Firms, Contracts, and Trade Structure

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Abstract

Roughly one-third of world trade is intrafirm trade. This paper starts by unveiling two systematic patterns in the volume of intrafirm trade. In a panel of industries, the share of intrafirm imports in total U.S. imports is higher, the higher the capital intensity of the exporting industry. In a cross-section of countries, the share of intrafirm imports in total U.S. imports is higher, the higher the capital-labor ratio of the exporting country. I then show that these patterns can be rationalized in a theoretical framework that combines a Grossman-Hart-Moore view of the firm with a Helpman-Krugman view of international trade. In particular, I develop an incomplete-contracting, property-rights model of the boundaries of the firm, which I then incorporate into a standard trade model with imperfect competition and product differentiation. The model pins down the boundaries of multinational firms as well as the international location of production, and it is shown to predict the patterns of intrafirm trade identified above. Econometric evidence reveals that the model is consistent with other qualitative and quantitative features of the data.

Keywords Property-rights theory, Multinational Firms, International Trade, Intrafirm Trade.

JEL Classification Numbers D23, F12, F14, F21, F23, I22, I33

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1 Introduction

Roughly one-third of world trade is intrafirm trade. In 1994, 42.7 percent of the total volume of U.S. imports of goods took place within the boundaries of multinational firms, with the share being 36.3 percent for U.S. exports of goods (cf. Mataloni, 1997). Given the clear significance of international flows of goods between affiliated units of multinational firms, one would expect that these trade flows would have been widely studied, and would by now be well understood. Although it would be unfair to claim that intrafirm trade has been an ignored topic in the literature, the available empirical studies on intrafirm trade provide little guidance to international trade theorists. In this paper I unveil some strong patterns exhibited by the volume of U.S. intrafirm imports. I then argue that these patterns can be rationalized combining a Grossman-Hart-Moore view of the firm, together with a Helpman-Krugman view of international trade.

Consider a hypothetical world in which firm boundaries had no bearing on the pattern of international trade. In such a world, we would expect only random differences between the behavior of the volume of intrafirm trade and that of the total volume of trade. In other words, the share of intrafirm trade in total trade would not be expected to correlate significantly with any of the classical determinants of international trade.

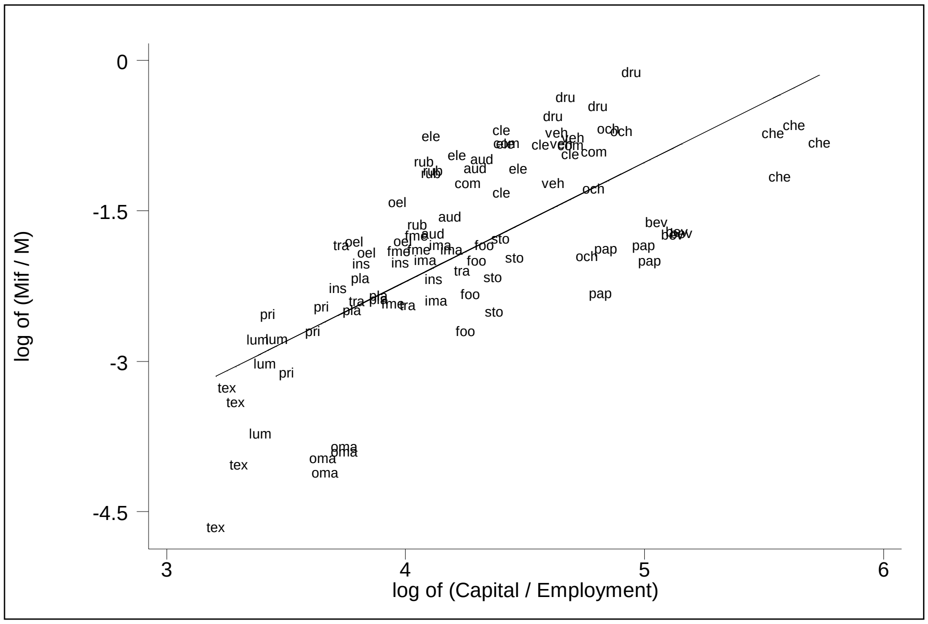
Figure 1 provides a first illustration of how different the real world is from this hypothetical world. In a panel consisting of 23 manufacturing industries and four years of data (1987, 1989, 1992, and 1994), the share of intrafirm imports in total U.S. imports is significantly higher, the higher the capital intensity in production of the exporting industry. Figure 1 indicates that firms in the U.S. tend to import capital-intensive goods, such as chemical products, within the boundaries of their firms, while they tend to import labor-intensive goods, such as textile products, from unaffiliated parties.[1]

Figure 2 unveils a second strong pattern in the share of intrafirm imports. In a cross-section of 28 countries, the share of intrafirm imports in total U.S. imports is significantly higher, the higher the capital-labor ratio of the exporting country. U.S. imports from capital-abundant countries, such as Switzerland, tend to take place between affiliated units of multinational firms. Conversely, U.S. imports from capital-scarce countries, such as Egypt, occur mostly at arm's length. This second fact suggests that the well-known predominance of North-North trade in total world trade is even more pronounced within the intrafirm component of trade.[2]

[1] The pattern in Figure 1 is consistent with Gereffi's (1999) distinction between "producer-driven" and "buyer-driven" international economic networks. The first, he writes, is "characteristic of *capital-* and *technology-intensive* industries [...] in which large, usually *transnational*, manufacturers play the central roles in coordinating production networks" (p.41). Conversely, "buyer-driven" networks are common in "*labor-intensive*, consumer goods industries" and are characterized by "highly competitive, *locally owned*, and globally dispersed production systems" (pp. 42-43). The italics are my own.

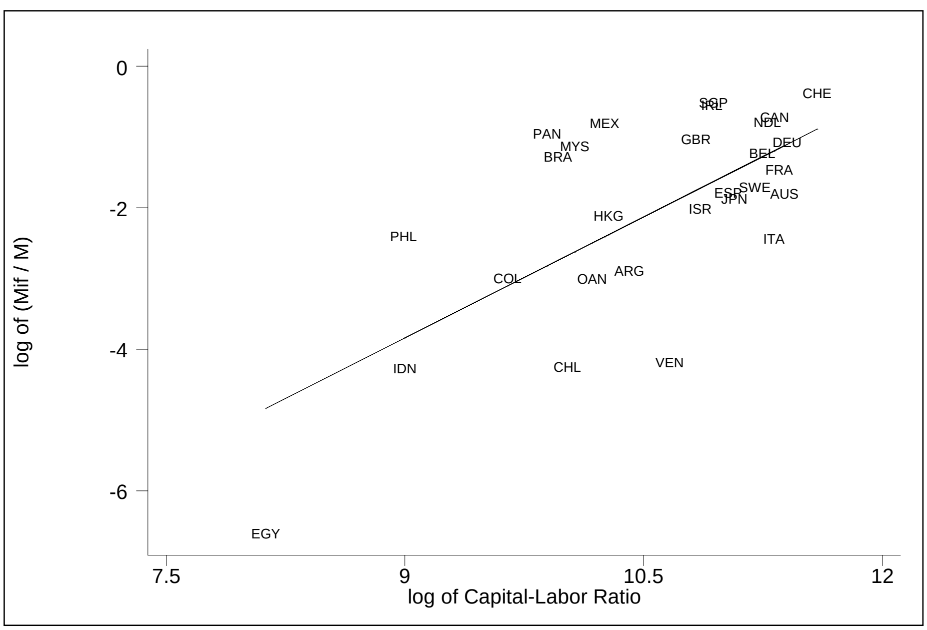
[2] This is consistent with comparisons based on foreign direct investment (FDI) data. In the year 2000, more than 85% of FDI flows occured between developed countries (UNCTAD, 2001), while the share of North-North trade in total world trade was only roughly 70% (World Trade Organization, 2001).

Figure 1: Share of Intrafirm Imports and Relative Factor Intensities



Notes: The Y-axis corresponds to the logarithm of the share of intrafirm imports in total U.S. imports for 23 manufacturing industries and 4 years: 1987, 1989, 1992, 1994. The X-axis measures the log of that industry's ratio of capital stock to total employment in the corresponding year, using U.S. data. See Table A.1. for industry codes and Appendix A.4. for data sources.

Figure 2: Share of Intrafirm Imports and Relative Factor Endowments



Notes: The Y-axis corresponds to the logarithm of the share of intrafirm imports in total U.S. imports for 28 exporting countries in 1992. The X-axis measures the log of the exporting country's physical capital stock divided by its total number of workers. See Table A.2. for country codes and Appendix A.4. for details on data sources.

Why are certain transactions carried out within the boundaries of multinational firms, while others are undertaken at arm's length? This paper takes the view, initially exposed in Coase (1937) and later developed by Williamson (1985), that activities take place wherever transaction costs are minimized. If, as Figure 1 indicates, the share of intrafirm imports is especially high in capital-intensive sectors, then it must be the case that transaction costs associated with using the market are increasing in the capital intensity of the imported good. On the other hand, in a world obeying the law of comparative advantage, countries capture larger shares of world production of commodities that more intensively use their abundant factors. Capital-abundant countries export mostly capital-intensive goods, while labor-abundant countries tend to specialize in labor-intensive commodities. The pattern of Figure 2 therefore results from the interaction of comparative advantage and transaction-cost minimization.[3]

What is the source of these transactions costs? In a world in which specifying all contractual rights is too costly, contracts will remain incomplete, and the allocation of residual rights of control will become crucial. In this paper, I will adhere to a Grossman-Hart-Moore view of the firm, by which ownership corresponds to the entitlement to these residual rights of control. When parties undertake noncontractible, relationship-specific investments, the allocation of residual rights will have a critical effect on each party's *ex-post* outside option, which in turn will determine each party's *ex-ante* incentives to invest. Ex-ante efficiency (i.e., transaction-cost minimization) will then dictate that residual rights should be controlled by the party undertaking a relatively more important investment.

In situations in which the default option for one of the parties (e.g., a supplier) is too unfavorable, the allocation of residual rights may not suffice to induce adequate levels of investment. In such situations, the hold-up problem faced by the party with the weaker bargaining position may be alleviated by having the other party (e.g., a final-good producer) contribute to the former's relationship-specific investments. Investment-sharing alleviates the hold-up problem for one of the parties, but naturally increases the exposure of the other party to opportunistic behavior, with the exposure being an increasing function of the contribution to investment costs. If cost-sharing is large enough, ex-ante efficiency will then command that residual rights of control, and thus ownership, be assigned to the party with the initially stronger bargaining position.

What determines then the extent of cost-sharing? Business practices suggest that, in many situations, investments in physical capital are easier to share than investments in physical labor. Dunning (1993, p. 455-456) describes several cost-sharing practices of multinational firms in their relations with independent subcontractors. Among others, these include provision of used machinery and specialized tools and equipment, prefinancing of machinery and tools, and procurement assistance in obtaining capital equipment and

[3] At this point, a natural question is whether capital intensity and capital abundance are truly the crucial factors driving the correlations in Figures 1 and 2. In particular, these patterns could in principle be driven by other omitted factors. Section 8 will present formal econometric evidence in favor of the emphasis placed on capital intensity and capital abundance in this paper.

raw materials. There is no reference to cost-sharing in labor costs, other than in labor training. Similarly, in his review article on Japanese firms, Aoki (1990) describes the close connections between final-good manufacturers and their suppliers, but writes that "suppliers have considerable autonomy in other respects, for example in personnel administration" (p. 25). Even within firm boundaries, cost-sharing seems to mostly take place when capital investments are involved. In particular, Table 1 (reproduced from Dunning, 1993), indicates that British affiliates of U.S. based multinationals tend to have much more independence in their employment decisions (e.g., in hiring of workers) than in their financial decisions (e.g., in their choice of capital investment projects).

Table 1. Decision-Making in U.S. based multinationals

% of British affiliates in which parent influence on decision is strong or decisive			
Financial decisions		Employment/personnel decisions	
Setting of financial targets	51	Union recognition	4
Preparation of yearly budget	20	Collective bargaining	1
Acquisition of funds for working capital	44	Wage increases	8
Choice of capital investment projects	33	Numbers employed	13
Financing of investment projects	46	Lay-offs/redundancies	10
Target rate of return on investment	68	Hiring of workers	10
Sale of fixed assets	30	Recruitment of executives	16
Dividend policy	82	Recruitment of senior managers	13
Royalty payments to parent company	82		

Source: Dunning (1993, p. 227). Originally from Young, Hood and Hamill (1985).

The model described in the next section uses these ideas to rationalize the strong pattern shown in Figure 1. In a set-up of incomplete contracts, I develop a general-equilibrium model in which final-good producers in two industries produce a continuum of varieties under monopolistic competition. Each final-good producer requires a specific and distinct intermediate input from its unique supplier, which it can choose to vertically integrate or not. Suppliers have a relatively weak bargaining power, so that final-good producers find it profitable to contribute to the suppliers' investment in relationship-specific physical capital. As in Grossman and Hart (1986), by vertically integrating their suppliers, final-good producers acquire some residual rights of control which reduce their exposure to a hold-up, therefore enhancing their own ex-ante investments in physical capital. But by depriving suppliers of these residual rights, vertical integration comes at the cost of reduced incentives to invest by suppliers. Because final-good producers invest only in physical capital, the relative importance of their relationship-specific investment will tend to increase with the overall capital intensity of the manufacturing process. If production of intermediate inputs requires a sufficiently high capital-labor ratio, transaction-cost minimization will therefore dictate that the activity be undertaken within the final-good producer's boundaries.

In order to explain the pattern shown in Figure 2, I then open this economy to international trade, by allowing final-good producers to obtain intermediate inputs from foreign suppliers.[4] In doing so, I embrace a Helpman-Krugman view of international trade with imperfect competition and product differentiation, by which countries specialize in producing certain varieties of intermediate inputs and export them worldwide. Trade in capital-intensive intermediate inputs will be transacted within firm boundaries. Trade in labor-intensive goods will instead take place at arm's length. In the general equilibrium of the world economy, capital-abundant countries will tend to produce more of the capital-intensive varieties, while labor-abundant countries will specialize more in varieties of the labor-intensive industry. On the demand side, final-producers located in a given country demand a share in world production of each variety that corresponds to the share of that country's income in world GDP. The model solves for bilateral trade flows between any two countries, and predicts the share of intrafirm imports in total imports to be increasing in the capital-labor ratio of the exporting country. This is the correlation implied by Figure 2. Transaction-cost minimization and comparative advantage interact to produce the strong patterns unveiled above.

This second part of the argument is based on the premise that capital-abundant countries tend to produce mostly capital-intensive commodities. In an important contribution, Romalis (2002) has recently shown that empirical evidence is indeed consistent with factor proportions being an important determinant of the structure of international trade. In particular, using detailed data on commodity trade, he finds that capital-abundant countries tend to capture shares of U.S. imports that are significantly larger than those captured by labor-abundant countries.

This paper is related to several branches in the literature. On the one hand, it is related to previous theoretical studies that have rationalized the existence of multinational firms in general-equilibrium models of international trade.[5] Helpman's (1984) model introduced a distinction between firm-level and plant-level economies of scale that has proven crucial in later work. In his model, multinationals arise only outside the factor price equalization set, when a firm has an incentive to geographically separate the capital-intensive production of an intangible asset (headquarter services) from the more labor-intensive production of goods. Following the work of Markusen (1984) and Brainard (1997), an alternative branch of the literature has developed models rationalizing the emergence of multinational firms in the absence of factor endowment differences.[6] In these models, multinationals will exist in equilibrium whenever transport costs are high and whenever firm-specific economies of scale are high relative to plant-specific economies of scale.[7,8]

[4] For simplicity, I abstract from trade in final goods. In section 7.2, I briefly relax this assumption.

[5] The literature builds on the seminal work of Helpman (1984) and Markusen (1984). For extensive reviews see Caves (1996) and Markusen and Maskus (2001).

[6] Markusen and Venables (1998) is an important contribution in this literature.

[7] The intuition for this result is straightforward: when firm-specific economies of scale are important, costs are minimized by undertaking all production within a single firm. If transport costs are high and plant-specific economies of scale are small, then it will be profitable to set-up multiple production plants to service the different local markets. Multinationals are thus of the "horizontal type".

[8] In recent years, the literature seems to have converged to a "unified" view of the multinational firm,

These two approaches to the multinational firm share a common failure to properly model the crucial issue of internalization. These models can explain why a domestic firm might have an incentive to outsource part of its production process abroad, but they fail to explain why this outsourcing will occur within firm boundaries (i.e., within multinationals), rather than through arm's length subcontracting or licensing. In the same way that a theory of the firm based purely on technological considerations does not consitute a proper theory of the firm (c.f. Tirole 1988, Hart 1995), a theory of the multinational firm based solely on economies of scale and transport costs cannot be satisfactory either. As described above, I will instead set forth a purely organizational or property-rights model of the multinational firm. My model will have no distinction between firm-specific and plant-specific economies of scale. Furthermore, trade will be costless and factor prices will not differ across countries. Yet, multinationals will emerge in equilibrium, and their implied intrafirm trade flows will match the strong patterns identified above.

This paper is also related to previous attempts to model the internalization decision of multinationals firms. Following the insights from the seminal work of Casson (1979), Rugman (1981) and others, this literature has constructed models studying the role of informational asymmetries and knowledge non-excludability in determining the choice between direct investment and licensing (e.g. Ethier, 1986, Ethier and Markusen, 1996). Among other things, this paper differs from this literature in stressing the importance of capital intensity and the allocation of residual rights in the internalization decision, and perhaps more importantly, in describing and testing the implications of such a decision for the pattern of intrafirm trade.

Finally, this paper is also related to an emerging literature on general-equilibrium models of industry structure. More specifically, my theoretical framework shares some features with a recent contribution by Grossman and Helpman (2002). In their model, however, the costs of transacting inside the firm are exogenously introduced by having integrated suppliers incur higher variable costs (as in Williamson, 1985). More importantly, theirs is a closed-economy model, and therefore does not deal with international trade, which of course is crucial in my contribution.[9,10]

The rest of the paper is organized as follows. Section 2 describes the closed-economy version of the model. In section 3, I characterize the partial equilibrium behavior of firms. In section 4, I solve for the industry equilibrium. Section 5 contains some comparative statics,

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merging the factor-proportions (or "vertical") approach of Helpman (1984), together with the "proximity-concentration" trade-off implicit in Brainard (1993a) and others. Markusen and Maskus (2001) refer to this approach as the "Knowledge-Capital Model", and claim that its predictions are widely supported by the evidence.

[9] In order to isolate the effect of contract incompleteness, I will abstract from the search technology present in their model. This naturally reduces the richness of general-equilibrium interactions between firms' decisions.

[10] Although in this paper I show that a Grossman-Hart-Moore view of the form is consistent with the facts in Figures 1 and 2, neither my theoretical model nor the available empirical evidence is rich enough to test this view of the firm against alternative ones. This would be a major undertaking on its own. See Baker and Hubbard (2002) and Whinston (2002) for more formal treatments of these issues.

with a special emphasis on the role of factor intensity in determining the equilibrium mode of organization in a given industry. Then, in section 6, I solve for the general equilibrium of the closed economy. Section 7 describes the multi-country version of the model and discusses the international location of production as well as the implied patterns of intrafirm trade. Section 8 presents some econometric evidence supporting the view that both capital intensity and capital abundance are significant factors in explaining the pattern of \intrafirm U.S. imports. Section 9 concludes. The proofs of the main propositions are relegated to the Appendix.

2 The Closed-Economy Model

This section describes the closed-economy version of the model. In section 7 below, I will reinterpret the equilibrium of this closed-economy as that of an integrated world economy. The features of this equilibrium will then be used to analyze the patterns of specialization and trade in a world in which the endowments of the integrated economy are divided up among countries.

Environment Consider a closed economy that employs two factors of production, capital and labor, to produce a continuum of varieties in two sectors, Y and Z. Capital and labor are inelastically supplied and freely mobile across sectors. The economy is inhabited by a unit measure of identical consumers that view the varieties in each industry as differentiated. In particular, letting $y(i)$ and $z(i)$ be consumption of variety i in sectors Y and Z, preferences of the representative consumer are of the form

$$U = \left(\int_0^{n_Y} y(i)^\alpha di \right)^{\frac{\mu}{\alpha}} \left(\int_0^{n_Z} z(i)^\alpha di \right)^{\frac{1-\mu}{\alpha}}, \tag{1}$$

where n_Y (n_Z) is the endogenously determined measure of varieties in industry Y (Z). Consumers allocate a constant share $\mu \in (0,1)$ of their spending in sector Y and a share $1-\mu$ in sector Z. The elasticity of substitution between any two varieties in a given sector, $1/(1-\alpha)$, is assumed to be greater than one.[11]

Technology Goods are also differentiated in the eyes of producers. In particular, each variety $y(i)$ requires a special and distinct intermediate input which I denote by $x_Y(i)$. Similarly, in sector Z each variety $z(i)$ requires a distinct component $x_Z(i)$. The specialized intermediate input must be of high quality, otherwise the output of the final good is zero. If the input is of high quality, production of the final good requires no further costs and $y(i) = x_Y(i)$ (or $z(i) = x_Z(i)$ in sector Z).

[11] The assumption that the both sectors share a common degree of differentiation is not crucial for the results below.

Production of a high-quality intermediate input requires capital and labor. For simplicity, technology is assumed to be Cobb-Douglas:

$$x_k(i) = \left(\frac{K_{x,k}(i)}{\beta_k}\right)^{\beta_k} \left(\frac{L_{x,k}(i)}{1-\beta_k}\right)^{1-\beta_k}, \quad k \in \{Y, Z\} \tag{2}$$

where $K_{x,k}(i)$ and $L_{x,k}(i)$ denote the amount of capital and labor employed in production of variety i in industry $k \in \{Y, Z\}$.[12] I assume that industry Y is more capital-intensive than industry Z, i.e. $1 > \beta_Y > \beta_Z > 0$.

Low-quality intermediate inputs can be produced at a negligible cost in both sectors.

There are also fixed costs associated with the production of an intermediate input. For simplicity, it is assumed that fixed costs in each industry have the same factor intensity as variable costs, so that the total cost functions are homothetic. In particular, fixed costs for each variety in industry $k \in \{Y, Z\}$ are $fr^{\beta_k}w^{1-\beta_k}$, where r is the rental rate of capital and w the wage rate.

Firm structure Before any investment is made, a final-good producer decides whether it wants to enter a given market, and if so, whether to obtain the component from a vertically integrated supplier or from a stand-alone supplier. Upon entry, the supplier makes a lump-sum transfer $T_k(i)$ to the final-good producer, which can vary by industry and variety. I assume that, ex-ante, there is large number of identical, potential suppliers for each variety in each industry, so that competition among these suppliers will make $T_k(i)$ adjust so as to make them break even. The final-good producer chooses the mode of organization so as to maximize its ex-ante profits.

An integrated supplier is just a division of the final-good producer and thus has no control rights on the amount of input produced. Figuratively, at any point in time the parent firm could selectively fire the manager of the supplying division and seize production. Conversely, a stand-alone supplier does indeed have these residual rights of control. In Hart and Moore's (1990) words, in such case the final-good producer could only "fire" the entire supplying firm, including its production. Integrated and non-integrated suppliers differ only in the residual rights they are entitled to, and in particular both have access to the same technology as specified in (2).[13]

As discussed in the introduction, a premise of this paper is that investments in physical capital are easier to share than investments in labor input. To capture this idea, I assume that while labor variable costs $wL_{x,k}(i)$ are inalienable to the supplier, capital expenditures $rK_{x,k}(i)$ are instead transferable, in the sense that the final-good producer can decide whether to let the supplier incur this factor cost too, or rather rent the capital itself and

[12] The main results in the paper are robust to the use of more general functional forms for technology, such as a CES production function (see footnote 28 for more on this).

[13] This is in contrast with the transaction-cost literature that usually assumes that integration leads to an exogenous increase in variable costs (e.g. Williamson, 1985, Grossman and Helpman, 2002).

hand it to the supplier at no charge. In both cases, the investments in capital and labor are chosen simultaneously.[14]

Once a pair enters a market, it is locked into the relationship. In particular, the investments $rK_{x,k}(i)$ and $wL_{x,k}(i)$ are incurred upon entry and are useless outside the relationship. In Williamson's (1985) words, the initially *competitive* environment is *fundamentally transformed* into one of bilateral monopoly.

Regardless of firm structure and the choice of cost-sharing, fixed costs associated with production of the component are divided between the two firms in the following way: $f_F r^{\beta_k} w^{1-\beta_k}$ for the final-good producer and $f_S r^{\beta_k} w^{1-\beta_k}$ for the intermediate input producer, with $f_F + f_S = f$.[15]

Contract Incompleteness The setting is one of incomplete contracts. In particular, it is assumed that an outside party cannot distinguish between a high-quality and a low-quality intermediate input. Hence, input suppliers and final goods producers cannot sign enforceable contracts specifying the purchase of a certain type of intermediate input for a certain price. If they did, input suppliers would have an incentive to produce a low-quality input at the lower cost and still cash the same revenues. I take the existence of contract incompleteness as a fact of life, and will not complicate the model to relax the informational assumptions needed for this incompleteness to exist. It is equally assumed that no outside party can verify the amount of ex-ante investments $rK_{x,k}(i)$ and $wL_{x,k}(i)$. If these were verifiable, then final-good producers and suppliers could contract on that, and the cost-reducing benefit of producing a low-quality input would disappear. Similarly, it is assumed that the parties cannot write contracts contingent on the volume of sale revenues obtained when the final good is sold. Following Grossman and Hart (1986), the only contractibles ex-ante are the allocation of residual rights and the transfer $T_k(i)$ between the parties.

If the supplier incurs all variable costs, the contract incompleteness gives rise to a standard hold-up problem. The final-good producer will want to renegotiate the price after $x_k(i)$ has been produced, since at this point the intermediate input is useless outside the relationship. Foreseeing this renegotiation, the input supplier will undertake suboptimal investments. The severity of the underinvestment problem is directly related to how weak the supplier's bargaining power is ex-post.

[14] The assumption that the final-good producer decides between bearing *all* or *none* of the capital expenditures can easily be relaxed. For instance, imagine that $x_k(i)$ was produced according to:

$$x_k(i) = \left(\frac{K^F_{x,k}(i)}{\beta_k}\right)^{\beta_k} \left(\frac{K^S_{x,k}(i)}{\eta(\beta_k)\,(1-\beta_k)}\right)^{\eta(\beta_k)(1-\beta_k)} \left(\frac{L_{x,k}(i)}{(1-\eta(\beta_k))\,(1-\beta_k)}\right)^{(1-\eta(\beta_k))(1-\beta_k)}$$

where $K^F_{x,k}(i)$ represents the part of the capital input that is transferable, and where $K^S_{x,k}(i)$ is inalieanable to the supplier. As long as $\beta_k + \eta(\beta_k)\,(1-\beta_k)$ increases with β_k, all the results below would go through (see footnote 27). I follow the simpler specification in (2) because it greatly simplifies the algebra of the general equilibrium.

[15] Henceforth, I associate subscript F with the final-good producer and a subscript S with the intermediate input producer.

If the final-good producer shares capital expenditures with the supplier, then the hold-up problem becomes two-sided. Since the investment in capital is also specific to the pair, the final-good producer is equally locked in the relationship and thus its investment in capital will also tend to be suboptimal, with the extent of the underinvestment being inversely related to its bargaining power in the negotiation.

Since no enforceable contract will be signed ex-ante, the two firms will bargain over the surplus of the relationship after production takes place. At this point, the ex-ante investments as well as the quality of the input are observable to both parties and thus the costless bargaining will yield an ex-post efficient outcome. I assume that Generalized Nash Bargaining leaves the final-good producer with a fraction $\phi \in (0,1)$ of the surplus. For reasons that will become clear below, I make the following assumption:

Assumption 1: $\phi > 1/2$.

Following the work of Grossman and Hart (1986) and Hart and Moore (1990), and contrary to the older transaction-cost literature, I assume that integration of the supplier does not eliminate the opportunistic behavior at the heart of the hold-up problem. Bargaining will therefore occur even when the final-good producer and the supplier are integrated. Ownership, however, crucially affects the distribution of ex-post surplus through its effect on each party's outside option. More specifically, the outside option for a final-good producer will be different when it owns the supplier and when it does not. In the latter case, the amount $x_k(i)$ is owned by the supplier and thus if the two parties fail to agree on a division of the surplus, the final-good producer is left with nothing. Conversely, under integration, the manager of the final-food producer can always fire the manager of the supplying division and seize the amount of input already produced.

If the final-good producer could fully appropiate $x_k(i)$ under integration, there would be no surplus to bargain over after production, and the supplier would optimally set $L_{x,k}(i) = 0$ (which of course would imply $x_k(i) = 0$). In such case, integration would never be chosen. To make things more interesting, I assume that by integrating the supplier, the final-good producer obtains the residual rights over only a fraction $\delta \in (0,1)$ of the amount of $x_k(i)$ produced, so that the surplus of the relationship remains positive even under integration.[16]

On the other hand, and since the component is completely specific to the final-good producer, the outside option for the intermediate input producer is zero regardless of ownership structure.

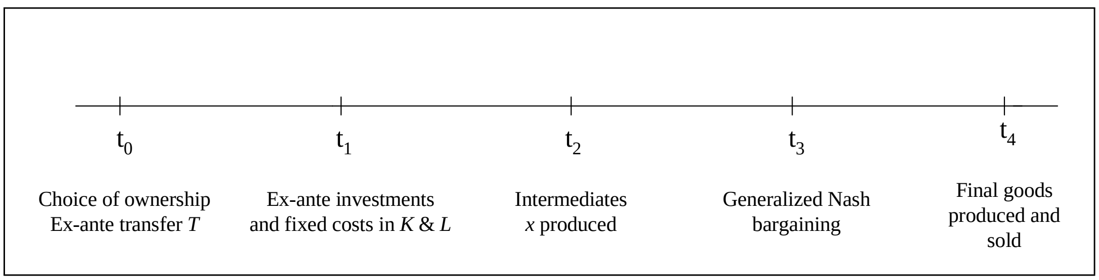
In chosing whether to enter the market with an integrated or a stand-alone supplier, the final-good producer thus considers the benefits and costs of integration. By owning

[16] An alternative set-up is the following. Assume that production of intermediates actually procedes in two stages. When firms enter the bargaining, only a fraction $\delta \in (0,1)$ of $x_k(i)$ has been produced. After the bargaining and immediately before the delivery of the input, the supplier can costlessly refine the component, increasing the amount produced from $\delta x_k(i)$ to $x_k(i)$ (one could think of this second stage as the branding of the product). Suppose, further, that the supplier does not perform this product refinement unless the two firms agree in the bargaining (this strategy is, in fact, subgame perfect). In such case, the surplus of the relationship would also be strictly positive.

the supplier, the final-good producer tilts the bargaining power in its favor but reduces the incentives for the supplier to make an efficient ex-ante investment in labor (and perhaps capital). As in Grossman and Hart (1986), and in contrast to the transaction-cost literature, the costs of integration are here endogenous.[17]

I now summarize what the timing of events is (see also Figure 3). At t_0, the final-good producer decides whether it wants to enter a given market. At this point, residual rights are assigned and the supplier makes a lump-sum transfer to the final-good producer. At t_1, firms choose their investments in capital and labor and also incur their fixed costs. At t_2, the final-good producer hands the specifications of the component (and perhaps the capital stock $K_{x,k}$) to its partner, and this latter produces the intermediate input (which can be of high or low quality). At t_3, the quality of the component becomes observable and the two parties bargain over the division of the surplus. Finally at t_4, the final good is produced and sold. For simplicity, I assume that agents do not discount the future between t_0 and t_4.

Figure 3: Timing of Events



3 Firm Behavior for a Given Demand

The model is solved by starting at t_4 and moving backwards. I will initially assume that final-good producers always choose to incur the variable costs $rK_{x,k}(i)$ themselves. In section 3.4 below, I will show that Assumption 1 is in fact sufficient to ensure that this is the case in equilibrium.

The assumption of a unit elasticity of substitution between varieties in industry Y and Z implies that we can analyze firm behavior in each industry independently. Consider industry Y, and suppose that at t_4, $n_{Y,V}$ pairs of integrated firms and $n_{Y,O}$ pairs of stand-alone firms are producing.[18] Let $p_{Y,V}(i)$ be the price charged by an integrating final-good producer

[17] One feature that distinguishes this model from that of Grossman and Hart (1986) is that ex-ante investments are not always inalienable. As discussed above, the final-good producer is allowed to choose between incurring the cost $rK_{x,k}(i)$ itself or making the supplier bear it.

[18] Henceforth, a subscript V will be used to denote equilibrium values for final-good producers that vertically integrate their suppliers. A subscript O will be used for those that outsource the production of the input.

for variety i in industry Y. Let $p_{Y,O}(i)$ be the corresponding price for a non-integrating final-good producer.

From equation (1), demand for a variety i in industry Y is given by

$$y(i) = A_Y p_Y(i)^{-1/(1-\alpha)}, \tag{3}$$

where

$$A_Y = \frac{\mu E}{\int_0^{n_{Y,V}} p_{Y,V}(j)^{-\alpha/(1-\alpha)} dj + \int_0^{n_{Y,O}} p_{Y,O}(j)^{-\alpha/(1-\alpha)} dj}, \tag{4}$$

and E denotes total spending in the economy. I treat the number of firms as a continuum, implying that firms take A_Y as given.

3.1 Integrated pairs

Consider first the problem faced by a final-good producer and its integrated supplier. If the latter produces a high-quality intermediate input and the firms agree in the bargaining, the potential revenues from the sale of the final good are $R_Y(i) = p_Y(i)y(i)$, which using (2) and (3) can be written as

$$R_Y(i) = A_Y^{1-\alpha} \left(\frac{K_{x,Y}(i)}{\beta_Y} \right)^{\alpha\beta_Y} \left(\frac{L_{x,Y}(i)}{1-\beta_Y} \right)^{\alpha(1-\beta_Y)}.$$

On the other hand, if the parties fail to agree in the bargaining, the final good producer will be able to sell no more than an amount $\delta y(i)$, which again using (3) will translate into sale revenues of $\delta^{\alpha} R_Y(i)$. The ex-post opportunity cost for the supplier is zero. The quasi-rents of the relationship are therefore $(1-\delta^{\alpha}) R_Y(i)$.

The contract incompleteness will give rise to renegotiation at t_3. In the bargaining, Generalized Nash bargaining leaves the final-good division with its default option plus a fraction ϕ of the quasi-rents. On the other, the integrated supplier receives the remaining fraction $1-\phi$ of the quasi-rents. Since both ϕ and δ are assumed to be strictly less than one, the supplier's ex-post revenues from producing a high-quality input are always strictly positive. Low-quality inputs will therefore never be produced.

Rolling back to t_1, the final-good producer will therefore set its investment in capital $K_{x,Y}(i)$ to maximize $\overline{\phi} R(i) - rK_{x,Y}(i)$ where

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

The program yields a best-response investment $K_{x,Y}(i)$ in terms of factor prices, the level of demand as captured by A_Y and the investment in labor $L_{x,Y}(i)$. On the other hand, the integrated supplier simultaneously sets $L_{x,Y}(i)$ to maximize $\left(1-\overline{\phi}\right) R(i) - wL_{x,Y}(i)$, from which an analogous reaction function $L_{x,Y}(i)$ is obtained.[19] Solving for the intersection

[19] The supplier could in principle find it optimal to complement the capital investment of the final-good division with some extra investment of its own, call it $K_{x,Y}^S$. Nevertheless, if the two investments in capital are perfect subsitutes in the production of $x_Y(i)$, Assumption 1 is sufficient to ensure that the optimal capital investment of the supplier is 0. To see this, notice that $\overline{\phi}\left(\partial R(i)/\partial K_{x,Y}\right) > \left(1-\overline{\phi}\right)\left(\partial R(i)/\partial K_{x,Y}^S\right)$ for $\overline{\phi} > \phi > 1/2$. The complementary slackness condition thus implies that $K_{x,Y}^S = 0$.

of the two best-response functions yields the equilibrium ex-ante investments.[20] Plugging these investments into (2) and (3) and rearranging, yields the following identical optimal output and price for all varieties in industry Y:

$$y_V = x_{Y,V} = A_Y \left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha \overline{\phi}^{\beta_Y} \left(1-\overline{\phi}\right)^{1-\beta_Y}} \right)^{-1/(1-\alpha)} \tag{5}$$

$$p_{Y,V} = \frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha \overline{\phi}^{\beta_Y} \left(1-\overline{\phi}\right)^{1-\beta_Y}}. \tag{6}$$

Facing a constant elasticity of demand, the final-good producer charges a constant mark-up over marginal cost. The mark-up, however, is $1/(\overline{\phi}^{\beta_Y}\left(1-\overline{\phi}\right)^{1-\beta_Y})$ times higher than the mark-up that would be charged if contracts were complete. From equation (6), if β_Y is high, the mark-up is relatively higher, the lower is $\overline{\phi}$. Conversely, if production of x_Y requires mostly labor (β_Y low), the mark-up is relatively higher, the higher is $\overline{\phi}$.

Using the expressions for y_V and $p_{Y,V}$, it is easy to check that the equilibrium investment levels are also identical for all varieties and satisfy $rK_{x,Y,V} = \alpha\beta_Y\overline{\phi}p_{Y,V}y_V$ and $wL_{x,Y,V} = \alpha(1-\beta_Y)(1-\overline{\phi})p_{Y,V}y_V$.

At t_1, the two parties also choose how much capital and labor to rent in incurring the fixed costs. Applying Shepard's lemma, factor demands in the fixed costs sector are

$$\begin{aligned} K_{f,h} &= \beta_Y f_h \left(\frac{w}{r}\right)^{1-\beta_Y} \\ L_{f,h} &= (1-\beta_Y) f_h \left(\frac{w}{r}\right)^{-\beta_Y}, \end{aligned} \tag{7}$$

for $h \in \{F, S\}$.

Finally, at t_0, the supplier makes a lump-sum transfer $T_{Y,V}$ to the final-good producer. As discussed above, at t_0, there is a large number of potential suppliers, so that ex-ante competition among them ensures that this transfer exactly equals the supplier's ex-ante profits.[21] Using the value of this transfer, ex-ante profits for an integrating final-good producer can finally be expressed as

$$\pi_{F,V,Y} = \left(1-\alpha(1-\beta_Y)+\alpha\overline{\phi}(1-2\beta_Y)\right) A_Y p_{Y,V}^{-\alpha/(1-\alpha)} - f r^{\beta_Y} w^{1-\beta_Y}, \tag{8}$$

where $p_{Y,V}$ is given in (6).

3.2 Pairs of stand-alone firms

If the firms enter the market as stand-alone firms, the supplier is entitled to the residual rights of control over the amount of input produced at t_2. The ex-post opportunity cost

[20] In particular, these are $K_{x,Y,V}(i) = \frac{\alpha\beta_Y\overline{\phi}}{r} A_Y \left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha\overline{\phi}^{\beta_Y}\left(1-\overline{\phi}\right)^{1-\beta_Y}} \right)^{-\alpha/(1-\alpha)}$ and $L_{x,Y,V}(i) = \frac{\alpha(1-\beta_Y)(1-\overline{\phi})}{w} A_Y \left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha\overline{\phi}^{\beta_Y}\left(1-\overline{\phi}\right)^{1-\beta_Y}} \right)^{-\alpha/(1-\alpha)}$.

[21] In particular, this transfer is $T_{Y,V} = (1-\overline{\phi})(1-\alpha(1-\beta_Y))A_Y p_{Y,V}^{-\alpha/(1-\alpha)} - f_S r^{\beta_Y} w^{1-\beta_Y}$.

for the final-good producer is therefore zero in this case. As for the supplier, since the component is specific to the final-producer, the value of $x_Y(i)$ outside the relationship is also again zero. It follows that if the intermediate input producer hands a component with the correct specification, the potential sale revenues $R(i)$ will entirely be quasi-rents. The final-good producer will obtain a fraction ϕ of this surplus in the bargaining so at t_1 it will choose $K_{x,Y}(i)$ to maximize $\phi R(i) - rK_{x,Y}(i)$. On the other hand, the supplier will set $L_{x,Y}(i)$ so as to maximize $(1-\phi)\, R(i) - wL_{x,Y}(i)$.

From here on, it is clear that the solution to the problem is completely analogous to that for pairs of integrated firms, with ϕ substituting for $\overline{\phi}$ in equations (5) through (8). In particular, profits for a final-good producer that chooses to outsource the production of the intermediate input will be

$$\pi_{F,Y,O} = \left(1 - \alpha(1-\beta_Y) + \alpha\phi(1-2\beta_Y)\right) A_Y p_{Y,O}^{-\alpha/(1-\alpha)} - f r^{\beta_Y} w^{1-\beta_Y}, \tag{9}$$

where $p_{Y,O} = r^{\beta_Y} w^{1-\beta_Y} / (\alpha\phi^{\beta_Y} (1-\phi)^{1-\beta_Y})$.

3.3 Comparison with an environment with complete contracts

We can compare the previous two situations to one in which the quantity and quality of the component (as well the ex-ante investments) were verifiable. In such case, the two parties would bargain over the division of the surplus upon entry and the contract would not be renegotiated ex-post. Upon entry, the threat point for both parties would be zero . The surplus of the relationship would thus be given by $S_Y(i) = p_Y(i)y(i) - rK_{x,Y}(i) - wL_{x,Y}(i) - f r^{\beta_Y} w^{1-\beta_Y}$. At t_1, the final-good producer would choose $K_{x,Y}(i)$ to maximize $\phi S_Y(i)$, while the supplier would set $L_{x,Y}(i)$ to maximize $(1-\phi)\, S_Y(i)$. It is straightforward to check that the impossibility of writing enforceable contracts leads to underinvestment in both $K_{x,Y}$ and $L_{x,Y}$. In particular, letting $K_{x,Y}^*$ and $L_{x,Y}^*$ denote the optimal contractible investments, it is easy to show that $K_{x,Y}^* > \max\{K_{x,Y,V}, K_{x,Y,O}\}$ and $L_{x,Y}^* > \max\{L_{x,Y,V}, L_{x,Y,O}\}$.[22]

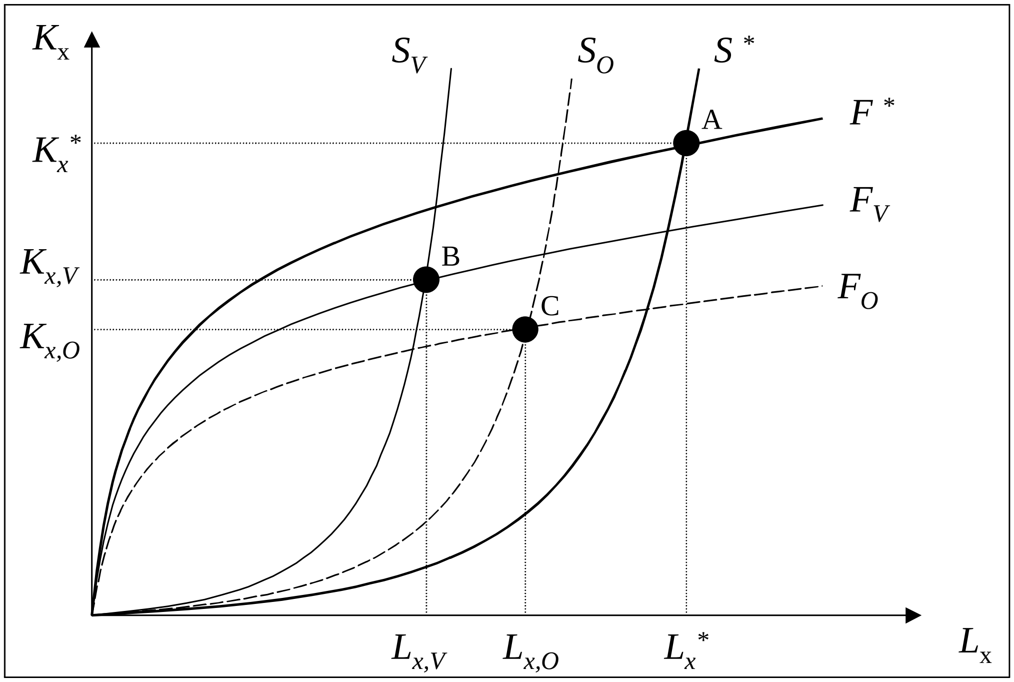
Underinvestment stems from the fact that, with incomplete contracts, each firm receives only a fraction of the marginal return to its ex-ante investment. The inefficiency is depicted in Figure 4. The curves F^* and I^* represent the reaction functions $K_{x,Y}^*(L_{x,Y})$ and $L_{x,Y}^*(K_{x,Y})$ under complete contracts, with the corresponding equilibrium in point A. Similarly, B and C depict the incomplete-contract equilibria corresponding to integration and outsourcing. An important point to notice from Figure 4 is that the underinvestment in labor relative to that in capital tends to be greater under integration that under outsourcing.[23] This follows from the fact that under integration, the supplier has a relatively weaker bargaining power and thus receives a smaller fraction of the marginal return to its

[22] In the case of capital this follows from

$$\frac{\alpha\beta_Y A_Y}{r}\left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha}\right)^{\frac{-\alpha}{1-\alpha}} > \max\left\{\frac{\alpha\beta_Y\overline{\phi}A_Y}{r}\left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha\overline{\phi}^{\beta_Y}\left(1-\overline{\phi}\right)^{1-\beta_Y}}\right)^{\frac{-\alpha}{1-\alpha}}, \frac{\alpha\beta_Y\phi A_Y}{r}\left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha\phi^{\beta_Y}(1-\phi)^{1-\beta_Y}}\right)^{\frac{-\alpha}{1-\alpha}}\right\}.$$

[23] By this I mean that $\left(L_{x,Y}^*/L_{x,Y,V}\right) / \left(K_{x,Y}^*/K_{x,Y,V}\right) > \left(L_{x,Y}^*/L_{x,Y,O}\right) / \left(K_{x,Y}^*/K_{x,Y,O}\right)$. Note that this also implies that controlling for industry characteristics, integrated suppliers should be using a higher capital-labor ratio in production than nonintegrated ones. This is consistent with the results of some empirical

Figure 4: Complete vs. Incomplete Contracts



ex-ante investment. A similar argument explains why the investment in capital tends to be relatively more inefficient under outsourcing.

3.4 The rationale for cost-sharing

Consider now the problem faced by an independent supplier when the final-good producer decides not to contribute to variable costs. In such case, the supplier chooses $K_{x,Y}(i)$ and $L_{x,Y}(i)$ to maximize $(1-\phi)\,R_Y(i)-rK_{x,Y}(i)-wL_{x,Y}(i)$, and the final-good producer simply receives $\phi R_Y(i)$ ex-post. Following similar steps as before, it is easy to show that ex-ante profits for a final-good producer can now be expressed as

$$\widetilde{\pi}_{F,Y,O}=(\phi+(1-\alpha)(1-\phi))\,A_Y\left(\frac{r^{\beta_Y}w^{1-\beta_Y}}{\alpha(1-\phi)}\right)^{-\alpha/(1-\alpha)}-fr^{\beta_Y}w^{1-\beta_Y}. \qquad (10)$$

The case of an integrated supplier is completely analogous. In particular, the same expression (10) applies, with $\overline{\phi}$ substituting for ϕ.

The following result follows from comparing equation (10) with (8) and (9):

Proposition 1 *Under Assumption 1 (i.e. if $\phi>1/2$), final-good producers will always decide to bear the cost of renting the capital required to produce the intermediate input.*

Proof. *See Appendix A.1.* ■

studies, discussed in Caves (1996, pp. 230-231), that compare capital intensity in overseas subsidiaries of multinational firms with that of independent domestic firms in the host country.

The intuition for this result is that the higher is ϕ, the smaller is the fraction of the marginal return to its ex-ante investments that the supplier receives, and thus the less it will invest in $K_{x,Y}$. This underinvestment will have a negative effect on the value of the relationship, which is what the final-good producer maximizes ex-ante. For a large enough ϕ (in this case 1/2), the detrimental effect of the underinvestment in capital is large enough so as to make it worthwile for the final-good producer to bear the cost of renting $K_{x,Y}$ itself, even if by doing so it now exposes itself to a hold-up by the supplier. In other words, for $\phi > 1/2$, a supplier incurring all variable costs faces a too severe hold-up problem, which the final-good producer finds it optimal to alleviate by sharing part of the required ex-ante investments.[24]

4 Industry Equilibrium

In this section, I describe the partial equilibrium in a particular industry taking factor prices as given. Again, without loss of generality, I focus on industry Y. In equilibrium, free entry implies that no firm makes positive expected profits. In principle, three equilibrium modes of organization are possible: (i) a mixed equilibrium with some varieties being produced by integrated pairs and others by non-integrated pairs; (ii) an equilibrium with pervasive integration in which no final-good producer finds it profitable to ousource the production of the intermediate input; and (iii) an equilibrium with pervasive outsourcing in which no final-good producer chooses to vertically integrate its supplier.[25]

4.1 Mixed Equilibrium

In order for both pairs of integrated firms and pairs of stand-alone firms to simultaneously sell in a market, it must be the case that all firms expect to break-even at t_0. As discussed above, the ex-ante transfers $T_{Y,V}$ and $T_{Y,O}$ ensure that suppliers always break even. On the other hand, from equation (8), for integrating final-good producers to make zero profits, demand must satisfy:

$$A_{Y,V} = \frac{f r^{\beta_Y} w^{1-\beta_Y}}{1-\alpha(1-\beta_Y)+\alpha\overline{\phi}(1-2\beta_Y)} p_{Y,V}^{\alpha/(1-\alpha)}. \tag{11}$$

But, from equation (9), for non-integrating final-good producers to simultaneously break-even, demand must also equal:

$$A_{Y,O} = \frac{f r^{\beta_Y} w^{1-\beta_Y}}{1-\alpha(1-\beta_Y)+\alpha\phi(1-2\beta_Y)} p_{Y,O}^{\alpha/(1-\alpha)}. \tag{12}$$

Plugging the optimal values for $p_{Y,V}$ and $p_{Y,O}$ into (11) and (12), and using $\overline{\phi} = \delta^\alpha + \phi(1-\delta^\alpha)$, it is possible to express the ratio $\Theta(\beta_Y, \alpha, \phi, \delta) = A_{Y,O}/A_{Y,V}$ as a function of

[24] Hashimoto (1981) presents a somewhat related rationale for the sharing of firm-specific human capital investments between a worker and her employer.

[25] The analysis here borrows terminology and methodology from Grossman and Helpman (2002).

the fundamental parameters of the model:

$$\Theta(\cdot) = \left(1 + \frac{\alpha(1-\phi)\,\delta^{\alpha}(1-2\beta_Y)}{1-\alpha(1-\beta_Y)+\alpha\phi(1-2\beta_Y)}\right)\left(\frac{1+\frac{1-\phi}{\phi}\delta^{\alpha}}{1-\delta^{\alpha}}\right)^{\frac{\alpha\beta_Y}{1-\alpha}}(1-\delta^{\alpha})^{\frac{\alpha}{1-\alpha}}. \qquad (13)$$

The existence of a mixed equilibrium requires that $\Theta(\beta_Y, \alpha, \phi, \delta) = 1$. But for $\delta \in (0,1)$, this will only be true in a knife-edge case.

4.2 Equilibrium with Pervasive Integration

Consider now an equilibrium in which only integrating final-good producers enter the market. I will first describe such an equilibrium and then discuss under what conditions it will exist.

If no final-good producer outsources the production of x_Y, all firms will charge a price for $y(i)$ given by equation (6). Since $n_{Y,O} = 0$, equation (4) simplifies to $A_{Y,V} = \mu E p_{Y,V}^{\alpha/(1-\alpha)}/n_{Y,V}$, which together with the free-entry condition (11) implies

$$n_{Y,V} = \frac{1-\alpha(1-\beta_Y)+\alpha\overline{\phi}(1-2\beta_Y)}{f r^{\beta_Y} w^{1-\beta_Y}}\mu E. \qquad (14)$$

Naturally, the equilibrium number of varieties in industry Y depends positively on total spending in the industry and negatively on fixed costs. The equilibrium level of output of each variety can be obtained by plugging the equilibrium demand (11) in equation (5):

$$y_V = \frac{\alpha\overline{\phi}^{\beta_Y}\left(1-\overline{\phi}\right)^{1-\beta_Y} f}{1-\alpha(1-\beta_Y)+\alpha\overline{\phi}(1-2\beta_Y)}. \qquad (15)$$

Equilibrium factor demands can similarly be obtained by plugging (11) into the expressions in footnote 20.

In order to prove that the previous equilibrium does in fact exist, I still need to show that a non-integrating final-good producer does not have an incentive to enter the market. Such an entrant firm would face demand given by $y(i) = A_{Y,V} p_Y(i)^{-1/(1-\alpha)}$. Using equations (9) and (12), the profits for such a deviating firm can be expressed as $f r^{\beta_Y} w^{1-\beta_Y}(A_{Y,V}/A_{Y,O} - 1)$. It thus follows that if $A_{Y,V} \geq A_{Y,O}$, profits for a stand-alone firm will be non-negative and thus they will choose not to exit the market. An equilibrium with with pervasive integration thus requires $A_{Y,V} < A_{Y,O}$. In words, an equilibrium with pervasive integration exists when the minimum demand that makes integration viable is lower than the minimum demand that makes outsourcing viable.

4.3 Equilibrium with Pervasive Outsourcing

Finally, consider an equilibrium in which no firm vertically integrates its supplier. In such an equilibrium every firm charges a price given by $p_{Y,O}$ which makes equation (4) simplify to $A_{Y,O} = \mu E p_{Y,O}^{\alpha/(1-\alpha)} / n_{Y,O}$. Combining this expression with the free-entry condition (12), yields the equilibrium number of pairs undertaking outsourcing,

$$n_{Y,O} = \frac{1 - \alpha(1 - \beta_Y) + \alpha\phi(1 - 2\beta_Y)}{f r^{\beta_Y} w^{1-\beta_Y}} \mu E. \tag{16}$$

which is identical to (14) with ϕ substituting for $\overline{\phi}$. The equilibrium values for output and factor demands are also analogous to those for the equilibrium with pervasive integration.

Once again, in order to prove that the previous equilibrium does in fact exist, we need to check that no integrating final-good producer has an incentive to enter the market. Given the equilibrium above, such a deviator would face demand given by $y(i) = A_{Y,O} p_Y(i)^{-1/(1-\alpha)}$. Plugging (11) in (8), ex-ante profits for the integrated entrant can be expressed as $f r^{\beta_Y} w^{1-\beta_Y} (A_{Y,O}/A_{Y,V} - 1)$. Hence, it follows that an equilibrium with pervasive outsourcing exists when $A_{Y,V} > A_{Y,O}$, i.e. when outsourcing requires a lower minimum demand to be viable.

Although I have focused on industry Y, it should be clear that the analysis of industry Z is completely analogous. Letting $A_{Z,V}$ and $A_{Z,O}$ be the minimum demands that make integration and outsourcing viable in industry Z, the following Proposition summarizes the main results in this section:

Proposition 2 *A mixed equilibrium does not generically exist in any industry. An equilibrium with pervasive integration in industry $k \in \{Y, Z\}$ exists only if $A_{k,V} < A_{k,O}$. An equilibrium with pervasive outsourcing in industry $k \in \{Y, Z\}$ exists only if $A_{k,V} > A_{k,O}$.*

5 Factor Intensity and the Equilibrium Mode of Organization

In this section, I study the determinants of the equilibrium mode of organization, with a particular emphasis on the role of capital intensity. From Propositions 2, it follows that an equilibrium with pervasive integration (outsourcing) in industry $k \in \{Y, Z\}$ is more likely the higher (lower) is the ratio $A_{k,O}/A_{k,V}$. From equation (13) above, this ratio is a function of the exogenous parameters of the model, namely β_k, α, ϕ and δ.

The following lemma states that $\Theta(\beta_k, \alpha, \phi, \delta)$ is an increasing function of β_k.

Lemma 1 $\partial\Theta(\cdot)/\partial\beta_k > 0$ *for all* $\beta \in (0, 1)$.

Proof. *See Appendix A.2.* ■

The intuition for why $\Theta(\beta_k, \alpha, \phi, \delta)$ is increasing in β_k is straightforward. The higher the capital intensity of an industry, the more value-reducing will the underinvestment in capital be. Furthermore, as discussed in section 3.3, the underinvestment in capital tends to be more severe under integration than under outsourcing. It thus follows that when capital intensity is high, the minimum demand that makes integration viable will tend to be relatively higher than the minimum demand that makes outsourcing viable.[26]

Lemma 1 paves the way for the following crucial result:

Proposition 3 *Given a triplet* $(\alpha, \phi, \delta) \in (0,1)^3$*, there exists a unique* $\widehat{\beta} \in (0,1)$ *such that* $\Theta(\widehat{\beta}, \cdot) = 1$*. Furthermore, for all* $\beta < \widehat{\beta}$*,* $\Theta(\beta, \cdot) < 1$*, and for all* $\beta > \widehat{\beta}$*,* $\Theta(\beta, \cdot) > 1$*.*

Proof. *See Appendix A.3.* ■

In words, an equilibrium with pervasive outsourcing exists only for industries with capital intensity below a certain threshold $\widehat{\beta} \in (0,1)$. Conversely, an equilibrium with pervasive integration will exist for industries with $\beta > \widehat{\beta}$.[27,28]

The logic of this result lies at the heart of Grossman and Hart's (1986) seminal contribution. Ex-ante efficiency dictates that residual rights should be controlled by the party undertaking a relatively more important investment. If production of the intermediate input requires mostly labor, then the investment made by the final-good producer will be relatively small, and thus it will be optimal to assign the residual rights of control to the supplier. Conversely, when the capital investment is important, the final-good producer will optimally choose to tilt the bargaining power in its favor by obtaining these residual rights.

Proposition 3 provides a potential rationale for the first fact identified in the introduction. To the extent that vertical integration of suppliers occurs mostly in capital-intensive industries, we should expect the share of intrafirm trade in those industries to be relatively higher than that in labor-intensive industries.

Equation (13) lends itself to other comparative static exercises. For instance, it is possible to show that $\Theta(\cdot)$ is a decreasing function of ϕ, which by the implicit function theorem implies that the cut-off $\widehat{\beta}$ is an increasing function of ϕ. To understand this result, notice that an increase in ϕ shifts bargaining power from the supplier to the final-good

[26] Despite this clear intuition, proving that $\partial\Theta(\cdot)/\partial\beta_k$ is positive is somewhat cumbersome (see Appendix A.2). This is due to a counterbalancing effect. Integration enhances efficiency in capital-intensive industries by reducing the underinvestment problem. But this, of course, comes at the expense of higher capital expenditures which, *ceteris paribus,* tend to reduce profits. Lemma 1 shows, however, that this latter effect is always outweighted by the former.

[27] The result goes through if the input is produced according to the technology in footnote 14 and $\beta_k + \eta(\beta_k)(1-\beta_k)$ increases with β_k. In particular, the function $\Theta(\beta_k, \alpha, \phi, \delta)$ is identical in this more general case, so that Proposition 3 still holds for the same $\widehat{\beta}$. Having the final-good producer incur all capital expenditures is therefore not a crucial asumption.

[28] The result is also robust to relaxing the Cobb-Douglas assumption of a unit elasticity of substitution between capital and labor, provided that this elasticity is not too high. In particular, simulations with the more general CES technology

$$x_k = \left(\beta_k \left(\frac{K_{x,k}}{\beta_k} \right)^{\frac{\sigma-1}{\sigma}} + (1-\beta_k) \left(\frac{L_{x,k}}{1-\beta_k} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

indicate that the function $\Theta(\cdot)$ is increasing in β_k for $\sigma \leq \overline{\sigma}$, where $\overline{\sigma}$ appears to be well above one. Interestingly, with this more general specification, $\Theta(\cdot)$ is also a function of the wage-rental ratio in the economy. For $\sigma < 1$, the model predicts that, *ceteris paribus*, countries with a higher wage-rental will have a larger measure of industries doing outsourcing (i.e. $\partial\widehat{\beta}/\partial w/r) > 0$).

producer regardless of ownership structure (since $\overline{\phi}$ increases with ϕ). It thus follows that increasing ϕ necessarily worsens the incentives for the supplier. To compensate for this, the final-good will now find it profitable to outsource in a larger measure of industries.[29]

The effect of α is in general ambiguous as it appears in several terms in equation (13). Simulations indicate, however, that an increase in competition (a higher α) tends to enhance outsourcing in sufficiently labor-intensive industries, while fostering integration in the most capital-intensive ones. The intuition for this result is that the higher the elasticity of substitution in demand, the more sensitive will profits be to the price charged by the final-good producer. A natural response to an increase in α is thus a shift towards higher efficiency, which translates into giving more bargaining power to suppliers in labor-intensive industries, and better incentives to final-good producers in capital-intensive industries.[30]

Finally, an increase in δ corresponds to an increase in $\overline{\phi}$ holding constant ϕ, i.e. a fall in the bargaining power of the supplier under integration. The effect of such an increase depends again on the capital intensity of the production process. In labor-intensive sectors the incentives of the supplier are very important and thus efficiency considerations will dictate a shift towards more outsourcing in response to an increase in δ. On the other hand, in capital-intensive industries, an increase in δ may make integration more attractive, as it now secures the more significant investor a larger fraction of the marginal return to its investment. Simulations tend to broadly support these intuitions.

6 General Equilibrium

Having described the equilibrium in each industry, we can now move to the general equilibrium of the closed economy. In particular, I will characterize a general equilibrium in which income equals spending

$$E = rK + wL, \tag{17}$$

and both product, capital and labor markets clear.[31]

By Walras' law, we can focus on the equilibrium in the labor market. Letting L_Y and L_Z denote total labor demand in industries Y and Z, labor market clearing requires $L_Y + L_Z = L$. We can decompose L_Y into three components, depending on the equilibrium mode of organization. In an equilibrium with pervasive integration,

$$L_Y = n_{Y,V} L_{x,Y,V} + n_{Y,V} L_{f,Y,F} + n_{Y,V} L_{f,Y,S}. \tag{18}$$

[29] Due again to a counterbalancing effect, it takes some work to prove that $\partial\Theta(\cdot)/\partial\phi$. Nevertheless, the negative effect captured in the second term of (13) always dominates (details available upon request).

[30] To see where the result is coming from, ignore the first term in (13) as well as the effect of α through the terms δ^{α}. Then the effect of α is positive as long as $(1-\delta^{\alpha})\left(1+\delta^{\alpha}/\left(\phi\left(1-\delta^{\alpha}\right)\right)\right)^{\beta} > 1$, that is if $\beta > \overline{\beta}$ for some $\overline{\beta}(\phi, \delta, \alpha) \in (0, 1)$. Naturally, the sign of the derivative also depends on the values of ϕ and δ. I stress the role of factor intensity here since the channel is absent in other papers that have studied the relationship between market competition and the attractiveness of outsourcing (e.g. Grossman and Helpman, 2002, and Marin and Verdier, 2001).

[31] The product market has already been assumed to clear in the previous sections.

The first term is the total amount of labor hired by the integrated suppliers for the manufacturing of intermediate inputs. The remaining terms are the amounts of labor hired to cover fixed costs. $L_{f,Y,F}$ is the amount of labor employed in total fixed costs by final-good producers. $L_{f,Y,S}$ is the analogous demand by suppliers. Notice from equation (7) that neither $L_{f,Y,F}$ nor $L_{f,Y,S}$ are affected by the equilibrium organization mode.

Plugging (7) and (17) into equation (18), and substituting $n_{Y,V}$ and $L_{x,Y,V}$ for their equilibrium values, it is possible to simplify to:

$$L_Y = (1-\beta_Y)\left(1-\alpha\beta_Y(2\overline{\phi}-1)\right)\frac{\mu\,(rK+wL)}{w}. \tag{19}$$

Following the same steps, it is straightforward to show that in an equilibrium with pervasive outsourcing,

$$L_Y = (1-\beta_Y)\left(1-\alpha\beta_Y(2\phi-1)\right)\frac{\mu\,(rK+wL)}{w}. \tag{20}$$

Equations (19) and (20) imply that the share of income that labor receives is sensitive to the equilibrium mode of organization. Given the assumption of Cobb-Douglas technology, in a world of complete contracts, the share of income accruing to labor in industry Y would be $\mu(1-\beta_Y)$. With incomplete contracts, the share received by labor will be larger or smaller than $\mu(1-\beta_Y)$ depending on whether ϕ and/or $\overline{\phi}$ are greater or smaller than 1/2. Under Assumption 1, incomplete contracts tend to bias the distribution of income towards owners of capital. Intuitively, with $\phi > 1/2$, the underinvestment in labor is relatively more severe. For a given supply of factors, the relatively higher demand for capital tends to push up its price and thus its share in total income. As is clear from equations (19) and (20), this bias is greater under integration than under outsourcing.

To set the stage for an analysis of the share of intrafirm trade in total trade, I make the following assumption:

Assumption 2: $\beta_Y > \widehat{\beta} > \beta_Z$.

In words, I assume that the equilibrium in industry Y is one with pervasive integration. Conversely, firms in the more labor-intensive industry Z are assumed outsource pervasively. It is useful to define the shares of income that accrues to capital in each sector, which using equations (19) and (20) are given by

$$\widetilde{\beta_Y} = \beta_Y(1+\alpha\,(1-\beta_Y)\,(2\overline{\phi}-1))$$

and

$$\widetilde{\beta_Z} = \beta_Z\,(1+\alpha\,(1-\beta_Z)\,(2\phi-1))\,.$$

Notice that $\beta_Y > \beta_Z$ implies $\widetilde{\beta_Y} > \widetilde{\beta_Z}$ and the presence of incomplete contracts does not create factor intensity reversals. With this notation at hand, the equilibrium wage-rental ratio in the economy can be expressed as:

$$\frac{w}{r} = \frac{\mu(1-\widetilde{\beta_Y})+(1-\mu)(1-\widetilde{\beta_Z})}{\mu\widetilde{\beta_Y}+(1-\mu)\widetilde{\beta_Z}}\frac{K}{L} = \frac{\sigma_L}{1-\sigma_L}\frac{K}{L}. \tag{21}$$

The equilibrium wage-rental ratio is a linear function of the aggregate capital-labor ratio. This is a direct implication of the assumption of a Cobb-Douglas technology in both industries. The factor of proportionality is equal to the average labor share in the economy (which I denote by σ_L) divided by the average capital share. As discussed above, Assumption 1 implies that labor shares are depressed relative to their values in a world with complete contracts. It follows that incomplete contracts also tend to depress the equilibrium wage-rental in the economy.

7 The Multi-Country Model

Suppose now that the closed-economy described above is split into $J \geq 2$ countries, with each country receiving an endowment K^j of capital and an endowment L^j of labor. Factors of production are internationally immobile. Countries differ only in their endowments. In particular, individuals in all J countries have identical preferences as specified in (1) and share access to the same technology in (2). The parameters ϕ and δ are also assumed to be identical everywhere. Countries are allowed to trade intermediate inputs at zero cost. Final goods are instead assumed to be nontradable, so that final-good producers produce their varieties in all J countries. To be more specific, each final-good producer has a (costless) plant in each of the J countries.[32] Conversely, varieties of intermediates inputs will be produced in only one location in order to exploit economies of scale.

I assume that for all $j \in J$, the capital-labor ratio K^j/L^j is not *too different* from K/L, so that factor price equalization (FPE) holds, and the equilibrium prices and aggregate allocations are those of the integrated economy described above. Below, I will derive sufficient conditions that ensure that FPE is achieved.

I first study the international location of production of intermediate inputs and then analyze the patterns of international trade it implies.

7.1 Pattern of Production

Since countries differ only in their factor endowments, the cut-off capital intensity $\widehat{\beta}$ will be identical in all countries, and by Assumption 2, suppliers in industry Y will be vertically integrated while those in industry Z will remain non-integrated.

The factor market clearing conditions in country $j \in J$ can therefore be written as:

$$n_Y^j \left(K_{x,Y}^j + K_{f,Y,F}^j + K_{f,Y,S}^j \right) + n_Z^j \left(K_{x,Z}^j + K_{f,Z,F}^j + K_{f,Z,S}^j \right) = K^j$$

and

$$n_Y^j \left(L_{x,Y}^j + L_{f,Y,F}^j + L_{f,Y,S}^j \right) + n_Z^j \left(L_{x,Z}^j + L_{f,Z,F}^j + L_{f,Z,S}^j \right) = L^j,$$

[32] Since final goods are costlessly produced, the model cannot not endogenously pin down where their production is located. Assuming that they are not traded resolves this indeterminacy. At the end of section 7.2, I show that the main result goes through under an alternative set-up that equally resolves the indeterminacy.

where n_k^j refers now to the number of industry k varieties of *intermediate inputs* produced in country j.[33] It is straightforward to check that factor demands *for each variety* depend only on worldwide identical parameters and on aggregate prices, which by assumption are also common in all countries. This implies that differences in the production patterns between countries will be channelled through the number of industry varieties produced in each country. In particular, using the integrated economy equilibrium values for n_Y and n_Z, the factor demand conditions can be simplified to:

$$\begin{aligned}(rK+wL)\left(\mu\widetilde{\beta_Y}\frac{n_Y^j}{n_Y}+(1-\mu)\widetilde{\beta_Z}\frac{n_Z^j}{n_Z}\right) &= rK^j \\ (rK+wL)\left(\mu\left(1-\widetilde{\beta_Y}\right)\frac{n_Y^j}{n_Y}+(1-\mu)\left(1-\widetilde{\beta_Z}\right)\frac{n_Z^j}{n_Z}\right) &= wL^j\end{aligned}$$

Combining these two expressions and plugging the equilibrium wage-rental of the integrated economy, $w/r = (\sigma_L/1-\sigma_L)\,K/L$, yields the number of varieties of intermediate inputs produced in each industry and each country:

$$n_Y^j = \left(\left(1-\widetilde{\beta_Z}\right)(1-\sigma_L)\frac{K^j}{K} - \widetilde{\beta_Z}\sigma_L\frac{L^j}{L}\right)\frac{n_Y}{\left(\widetilde{\beta_Y}-\widetilde{\beta_Z}\right)\mu} \tag{22}$$

and

$$n_Z^j = \left(\widetilde{\beta_Y}\sigma_L\frac{L^j}{L} - \left(1-\widetilde{\beta_Y}\right)(1-\sigma_L)\frac{K^j}{K}\right)\frac{n_Z}{\left(\widetilde{\beta_Y}-\widetilde{\beta_Z}\right)(1-\mu)}, \tag{23}$$

where n_Y is given by (14) and n_Z by (16) with β_Z instead of β_Y. Equation (22) states that a country j will produce a larger measure of varieties of intermediates in industry Y the larger its capital-labor ratio. Conversely, from equation (22), the measure of industry Z varieties it produces is a decreasing function of its capital-labor ratio.

Note also that for a given K^j/L^j both n_Y^j and n_Z^j are increasing in the size of the country, as measured by its share in world GDP, $s_j \equiv \left(rK^j + wL^j\right)/(rK+wL)$. In fact, it straightforward to check that $n_Y^j > s^j n_Y$ if and only if $K^j/L^j > K/L$, and $n_Z^j > s^j n_Z$ if and only if $K^j/L^j < K/L$. In words, capital (labor)-abundant countries tend to produce a share of input varieties in the capital (labor)-intensive industries that exceeds their share in world income.

For the above allocation to be consistent with FPE, it is necessary that $n_Y^j > 0$ and $n_Z^j > 0$. To see this, note that when factor prices depend only on world factor endowments (K and L), the capital-labor ratio used in each sector is fixed. Therefore, a given country cannot employ all its factors by producing in only one industry unless in the knife-edge case in which its endowment of K^j and L^j exactly match that industry's factor intensity.

A sufficient condition for FPE is therefore:

[33] To simplify notation, I drop all subscripts associated with the equilibrium mode of organization. For instance, I will denote the equilibrium number of industry Y (X) varieties of intermediate inputs produced in country j as n_Y^j (n_Z^j) instead of $n_{Y,V}^j$ ($n_{Z,O}^j$).

Assumption 3: $\overline{\kappa} = \frac{\widetilde{\beta_Y}\sigma_L}{\left(1-\widetilde{\beta_Y}\right)(1-\sigma_L)} > \frac{K^j/L^j}{K/L} > \frac{\widetilde{\beta_Z}\sigma_L}{\left(1-\widetilde{\beta_Z}\right)(1-\sigma_L)} = \underline{\kappa}$ for all $j \in J$.

It can be checked that the upper bound $\overline{\kappa}$ is greater than one, while the lower bound $\underline{\kappa}$ is smaller than one. Assumption 3 thus requires the capital-labor ratio K^j/L^j to be sufficiently similar to K/L.

Figure 5: Pattern of Production for $J = 2$

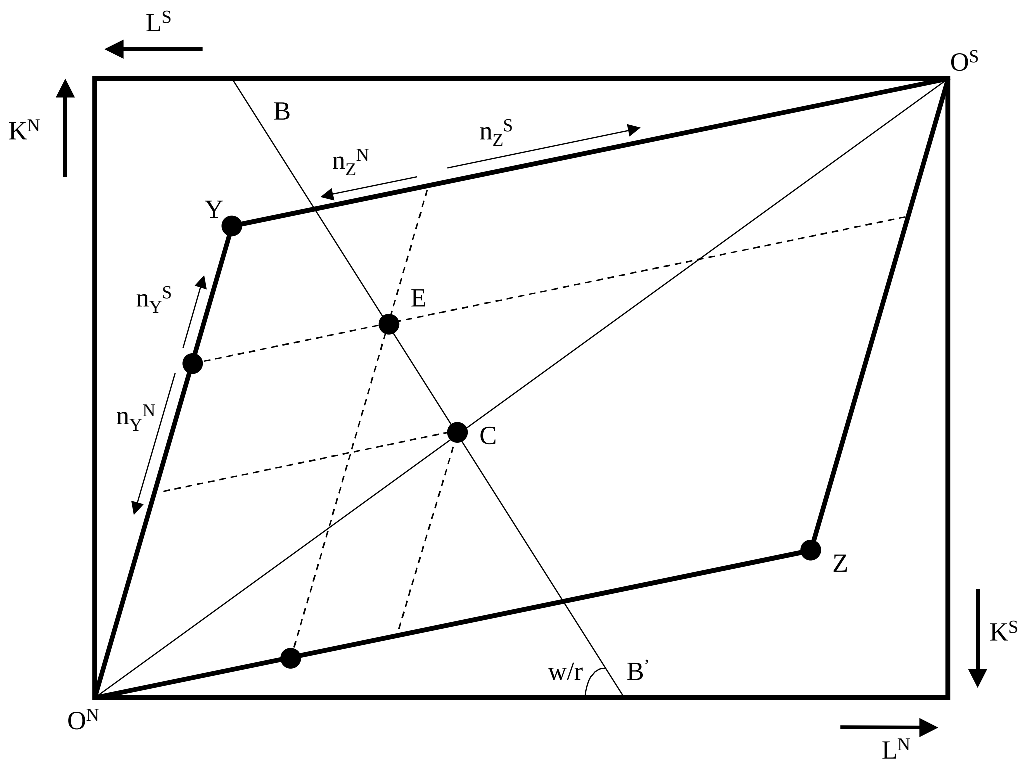


Figure 5 provides a graphical representation of the production pattern for the case of two countries, the North (N) and the South (S). The graph should be familiar to readers of Helpman and Krugman (1985). O^N and O^S represent the origins for the North and the South, respectively. The vectors $O^N Y$ and $O^N Z$ represent world employment of capital and labor in industries Y and Z, respectively, in the equilibrium of the integrated economy. The set of factor endowments that satisfy Assumption 3 (i.e. FPE) corresponds to the parallelogram $O^N Y O^S Z$. Point E defines the distribution of factor endowments. In the graph, the North is capital-abundant relative to the South. Line BB' goes through point E and has a slope of w/r. The relative income of each country is thus held fixed for all points in line BB' and inside the FPE set.

To map this figure to the pattern of production described above, I follow Helpman and Krugman (1985) in choosing units of measurement so that $\left\|O^N Y\right\| = n_Y y$, $\left\|O^N Z\right\| = n_Z y$, and $\left\|O^N O^S\right\| = E = rK + wL$. With the first two normalizations, we can graphically determine the number of varieties of intermediate inputs produced in each country. Moreover, with the last normalization, we can write $s^j = \left\|O^N C\right\| / \left\|O^N O^S\right\|$. Basic geometry then implies that $n_Y^N > s^N n_Y$ and $n_Z^N < s^N n_Z$, which is what we expected given that the North is capital abundant.[34]

7.2 Pattern of Trade

Having described the international location of production of intermediate inputs, we can now move to a study of trade patterns, with a special emphasis on the share of intrafirm imports. Since the final-good is nontradable, the entire volume of world trade will be in intermediate inputs.

A given country $N \in J$, will host $n_Y + n_Z$ plants producing an identical measure of varieties of final goods. Of the n_Y plants in industry Y, a measure n_Y^j will be importing the intermediate input from their integrated suppliers in country $j \neq N$. This volume of trade will thus be *intrafirm* trade. On the other hand, of the n_Z plants in industry Z, a measure n_Z^j will be importing the input from independent suppliers in country $j \neq N$. These transactions will thus occur at *arm's length*.

Before describing in more detail these flows, we must first confront the problem of how to value them. As I discussed above, the fact that contracts are incomplete precludes the purchase of a certain type of intermediate input for a certain price. In fact, there is no explicit price for these varieties. Since all variable costs are incurred in the country where the input is produced, a plausible assumption is to value these intermediates at average cost. But since the final good is produced at no cost, this implies that the *implicit* price of an intermediate input is simply $p_{Y,V}$ in industry Y and $p_{Z,O}$ in industry Z.[35]

Without loss of generality, consider now a given country $N \in J$. On the production side, suppliers in country N will be producing n_Y^N and n_Z^N varieties of intermediate inputs. On the consumption side, and since preferences are identical everywhere, consumers in country N will incur a fraction s^N of world spending on each variety. Since the final good is nontradable, this implies that country N will be exporting a fraction $1 - s^N$ of the output each variety of intermediate input it produces, and will be importing a fraction s^N of the output of each variety it does not produce.

Consider now a second country $S \in J$. From the above discussion, it is clear that the

[34] It is well-known that the assumption of an equal number of industries and factors is crucial in order to obtain a fully determined structure of production. As recently shown by Romalis (2002), however, the inclusion of transport costs in an otherwise standard trade model with monopolistic competition generates a unique pattern of production even with a continuum of industries. Furthermore, his model has a quasi-Heckshe r-Ohlin prediction analogous to the one derived below for the two-industry case.

[35] Alternatively, intermediates could be valued according to the supplier's average revenues. In such case, the implicit prices would be $\left(1 - \overline{\phi}\right) p_{Y,V}$ and $\left(1 - \phi\right) p_{Z,O}$. Since, $\overline{\phi} > \phi$, the value of trade flows in industry Y would be relatively more depressed. This would tend to atenuate the link between factor endowments and the volume of trade established in Proposition 5 below.

volume of N imports from S will be $s^N \left(n_Y^S p_Y y + n_Z^S p_Z z\right)$, or simply

$$M^{N,S} = s^N s^S \left(rK + wL\right). \tag{24}$$

Similarly, the volume of country N exports to country S is $s^S s^N \left(rK + wL\right)$. It thus follows that trade is balanced. Since both industries produce differentiated goods, for a given $s^N + s^S$, the volume of bilateral trade is maximized when both countries are of equal size (c.f., Helpman and Krugman, 1985).

Now let us look more closely at the composition of imports. Since only in industry Y do final-good producers vertically integrate their suppliers, only imports in this industry will occur within firm boundaries. Denoting the volume of country N intrafirm imports from S by $M_{i-f}^{N,S}$, it follows that $M_{i-f}^{N,S} = n_Y^S p_Y y$. Plugging the equilibrium value for n_Y^S yields

$$M_{i-f}^{N,S} = \frac{s^N L^j}{K}\left(\frac{\left(1-\widetilde{\beta_Z}\right)\left(1-\sigma_L\right)\frac{K^j}{L^j} - \widetilde{\beta_Z}\sigma_L\frac{K}{L}}{\widetilde{\beta_Y} - \widetilde{\beta_Z}}\right). \tag{25}$$

Intrafirm imports are thus increasing in the size of both the importing and exporting countries, and also increase in the capital-labor ratio of the exporting country.

Figure 6: Volume of Intrafirm Imports

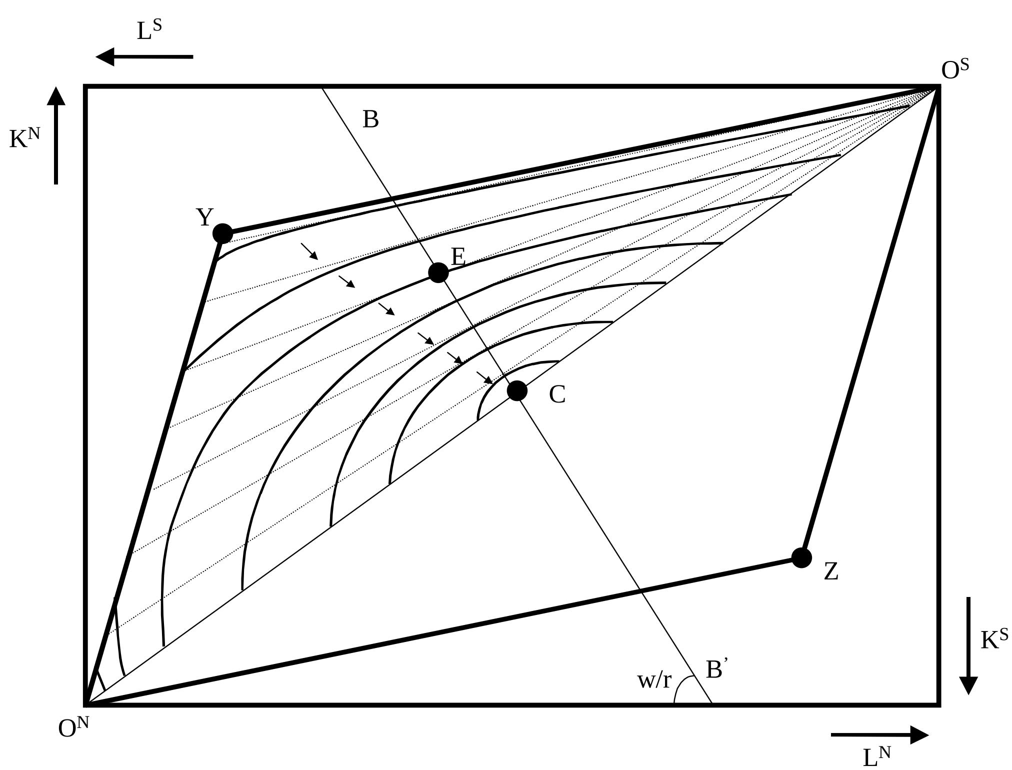


Figure 6 depicts combinations of factor endowments that yield the same volume of intrafirm imports $M_{i-f}^{N,S}$, for the case in which there are only two countries, N and S. The arrow in the graph point at the direction of increasing intrafirm imports. Point C is such that $\|O^N C\| = \|CO^S\|$, implying that the line BB' contains all points for which $s^N = s^S$. The graph shows how for a given capital-labor ratio of the exporting country (i.e. the South), $M_{i-f}^{N,S}$ is maximized when the two countries are of equal size. On the other hand, for a given relative size of the two countries, $M_{i-f}^{N,S}$ is increasing in the capital-labor ratio of the exporting country.

In sum,

Proposition 4 *For any $N, S \in J$ with $S \neq N$, the volume of intrafirm imports $M_{i-f}^{N,S}$ is an increasing function of the capital-labor ratio K^S/L^S and the size s^S of the exporting country. Furthermore, for a given K^S/L^S and s^S, $S_{i-f}^{N,S}$ is also increasing in the size of the importing country.*

Finally, let $S_{i-f}^{N,S}$ denote the share of intrafirm imports in total imports, i.e. $S_{i-f}^{N,S} \equiv M_{i-f}^{N,S}/M^{N,S}$. Dividing equation (25) by (24) and substituting for the equilibrium value of n_Y^S, it is possible to simplify to

$$S_{i-f}^{N,S} = \frac{\left(\left(1 - \widetilde{\beta_Z}\right)(1 - \sigma_L)\frac{K^S}{L^S} - \widetilde{\beta_Z}\sigma_L \frac{K}{L}\right)}{\left(\widetilde{\beta_Y} - \widetilde{\beta_Z}\right)\left((1 - \sigma_L)\frac{K^S}{L^S} + \sigma_L \frac{K}{L}\right)}. \tag{26}$$

Notice that by Assumption 3, $S_{i-f}^{N,S} \in (0, 1)$. Furthermore, when K^S/L^S goes to $\underline{\kappa} \cdot K/L$, the South stops producing varieties of intermediates in industry Y, and thus $S_{i-f}^{N,S}$ goes to 0. Similarly, when K^S/L^S goes to $\overline{\kappa} \cdot K/L$, the South fully specializes in industry Y, and thus $S_{i-f}^{N,S}$ goes to 1. More importantly, simple differentiation of (26) reveals that:

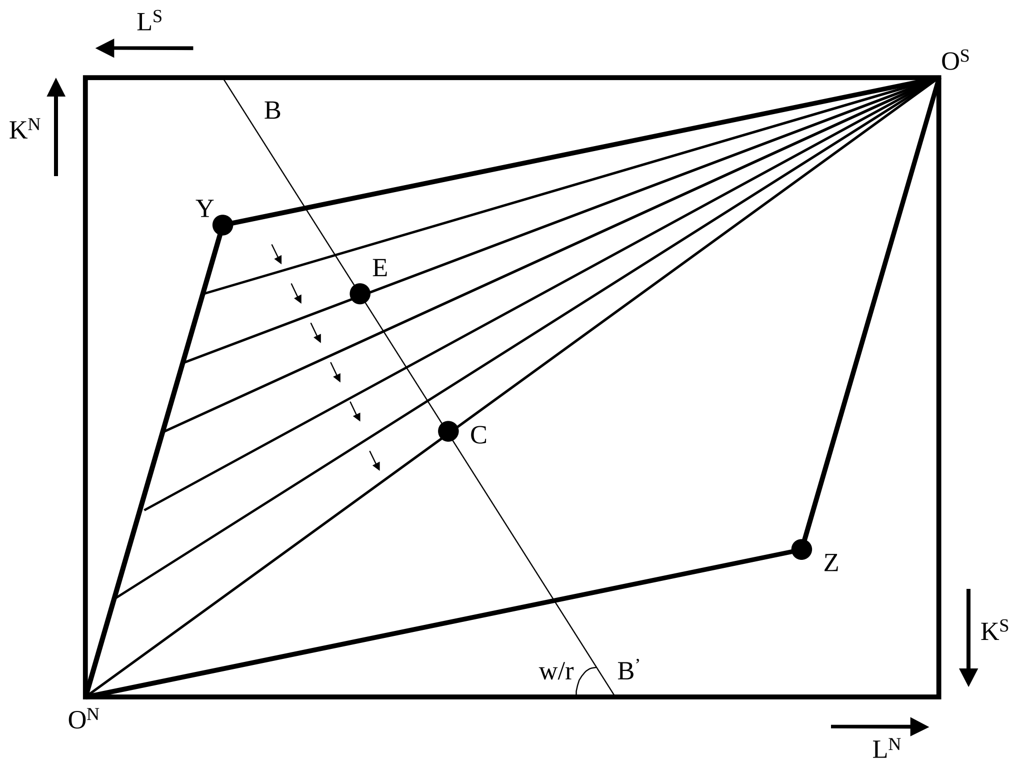
Proposition 5 *For any $N, S \in J$ with $S \neq N$, the share $S_{i-f}^{N,S}$ is an increasing function of the capital-labor ratio K^S/L^S of the exporting country. Furthermore, for a given K^S/L^S, $S_{i-f}^{N,S}$ is unaffected by the relative size of each country.*

The first statement is one of the key results of the paper. In particular, it shows how in a world with international trade, the pattern of Figure 2 in the introduction is a direct implication of the pattern in Figure 1.

Figure 7 provide a graphical illustration of Proposition 5 for the case of two countries. Since $S_{i-f}^{N,S}$ is uniquely determined by K^S/L^S, the sets of points for which $S_{i-f}^{N,S}$ is constant are simple straight lines from the origin of the South. The arrows indicate that for any relative size of each country, $S_{i-f}^{N,S}$ is increasing in K^S/L^S.

In the next section, I will test the theoretical predictions on $S_{i-f}^{N,S}$ and $M_{i-f}^{N,S}$ using data on U.S. imports. Before doing so, I briefly argue that the assumption of nontradability of

Figure 7: Share of Intrafirm Imports



the final-good varieties is not crucial for the results derived above.[36] Consider the following perhaps more realistic alternative set-up. Countries not only differ in factor endowments but also in their stock of knowledge. In particular, there is a set of countries that possess the know-how to produce varieties of final-goods. On the other hand, the remaining countries do not have this know-how and thus export only intermediate inputs and import only final goods. Denote the former set as $\mathcal{N} \subseteq J$ and the latter as $\mathcal{S} \subseteq J$. The final good is tradable at a negligible but positive cost. Since production of final varieties is costless, this implies that countries belonging to $\mathcal{N}$ will only trade intermediates inputs between themselves. It follows that if $\mathcal{S} = \emptyset$, the pattern of trade would be identical to the one discussed above. Assume also that production of final varieties in any country $n \in \mathcal{N}$ is not biased towards any particular industry. More specifically, if country $n \in \mathcal{N}$ produces a fraction η_n of the world production of final varieties in industry Y, then it also produces a fraction η_n of the world production of final varieties in industry Z.

[36] This is not to say that the location of final-good producers is unessential. For instance, if for some reason, the final-good had to be produced close to the supplier's plant, then all trade between final-good producers and suppliers would be domestic and the theory would have no bearing on international trade flows. The following discussion is meant to illustrate that Proposition 5 does not *require* final goods to be entirely nontradable.

Since countries in $\mathcal{S}$ import only final-good varieties, the bilateral share of intrafirm imports in total imports is trivially 0 for all $s \in \mathcal{S}$. Consider now a given country $n \in \mathcal{N}$ and its bilateral trade with another country $j \in J$. If $j \in \mathcal{N}$, we are back to the situation discussed above, so that $S_{i-f}^{n,j}$ will be given by

$$S_{i-f}^{n,j} = \frac{\left(\left(1-\widetilde{\beta_Z}\right)(1-\sigma_L)\frac{K^j}{L^j} - \widetilde{\beta_Z}\sigma_L\frac{K}{L}\right)}{\left(\widetilde{\beta_Y}-\widetilde{\beta_Z}\right)\left((1-\sigma_L)\frac{K^j}{L^j}+\sigma_L\frac{K}{L}\right)} \tag{27}$$

which is identical to (26). If $j \in \mathcal{S}$, trade flows will be different. Country n will import a fraction η_n of total production in country j, and will export back to j a fraction $\eta_n s^j$ of its own production of final-good varieties. Total imports from j will thus be $M^{n,j} = \eta_n s^j (rK + wL)$, while intrafirm imports will be given by $M_{i-f}^{n,j} = \eta_n n_Y^j p_Y y$. When taking the ratio, the term η_n will cancel, and the share of intrafirm imports will thus be again given by (27). Conditional on the importing country belonging $\mathcal{N}$, Proposition 5 thus still remains valid. Notice also that the total volume of intrafirm imports $M_{i-f}^{n,j}$ will again increase in the capital-labor ratio and the size of the exporting country. Furthermore, if η_n were increasing in the size of the importing country n, the second statement in Proposition 4 would also still apply.

8 Econometric Evidence

In this section, I will use data on intrafirm and total U.S. imports to test more formally the empirical validity of the main results of the paper. I will start by studying more closely the relationship between the factor intensity of the exporting industry and the share of intrafirm imports in total imports. In particular, I will show that the clear correlation in Figure 1 does not seem to be driven by the omission of other relevant variables. Next, I will move on to the relationship between relative factor endowments and the share of intrafirm imports. There, I will show that the link predicted in Proposition 5 is confirmed even after controlling for other factors that could reasonably be expected to also affect the share. Furthermore, as predicted by the theory, the size of the exporting country is shown not to have independent effect on the share of intrafirm imports. Finally, I will analyze the determinants of the total volume of intrafirm imports and I will show that, consistently with Proposition 4 total intrafirm imports are indeed significantly affected by the size of the exporting country.

Before discussing the econometric results, however, the next two sections will discuss the structural specification and the data I use to test the hypotheses.

8.1 Specification

The first hypothesis to test is that the share of intrafirm imports is higher, the higher the capital intensity of the exporting industry. The model presented above, actually predicts that the share should be 0 for industries with capital intensity β_k below a certain threshold $\widehat{\beta}$ and 1 for industries with with $\beta_k > \widehat{\beta}$. To smooth this prediction, imagine that there is some heterogeneity in factor intensity between firms in the same industry. In particular, let firms in a given industry k have capital shares β distributed in the interval $(0,1)$ according to the distribution function $F_k(\beta)$. This implies that in industry k, a fraction $1 - F_k(\widehat{\beta})$ of intermediate inputs would be produced by vertically integrated suppliers. With a common distribution function for all firms in all countries, the share of intrafirm imports in total imports in industry k would also be given by $1 - F_k(\widehat{\beta})$.

Under weak assumptions on the distribution function $F_k(\beta)$, the value $F_k(\widehat{\beta})$ will be decreasing in the average capital intensity in industry k. Intuitively, in very capital-intensive industries, most firms should have a capital share above $\widehat{\beta}$, and conversely in labor-intensive industries. It thus follows that the share of intrafirm imports should smoothly increase with the average capital-labor ratio of the industry.

Since we have no information on the actual distributions $F_k(\beta)$, it is impossible to derive a unique specification from the model. In the results below, I will report the estimates from regressions of the form:

$$\ln\left(S_{i-f}^{USA,ROW}\right)_k = \theta_1 + \theta_2 \ln\left(K/L\right)_k + W_k'\theta_3 + \epsilon_k, \tag{28}$$

where $(S_{i-f}^{USA,ROW})_k$ is industry k's share of intrafirm imports in total U.S. imports from the rest of the world, $(K/L)_k$ is the average capital-labor ratio in the exporting industry, W_k is a vector of controls, and ϵ_k is an error term, which is assumed to be orthogonal to the regressors. The vector W_k is included to control for other possible industry-specific determinants of vertical integration. Since I observe the share $(S_{i-f})_k$ in four different years, I also include industry effects in some of the regressions. In light of Proposition 3, I expect $\theta_2 > 0$.

The second hypothesis that I test is that the share of intrafirm imports in total imports is higher, the higher the capital-labor ratio of the exporting country. Equation (26) in the model actually provides a closed-form solution for this relationship. Denote the importing country by USA and the exporting country by j. Applying a log-linear approximation to (26) leads to the following specification:[37]

$$\ln\left(S_{i-f}^{USA,j}\right) = \gamma_1 + \gamma_2 \ln\left(K^j/L^j\right) + \gamma_3 \ln\left(L^j\right) + W_j'\gamma_4 + \varepsilon_j, \tag{29}$$

where $S_{i-f}^{USA,j}$ is the share of intrafirm imports in total U.S. imports from country j, K^j/L^j is capital-labor ratio of country j, W_j is a vector of controls, and ϵ_j is an orthogonal error term.

[37] In particular, I log-linearize (25) around $K^j/L^j = K/L$, and obtain:

$$\ln S_{i-f}^{0,j}\Big|_{K^j/L^j = K/L} \simeq \ln\left(\mu\right) + \frac{\left(1-\sigma_L\right)\sigma_L}{1-\sigma_L-\widetilde{\beta}_Z}\left(\ln K^j/L^j - \ln K/L\right).$$

The theory predicts that γ_2 should be positive. In fact, from the log-linearization, we can derive a much more precise prediction, i.e. $\gamma_2 = (1 - \sigma_L)\, \sigma_L / \left(1 - \sigma_L - \widetilde{\beta_Z}\right)$. Assuming an empirically plausible labor-share of around 2/3, and a capital share in the labor-intensive industry of 0.15, leads us to expect γ_2 to be around 1.2. On the other hand, from Proposition 5, we should not expect to γ_3 to be significantly different from zero.

Finally, I run a regression analogous to (29) but with the log of total intrafirm imports (i.e. $\ln M_{i-f}^{USA,j}$) in the left-hand side instead of $\ln S_{i-f}^{USA,j}$, i.e.

$$\ln \left(M_{i-f}^{USA,j}\right) = \omega_1 + \omega_2 \ln \left(K^j / L^j\right) + \omega_3 \ln \left(L^j\right) + W_j' \omega_4 + \varepsilon_j. \qquad (30)$$

In view of Proposition 4, we expect both ω_2 *and* ω_3 to be significantly positive. Furthermore, from a log-linear approximation of (25), and given $\sigma_L = 2/3$ and $\widetilde{\beta_Z} = 0.15$, ω_2 should be close to 1.55 and ω_3 close to 1.[38]

8.2 Data

The left-hand side variables are constructed combining data on intrafirm U.S. imports and on overall U.S. imports. Intrafirm U.S. imports include (i) imports shipped by overseas affiliates to their U.S. parents; (ii) imports shipped to U.S. affiliates by their foreign parent group, and; (iii) imports shipped to U.S. affiliates by other foreign affiliates. The series were obtained from the direct investment dataset available from the Bureau of Economic Activity (BEA) website. The BEA supresses data cells in order to avoid disclosure of individual firm data. This severely limits the scope for adequately testing the hypotheses of the paper. For reasons discussed extensively in Appendix A.4, I end up running equation (28) for a panel consisting of 23 manufacturing industries and four years: 1987, 1989, 1992, and 1994. As for equations (29) and (30), data availability limits the analysis to a cross-section of 28 countries in 1992 (see Appendix A.5 for a complete list of the industries and countries included in the regressions).

In the panel of industries, the share of intrafirm imports in total U.S. imports ranges from a value slightly below 1% for textiles in 1987 to around 85% for drugs in 1994, for an overall average of 21.5%. In the cross-section of countries, the share ranges from an almost negligible 0.1% for Egypt up to 64% for Switzerland, for an overall average of 22.4%.

Most right-hand side variables in the cross-industry regressions were obtained from the Manufacturing Industry Productivity Database, available from the NBER website. Capital intensity is measured as the ratio of the total capital stock to total employment in the corresponding exporting industry. This presuposes that U.S. industry capital intensities are similar to those in the rest of the world. In a world of FPE, this would naturally be the

[38] Log-linearizing (25) around $K^j/L^j = K/L$ yields:

$$\ln M_{i-f}^{USA,j}\Big|_{K^j/L^j = K/L} \simeq \text{constant} + L^j + \frac{(1-\sigma_L)\left(1 - \widetilde{\beta_Z}\right)}{1 - \sigma_L - \widetilde{\beta_Z}} \left(\ln K^j/L^j - \ln K/L\right).$$

case. In a more general set-up, the much weaker assumption of no factor intensity reversals is sufficient to ensure that qualitative results would still hold under the use of foreign factor intensity data.

To control for other potential determinants of internalization, I run equation including other industry characteristics one at a time. First, I allow for the possibility that the decision of integration might actually be determined by the human capital intensity of the production process. In particular, under the premise that human capital investments are easier to share than labor costs, a model identical to the one developed above with H substituting for K would naturally lead to this conclusion. To the extent that physical capital and human capital intensity are positively correlated, the patterns in Figure 1 would then be overstating the effect of capital intensity. I measure human capital intensity as the ratio of nonproduction workers to production workers in a given industry, as reported in the NBER dataset on manufacturing. A completely analogous argument could be used to defend the inclusion of some measure of the importance of R&D in the production process. R&D intensity is defined as the ratio of R&D expenditures to total sales in the industry, and was obtained from Cohen and Klepper' (1992). Finally, the decision of integration could also be related to the importance of the supplier's production in the overall value chain. A rough way of proxying for this is to include the share of value added in total industry sales. This variable was constructed using again the NBER manufacturing dataset.

The main right-hand side variables in equations (29) and (30), including the capital-labor ratio of the exporting country and its total population, were obtained from the cross-section of country variables for the year 1988 used by Hall and Jones (1999). In the present paper, I have pushed the view that capital abundance is a crucial determinant of the amount of multinational activity in a given country. Zhang and Markusen (2001) develop a model in which the volume of foreign direct investment in a given country is crucially affected by its skilled-labor abundance. To control for these possible effects, I include the measure of human capital abundance reported in Hall and Jones (1999).

Others authors have stressed the importance of institutional factors in determining the attractiveness of inward foreign direct investment in a given country. Countries that are open to FDI should, in principle, be more prone to hosting affiliates of U.S. firms than countries that are more hostile to foreign control of domestic production plans.[39] On the other hand, a country's degree of openness to international trade, through its effect on the trade-off between servicing the foreign market with exports or with local production, could also have some indirect influence on the volume of its intrafirm exports. Indices of openess to FDI and trade were obtained from survey data reported in the World Competitiveness Report (1992).

Finally, and to the extent that language barriers can be significant deterrents of FDI, I also control for the fraction of the exporting country's population that speaks English.

[39] This is not to say that in light of the model I developed above, we should expect such countries to attract more FDI (more on this below).

This variable was obtained from Hall and Jones (1999).

Table A.3. in Appendix A.5 reports descriptive statistics for all variables included in the regressions.

8.3 Results

Table 2 presents estimates of equation (28). The first four columns report OLS estimates on the pooled data. Columns V through VIII report random effects (RE) estimates. Column I includes no controls in the regression and is therefore the econometric analog to Figure 1. It should hence come as no surprise that the coefficient on $\ln(K/L)_k$ is positive and significantly different from zero at the 1% significance-level. The estimated elasticity of the share of intrafirm imports with respect to the capital-labor ratio in production implies that a 10% increase in K/L, increases the share of intrafirm imports by around 12%.

Table 2. Factor Intensity and the Share $S_{i-f}^{USA,ROW}$

Dep. var. is $\ln\left(S_{i-f}^{US,ROW}\right)_k$	Pool I	Pool II	Pool III	Pool IV	RE V	RE VI	RE VII	RE VIII
$\ln(K/L)_k$	1.188**	1.030**	0.818**	0.779**	1.030**	0.941**	0.802**	0.881**
	(0.139)	(0.129)	(0.105)	(0.112)	(0.195)	(0.199)	(0.178)	(0.200)
$\ln(H/L)_k$		0.399**	0.123	0.167		0.359	0.084	-0.011
		(0.107)	(0.095)	(0.106)		(0.222)	(0.198)	(0.226)
$\ln(R\&D/Sales)_k$			0.553**	0.563**			0.573**	0.550**
			(0.072)	(0.075)			(0.158)	(0.165)
$\ln(VAD/Sales)_k$				-0.249				0.589
				(0.401)				(0.620)
R^2	0.50	0.55	0.69	0.69	0.50	0.55	0.70	0.68
No. of obs.	92	92	92	92	92	92	92	92
p-value in H.T.					0.25	0.32	0.62	0.25

Note: Robust standard errors in parenthesis; * and ** are 5 and 1% significance levels

Column II includes human-capital intensity in the regression. As expected, this leads to a reduction on the estimate of θ_2, which remains however highly significant. The estimates suggest that integration is also more likely in industries that use a relatively larger number of nonproduction workers. This human-capital effect disappear however in column III, where the ratio of R&D expenditures to sales is also included in the regression. This suggests that the significant effect of $\ln(H/L)$ in column 2 seems to be driven by the fact that R&D intensive industries are prone to integration *and* they also tend to employ more nonproduction workers. More importantly, the estimates in column III indicate that even controlling for R&D intensity, the share of intrafirm imports is significantly higher in capital-intensive industries. The estimate of θ_2 in column III is lower than that implied by Figure 1, but it still implies that a 10% increase in K/L, should lead to an 8% increase in the share of intrafirm imports. Finally, Column IV shows that including the share of value added in total sales in the regression has only a marginal effect on the estimates.

As is clear from the results in columns V through VIII, exploiting the time dimension in the data has no bearing in the results. The random effects estimates of θ_2 are practically indistinguishable from the OLS ones. The positive effect of capital-intensity remains significant at the 1% level. The share of intrafirm imports is also appears to significantly increase with the R&D intensity of the industry. The only main difference is that the significant effect of $\ln(H/L)$ in column II is not robust to the use of random effects.

Under the null hypothesis that the industry effects are uncorrelated with the residual, random effects estimates are both consistent and efficient, while fixed effects are also consistent but inefficient. Under the alternative hypothesis, random effects estimates are inconsistent, while fixed effects remain consistent. In the last row of Table 2, I report the p-values of a Hausman test for exogeneity of the industry effects in each of the regressions in V through VIII. The results indicate that the null hypothesis of exogeneity cannot be rejected even at significance levels well above 10%.

Table 3 reports OLS estimates of equation (29) for the cross-section of 28 countries. The estimates in column I correspond to the simple correlation depicted in Figure 2. The elasticity of the share of intrafirm imports with respect to the capital-labor ratio of the exporting country is indeed significantly different from zero. Furthermore, the point estimate is not significantly different from the approximate value predicted by the theory, namely $\gamma_2 = 1.2$.

Column II confirms the claim in Proposition 5 that for a given K^j/L^j, the size of the exporting country should not affect the share $S_{i-f}^{US,j}$. The effect of $\ln(L)_j$ is in fact statistically indistinguishable from zero. Column III introduces a measure of human-capital abundance in the regression. Contrary to what it might have been expected, the coefficient on $\ln(H/L)_j$ appears to be negative, although insignificantly different from zero. Conversely, the effect of physical capital abundance remains significantly positive at the 1% level.

As shown in column IV, controlling for the exporting country's openness to FDI does not overturn the results. The coefficient on $OpFDI$ is negative but not significant, while the estimate of γ_2 remains significant. Similarly, controlling for openness to trade and for the fraction of population that speaks English has only a marginal effect on the estimates.[40]

In sum, the significant effect of the capital-labor ratio of the exporting country on the share of intrafirm imports seems to be robust to the inclusion in the regression of other potential determinants of $S_{i-f}^{US,j}$. Of special interest is the result that human capital abundance and openness to FDI have no independent effect on the share of intrafirm imports, after controlling for physical capital abundance.

[40] Including $OpFDI$ and $OpTrade$ reduces the number of observation to 26, since I have no data on these variables for Egypt and Panama. I re-run the regressions in columns I, II and III, without these two countries and obtained identical qualitative results.

Table 3. Factor Endowments and the Share $S_{i-f}^{US,j}$

Dep. var. is $\ln\left(S_{i-f}^{US,j}\right)$	I	II	III	IV	V
$\ln(K/L)_j$	1.141**	1.110**	1.244**	1.049**	1.154**
	(0.289)	(0.299)	(0.427)	(0.368)	(0.391)
$\ln(L)_j$		-0.133	-0.159	-0.090	0.013
		(0.168)	(0.164)	(0.177)	(0.219)
$\ln(H/L)_j$			-1.024	-0.374	-0.889
			(1.647)	(1.584)	(1.563)
$OpFDI$				-0.202	-0.363
				(0.156)	(0.236)
$OpTrade$					0.283
					(0.323)
$EngFrac$					0.522
					(0.781)
R^2	0.46	0.47	0.48	0.36	0.43
No. of obs.	28	28	28	26	26

Note: Robust std. errors in parenthesis; *, ** are 5%, 1% sig.lev.

Table 4. Factor Endowments and the volume $M_{i-f}^{US,j}$

Dep. var. is $\ln\left(M_{i-f}^{US,j}\right)$	I	II	III	IV	V
$\ln(K/L)_j$	2.048**	2.192**	2.188**	1.841**	2.077**
	(0.480)	(0.458)	(0.716)	(0.623)	(0.651)
$\ln(L)_j$		0.607*	0.608*	0.435	0.687
		(0.229)	(0.268)	(0.332)	(0.415)
$\ln(H/L)_j$			0.031	0.892	0.520
			(3.289)	(3.147)	(3.034)
$OpFDI$				-0.624*	-0.998*
				(0.259)	(0.439)
$OpTrade$					0.652
					(0.547)
$EngFrac$					0.115
					(1.638)
R^2	0.44	0.47	0.52	0.42	0.49
No. of obs.	28	28	28	26	26

Note: Robust std. errors in parenthesis; *, ** are 5%, 1% sig.lev.

Table 4 presents the OLS estimates of equation (30). Columns I and II confirm that the theoretical predictions in Proposition 4 are born by the data. In particular, both the capital-labor of the exporting country and its size seem to have a significant positive effect on the volume of U.S. intrafirm imports. The elasticity of $M_{i-f}^{US,j}$ with respect to K^j/L^j seems to be around 2 and not statistically different from the value of 1.55 predicted by the theory. On top of that, the elasticity of $M_{i-f}^{US,j}$ with respect to L^j is not significantly different from one.

Controlling for human capital abundance has a negligible effect on the coefficients. Conversely, the significance of the coefficient on $\ln(L)$ disappears when the variable $OpFDI$ is included in the regression. More importantly, column IV and V indicate that controlling for the capital-labor ratio of the exporting country, intrafirm imports are negatively affected by the openness to FDI of that country. This may seem puzzling, but the model presented above could actually provide a rationale for this fact. Remember from section 5 that the likelihood of integration is a decreasing function of the share ϕ of surplus accruing to the final-good producer. If a higher openness to FDI corresponds to a larger bargaining power for foreign firms (here the final-good producer), then on this account the model is consistent with the coefficient on $OpFDI$ being significantly negative.[41]

9 Conclusions

This paper unveiled two strong patterns in the intrafirm component of international trade and provided a simple rationale for them. It has been argued that intrafirm U.S. imports are heavily concentrated in capital-intensive industries because the costs of market transactions with suppliers are increasing in the amount of capital required by suppliers. In a general-equilibrium framework with international trade, this first pattern is shown to imply that intrafirm trade in goods will mostly flow between capital-abundant countries, which is the second systematic pattern initially discerned. On a methodological level, I provided a tractable general-equilibrium framework for incorporating incomplete-contracting into standard trade models.

One of the results of the paper is that foreign direct flows should be heavily concentrated among capital-abundant, developed countries. In other words, the share of arm's length trade in total trade should be especially high for developing economies. This provides support for the view that international outsourcing to developing countries can be significant even when foreign direct flows are not (e.g. Feenstra and Hanson, 1996). In particular, the model developed above can help rationalize the recent surge in global production sharing (c.f. Feenstra, 1998 and references therein), and the lack of a parallel increase in foreign direct flows to developing countries (UNCTAD, 2001). For instance, an increase in the

[41] Note, however, that this is not the only effect of ϕ on the volume of intrafirm imports. From equation (25), ϕ also affects $M_{i-f}^{US,j}$ through the terms in $\widetilde{\beta_Y}$ and $\widetilde{\beta_Z}$ which are increasing in ϕ, and through σ_L, which is decreasing in ϕ. The overall effect of ϕ is in general ambiguous.

relative capital-labor ratio of developed countries, caused by trade integration with labor-abundant countries, could predict these trends.

Finally, the model may also have implications for technological diffusion. To the extent that multinational firms play a leading role in the international dissemination of technological know-how (e.g. Xu, 2000), the choice of internalization can have significant effects on the speed and nature of technological diffusion. Growth models of technological catch-up have largely ignored the role played by firm boundaries. Understanding where multinationals locate and why they do so could greatly enrich our comprehension of the fundamental process of economic growth. This is the next step on my research agenda.

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A Appendix

A.1 Proof of Proposition 1

Combining equations (9) and (10), it follows that regardless of the level of demand A_Y the final-good producer in a pair of stand-alone firms will decide to incur the capital expenditures itself whenever:

$$(1-\alpha(1-\beta_Y)+\alpha\phi(1-2\beta_Y))\left(\frac{\phi}{1-\phi}\right)^{\frac{\alpha\beta_Y}{1-\alpha}} > \phi+(1-\alpha)(1-\phi),$$

which holds whenever $\phi > 1/2$. To see this, define the function

$$H(\phi)=(1-\alpha(1-\beta)+\alpha\phi(1-2\beta))\left(\frac{\phi}{1-\phi}\right)^{\frac{\alpha\beta}{1-\alpha}}-\phi-(1-\alpha)(1-\phi),$$

and notice first that $H(1/2)=0$. Next note that

$$H'(\phi)=\alpha\left(\left(\frac{\phi}{1-\phi}\right)^{\frac{\alpha\beta}{1-\alpha}}-1\right)+\alpha\beta\left(\frac{\phi}{1-\phi}\right)^{\frac{\alpha\beta}{1-\alpha}}\left(\frac{1-\alpha(1-\beta)+\alpha\phi(1-2\beta)}{(1-\alpha)(1-\phi)\phi}-2\right).$$

The first term is clearly positive when $\phi > 1/2$. Since $\frac{(1-\alpha(1-\beta)+\alpha\phi(1-2\beta))}{(1-\alpha)(1-\phi)\phi}$ increases with α, it follows that $\frac{(1-\alpha(1-\beta)+\alpha\phi(1-2\beta))}{(1-\alpha)(1-\phi)\phi}-2 \geq \frac{1}{(1-\phi)\phi}-2 \geq 0$ and the second term is also positive. Hence, $H(\phi) > 0$ for all $\phi > 1/2$. Since $\overline{\phi} > \phi$, as long as $\phi > 1/2$, final-good producers in integrated pairs will also decide to rent $K_{x,Y}$ and hand it to the supplier. QED.

A.2 Proof of Lemma 1

From simple differentiation of (13), it follows that $\partial\Theta(\cdot)/\partial\beta_k > 0$ if and only if

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

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

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

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

A.3 Proof of Proposition 3

From equation (13) and the definition of $\overline{\phi}$, we can write $\Theta(0,\cdot) = \frac{1-\alpha(1-\overline{\phi})}{1-\alpha(1-\phi)}\left(\frac{1-\overline{\phi}}{1-\phi}\right)^{\frac{\alpha}{1-\alpha}} < 1$ and $\Theta(1,\cdot) = \frac{1-\alpha\overline{\phi}}{1-\alpha\phi}\left(\frac{\overline{\phi}}{\phi}\right)^{\frac{\alpha}{1-\alpha}} > 1$. The inequalities follow from $\overline{\phi} > \phi$ and the fact that $(1-\alpha x)x^{\frac{\alpha}{1-\alpha}}$ is an increasing function of x for $\alpha \in (0,1)$ and $x \in (0,1)$. The rest of the Proposition is a direct implication of Lemma 1. QED.

A.4 Data Appendix

This Appendix discusses in more detail the construction of the share of intrafirm imports in total U.S. imports. Intrafirm imports were obtained from the "Financial and Operating Data" on multinational firms downloadable from the BEA website. Since in the model ownership is associated with control, I restricted the sample to majority-owned affiliates. As discussed in the main text, the BEA supresses data cells in order to avoid disclosure of individual firm data. The unsupressed data is only available to researchers affiliated to the BEA. Unfortunately, one of the requirements for affiliation is being a U.S. citizen (which I am not).

To construct intrafirm imports by industry, I combine data from foreign affiliates of U.S. firms and U.S. affiliates of foreign firms. Intrafirm imports comprise (i) imports shipped by overseas affiliates to their U.S. parents, by industry of affiliate; (ii) imports shipped to U.S. affiliates by their foreign parent group, by industry of affiliate, and; (iii) imports shipped to U.S. affiliates by other foreign affiliates, by industry of affiliate.[42] The sum of these three elements was done at the finest level of disaggregation available, focusing on manufacturing industries and excluding natural-resource industries (in particular, petrolium, ferrous metals and non-ferrous metals).[43] I also restricted the sample to years in which benchmark surveys were conducted. Overall, I end up with 23 industries and four years: 1987, 1989, 1992 and 1994.

To construct intrafirm imports by country, I add up (i) imports shipped by overseas affiliates to their U.S. parents, by country of origin, and (ii) imports shipped to U.S. affiliates by their foreign parent group, by country of origin. In both cases, I restrict the analysis to manufacturing industries, although in this case it was impossible to remove those transactions involving natural resources (this might explain why intrafirm imports from Chile and Venezuela are lower than predicted in Figure 2). The BEA performs two types of manipulations to the data. Apart from suppressing cells to avoid disclosure of data of individual companies, it also assigns a unique symbol to trade flows inferior in value to \$500,000. I assign a value of \$250,000 to these cells.[44] Overall, I end up with a single cross-section with 28 countries in 1992. All the other benchmark survey years lack at least one of the components of intrafirm imports.

[42] The conceptually correct disaggregation level for cases (ii) and (iii) would have been the industry of the exporter (i.e. the foreign company or other foreign affiliates). These series were, however, not available. Nevertheless, intrafirm imports of type (i) constitute more than 65% of all intrafirm imports.

[43] Patterns of ownership in natural-resource sectors are likely to be determined by factors, such as national sovereignty, that are absent in the model.

[44] This is only done for two observations. The results are robust to imputing alternative values between 0 and \$500,000.

Finally, in order to compute the share of intrafirm imports, I construct total U.S. imports by industry and year, and then by country of origin, using data put together by Robert Feenstra and available from the NBER website. Import figures correspond to their c.i.f. values. Feenstra's four-digit industry classification was matched to the 23 BEA industries using a conversion table available from BEA and reproduced in Table A.1. below.

A.5 Additional Tables

Table A.1. Industry Description and Classification

Code	Description	Corresponding Industry SIC Classification
BEV	Beverages	208
FOO	Other food and kindred products	201-207, 209
CHE	Industrial chemicals and synthetics	281, 282, 286
DRU	Drugs	283
CLE	Soap, cleaners and toilet goods	284
OCH	Other chemical products	285, 287, 289
FME	Fabricated metal products	341-349
COM	Computer and office equipment	357
IMA	Other industrial machinery and equipment	351-356, 358, 359
AUD	Audio, video and communications equipment	365, 366
ELE	Electronic components and accessories	367
OEL	Other electronic and electrical machinery	361-364, 369
TEX	Textile products and apparel	221-229, 231-39
LUM	Lumber, wood, furniture and fixtures	241-49, 251-59
PAP	Paper and allied products	261-263, 265, 267
PRI	Printing and publishing	271-279
RUB	Rubber products	301, 302, 305, 306
PLA	Miscellaneous plastics products	308
STO	Stone, clay, and glass product	321-29
VEH	Motor vehicles and equipment	371
TRA	Other transportation equipment	372-376, 379
INS	Instruments and related products	381, 382, 384-387
OMA	Other manufacturing	211-19, 311-19, 391-99

Table A.2. Country Codes

Code	Country	Code	Country
ARG	Argentina	IDN	Indonesia
AUS	Australia	IRL	Ireland
BEL	Belgium	ISR	Israel
BRA	Brazil	ITA	Italy
CAN	Canada	JPN	Japan
CHE	Switzerland	OAN	Taiwan
CHL	Chile	PAN	Panama
COL	Colombia	PHL	Philippines
DEU	Germany	MEX	Mexico
EGY	Egypt	MYS	Malaysia
ESP	Spain	NDL	Netherlands
FRA	France	SGP	Singapore
GBR	United Kingdom	SWE	Sweden
HKG	Hong Kong	VEN	Venezuela

Table A.3. Descriptive Statistics

	Obs	Mean	St. dev.	Min	Max
$\ln\left(S_{i-f}^{US,ROW}\right)_k$	92	-1.90	0.96	-4.70	-0.17
$\ln(K/L)_k$	92	4.26	0.57	3.21	5.73
$\ln(H/L)_k$	92	-0.69	0.60	-1.78	0.60
$\ln(R\&D/Sales)_k$	92	0.29	0.78	-1.26	1.35
$\ln(VAD/Sales)_k$	92	-0.66	0.18	-1.12	-0.32
$\ln\left(S_{i-f}^{US,j}\right)$	28	-2.08	1.44	-6.67	-0.45
$\ln\left(K/L\right)_j$	28	10.54	0.86	8.13	11.59
$\ln\left(L\right)_j$	28	16.03	1.20	13.63	18.16
$\ln\left(H/L\right)_j$	28	28.82	0.19	0.47	1.10
$OpFDI$	26	7.83	1.23	4.73	9.57
$OpTrade$	26	6.70	1.22	3.52	8.67
$EngFrac$	28	0.13	0.30	0	0.97
$\ln\left(M_{i-f}^{US,j}\right)$	28	6.36	2.64	-1.39	10.49