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, the incompleteness of international contracts is shown to lead to the emergence of product cycles. Because of contractual frictions, goods are initially manufactured in the North, where product development takes place. As the good matures and becomes more standardized, the manufacturing stage of production 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. The model gives rise to a new version of the product cycle 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), as well as microeconomic implications consistent with the findings of the empirical literature on the product cycle.

Keywords 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 emerging from this literature turned out to be much richer than Vernon originally envisioned. 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 by 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

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

[2] See, 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 in section 4 below.

(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 it, was later endogenized by Grossman and Helpman (1991a,b) using the machinery developed by the endogenous growth literature.[3] 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.[4]

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, from that in Grossman and Helpman (1991a,b) in that 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, as well as their 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's life cycle entail substantial testing and re-testing of prototypes as well as considerable marketing efforts to make consumers aware of the ex-

[3]See Jensen and Thursby (1987), and Segerstrom et al. (1990) for related theories of endogenous product cycles.

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

istence of the good. As the good matures and production techniques become standardized, 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 Northern firms to split the production process internationally and transact with manufacturing plants in the South.[5] 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 delayed 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 hold-up problems, which in turn give rise to suboptimal relationship-specific investments by the parties involved in an international 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 and overseas manufacturing, the product development manager therefore faces a trade-off between the lower costs of Southern manufacturing and the higher incomplete-contracting distortions associated with it. 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 (which affects both the manufacturing *and* the product development inputs in production) 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

[5] There 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 others. Feenstra (1998) discusses the widely cite 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.

produced in the South.

The model developed in section 2 focuses first on the profit-maximizing choice of location by a single Northern product development manager. In section 3, I embed this choice in a general-equilibrium, dynamic 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 incompleteness of contracts in international transactions. I also show how these same forces bring about an equilibrium wage in the North that exceeds that in the South.

I next study the effect of an acceleration of technological change in the North on the world distribution of income. I show that Krugman's (1979) 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, the converse result is shown to apply and relative wages move in favor of the South. Section 3 concludes with an analysis of 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. I discuss the relationship between this result and Helpman's (1993) analysis of the welfare effects of a tightening of intellectual property rights in models of imitation.

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 in the model, i.e., incomplete contracts, opens the door to a parallel analysis of the determinants of ownership structure, which I carry out in section 4. 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 these 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) is shown to dictate that residual rights be controlled by the party whose investment contributes most to the value of the relationship. In terms of the model, the attractiveness for a Northern product-development manager of integrating the transfer of production to the South is shown to be increasing in the output elasticity of product development, and thus decreasing in the maturity of the good at the time of the transfer.

As a result, a new version of the product cycle emerges. If the threshold maturity at which manufacturing is shifted to the South is low enough, production will be transferred internally to a wholly-owned foreign affiliate in the South, and the Northern firm will become a multinational firm. In that case, only at a later stage in the product life-cycle will the product development manager find it optimal to give away the residual rights of control, and assign assembly to an independent subcontractor in the South, an arrangement which is analogous to the Northern firm licensing its technology (hi-tech input). 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 with only arm's length transactions, allowing for 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 discuss several cross-sectional and time-series implications of the model and relate them to the empirical literature on the product cycle. For instance, the model is shown to be useful for understanding the evolution of the Korean electronics industry after the Korean War.

The rest of the paper is structured as follows. Section 2 develops 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 transfers 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 production transfer. In section 4, I allow for intrafirm production transfers and describe the richer product life-cycle that emerges from it, both in partial and in general equilibrium. Section 5 offers some concluding comments.

2 Incomplete Contracts and the Life Cycle of a Product

This section develops a simple model in which a product development manager decides 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 simple dynamic extension in which the good gets standardized over time.

2.1 Set-up

Consider a world with 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:

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

where p is the price of the good and λ is a parameter that the producer takes as given.[6]

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, marketing, and other similar skill-demanding tasks. The low-tech input is instead meant to capture the mere manufacturing or assembly of the good. 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:

$$y = \zeta_z x_h^{1-z} x_l^z, \qquad 0 \leq z \leq 1, \tag{2}$$

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 one 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. For simplicity, 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 good-quality, low-tech input also requires labor, but the unit input requirement is assumed to be equal to 1 in both countries. Finally, production of any type of bad-quality input can be undertaken at

[6] This demand function will be derived from preferences in the general-equilibrium model.

a positive but negligible cost. Both the hi-tech and the low-tech inputs are assumed to be freely tradable.

There are two types of producers: a research center and a manufacturing 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.[7] As discussed in the introduction, I allow for an international fragmentation of the production process. Before any investment is made, a research center decides whether to produce a hi-tech input, and if so, whether to obtain the low-tech input from an independent manufacturing plant in the North or from one in the South. Upon entry, the manufacturer makes a lump-sum transfer T to the research center.[8] 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.[9] The research center chooses the location of manufacturing to maximize its ex-ante profits, which include the transfer.

Investments are assumed to be relationship-specific. The research center tailors the hi-tech input specifically to the manufacturing 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.

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 manufacturing 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 negligible cost. It is equally assumed that no outside

[7] In section 4, I allow the research center to obtain the low-tech input from an integrated manuacturing plant.

[8] For the purposes of this paper it is not necessary to specify which of the two types of firms produces the final good. When y is produced by the manufacturing plant, this transfer T can be interpreted as a lump-sum licensing fee for the use of the hi-tech input.

[9] This assumption simplifies the description of the industry equilibrium in section 3. For the results in the present section, it would suffice to assume that no firm is cash-constrained, so that the equilibrium location of manufacturing maximizes the joint value of the relationship.

[10] This can be interpreted as a physical constraint imposed on the outside party, which might not be able to verify the quality of both inputs when these are produced in distant locations More generally, the 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.

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 a manufacturing 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 the low-tech input is produced 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 model this ex-post bargaining as a Generalized Nash Bargaining game in which the research center obtains a fraction $\phi > 0$ of the ex-post gains from trade. Because 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, when the production process is fragmented internationally, the incompleteness of contracts will lead to underinvestment in both the product development and manufacturing inputs. 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. In order to simplify the derivation of some of the results below, it is useful to assume that the product development input 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, Assumption 1 is consistent with available evidence: "*the empirical evidence on licensing convincingly shows that licensors on average can appropriate less than half of the surplus associated with the license transaction*" (Caves, 1996, p. 167).

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

[11] I take the fact that contracts are incomplete as given. Aghion et al. (1994), Nöldeke and Schmidt (1995) and others, have shown that allowing for specific-performance contracts may lead to efficient ex-ante relationship-specific investments. Nevertheless, Che and Hausch (1997) have identified conditions under which specific-performance contracts do not lead to first-best investment levels and may actually have no value.

Figure 1: Timing of Events

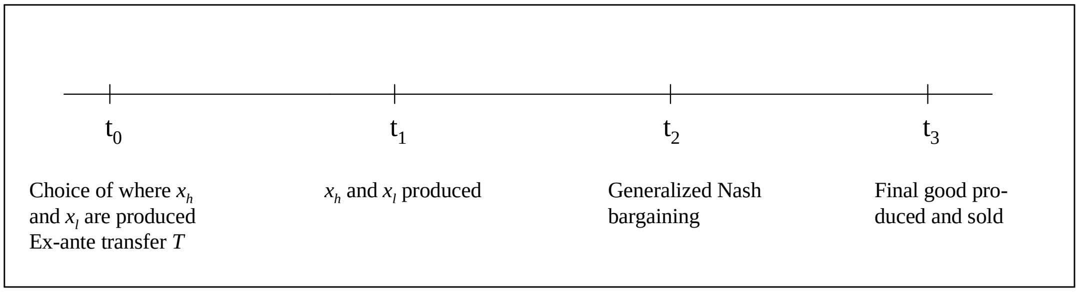


Figure 1.

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. The decision of where to produce the low-tech input is instead nontrivial. In his choice, the manager of the research center compares the ex-ante profits associated with two options, which I analyze in turn.

A. Manufacturing by an Independent Plant in the North

Consider first the case of a research center who decides to deal with an independent manufacturing plant in the North. In that 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 the following optimal price for the final good:

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

Because 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 in turn equal to

$$\pi^N(z) = (1-\alpha)\lambda\left(\frac{w^N}{\alpha}\right)^{-\alpha/(1-\alpha)}. \tag{3}$$

B. Manufacturing by an Independent Plant in the South

Consider next the problem faced by a research center that decides to transact with a plant in the South. As discussed above, in this case the initial contract only stipulates the transfer T. The game played by the manager of the research center and that of the manufacturing plant is solved by backwards induction. 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 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. Generalized Nash bargaining leaves the research center manager with a fraction ϕ of these quasi-rents, while the manufacturing plant manager in the South receives the remaining fraction $1 - \phi$. Because ϕ is assumed to be in $(0, 1)$, both parties receive strictly positive ex-post revenues from producing a good-quality input and bad-quality inputs are never produced. Rolling back in time, the research center manager sets x_h to maximize $\phi R - w^N x_h$. The manufacturing plant simultaneously chooses 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:

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

If contracts were also complete for international transactions, the research center would instead set a price equal to $\left(w^N\right)^{1-z} \left(w^S\right)^z / \alpha$. Incomplete contracting therefore inflates the optimal mark-up by a factor that is inversely related to $\phi^{1-z} (1-\phi)^z$. Notice that when z is low, the distortion is relatively higher, the lower is the bargaining power of research centers 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 manufacturing plant break even leads to the following expression for the research center's ex-ante profits:

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

2.3 The Equilibrium Choice

From comparison of equations (3) and (4), it follows that the low-tech input will be produced in the South only if $A(z) \leq \omega \equiv w^N / w^S$, where

$$A(z) \equiv \left(\frac{1-\alpha}{1 - \alpha(\phi(1-z) + (1-\phi) z)} \right)^{(1-\alpha)/\alpha z} \frac{\phi^{-(1-z)/z}}{1-\phi}. \tag{5}$$

It is straightforward to show that $\lim_{z \to 0} A(z) = +\infty$ and that $A(z) > 1$ for all $z \in [0, 1]$. This implies that (i) for high enough product-development intensities of final-good production, manufacturing is assigned to a manufacturing plant in the North; and (ii) unless the wage in the North is higher than that in the South, manufacturing by an independent plant in the South will never be chosen. Intuitively, the benefits of Southern assembly are able to offset the distortions created by incomplete contracting only when the manufacturing stage is sufficiently important in production or when the wage in the South is sufficiently lower than that in the North. To make matters interesting, I assume that ω is high enough to ensure that $\pi^N(z_c) < \pi^S(z_c)$ for some $z_c \in (0,1)$:

Condition 1: There exists a $z_c \in (0,1)$ such that $A(z_c) < \omega$.[12]

Figure 2 depicts the profit-maximizing choice of location as a function of z. Assumption 1 ensures that the $A(z)$ curve is decreasing in z for all $z \in [0,1]$, while by Condition 1, $A(1) < \omega$.[13] It follows that:

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 (5) and ω is the relative wage in the North.*

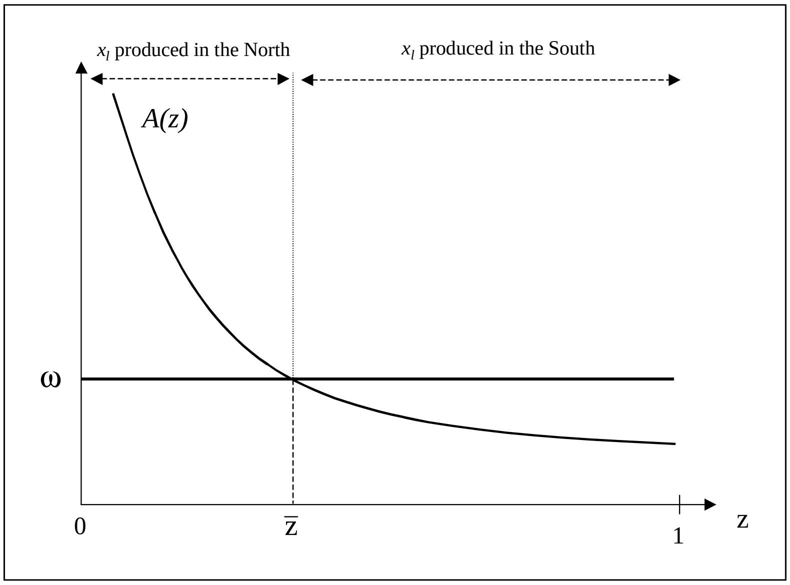
Proof. *See Appendix A.1.* ■

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 leads to a reduction in the measure of product-development 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. This result will be discussed at length in section 4, when I introduce multinational firms.

[12] This condition will in fact be shown to necessarily hold in the general-equilibrium model (this is why I avoid labelling it as an assumption), where the relative wage in the North will necessarily adjust to ensure positive labor demand in the South.

[13] The $A(z)$ curve is decreasing in z for low values of z even when ϕ approaches one. Assumption 1 rules out cases in which $A(z)$ might tilt up for a high enough z (see Appendix A.1). In those cases, the result in Lemma 1 would still go through as long as $A(1) < \omega$.

Figure 2: The Choice of Location



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.[14] Vernon believed that the unstandardized nature of new goods was crucial for understanding that they would be first produced in a high-wage country.

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 parameter ϕ and the relative wage ω are assumed to be time-invariant.[15] The output elasticity of the low-tech input is instead assumed to increase through time. In particular, this elasticity is given by

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

[14] In discussing 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).

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

I therefore assume that the product-development intensity of the good is inversely related to its maturity. Following the discussion in the introduction, this is meant to capture the idea that most goods require a lot of R&D and product development in the early stages of their life cycle, while 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.[16] Finally, I assume that the structure of firms 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 future profit streams are sufficiently discounted.

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 good is relatively new or unstandardized, i.e.,* $t \leq h^{-1}(\bar{z})$*, the manufacturing stage of production takes place in the North. When the good is relatively mature or standardized, i.e.,* $t > h^{-1}(\bar{z})$*, manufacturing is undertaken in 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, because the cut-off $\bar{z}$ is itself a decreasing function of ω, it follows that the higher is the relative wage in the North, the earlier will production transfer occur.[17]

[16] For instance, if such costs were increasing in dz/dt, then a discrete increase in z would be infinitely costly. A full fledged modeling of the standardization decision is left for future research.

[17] Vernon (1966) hypothesized instead that before being transferred to low-wage countries, production would

As argued in the introduction, the fact that contracts cannot be perfectly enforced in international transactions is of crucial importance for understanding the emergence of product cycles. In order to illustrate this, consider the case in which the quality of intermediate inputs were verifiable by an outside court even in international transactions, so that the manager of the research center and that of the Southern manufacturing plant could also write enforceable contracts. It is straightforward to check that, in such case, profits for the research center would be $\pi^S(z) = (1-\alpha)\lambda\left(\left(w^N\right)^{1-z}\left(w^S\right)^z/\alpha\right)^{-\alpha/(1-\alpha)}$. Comparing this expression with equation (3), it follows that labor demand in the South would be positive if and only if $\omega \geq 1$ (this is the analog of Condition 1 above). If $\omega > 1$, profits would satisfy $\pi^N(z) \leq \pi^S(z)$ for all $z \in [0,1]$, with strict inequality for $z > 0$. The production process would therefore be broken up from time 0 and no product cycles would arise. If instead $\omega = 1$, profits would satisfy $\pi^N(z) = \pi^S(z)$ for all $z \in [0,1]$ and the location of manufacturing would be indeterminate, in which case product cycles would emerge with probability zero.

Arguably, incomplete contracting is just one of several potential frictions that would make manufacturing stay in the North for a period of time. It is important to emphasize, however, that not any type of friction would give rise to product cycles in the model. The fact that incomplete contracts distorts both the manufacturing stage and the product development stage in production is of crucial importance. For instance, introducing a transport cost or a communication cost that created inefficiencies *only* in the provision of the low-tech input would not suffice to give rise to product cycles in the model. In this paper, I choose to emphasize the role of incomplete contracts because they are an important source of frictions in the real world and, also, because they are a very useful theoretical tool for understanding firm boundaries, which are the focus of section 4 below. In particular, the type of organizational cycles unveiled by the empirical literature on the product cycle could not be easily rationalized in theoretical frameworks in which production transfer to low-wage countries was delayed merely by transport costs or communication costs.[18]

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. Recent empirical studies suggest 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 might not be transferred earlier, the higher ω.

[18] To illustrate this point, consider the case in which the Northern productivity advantage in product development is bounded and the production process cannot be fragmented across borders (e.g., because of prohibitive transport costs or communication costs). Under these circumstances, the whole production process would shift from the North to the South at some point along the life-cycle of the good, but the model would deliver no predictions for the dynamic organizational structure of firms.

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

Consider again a world with two countries, the North and the South. The North is endowed with L^N units of labor at any time $t \in (0, \infty)$, 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. I consider an economy in which exogenous inventions continuously increase 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. Preferences of the infinitely-lived representative consumer in each country are given by:

$$U = \int_0^\infty e^{-\rho t} \int_0^{N(t)} \log \left(\int_0^{n_j(t)} y_j(i,t)^\alpha \, di \right)^{1/\alpha} dj dt, \tag{6}$$

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 (6), 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 discount rate plays no role in the model (other than to make the problem bounded).[19] As is well known, the instantaneous utility function in (6) gives rise to a constant price-elasticity of demand for any variety i in any industry j:

$$y_j(i,t) = \lambda_j(t) p_j(i,t)^{-1/(1-\alpha)}, \tag{7}$$

[19] For simplicity, equation (6) assumes an infinite intertemporal elasticity of substitution in aggregate consumption. Because of the static nature of the consumer's problem, this is an immaterial assumption and the exact same results would apply for any well-behaved instantaneous utility function.

where

$$\lambda_j(t) = \frac{1}{N(t)} \frac{E\,(t)}{\int_0^{n_j(t)} p_j(i', t)^{-\alpha/(1-\alpha)} di'} \tag{8}$$

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) in the partial-equilibrium model above.

At each point in time, production of each final-good variety is also as described in section 2, 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 $z_j'(\cdot) > 0$, $z_j(t_{0j}) = 0$, and $\lim_{t-t_{0j}\to\infty} z_j(t-t_{0j}) = 1$. 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. 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. These assumptions, coupled with the absence of means of saving in the model, permit a period-by-period analysis of the dynamic, general-equilibrium model.

3.2 Industry Equilibrium

Consider now the industry equilibrium in any period $t \in [0, \infty)$. 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 producers 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 if $z_j(t - t_{0j}) > \bar{z}(t)$, with the choice remaining indeterminate for $z_j(t - t_{0j}) = \bar{z}(t)$.

In order to characterize the industry equilibrium, notice first that because all firms in a given industry j charge an identical optimal price $p(z_j(\cdot))$, the implied value of $\lambda_j(t)$ in equation (8) is easily computed. The equilibrium number of varieties produced in industry j at time t can be solved for by plugging the value of $\lambda_j(t)$ in the profit functions (3) and (4), and setting operating profits equal to fixed costs, as dictated by free entry. This yields

$$n_j(t) = \begin{cases} \frac{(1-\alpha)E(t)}{N(t)w^N(t)f} & \text{if } z_j(t-t_{0j}) < \bar{z}(t) \\ \frac{(1-\alpha(\phi(1-z_j(t-t_{0j}))+(1-\phi)z_j(t-t_{0j})))E(t)}{N(t)w^N(t)f} & \text{if } z_j(t-t_{0j}) > \bar{z}(t) \end{cases} . \tag{9}$$

Naturally, the equilibrium number of varieties in industry j depends positively on total spending in the industry and negatively on fixed costs.

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

$$w^N(t)L^N + w^S(t)L^S = E(t) \tag{10}$$

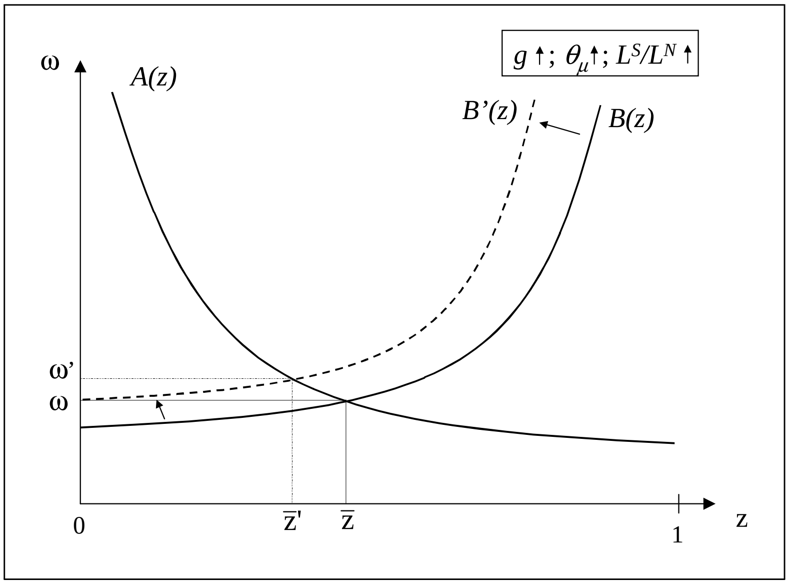
and the labor market clears in each country. By Walras' law, we can focus on the equilibrium in the labor market in the South. Southern labor will only be demanded by those manufacturing plants belonging to an industry with $z_j(t - t_{0j}) > \bar{z}(t)$. It is straightforward to show that labor demand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

$$\int_{\bar{z}(t)}^{1} \alpha(1-\phi) z E(t) f_{z,t}(z) dz = w^S(t) L^S. \tag{11}$$

Defining $\xi_t(a,b) \equiv \int_a^b z f_{z,t}(z) dz$ and using (10), equation (11) can be rewritten as follows:

$$\omega(t) = B_t(\bar{z}(t)) \equiv \frac{1 - \alpha(1-\phi)\xi_t(\bar{z}(t), 1)}{\alpha(1-\phi)\xi_t(\bar{z}(t), 1)} \frac{L^S}{L^N}. \tag{12}$$

Figure 3: General Equilibrium



$B_t(\bar{z}\,(t))$ is an increasing function of $\bar{z}\,(t)$ satisfying $B_t(0) > 0$ and $\lim_{\bar{z}(t)\to 1} B_t(\bar{z}\,(t)) = +\infty$. Intuitively, the higher is $\bar{z}\,(t)$, the lower is labor demand in the South for a given $\omega\,(t)$, so an increase in $\omega\,(t)$ is necessary to bring the Southern labor market 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 hence $B_t(0)$ 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 the equal profitability condition $\omega\,(t) = A(\bar{z}\,(t))$, where $A(\cdot)$ is defined in equation (5). As discussed above, under Assumption 1, $A(\bar{z}\,(t))$ is a decreasing function of $\bar{z}\,(t)$ satisfying $\lim_{\bar{z}(t)\to 0} A(\bar{z}\,(t)) = +\infty$ and $A(1) > 1$. The function $A(\cdot)$ is depicted in Figure 3 together with the function $B_t(\cdot)$. It is apparent from Figure 3 that there exists a unique equilibrium pair $(\bar{z}\,(t)\,, \omega\,(t))$ at each period $t \in [0, \infty)$. Furthermore, the fact that $A(1)$ is greater than 1, ensures that the equilibrium wage in the North is higher than that in the South, i.e., $\omega\,(t) > 1$.

The general equilibrium of the dynamic model is simply the sequence of period-by-period general equilibria. Moreover, if the distribution function $F_{z,t}(z)$ is (or converges to) a time-invariant distribution, the steady-state 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 being manufactured first in the North and later in the South.[20] 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.

To illustrate the properties of the general equilibrium, consider again the particular functional form:

$$z_j(t, t_{0j}) = 1 - e^{-(t-t_{0j})/\theta_j}, \tag{13}$$

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 all industries, the model predicts that industries with higher rates of standardization will transfer manufacturing to the South earlier. Furthermore, in the general equilibrium, the cross-industry distribution of standardization rates will have an additional effect on the timing of production transfer, through its impact on the world distribution of product-development 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 the 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:

$$F_z(z) = \frac{g\theta_\mu \ln\left(\frac{1}{1-z}\right)}{1 + g\theta_\mu \ln\left(\frac{1}{1-z}\right)}. \tag{14}$$

Computing the corresponding density function, $\xi_t(a,b)$ can be shown to converge to

$$\xi(a,b) \equiv \int_a^b z f_z(z) dz = \int_a^b \frac{zg\theta_\mu}{\left(1 + g\theta_\mu \ln\left(\frac{1}{1-z}\right)\right)^2 (1-z)} dz. \tag{15}$$

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

In light of equations (12) and (15), 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 both unique and time-invariant.

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 (13), an increase in the exogenous rate of invention (g) or a fall in the average 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 $\bar{z}$.[21] As it is apparent from equation (14), increases in g or θ_μ tend to transfer probability mass from high z's to low z's, thus creating again an excess supply of labor in the South 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 manufacturing 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 to an increase

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

in the relative wage in the North. 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 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 down the transfer of production in industry j.[22]

3.5 Welfare: Comparison with the Case of Complete Contracts

As in section 2, the incompleteness of contracts governing international transactions is crucial for the existence of product cycles. If contracts could be perfectly enforced in international transactions, Northern and Southern assembly would be equally profitable if and only wages were equal in both countries, from which it follows that the $A(\cdot)$ curve would become a step function with a flat segment at $\omega = 1$ for $z \in (0,1)$. Solving for Southern labor demand under complete contracts, the analogous of the $B(\cdot)$ curve would be given by $B_C(\bar{z}) = \frac{1-\alpha\xi_t(\bar{z},1)}{\alpha\xi_t(\bar{z},1)}\frac{L^S}{L^N}$. Relative to a world with incomplete contracts, the introduction of complete contracts would shift the $B(\bar{z})$ down and to the right (since $\alpha(1-\phi) < 1$). The general equilibrium under complete contracts would be as follows. If $B_C(0) > 1$, then $\omega > 1$ and assembly would always be done in the South. As before, production transfer would occur instantly and no product

[22] 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.

cycles would emerge. If instead $B_C(0) < 1$, wages would be equalized and the location of production of low-tech inputs would be indeterminate.[23] Clearly, in such case product cycles would emerge again with probability zero.

Consider next the welfare implications for each country of a shift from a steady-state equilibrium with incomplete contracts to a steady-state equilibrium with complete contracts. 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 from incomplete contracting. In a world of complete contracts, this rent disappears and the relative wage in the North is lower.[24] 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 that relates to the fact that complete contracts lead to a shift of production towards the lower-wage country. The third effect relates to the endogenously determined measure of varieties in each industry. Preferences of the representative consumer feature a love for variety, implying that welfare is increasing in this measure. Because fixed costs of production are in terms of Northern labor, the lower relative wage under complete contracts is associated with a higher measure of varieties available to consumers.

It follows that on account of all three effects, the South is better off under complete contract, while the North also benefits from the second and third effects, but loses from the first. The details are worked out in Appendix A.3, where it is proven 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 relate the shift towards better enforcement of international contracts to a tightening

[23] Labor market clearing in the South would only require that the set of industries $\mathcal{Z} \subset [0,1]$ that choose to manufacture in the South satisfy $L^S \left(1 - \int_{z\in\mathcal{Z}} z f_{z,t}(z)dz\right) = L^N \int_{z\in\mathcal{Z}} z f_{z,t}(z)dz$.

[24] The 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.

of intellectual property rights (IPRs) in the South, Proposition 3 contrasts with the results in Helpman (1993).[25] Helpman analyzed the welfare implications of a shift to better enforcement of IPRs in models with both exogenous and endogenous innovation and imitation, and concluded that such type of policies would unambiguously decrease welfare in the low-wage South, with the effect on Northern welfare being, in general, ambiguous. Our different conclusions stem from our different modeling of the vehicle of production transfer.[26] When the South gains market share by imitating Northern technologies, 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

This paper has so far focused on developing a new theory of the product cycle based on the existence of incomplete contracting, and on analyzing its macroeconomic implications. The recent literature on the theory of the firm has shown that incomplete contracts are also a useful tool for understanding the determinants of ownership structure. In this section, I will build on this literature to draw firm boundaries in a simple extension of the model. From the analysis will emerge a much richer version of the product cycle, with implications for the choice between intrafirm and arm's length production transfer along the life cycle of a product.

4.1 Set-up

The set-up of the model is the same as before with just one new feature. The research center is now given the option of vertically integrating the manufacturing plant and becoming 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

[25] Admittedly, 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.

[26] Lai (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.

party (the research center), but the cost of reducing the ex-post bargaining power of the integrated party (the manufacturing plant). In particular, by integrating the production of the low-tech input, the manager of the manufacturing plant becomes an employee of the research center manager. This implies that if the manufacturing plant manager refuses to trade after the sunk costs have been incurred, the research center manager now has the option of firing the overseas manager and seizing 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.[27] If there were no costs associated with firing the manufacturing plant manager, there would be no surplus to bargain over after production, and the manufacturing plant manager would ex-ante optimally set $x_l = 0$ (which of course would imply $y = 0$). In that case, integration would never be chosen. To make things more interesting, I assume that firing the manufacturing plant manager results in a negative productivity shock that leads to a loss of a fraction $1-\delta$ of final-good production. Under this assumption, the surplus of the relationship remains positive even under integration.[28] 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 useful, 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.

4.2 Firm Behavior

In section 2.2, I computed ex-ante profits for the research center under two possible modes of organization: (A) manufacturing by an independent plant in the North; and (B) manufacturing by an independent plant in the South. The possibility of vertical integration introduces two additional options: manufacturing in the North by a vertically integrated plant and manufacturing in the South by a vertically integrated plant. Because contracts are assumed to be perfectly enforceable in transactions involving two firms located in the same country, it is

[27] See Antràs (2003) for a related set-up.

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

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. Manufacturing by a Vertically-Integrated Plant in the South

Consider the problem faced by a research center and its integrated manufacturing 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 manufacturing 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 $(1-\delta^{\alpha})R$. Generalized Nash bargaining leaves the research center with its default option plus a fraction ϕ of the quasi-rents. The manager of the integrated manufacturing plant receives the remaining fraction $1-\phi$ of the quasi-rents. The research center therefore sets x_h to maximize $\bar{\phi}R - w^N x_h$, where

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

while the Southern manufacturing plant simultaneously chooses x_l to maximize $\left(1-\bar{\phi}\right)R - w^S x_l$. Relative to case (B) in section 2, integration enhances the research center's incentives to invest ($\bar{\phi} > \phi$) but, at the same time, it reduces the manufacturing plant's incentives to invest. Combining the first-order conditions of these two programs yields the following optimal price for the final good:

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

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

$$\pi_M^S(z) = \left(1-\alpha\left(\bar{\phi}(1-z)+\left(1-\bar{\phi}\right)z\right)\right)\lambda\left(\frac{\left(w^N\right)^{1-z}\left(w^S\right)^{z}}{\alpha\bar{\phi}^{1-z}\left(1-\bar{\phi}\right)^{z}}\right)^{-\alpha/(1-\alpha)}, \tag{16}$$

which is identical to (4) 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 $z > \bar{z}$. The cut-off level $\bar{z}$ is implicitly defined by $\bar{z} = A^{-1}(\omega)$, where $A(z)$ is given in equation (5). Consider next the choice between Northern assembly and Southern assembly by an integrated firm. Comparing equations (3) and (16), it follows that $\pi_M^S(z) \geq \pi^N(z)$ only if $\bar{A}(z) \leq \omega$, where

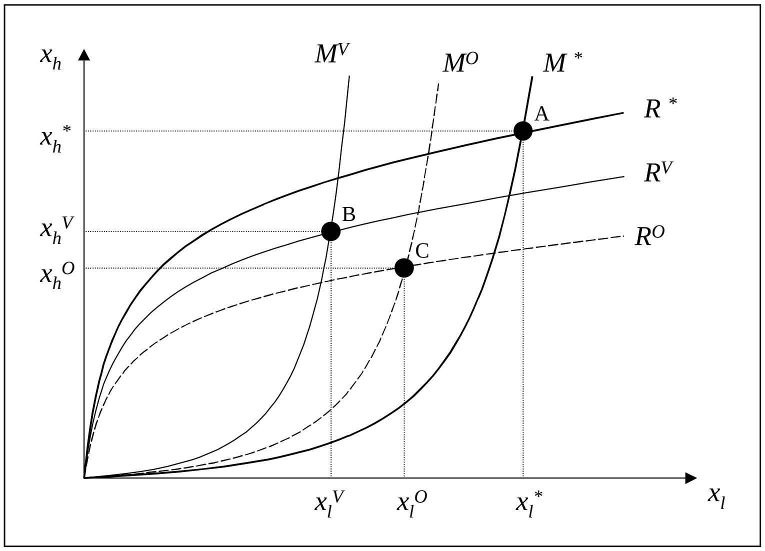
$$\bar{A}(z) = \left(\frac{1-\alpha}{1-\alpha\left(\bar{\phi}(1-z) + \left(1-\bar{\phi}\right)z\right)}\right)^{(1-\alpha)/\alpha z} \frac{\bar{\phi}^{-(1-z)/z}}{1-\bar{\phi}}. \tag{17}$$

Notice that $\bar{A}(z)$ is identical to $A(z)$ with $\bar{\phi}$ replacing ϕ. Under Assumption 2, $\bar{\phi}$ is less or equal to 3/4, and from the above discussion of the properties of $A(z)$ it follows that $\bar{A}'(z) < 0$ (see Appendix A.1). Furthermore, $\lim_{z\to 0} \bar{A}(z) = +\infty$, $\bar{A}(z) > 1$ for all $z \in [0,1]$, and if the relative wage is high enough (namely, $\bar{A}(1) < \omega$), there exists a unique cutoff $\bar{z}_{MN} = \bar{A}^{-1}(z) \in (0,1)$ such that $\pi^N(z) > \pi_M^S(z)$ for $z < \bar{z}_{MN}$, and $\pi^N(z) < \pi_M^S(z)$ for $z > \bar{z}_{MN}$.[29] As with the comparison involving arm's length production transfer, when the low-tech input is not very important in production, 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 production, then lower wage in the South is relatively more profit enhancing, and Southern manufacturing becomes more attractive. 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 (4) and (16), it

[29] If instead $\bar{A}(1) > \omega$, then $\pi^N(z) > \pi_M^S(z)$ for all $z \in [0,1]$ and vertical integration is never chosen in equilibrium.

Figure 4: Underproduction and Ownership Structure



follows that $\pi_M^S(z) > \pi^S(z)$ if and only if

$$1 < \Theta(z) \equiv \frac{1-\alpha\left(\bar{\phi}(1-z)+\left(1-\bar{\phi}\right)z\right)}{1-\alpha\left(\phi(1-z)+(1-\phi)z\right)}\left(\left(\frac{\bar{\phi}}{\phi}\right)^{1-z}\left(\frac{1-\bar{\phi}}{1-\phi}\right)^{z}\right)^{\frac{\alpha}{1-\alpha}} \tag{18}$$

The curve $\Theta(z)$ is a decreasing function of z, satisfying $\Theta(0) > 1$ and $\Theta(1) < 1$ (see Antràs, 2003, for a formal proof). This implies that there exists a 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 lies at the heart of Grossman and Hart's (1986) seminal contribution. In a world of incomplete contracts, ex-ante efficiency dictates that residual rights should be controlled by the party undertaking a relatively more important investment in a relationship. If production of the final good requires mostly product development (i.e., z is low), then the investment made by the manufacturing 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 manufacturing 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. 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. It is clear from the graph that incomplete contracting leads to underproduction of both x_h and x_l. The crucial point to notice from Figure 4, however, is that because the manufacturing plant has a relatively weaker bargaining power under integration, the underproduction in x_l is relatively higher under integration that under outsourcing. Furthermore, 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 $\bar{z}_{MS}$. Notice, however, that $\Theta(z) = \left(A(z)/\bar{A}(z)\right)^{\alpha z/(1-z)}$. This can be shown to imply that $\bar{z}$, $\bar{z}_{MN}$, and $\bar{z}_{MS}$ must satisfy one of the following: (i) $\bar{z}_{MS} = \bar{z} = \bar{z}_{MN}$, (ii) $\bar{z}_{MS} < \bar{z} < \bar{z}_{MN}$, or (iii) $\bar{z}_{MN} < \bar{z} < \bar{z}_{MS}$.[30] 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 $A(z) < \bar{A}(z)$ for high enough z.[31] For any relative wage ω, it is clear that either $\bar{z}_{MS} < \bar{z} < \bar{z}_{MN}$ (left panel) or $\bar{z}_{MN} < \bar{z} < \bar{z}_{MS}$ (right panel). The case $\bar{z}_{MS} = \bar{z} = \bar{z}_{MN}$ occurs with probability zero and will be ignored hereafter.

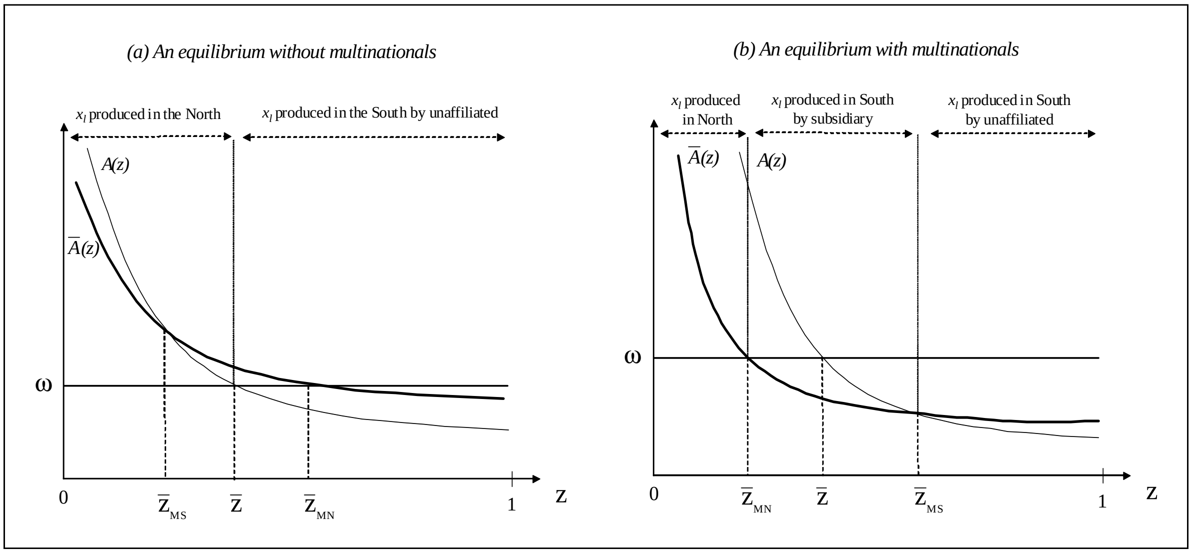
As indicated in both panels in Figure 5, for a low enough value for z, the benefits from Southern assembly are too low relative to the distortions from incomplete contracting, and x_l is produced in the North. Furthermore, for a sufficiently high value of z, a profit-maximizing research center will decide to outsource the manufacturing input to an independent manufacturing plant in the South. Whether for intermediate values of z the research center becomes a 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 $\pi_M^S > \max\left\{\pi^N, \pi^S\right\}$, 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*

[30] To 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 $\bar{z} < \bar{z}_{MN}$.

[31] Notice 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



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 $\bar{z} > \bar{z}_{MS}$.*

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 $\bar{A}'(z) < 0$, 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.[32] From this it follows that the measure of product-development 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.

4.3 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 $h'(t) > 0$,

[32] This 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.

$h(0) = 0$, and $\lim_{t \to \infty} h(t) = 1$. 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 good is relatively new or unstandardized, i.e., $t < h^{-1}(\bar{z}_{MN})$, the manufacturing stage of production takes place in the North. For an intermediate maturity of the good, $h^{-1}(\bar{z}_{MN}) < t < h^{-1}(\bar{z}_{MS})$, manufacturing is shifted to the South but is undertaken within firm boundaries. When the good is relatively standardized, i.e., $t > h^{-1}(\bar{z}_{MS})$, production is shifted to an unaffiliated party in the South.*

This is one of the crucial results of this paper. In words, it states that if the threshold maturity level $\min\{\bar{z}, \bar{z}_{MN}\}$ at which manufacturing is shifted to the South is high enough, the transfer of production will occur at arm's length and multinationals will not emerge in equilibrium. Conversely, if this threshold maturity level is low enough, manufacturing will be shifted to the South within the boundaries of the Northern firm by establishing a wholly-owned foreign affiliate. In that case, arm's length assembly in the South will only be observed at a later stage in the life cycle of the good.

The model is consistent with the evolution of the Korean electronics industry from the early 1960s to the late 1980s.[33] 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.[34] 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

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

[34] Motorola 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.

Original Equipment Manufacturing (OEM) transaction.[35] 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.[36]

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.[37] 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 US.-based multinational enterprises between 1945 and 1975. Their logit estimates indicated 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 $z(t) = 1 - e^{-\frac{t}{\theta}}$, 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

[35] OEM 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".

[36] There is also some evidence that Northern firms did not license their leading edge technologies 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.

[37] Their sample consisted of 39 internal transfer and 26 arm's length transfers.

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 4.2, the model also implies 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.

4.4 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 presence of 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.

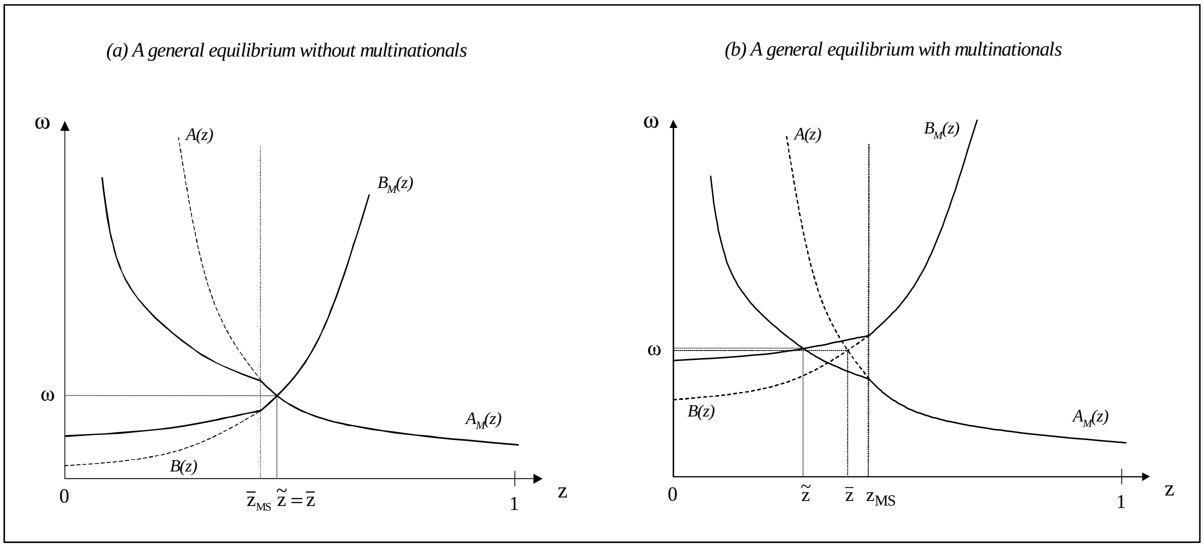
Because the analysis closely parallels that in section 3, the details of the derivations are relegated to Appendix A.4. In order to solve for the equilibrium relative wage, it is useful to define $\widetilde{z}(t) = \min\{\bar{z}_{MN}(t), \bar{z}(t)\}$, which according to Lemma 2 constitutes the threshold z above which production is shifted to the South regardless of ownership structure. 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 $\widetilde{z}(t) = \bar{z}_{MN}(t)$ and $\bar{z}(t)$ is irrelevant.

Computing labor demand by Southern manufacturing plants and imposing labor market clearing in the South yields the following equilibrium condition relating ω and $\widetilde{z}$ analogous to equation (12) (see Appendix A.4):

$$\omega = B_M(\widetilde{z}) \equiv \begin{cases} \dfrac{1-\alpha\left(1-\bar{\phi}\right)\xi(\widetilde{z},\bar{z}_{MS})-\alpha(1-\phi)\xi(\bar{z}_{MS},1)}{\alpha\left(1-\bar{\phi}\right)\xi(\widetilde{z},\bar{z}_{MS})+\alpha(1-\phi)\xi(\bar{z}_{MS},1)}\dfrac{L^S}{L^N} & \text{if } \widetilde{z} < \bar{z}_{MS} \\ \\ \dfrac{1-\alpha(1-\phi)\xi(\widetilde{z},1)}{\alpha(1-\phi)\xi(\widetilde{z},1)}\dfrac{L^S}{L^N} & \text{if } \widetilde{z} > \bar{z}_{MS} \end{cases}. \tag{19}$$

To save on notation, the distribution function $F_{z,t}(z)$ is assumed to converge to a time-

Figure 6: General Equilibrium and Firm Boundaries



invariant distribution, so that we can focus on the steady-state general equilibrium and safely drop time subscripts. Notice that if $\tilde{z} > \bar{z}_{MS}$ the equilibrium is one without multinationals and the equilibrium condition naturally 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 indeed arise in equilibrium. Furthermore, from the standard logic in Grossman and Hart (1986), an integrated manufacturing plant manager underinvests relatively more than a non-integrated one. Hence, for a given z, Southern labor demand is relatively lower for vertically-integrated manufacturing plants, implying that $B_M(\tilde{z}) > B(\tilde{z})$ for $\tilde{z} < \bar{z}_{MS}$. 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 a continuous and increasing function of $\tilde{z}$. Furthermore it satisfies $B_M(0) > B(0) > 0$ and $\lim_{\tilde{z}\to 1} B_M(\tilde{z}) = +\infty$.

As in section 3, the other equilibrium condition that pins down $\tilde{z}$ and ω comes from firm behavior. In particular, because $\bar{z}$ 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:

$$\omega = A_M(\tilde{z}) \equiv \begin{cases} \left(\frac{1-\alpha}{1-\alpha\left(\bar{\phi}(1-\tilde{z})+\left(1-\bar{\phi}\right)\tilde{z}\right)}\right)^{(1-\alpha)/\alpha\tilde{z}} \frac{\bar{\phi}^{-(1-\tilde{z})/\tilde{z}}}{1-\bar{\phi}} & \text{if } \tilde{z} < \bar{z}_{MS} \\ \left(\frac{1-\alpha}{1-\alpha(\phi(1-\tilde{z})+(1-\phi)\tilde{z})}\right)^{(1-\alpha)/\alpha\tilde{z}} \frac{\phi^{-(1-\tilde{z})/\tilde{z}}}{1-\phi} & \text{if } \tilde{z} > \bar{z}_{MS} \end{cases}. \tag{20}$$

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 in turn implies

$A_M(\widetilde{z}) = \bar{A}(\widetilde{z}) < A(\widetilde{z})$. Intuitively, 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 follows that in order to match the profitability of Northern assembly, an *active* integrated manufacturing plant in the South requires a lower relative wage than an independent one. This is again depicted in Figure 6. Notice that $A_M(\widetilde{z})$ is continuous and, under Assumptions 1 and 2, decreasing in $\widetilde{z}$. Furthermore, $\lim_{\widetilde{z}\to 0} A_M(\widetilde{z}) = +\infty$ and $A_M(1) > 1$.

As illustrated in Figure 6, there exists a unique general-equilibrium $(\widetilde{z}, \omega)$ pair. Depending on parameter values, the equilibrium is one without multinational firms (left panel) or one with multinational firms (right panel). The equilibrium without multinational firms is identical to that in section 3. As before, in the steady state, the general-equilibrium values of $\widetilde{z}$ and ω are time-invariant, and all industries necessarily follow product cycles, with varieties in those industries first being manufactured in the North and later in the South. On top of this endogenous product cycles, an equilibrium with multinational firms also features endogenous organizational cycles, with production being shifted to the South first within firm boundaries and only later to independent firms in the South. Furthermore, an interesting result follows from direct inspection of Figure 6:

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

Intuitively, the introduction of multinational firms in a world with only arm's length transacting helps to alleviate the distortions generated by the incompleteness of contracts. This is because the research center is now given the possibility to have the low-tech input produced in the South, while facing a less severe hold-up problem in its production of the hi-tech input. As a result, when multinationals arise in equilibrium, the threshold z above which x_l is produced in the South necessarily falls ($\widetilde{z}$ falls).[38] On top of this effect, there is a general-equilibrium effect. As discussed above, integrated manufacturing plants demand relatively less Southern labor than nonintegrated plants. As a result, clearing of 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 $\widetilde{z}$) or a fall in the relative wage in the South (a higher ω). Both

[38] Alternatively, for a given $\widetilde{z}$, the relative Northern wage above which x_l is produced in the South necessarily falls (remember that this is the reason why $\bar{A}(\widetilde{z}) < A(\widetilde{z})$ to the left of $\bar{z}_{MS}$).

the partial and general-equilibrium effects work to reduce $\widetilde{z}$, 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).

4.5 Comparative Statics

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

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

As in section 3.4, an increase in g, θ_μ or L^S/L^N shifts the $B_M(\widetilde{z})$ curve up and to the left (see Appendix A.2). This tends to increase the relative wage in the North and reduce $\widetilde{z}$, 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. 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 $(1-\widetilde{z})$ 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. In sum,

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*.*

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 footnote 22).

4.6 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 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, but the following result is straightforward to prove by extending the analysis in Appendix A.3:

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 and available-products effects are negligible, only the production efficiency is left, and 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 has 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 delivers a few macroeconomic implications that complement the work of Krugman (1979). For instance, I have shown 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, an acceleration of technological change will instead lead to a narrowing of the world distribution of income. Furthermore, the model predicts 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.[39] As in Antràs (2003), I instead set forth a purely organizational, property-rights model of the multinational firm.[40] 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, 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.

[39] This previous literature builds on the seminal work of Helpman (1984) and Markusen (1984), and is extensively reviewed in Caves (1996) and Markusen (1995). Ethier (1986), Ethier and Markusen (1996), and Glass and Saggi (2002) study the choice between foreign direct investment and licensing, but in frameworks in which the internalization decision is unrelated to the allocation of some residual rights of control.

[40] This paper is related to an emerging literature on general-equilibrium models of ownership structure (c.f., McLaren, 2000, Grossman and Helpman, 2002a, Antràs, 2003). In Antràs (2003), 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.

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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*

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

It is easy to show that $\partial r(\cdot)/\partial z \geq 0$ for all $z \in [0,1]$ (with strict inequality for $z > 0$), while more cumbersome algebra also delivers $\partial r(\cdot)/\partial\phi \geq 0$ for 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.[41] ■

Notice next that, as discussed in the main text, $\lim_{z\to 0} A(z) = +\infty > \omega$, 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 $A(z_c) < \omega$. Because $A(z)$ 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 (14). Note that from equation (13), $t_{0j} = t + \theta_j \ln\left(1 - z_j(t, t_{0j})\right)$. For a given θ_j, the fraction of industries with $z_j(t - t_{0j}) < z$ converges to

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

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

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

as claimed in equation (14) above.

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

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

[41] To 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.

Integrating by parts yields:

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

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 4.4 that an increase in g or θ_μ shifts the $B_M(\cdot)$ curve up and to the left, notice that $\xi(\widetilde{z},\bar{z}_{MS})+\xi(\bar{z}_{MS},1)=\xi(\widetilde{z},1)$, and therefore $\left(1-\bar{\phi}\right)\xi(\widetilde{z},\bar{z}_{MS})+(1-\phi)\xi(\bar{z}_{MS},1)=\left(1-\bar{\phi}\right)\xi(\widetilde{z},1)+\left(\bar{\phi}-\phi\right)\xi(\bar{z}_{MS},1)$. The result then follows again from $\partial\xi(z,1)/\partial\theta_\mu<0$ and $\partial\xi(z,1)/\partial g<0$.

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 (7) into (6), imposing the equality of income and spending, and rearranging, welfare in country $c=\{N,S\}$ can be expressed as:

$$u^c=\frac{w^cL^c}{N}\int_0^N\left(\int_0^{n_j}p_j(i)^{-\alpha/(1-\alpha)}di\right)^{(1-\alpha)/\alpha}dj$$

In an equilibrium with incomplete contracts, the North manufactures all low-tech inputs 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 (5), welfare in the North can be expressed as

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

while that in the South is simply $u^S_{IC}=u^N_{IC}L^S/\left(\omega L^N\right)$.

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

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

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 worse off under complete contracts. The result is ambiguous because, as is apparent in the first term of equation (A.2), the higher relative wage under incomplete contracts is associated with a relatively lower measure of available products. 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:

$$u^N_{CC'}=\alpha L^N\left(\frac{(1-\alpha)\left(L^N+L^S/\omega_C\right)}{Nf}\right)^{(1-\alpha)/\alpha}\int_0^1\omega_C^z f_z(z)dz,$$

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

A.4 General Equilibrium with Multinational Firms

Consider first the industry equilibrium with multinational firms. Because all producers in a given industry 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 (9).[42] If instead $\bar{z}_{MS} > \min\{\bar{z}(t), \bar{z}_{MN}(t)\}$, then it is straightforward to show that $n_j(t)$ is given by:

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

Defining $\widetilde{z}(t) = \min\{\bar{z}_{MN}(t), \bar{z}(t)\}$ and computing labor demand by Southern manufacturing plants yields a labor market clearing condition analogous to equation (11) in section 3:

$$\int_{\widetilde{z}(t)}^{1} \alpha\left(1-\phi_z\right) zE(t) f_{z,t}(z) dz = w^S(t) L^S, \tag{A.4}$$

where $\phi_z = \bar{\phi}$ if $\bar{z}_{MN}(t) < z < \bar{z}_{MS}(t)$, and $\phi_z = \phi$ otherwise. Plugging equation (10) into (A.4), and defining again $\xi(a,b) \equiv \int_a^b z f_z(z) dz$, yields equation (19) in the main text, where time subscripts have been dropped.

[42] Notice 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.