \ln(1 - z), t) = 1 - (1 - z)^{g\theta_j},$$

where I have used the fact that the distribution of birth dates converges to $F_{t_0}(t_0, t) = e^{-g(t-t_0)}$, as well as the fact that t_{0j} and θ_j are independent. If $F_\theta(\theta_j) = 1 - e^{-\theta_j/\theta_\mu}$, the limiting unconditional distribution is then given by

$$F_z(z) = 1 - \int_0^\infty (1 - z)^{g\theta_j} \cdot f_\theta(\theta_j) \cdot d\theta_j = \frac{g\theta_\mu \left(\ln \left(\frac{1}{1-z} \right) \right)}{1 + g\theta_\mu \left(\ln \left(\frac{1}{1-z} \right) \right)},$$

as claimed in equation (20) above.

³⁶To see that an upper bound on ϕ is required, notice that at $\phi = 1$, $r(z, 1, \alpha) = \ln \left(\frac{1 - \alpha(1-z)}{1-\alpha} \right) - \frac{\alpha z}{1 - \alpha(1-z)}$, which is positive for high enough z .

Letting $f_z(z)$ be the corresponding probability density function, it follows that

$$\xi(a, b) \equiv \int_a^b z f(z) dz = \int_a^b \frac{z g \theta_\mu}{\left(1 + g \theta_\mu \ln\left(\frac{1}{1-z}\right)\right)^2 (1-z)} dz$$

Integrating by parts yields:

$$\xi(a, b) = \frac{a}{1 + g \theta_\mu \ln\left(\frac{1}{1-a}\right)} - \frac{b}{1 + g \theta_\mu \ln\left(\frac{1}{1-b}\right)} + \int_a^b \frac{1}{1 + g \theta_\mu \ln\left(\frac{1}{1-z}\right)} dz \quad (\text{A.1})$$

To proof the claim in section 3.4 that an increase in g or θ_μ shifts the $B(\cdot)$ curve up and to the left, we need only show that $\partial \xi(\bar{z}, 1) / \partial g < 0$ and $\partial \xi(\bar{z}, 1) / \partial \theta_\mu < 0$. But this is follows from straightforward differentiation of $\xi(\bar{z}, 1)$ in (A.1). Similarly, to proof the claim in section 4.3 that an increase in g or θ_μ shifts the $B_M(\cdot)$ curve up and to the left, notice that $\xi(\tilde{z}, \bar{z}_{MS}) + \xi(\bar{z}_{MS}, 1) = \xi(\tilde{z}, 1)$, and therefore $(1 - \bar{\phi}) \xi(\tilde{z}, \bar{z}_{MS}) + (1 - \phi) \xi(\bar{z}_{MS}, 1) = (1 - \bar{\phi}) \xi(\tilde{z}, 1) + (\bar{\phi} - \phi) \xi(\bar{z}_{MS}, 1)$. The result then follows again from $\partial \xi(z, 1) / \partial \theta_\mu < 0$ and $\partial \xi(z, 1) / \partial g < 0$ for all z .

A.3 Proof of Proposition 3

The results in Proposition 3 follow from comparing instantaneous welfare in a steady-state equilibrium with incomplete contracts to that in a steady-state equilibrium with complete contracts. Let us first derive a general expression for instantaneous welfare. Plugging equation (11) into (10), imposing the equality of income and spending, and rearranging, welfare in country $c = \{N, S\}$ can be expressed as:

$$u^c = \frac{w^c L^c}{N} \int_0^N \left(\int_0^{n_j} p_j(i)^{-\alpha/(1-\alpha)} di \right)^{(1-\alpha)/\alpha} dj \quad (\text{A.2})$$

In an equilibrium with incomplete contracts, the North manufactures all varieties in industries with $z_j < \bar{z}$. Substituting the relevant values of $p_j(i)$ and $n_j(i)$ and using the definition of $A(z)$ in equation (7), welfare in the North can be expressed as

$$u_{IC}^N = \alpha L^N \left(\frac{(1-\alpha)(L^N + L^S/\omega)}{Nf} \right)^{(1-\alpha)/\alpha} \left(F(\bar{z}) + \int_{\bar{z}}^1 \left(\frac{\omega}{A(z)} \right)^z f_z(z) dz \right), \quad (\text{A.2})$$

while that in the South is simply $u_{IC}^S = u_{IC}^N L^S / (\omega L^N)$.

Under complete contracts and wage equalization (i.e., $B_C(0) < 1$), welfare in country c reduces to

$$u_{CC}^c = \alpha L^c \left(\frac{(1-\alpha)(L^N + L^S)}{Nf} \right)^{(1-\alpha)/\alpha}. \quad (\text{A.3})$$

Comparing equations (A.2) and (A.3) and given that $\omega > A(z)$ for all $z > \bar{z}$, it is easy to see that the North may indeed be better off under incomplete contracts. The result is ambiguous

because of the the second term in equation (A.2). In contrast, the South necessarily benefits from complete contracts because under incomplete contracts both $\omega > 1$ and $A(z) > 1$ for all $z \in [0, 1]$.

Finally consider the case of complete contracts and $B_C(0) > 1$. Denote the relative wage in this equilibrium by $\omega_C > 1$. In this case, welfare is given by:

$$u_{CC'}^N = \alpha L^N \left(\frac{(1-\alpha)(L^N + L^S/\omega_C)}{Nf} \right)^{(1-\alpha)/\alpha} \int_0^1 \omega_C^z f_z(z) dz, \quad (\text{A.4})$$

while that in the South is simply $u_{CC'}^S = u_{CC'}^N L^S / (\omega_C L^N)$. The South is again necessarily better off under complete contracts because $\omega > \omega_C$ and $A(z) > 1$ for all $z \in [0, 1]$. The effect on Northern welfare is again ambiguous.

A.4 Proof of Lemma 2

The only thing that was not proved in the main text is that $\Theta(z)$ is decreasing in z , and that both $\Theta(0) > 1$ and $\Theta(1) < 1$. Using $\bar{\phi} = \delta^\alpha + \phi(1 - \delta^\alpha)$, we can rewrite $\Theta(z)$ in equation (24) as

$$\Theta(z) = \left(1 + \frac{\alpha(1-\phi)\delta^\alpha(2z-1)}{1-\alpha(\phi(1-z) + (1-\phi)z)} \right) \left(1 + \frac{\delta^\alpha}{\phi(1-\delta^\alpha)} \right)^{\frac{\alpha(1-z)}{1-\alpha}} (1-\delta^\alpha)^{\frac{\alpha}{1-\alpha}}$$

From simple differentiation, it follows that $\partial\Theta(\cdot)/\partial z < 0$ if and only if

$$\Omega(z) \ln \left(1 + \frac{\delta^\alpha}{\phi(1-\delta^\alpha)} \right) > (2-\alpha)(1-\alpha)(1-\phi)\delta^\alpha$$

where $\Omega(z) = (1-\alpha(\phi(1-z) + (1-\phi)z))(1-\alpha(\bar{\phi}(1-z) + (1-\bar{\phi})z))$ and remember that $\bar{\phi} = \delta^\alpha + \phi(1 - \delta^\alpha)$. Now notice that if $\bar{\phi} > \phi \geq 1/2$ then $\Omega'(z) > 0 \forall z \in [0, 1]$, and if $\phi < \bar{\phi} \leq 1/2$, then $\Omega'(z) < 0 \forall z \in [0, 1]$. Furthermore, if $\bar{\phi} > 1/2 > \phi$, then $\Omega''(z) < 0 \forall z \in [0, 1]$. It thus follows that $\Omega(z) \geq \min\{\Omega(0), \Omega(1)\}$. Without loss of generality, assume that $\Omega(0) = (1-\alpha\phi)(1-\alpha(\phi + (1-\phi)\delta^\alpha)) < \Omega(1)$ (the case $\Omega(1) < \Omega(0)$ is entirely symmetric). We need to show that $\vartheta(\delta) > 0$ for all $\delta \in (0, 1)$ where

$$\vartheta(\delta) = \ln \left(1 + \frac{\delta^\alpha}{\phi(1-\delta^\alpha)} \right) - \frac{(2-\alpha)(1-\alpha)(1-\phi)\delta^\alpha}{(1-\alpha\phi)(1-\alpha(\phi + (1-\phi)\delta^\alpha))}$$

From simple differentiation of this expression, it follows that $\vartheta'(\delta) > 0$ if and only if $(1-\alpha\rho)^2 - (2-\alpha)(1-\alpha)(1-\rho)\rho > 0$ for some $\rho \in (0, 1)$. But it is simple to check that this is in fact true all $\alpha, \rho \in (0, 1)$, and therefore $\vartheta(\delta) > \vartheta(0) = 0$.

Finally, notice that $\Theta(0) = \frac{1-\alpha\bar{\phi}}{1-\alpha\phi} \left(\frac{\bar{\phi}}{\phi} \right)^{\frac{\alpha}{1-\alpha}} > 1$ and $\Theta(1) = \frac{1-\alpha(1-\bar{\phi})}{1-\alpha(1-\phi)} \left(\frac{1-\bar{\phi}}{1-\phi} \right)^{\frac{\alpha}{1-\alpha}} < 1$, where the inequalities follow from $\bar{\phi} > \phi$ and the fact that $(1-\alpha x)x^{\frac{\alpha}{1-\alpha}}$ is an increasing function of x for $\alpha \in (0, 1)$ and $x \in (0, 1)$. QED.