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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 significantly 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 significantly 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.

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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 (Zeile, 1997). In spite of the clear significance of these international flows of goods between affiliated units of multinational firms, the available empirical studies on intrafirm trade provide little guidance to international trade theorists. In this paper I unveil some novel patterns exhibited by the volume of U.S. intrafirm imports and I 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.

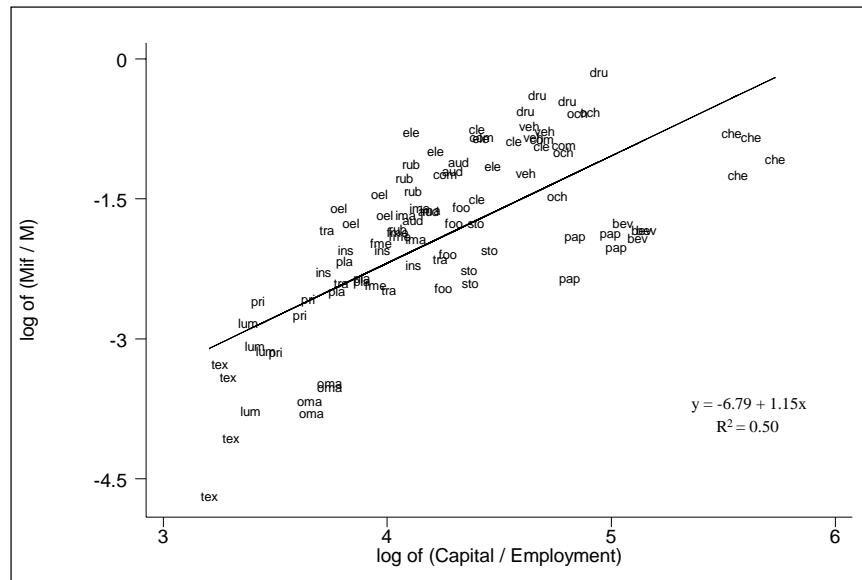
In a hypothetical world in which firm boundaries had no bearing on the pattern of international trade, one would expect only random differences between the behavior of the volume of intrafirm trade and that of the total volume of trade. In particular, the share of intrafirm trade in total trade would 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

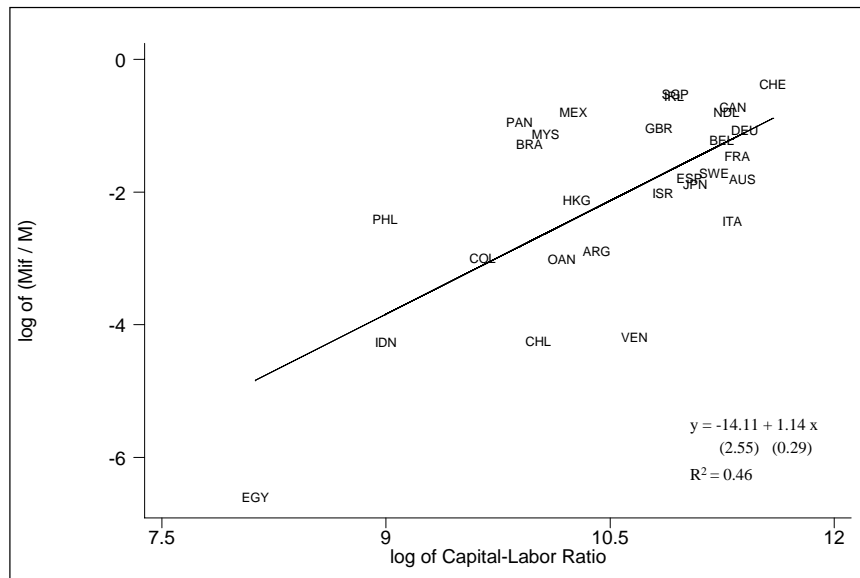
¹The pattern in Figure 1 is consistent with Gereffi's (1999) distinction between 'producer-driven' and 'buyer-driven' international economic networks. The first, he writes, is "characteristic of **capital-** and technology-intensive industries [...] in which large, usually **transnational**, manufacturers 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 emphasis is my own.

Figure 1: Share of Intrafirm U.S. 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 U.S. 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.

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

Why are capital-intensive goods transacted within the boundaries of multinational firms, while labor-intensive goods are traded at arm's length?³ To answer this question, I build on the theory of the firm initially explicated in Coase (1937) and later developed by Williamson (1985) and Grossman and Hart (1986), by which activities take place wherever transaction costs are minimized. In particular, I develop a property-rights model of the boundaries of the firm in which, in equilibrium, transaction costs of using the market are increasing in the capital intensity of the imported good. To explain the cross-country pattern in Figure 2, I embed this partial-equilibrium framework in a general-equilibrium, factor-proportions model of international trade, with imperfect competition and product differentiation, along the lines of Helpman and Krugman (1985). The model pins down the boundaries of multinational firms as well as the international location of production. Bilateral trade flows between any two countries are uniquely determined and the implied relationship between intrafirm trade and relative factor endowments is shown to correspond to that in Figure 2. The result naturally follows from the interaction of comparative advantage and transaction-cost minimization.

In drawing firm boundaries, I build on the seminal work of Grossman and Hart (1986). I consider a world of incomplete contracts in which ownership corresponds to the entitlement of some residual rights of control. When parties undertake non-contractible, relationship-specific investments, the allocation of residual rights has a critical effect on each party's *ex-post* outside option, which in turn determines each party's *ex-ante* incentives to invest. Ex-ante efficiency (i.e., transaction-cost mini-

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

³At 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 4 will present formal econometric evidence in favor of the emphasis placed on capital intensity and capital abundance in this paper.

mization) then dictates that residual rights should be controlled by the party whose investment contributes most to the value of the relationship.

To explain the higher propensity to integrate in capital-intensive industries, I extend the framework of Grossman and Hart (1986) by allowing the transferability of certain investment decisions. In situations in which the default option for one of the parties (a supplier in the model) is too unfavorable, the allocation of residual rights may not suffice to induce adequate levels of investment. In such situations, I show that the hold-up problem faced by the party with the weaker bargaining position may be alleviated by having another party (a final-good producer in the model) contribute to the former's relationship-specific investments. Investment-sharing alleviates the hold-up problem faced by suppliers, but naturally increases the exposure of final-good producers 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 is shown to command that residual rights of control, and thus ownership, be assigned to the final-good producer, thus giving rise to vertical integration. Conversely, when the contribution of the final-good producer is relatively minor, the model predicts outsourcing.

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 labor input. 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 raw materials. There is no reference to cost sharing in labor costs, other than in labor training. Milgrom and Roberts (1993) discuss the particular example of General Motors, which pays for firm- and product-specific capital equipment needed by their suppliers, even when this equipment is located in the suppliers' facilities. Similarly, in his review article on Japanese firms, Aoki (1990, p. 25) 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". Even within firm boundaries, cost sharing seems to mostly take place when capital investments are involved. In particular, Ta-

ble 1 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).

In this paper, I do not intend to explain why cost sharing is more significant in physical capital investments than in labor input investments. This may be the result of suppliers having superior local knowledge in hiring workers, or it may be explained by the fact that managing workers requires a physical presence in the production plant. Regardless of the source of this asymmetry, the model developed in section 2 shows that if cost sharing is indeed more significant in capital-intensive industries, the propensity to integrate will also be higher in these industries. In order to explain the trade patterns shown in Figures 1 and 2, I then embed the partial-equilibrium relationship between final-good producers and suppliers into a general-equilibrium framework with a continuum of goods in each of two industries. In section 3, I open this economy to international trade, allowing final-good producers to obtain intermediate inputs from foreign suppliers. 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. 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.⁴ This is the correlation implied by Figure 2. Moreover, some of the quantitative implications of the model are successfully tested in section 4.

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. 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.^{6,7}

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 undertake part of its production process abroad, but they fail to explain why this foreign production will occur within firm boundaries (i.e., within multinationals), rather than through arm's length subcontracting or licensing.

⁴This second part of the argument is based on the premise that capital-abundant countries tend to produce mostly capital-intensive commodities. Romalis (2002) has recently shown that the empirical evidence is indeed consistent with factor proportions being a key determinant of the structure of international trade.

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

⁶The 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".

⁷Recently, the literature seems to have converged to a "unified" view of the multinational firm, merging the factor-proportions (or "vertical") approach of Helpman (1984), together with the "proximity-concentration" trade-off implicit in Brainard (1997) 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.

In the same way that a theory of the firm based purely on technological considerations does not constitute a satisfactory 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, property-rights model of the multinational firm. My model will make 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 multinational 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 (e.g., McLaren, 2000, Grossman and Helpman, 2002a). My theoretical framework shares some features with the recent contribution by Grossman and Helpman. In their model, however, the costs of transacting inside the firm are introduced by having integrated suppliers incur exogenously higher variable costs (as in Williamson, 1985). More importantly, theirs is a closed-economy model and therefore does not consider international trade in goods, which of course is central in my contribution.⁸

The rest of the paper is organized as follows. Section 2 describes the closed-economy version of the model and studies the role of factor intensity in determining

⁸Although in this paper I show that a Grossman-Hart-Moore view of the firm 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.

the equilibrium mode of organization in a given industry. Section 3 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 4 presents 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 5 concludes. The proofs of the main results are relegated to the Appendix.

2 The Closed-Economy Model: Ownership and Capital Intensity

This section describes the closed-economy version of the model. In section 3 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.

2.1 Set-up

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

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

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.

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).

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

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

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 $k \in \{Y, Z\}$. I assume that industry Y is more capital-intensive than industry Z , i.e. $1 \geq \beta_Y > \beta_Z \geq 0$.

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 There are two types of producers: final-good producers and suppliers of intermediate inputs. 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. An integrated supplier is just a division of the final-good producer and thus has no control rights over 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 a 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).⁹

⁹This 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,

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 the labor input is necessarily provided by 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 hand it to the supplier at no charge.¹⁰ Irrespective of who bears their cost, the investments in capital and labor are chosen simultaneously and non-cooperatively.¹¹ Once a final-good producer and its supplier enter the market, they are locked into the relationship: 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 as follows: $f_F r^{\beta_k} w^{1-\beta_k}$ for the final-good producer and $f_S r^{\beta_k} w^{1-\beta_k}$ for the supplier, with $f_F + f_S = f$.¹²

Free entry into each sector ensures zero expected profits for a potential entrant. To simplify the description of the industry equilibrium, I assume that upon entry the supplier makes a lump-sum transfer $T_k(i)$ to the final-good producer, which can vary by industry and variety. Ex-ante, there is a large number of identical, potential suppliers for each variety in each industry, so that competition among these suppliers

2002a).

¹⁰Alternatively, one could assume that labor costs are also transferrable, but that their transfer leads to a significant fall in productivity. This fall in productivity could be explained, in an international context, by the inability of multinational firms to cope with idiosyncratic labor markets (c.f., Caves, 1996, p. 123).

¹¹The assumption that the final-good producer decides between bearing *all* or *none* of the capital expenditures can be relaxed to a case of partial transferability. For instance, imagine that $x_k(i)$ was produced according to:

$$x_k(i) = \left(\frac{K_{x,k}^F(i)}{\beta_k} \right)^{\beta_k} \left(\frac{K_{x,k}^S(i)}{\eta(\beta_k)(1-\beta_k)} \right)^{\eta(\beta_k)(1-\beta_k)} \left(\frac{L_{x,k}(i)}{(1-\eta(\beta_k))(1-\beta_k)} \right)^{(1-\eta(\beta_k))(1-\beta_k)}$$

where $K_{x,k}^F(i)$ represents the part of the capital input that is transferable, and where $K_{x,k}^S(i)$ is inalienable to the supplier. As long as the elasticity of output with respect to transferable capital is higher, the higher the capital intensity in production, the same qualitative results would go through. In particular, as long as $\beta_k + \eta(\beta_k)(1-\beta_k)$ increases with β_k , the model would still predict more integration in capital-intensive industries (see footnote 24). I follow the simpler specification in (2) because it greatly simplifies the algebra of the general equilibrium.

¹²Henceforth, I associate a subscript F with the final-good producer and a subscript S with the supplier.

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, which include the transfer.

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-good 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.¹³ 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 them, and the cost-reducing benefit of producing a low-quality input would disappear. For the same reason, it is assumed that the parties cannot write contracts contingent on the volume of sale revenues obtained when the final good is sold. 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.¹⁴

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

¹³From the work of Aghion, Dewatripont and Rey (1994), Nöldeke and Schmidt (1995) and others, it is well-known that allowing for specific-performance contracts can lead, under certain circumstances, to efficient ex-ante relationship-specific investments. Che and Hausch (1997) have shown, however, that when ex-ante investments are cooperative (in the sense, that one party's investment benefits the other party), specific-performance contracts may not lead to first-best investment levels and may actually have no value.

¹⁴The assumption of non-contractibility of ex-ante investments could be relaxed to a case of partial contractibility. I have investigated an extension of the model in which production requires both contractible and non-contractible investments. If the marginal cost of non-contractible investments is increasing in the amount of contractible investments, the ability to set the contractible investments in the ex-ante contract is not sufficient to solve the underinvestment problem discussed below, and the model delivers results analogous to the ones discussed in the main text.

undertake suboptimal investments. The severity of the underinvestment problem is directly related to how weak the supplier's bargaining power is ex-post.

If the final-good producer shares capital expenditures with the supplier, the hold-up problem becomes two-sided. Because 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.

Because 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 ex-post gains from trade.

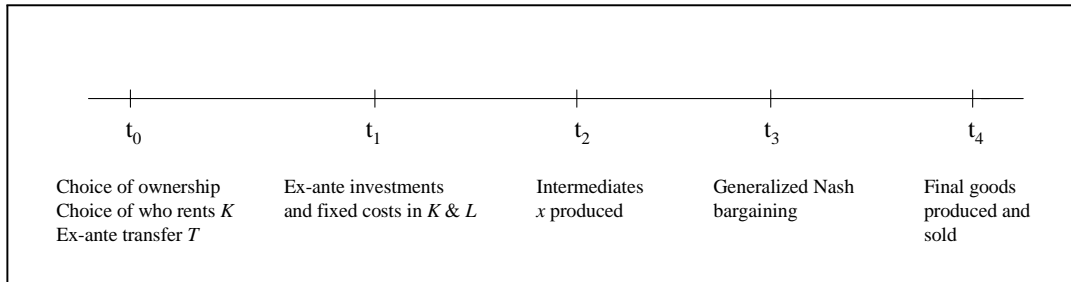
As discussed in the introduction, cost-sharing will emerge in equilibrium whenever the bargaining power of suppliers is low. I hereafter assume that:

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-good 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 appropriate $x_k(i)$ 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

Figure 3: Timing of Events



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. I take the fact that δ is strictly less than one as given, but this assumption could be rationalized in a richer framework.¹⁵

On the other hand, and because 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 choosing whether to enter the market with an integrated or a stand-alone supplier, the final-good producer considers the benefits and costs of integration. By owning 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).

I now summarize the timing of events (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, the extent of cost sharing is decided, 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

¹⁵For instance, consider the following alternative set-up. Production of intermediates proceeds 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 (and only him) 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.

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 .

2.2 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. 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.¹⁶ Let $p_{Y,V}(i)$ be the price charged by an integrating final-good producer 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 variety i in industry Y is given by

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

where

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

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.

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

¹⁶Henceforth, 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.

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 only be able to sell 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 at t_2 .

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

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

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 $(1 - \bar{\phi}) R_Y(i) - w L_{x,Y}(i)$, from which an analogous reaction function $L_{x,Y}(i)$ is obtained.¹⁷ Solving for the intersection of the two best-response functions yields the equilibrium ex-ante investments.¹⁸ Plugging these investments into (2) and (3) and rearranging, yields

¹⁷The 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 substitutes in production, Assumption 1 is sufficient to ensure that the optimal capital investment of the supplier is 0. To see this, notice that $\bar{\phi} (\partial R_Y(i) / \partial K_{x,Y}) > (1 - \bar{\phi}) (\partial R_Y(i) / \partial K_{x,Y}^S)$ for $\bar{\phi} > \phi > 1/2$. The complementary slackness condition thus implies that $K_{x,Y}^S = 0$.

¹⁸In particular, these are $K_{x,Y,V}(i) = \frac{\alpha\beta_Y\bar{\phi}}{r} A_Y \left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha\bar{\phi}^{\beta_Y} (1-\bar{\phi})^{1-\beta_Y}} \right)^{-\alpha/(1-\alpha)}$ and $L_{x,Y,V}(i) = \frac{\alpha(1-\beta_Y)(1-\bar{\phi})}{w} A_Y \left(\frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha\bar{\phi}^{\beta_Y} (1-\bar{\phi})^{1-\beta_Y}} \right)^{-\alpha/(1-\alpha)}$.

the following identical optimal output and price for all varieties in industry Y :

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

$$p_{Y,V} = \frac{r^{\beta_Y} w^{1-\beta_Y}}{\alpha \bar{\phi}^{\beta_Y} (1 - \bar{\phi})^{1-\beta_Y}}. \quad (6)$$

Facing a constant elasticity of demand, the final-good producer charges a constant mark-up over marginal cost. The mark-up is $1/(\bar{\phi}^{\beta_Y} (1 - \bar{\phi})^{1-\beta_Y})$ 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 $\bar{\phi}$. Conversely, if production of x_Y requires mostly labor (β_Y low), the mark-up is relatively higher, the higher is $\bar{\phi}$.

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 $rK_{x,Y,V} = \alpha\beta_Y\bar{\phi}p_{Y,V}y_V$ and $wL_{x,Y,V} = \alpha(1 - \beta_Y)(1 - \bar{\phi})p_{Y,V}y_V$.

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

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

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.¹⁹ Using the value of this transfer, ex-ante profits for an integrating final-good producer can finally be expressed as

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

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

¹⁹In particular, this transfer is $T_{Y,V} = (1 - \bar{\phi})(1 - \alpha(1 - \beta_Y)) A_Y p_{Y,V}^{-\alpha/(1-\alpha)} - f_S r^{\beta_Y} w^{1-\beta_Y}$.

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 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 $R_Y(i)$ 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 $\phi R_Y(i) - rK_{x,Y}(i)$. On the other hand, the supplier will set $L_{x,Y}(i)$ so as to maximize $(1 - \phi) R_Y(i) - wL_{x,Y}(i)$.

From here on, it is clear that the solution to the problem is completely analogous to that for pairs of integrated firms, with ϕ replacing $\bar{\phi}$ 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

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

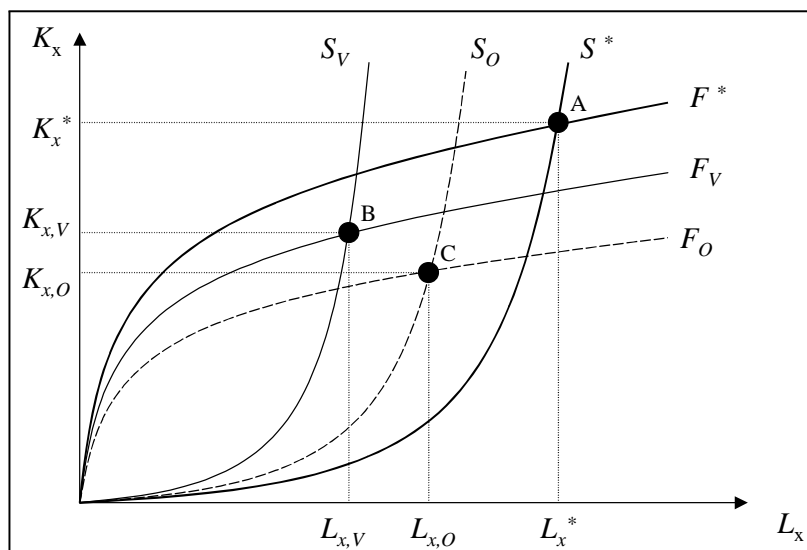
where $p_{Y,O} = r^{\beta_Y} w^{1-\beta_Y} / (\alpha\phi^{\beta_Y} (1 - \phi)^{1-\beta_Y})$.

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 a 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 $L_{x,Y}^* > \max \{L_{x,Y,V}, L_{x,Y,O}\}$.²⁰

²⁰In the case of capital this follows from

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

Figure 4: Complete vs. Incomplete Contracts



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 S^* 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, respectively. 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 than under outsourcing.²¹ 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 ex-ante investment. A similar argument explains why the investment in capital tends to be relatively more inefficient under outsourcing.

²¹By this I mean that $(L_{x,Y}^*/L_{x,Y,V}) / (K_{x,Y}^*/K_{x,Y,V}) > (L_{x,Y}^*/L_{x,Y,O}) / (K_{x,Y}^*/K_{x,Y,O})$. 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 studies, discussed in Caves (1996, pp. 230-231) and Dunning (1993, p. 296), that compare capital intensity in overseas subsidiaries of multinational firms with that of independent domestic firms in the host country.

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 a 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

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

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

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

Lemma 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. ■

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 worthwhile 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 optimal to alleviate by sharing part of the required ex-ante investments.

2.3 Factor Intensity and Ownership Structure

At t_0 , a final-good producer in industry $k = \{Y, Z\}$ chooses the ownership structure that maximizes its ex-ante profits. Comparing equations (8) and (9), it is straightforward to check that a final-good producer will choose to integrate its supplier whenever

$$\Theta = \frac{\pi_{F,V,k} + fr^{\beta_Y} w^{1-\beta_Y}}{\pi_{F,O,k} + fr^{\beta_Y} w^{1-\beta_Y}} = \frac{1 - \alpha(1 - \beta_Y) + \alpha\bar{\phi}(1 - 2\beta_Y)}{1 - \alpha(1 - \beta_Y) + \alpha\phi(1 - 2\beta_Y)} \left(\frac{p_{Y,V}}{p_{Y,O}} \right)^{-\alpha/(1-\alpha)} > 1.$$

This inequality is more likely to hold, the lower is $p_{Y,V}$ relative to $p_{Y,O}$, that is, the less distorted is the mark-up under integration relative to that under outsourcing. Plugging the equilibrium prices and using $\bar{\phi} = \delta^\alpha + \phi(1 - \delta^\alpha)$, it is possible to express Θ in terms of the fundamental parameters of the model:

$$\Theta(\beta_k, \alpha, \phi, \delta) = \left(1 + \frac{\alpha(1-\phi)\delta^\alpha(1-2\beta_k)}{1-\alpha(1-\beta_k) + \alpha\phi(1-2\beta_k)}\right) \left(1 + \frac{\delta^\alpha}{\phi(1-\delta^\alpha)}\right)^{\frac{\alpha\beta_k}{1-\alpha}} (1-\delta^\alpha)^{\frac{\alpha}{1-\alpha}}. \quad (11)$$

An important point to notice here is that $\Theta(\cdot)$ is not a function of factor prices. This follows directly from the assumption of Cobb-Douglas technology and isolates the partial equilibrium decision to integrate or outsource from any potential general-equilibrium feedbacks. This implied block-recursiveness is a useful property for solving the model sequentially, but the main results should be robust to more general specifications for technology.²²

In order to explain the pattern in Figure 1, it is central to understand how the relative attractiveness of integration (as captured by Θ) is affected by the capital intensity in production. The following lemma states that $\Theta(\beta_k, \alpha, \phi, \delta)$ is an increasing function of β_k .

Lemma 2 *The attractiveness of integration, as measured by $\Theta(\cdot)$, increases with the capital intensity of intermediate input production β_k : $\partial\Theta(\cdot)/\partial\beta_k > 0$ for all $\beta_k \in [0, 1]$.*

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 above, the underinvestment in

²²In particular, with a more general CES technology of the type

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

$\Theta(\cdot)$ also becomes a function of the wage-rental ratio in the economy. Interestingly, for $\sigma < 1$, the model predicts that, *ceteris paribus*, the propensity to outsource will be higher in countries with a higher wage-rental ratio. The drawback of this generalization is that the model turns out to be beyond the reach of paper-and-pencil analysis.

capital tends to be more severe under integration than under outsourcing. It thus follows that profits under integration relative to those under outsourcing will tend to be higher, the higher the capital intensity in production.²³

Lemma 2 paves the way for the following central result:

Proposition 1 *Given a triplet $\alpha, \phi, \delta \in (0, 1)$, there exists a unique threshold capital intensity $\hat{\beta}(\alpha, \phi, \delta) \in (0, 1)$ such that all firms with $\beta_k < \hat{\beta}(\alpha, \phi, \delta)$ choose to outsource production of the intermediate input (i.e., $\Theta(\beta_k, \cdot) < 1$), while all firms with $\beta_k > \hat{\beta}(\alpha, \phi, \delta)$ choose to integrate their suppliers (i.e., $\Theta(\beta_k, \cdot) > 1$). Only firms with capital intensity $\hat{\beta}(\alpha, \phi, \delta)$ are indifferent between these two options.*

Proof. See Appendix A.3. ■

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, thus giving rise to vertical integration.²⁴

Proposition 1 advances a rationale for the first fact identified in the introduction. To the extent that vertical integration of suppliers occurs mostly in capital-intensive industries, one would expect the share of intrafirm trade in those industries to be relatively higher than that in labor-intensive industries. Nevertheless, Proposition 1 cannot by itself justify the trade pattern in Figure 1. An explanation of this fact requires a proper modelling of international trade flows, which I carry out in section 3. Furthermore, the open-economy version of the model will naturally give

²³Despite 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 2 shows, however, that this latter effect is always outweighed by the former.

²⁴The result goes through if the input is produced according to the technology in footnote 11 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 1 still holds for the same $\hat{\beta}$. Having the final-good producer incur all capital expenditures is therefore not an important assumption.

rise to the cross-country pattern unveiled in Figure 2. Before moving on, however, a characterization of the general equilibrium of the closed economy is necessary.

Other comparative statics Equation (11) 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 $\widehat{\beta}(\alpha, \phi, \delta)$ 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 producer regardless of ownership structure (since $\bar{\phi}$ increases with ϕ). It thus follows that increasing ϕ necessarily worsens the incentives for the supplier. To compensate for this, the final-good producer will now find it profitable to outsource in a larger measure of capital intensities.

The effect of α is in general ambiguous as it appears in several terms in equation (11). Numerical analysis indicates, however, that an increase in competition (a higher α) tends to enhance outsourcing in sufficiently labor-intensive firms, while promoting 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 pairs, and better incentives to final-good producers in capital-intensive pairs.²⁵

Finally, an increase in δ corresponds to an increase in $\bar{\phi}$ 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 firms 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 firms, an increase in δ may make integration more attractive, as it now secures the more significant investor a larger fraction

²⁵To see where the result is coming from, ignore the first term in (11) as well as the effect of α through the terms δ^α . Then the effect of α is positive as long as $(1 - \delta^\alpha)(1 + \delta^\alpha / (\phi(1 - \delta^\alpha)))^\beta > 1$, that is if $\beta > \bar{\beta}$ for some $\bar{\beta}(\phi, \delta, \alpha) \in (0, 1)$. 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, 2002a, and Marin and Verdier, 2001).

of the marginal return to its investment. Numerical analysis tends to broadly support these intuitions.

2.4 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 outsource 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.

The assumption that all firms in a given industry share the same capital intensity greatly simplifies the analysis. In particular, the following is a straightforward corollary of Proposition 1:

Lemma 3 *A mixed equilibrium in industry Y only exists in a knife-edge case, namely when $\beta_Y = \widehat{\beta}(\alpha, \phi, \delta)$ (i.e., $\Theta(\beta_Y, \cdot) = 1$). An equilibrium with pervasive integration in industry Y exists only if $\beta_Y > \widehat{\beta}(\alpha, \phi, \delta)$ (i.e., $\Theta(\beta_Y, \cdot) > 1$). An equilibrium with pervasive outsourcing in industry Y exists only if $\beta_Y < \widehat{\beta}(\alpha, \phi, \delta)$ (i.e., $\Theta(\beta_Y, \cdot) < 1$).*

Since a mixed equilibrium does not generically exist, I focus below on a characterization of the two remaining types of equilibria.

Equilibrium with Pervasive Integration Consider an equilibrium in which only integrating final-good producers enter the market. As discussed above, the ex-ante transfer $T_{Y,V}$ ensures that suppliers always break even. 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 $A_{Y,V} = \mu E p_{Y,V}^{\alpha/(1-\alpha)} / n_{Y,V}$. On the other hand, from equation (8), for integrating final-good producers to make zero profits, demand must also satisfy:

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

It thus follows that the equilibrium number of varieties in an equilibrium with pervasive integration must be given by:

$$n_{Y,V} = \frac{1 - \alpha(1 - \beta_Y) + \alpha\bar{\phi}(1 - 2\beta_Y)}{fr^{\beta_Y}w^{1-\beta_Y}}\mu E. \quad (13)$$

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 (12) into equation (5):

$$y_V = \frac{\alpha\bar{\phi}^{\beta_Y} (1 - \bar{\phi})^{1-\beta_Y} f}{1 - \alpha(1 - \beta_Y) + \alpha\bar{\phi}(1 - 2\beta_Y)}. \quad (14)$$

Equilibrium factor demands can similarly be obtained by plugging (12) into the expressions in footnote 18.

Equilibrium with Pervasive Outsourcing Consider next an equilibrium in which no final-good producer 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

$$A_{Y,O} = \frac{fr^{\beta_Y}w^{1-\beta_Y}}{1 - \alpha(1 - \beta_Y) + \alpha\phi(1 - 2\beta_Y)} p_{Y,O}^{\alpha/(1-\alpha)}, \quad (15)$$

yields the equilibrium number of pairs undertaking outsourcing,

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

which is identical to (13) with ϕ replacing $\bar{\phi}$. The equilibrium values for output and factor demands are also analogous to those for the equilibrium with pervasive integration.

2.5 General Equilibrium

Having described the equilibrium in a particular industry, we can now move to the general equilibrium of the closed economy, in which income equals spending

$$E = rK + wL, \quad (17)$$

and the product, capital and labor markets clear.

By Walras' law, we can focus on the equilibrium in the labor market.²⁶ Letting L_Y and L_Z denote total labor demand by each pair in industries Y and Z , labor market clearing requires $n_Y L_Y + n_Z L_Z = L$. We can decompose L_Y into three components, depending on the equilibrium mode of organization. In an equilibrium with pervasive integration,

$$L_Y = L_{x,Y,V} + L_{f,F,Y} + L_{f,S,Y}. \quad (18)$$

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

$$n_{Y,V} L_Y = (1 - \beta_Y) (1 - \alpha \beta_Y (2\bar{\phi} - 1)) \frac{\mu (rK + wL)}{w}. \quad (19)$$

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

$$n_{Y,O} L_Y = (1 - \beta_Y) (1 - \alpha \beta_Y (2\phi - 1)) \frac{\mu (rK + wL)}{w}. \quad (20)$$

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 or $\bar{\phi}$ are smaller or greater 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.

²⁶The product market has already been assumed to clear in the previous sections.

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

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

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 to 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

$$\widetilde{\beta}_Y = \beta_Y(1 + \alpha(1 - \beta_Y)(2\bar{\phi} - 1))$$

and

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

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. Denoting the average labor share in the economy by $\sigma_L \equiv \mu(1 - \widetilde{\beta}_Y) + (1 - \mu)(1 - \widetilde{\beta}_Z)$ and imposing the condition $n_{Y,V}L_Y + n_{Z,O}L_Z = L$, the equilibrium wage-rental ratio in the economy can be expressed as:

$$\frac{w}{r} = \frac{\sigma_L}{1 - \sigma_L} \frac{K}{L}, \quad (21)$$

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 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 ratio in the economy.

3 The Multi-Country Model: Capital Abundance and Intrafirm Trade

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 factor 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.²⁷ Conversely, varieties of intermediate 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 derive both necessary and sufficient conditions for FPE to be achieved.

This section is in three parts. I first study the international location of production of intermediate inputs and show how the cross-country differences in factor endowments naturally give rise to cross-country differences in the relative number of varieties produced in each industry. I then analyze the implied patterns of international trade and discuss the determinants of its intrafirm component. Finally, I study the robustness of the results to alternative assumptions on the tradability of final goods.

3.1 Pattern of Production

Because 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 be written as:

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

and

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

²⁷Because final goods are costlessly produced, the model cannot endogenously pin down where their production is located. Assuming that they are not traded resolves this indeterminacy. In section 3.3, I show that the main result goes through under alternative set-ups that equally resolve the indeterminacy.

where n_k^j refers now to the number of industry k varieties of intermediate inputs produced in country j .²⁸ 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:

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

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

$$n_Y^j = \left((1 - \widetilde{\beta}_Z) (1 - \sigma_L) \frac{K^j}{K} - \widetilde{\beta}_Z \sigma_L \frac{L^j}{L} \right) \frac{n_Y}{(\widetilde{\beta}_Y - \widetilde{\beta}_Z) \mu} \quad (22)$$

and

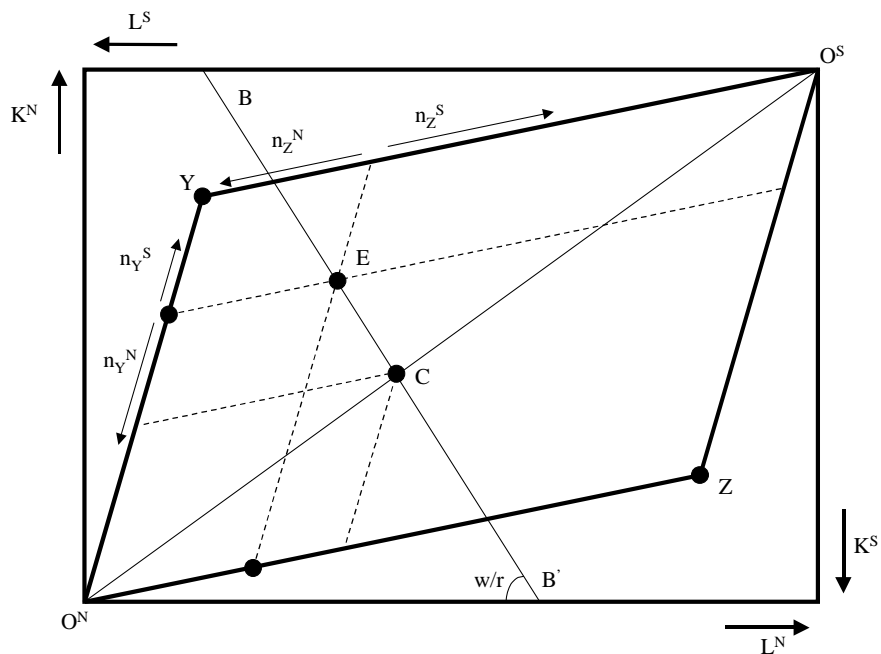
$$n_Z^j = \left(\widetilde{\beta}_Y \sigma_L \frac{L^j}{L} - (1 - \widetilde{\beta}_Y) (1 - \sigma_L) \frac{K^j}{K} \right) \frac{n_Z}{(\widetilde{\beta}_Y - \widetilde{\beta}_Z) (1 - \mu)}, \quad (23)$$

where n_Y is given by (13) and n_Z by (16) with β_Z replacing β_Y . Equation (22) states that a given country $j \in J$ 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, $s_j \equiv (rK^j + wL^j) / (rK + wL)$. In fact, it is 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

²⁸To 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 $n_{Y,V}^j$ ($n_{Z,O}^j$).

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



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 and sufficient that $n_Y^j > 0$ and $n_Z^j > 0$ for all $j \in J$, i.e., that no country fully specializes in any one sector.²⁹ Using equations (22) and (23), this condition can be written as:

Assumption 3: $\bar{\kappa} = \frac{\tilde{\beta}_Y \sigma_L}{(1-\tilde{\beta}_Y)(1-\sigma_L)} > \frac{K^j/L^j}{K/L} > \frac{\tilde{\beta}_Z \sigma_L}{(1-\tilde{\beta}_Z)(1-\sigma_L)} = \underline{\kappa}$ for all $j \in J$.

It can be checked that the upper bound $\bar{\kappa}$ 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 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

²⁹To understand necessity, notice that when factor prices depend only on *world* factor endowments, the capital-labor ratio in production is fixed and identical for all countries. Therefore, a given country cannot employ all its factors by producing in only one industry except in the knife-edge case in which its endowment of K^j and L^j exactly match that industry's factor intensity. For a discussion of sufficiency, see Helpman and Krugman (1985, p. 13-14).

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 in the equilibrium of the integrated economy. The set of factor endowments that satisfy Assumption 3 (i.e., FPE) corresponds to the set of points inside 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 $\|O^N Y\| = n_Y y$, $\|O^N Z\| = n_Z z$, and $\|O^N O^S\| = E = rK + wL$. 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 $s^N = \|O^N C\| / \|O^N O^S\|$. 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 in the graph.

So far I have assumed that factors of production are internationally immobile. I therefore have not allowed final-good producers to rent the capital stock in their home country and export it to the country where intermediates are produced. Allowing for such international factor movements would not invalidate the equilibrium described above. In fact, by equalizing factor prices everywhere, international trade in intermediate inputs eliminates the incentives for capital to flow across countries.³⁰

3.2 Pattern of Trade

Having described the international location of production of intermediate inputs, we can finally move to the study of trade patterns. Since the final good is nontradable, the entire volume of world trade will be in intermediate inputs. Before describing these flows in more detail, we must first confront the problem of how to value them.

³⁰More generally, I only require that costs of capital mobility are higher than costs of trading goods, so that international differences in rates of return are arbitrated away through trade flows rather than capital flows (c.f., Mundell, 1957).

The fact that contracts are incomplete implies that there is no explicit price for these varieties. Because all variable costs are incurred in the country where the input is produced, a plausible assumption is to value these intermediates at average cost. And because the final good is produced at no cost, the *implicit* price of an intermediate input is simply $p_{Y,V}$ in industry Y and $p_{Z,O}$ in industry Z .³¹

Without loss of generality, consider now a given country N 's imports from another country S . Country N will host $n_Y + n_Z$ plants producing final-good varieties. Of the n_Y plants in industry Y , a measure n_Y^S will be importing the intermediate input from their integrated suppliers in country S . 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^S will be importing the input from independent suppliers in country $j \neq N$. These transactions will thus occur at *arm's length*. Furthermore, because preferences are homothetic and identical everywhere, consumers in country N will incur a fraction s^N of world spending on each variety. It thus follows that the total volume of N imports from S will be $s^N (n_Y^S p_Y y + n_Z^S p_Z z)$, or simply

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

Similarly, the total volume of country N exports to country S is $s^S s^N (rK + wL)$, implying 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 $M_{i-f}^{N,S} = s^N n_Y^S p_Y y$. Plugging the equilibrium value for n_Y^S and rearranging, it is possible to express intrafirm imports as

$$M_{i-f}^{N,S} = s^N s^S (rK + wL) \frac{(1 - \widetilde{\beta}_Z) (1 - \sigma_L) \frac{K^S}{L^S} - \widetilde{\beta}_Z \sigma_L \frac{K}{L}}{(\widetilde{\beta}_Y - \widetilde{\beta}_Z) \left((1 - \sigma_L) \frac{K^S}{L^S} + \sigma_L \frac{K}{L} \right)}. \quad (25)$$

³¹As suggested by a referee, intermediates could alternatively be valued according to the supplier's average revenues. In such case, the implicit prices would be $(1 - \bar{\phi}) p_{Y,V}$ and $(1 - \bar{\phi}) p_{Z,O}$. This would reduce the value of trade flows, with a disproportionate reduction in industry Y . As a result, the link between factor endowments and the volume of trade established in Proposition 2 below would be attenuated.

Intrafirm imports are thus increasing in the size of both the importing and exporting countries, and, from simple differentiation of (25), are also increasing in the capital-labor ratio of the exporting country.

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 arrows in the graph point in 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,

Lemma 4 *For any pair of countries $N, S \in J$ with $S \neq N$, the volume of N 's intrafirm imports from S , $M_{i-f}^{N,S}$, is, for a given size s^N of the importing country, 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 s^N of the importing country.*

Now 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) yields

$$S_{i-f}^{N,S} = \frac{\left(1 - \widetilde{\beta}_Z\right) (1 - \sigma_L) \frac{K^S}{L^S} - \widetilde{\beta}_Z \sigma_L \frac{K}{L}}{\left(\widetilde{\beta}_Y - \widetilde{\beta}_Z\right) \left((1 - \sigma_L) \frac{K^S}{L^S} + \sigma_L \frac{K}{L} \right)}. \quad (26)$$

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 $\bar{\kappa} \cdot K/L$, 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 2 *For any pair of countries $N, S \in J$ with $S \neq N$, the share $S_{i-f}^{N,S}$ of intrafirm imports in total N 's imports from 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.*

Figure 6: Volume of Intrafirm Imports

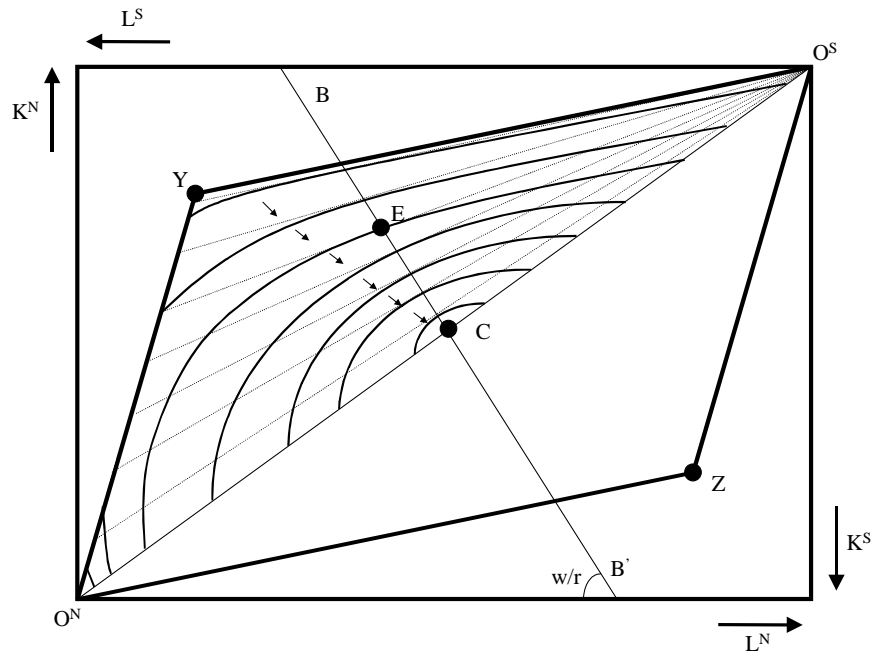
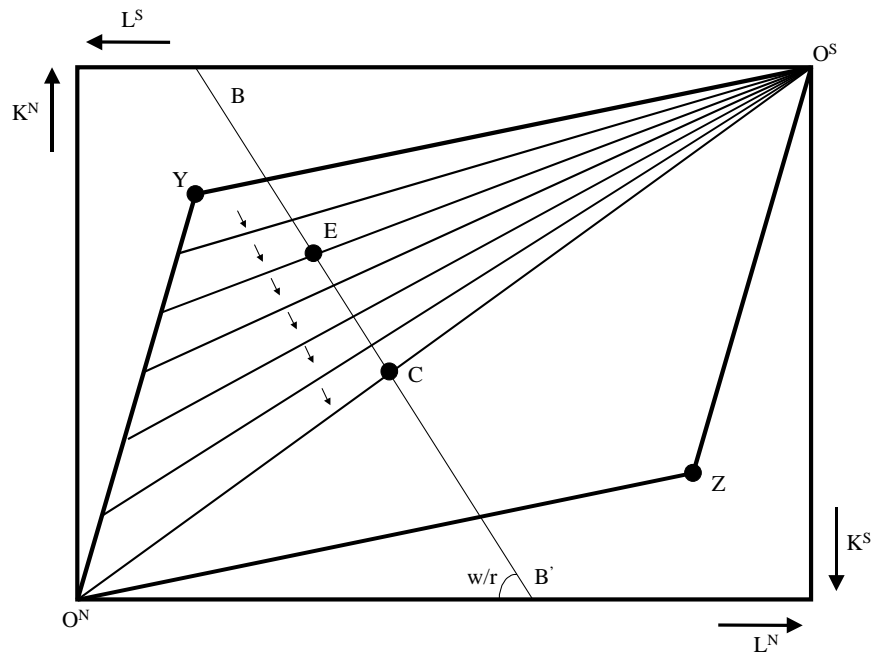


Figure 7: Share of Intrafirm Imports



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 provides a graphical illustration of Proposition 2 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 the final-good varieties is not crucial for the results derived above.

3.3 Alternative Assumptions on the Tradability of Final Goods

A. Probabilistic Location of Final-Good Production Consider the case in which final-good varieties can be traded, but assume that each variety is produced in only one location.³² Let final goods be traded only at arm's length. Assume also that production of these varieties is distributed across countries in a probabilistic manner. Denote by $P_k^j(i)$ the probability that a given final-good variety i of industry k is assigned to country j . Let $P_k^j(i|j')$ be the same probability conditional on the intermediate input corresponding to that variety being produced in country j' . The international location of intermediate-input production is as described in section 3.1. Consider the imports of a given country $N \in J$ from another country $S \in J$. These consist of final-good varieties assigned to country S , as well as of intermediate inputs required for the production of final-good varieties assigned to N . Expected total imports can be expressed as:

$$M^{N,S} = s^N p_{Yy} \int_0^{n_Y} P_Y^S(i) di + s^N p_{Zz} \int_0^{n_Z} P_Z^S(i) di + p_{Yy} \int_0^{n_Y^S} P_Y^N(i|S) di + p_{Zz} \int_0^{n_Z^S} P_Z^N(i|S) di,$$

where the first two terms correspond to imports of final-good varieties and the remaining ones are imports of intermediate inputs. Of these imports, only the third component will be traded within firm boundaries. As a benchmark, consider the case in which the location of final-good varieties is completely random and

³²Imagine, for instance, that there is a negligible but positive fixed cost of final-good production. The discussion characterizes the limit in which this cost goes to zero.

$P_k^j(i) = P_k^j(i|j') = s^j$. In words, the probability that a given final-good variety is produced in a certain country is proportional to the size of the country, but is independent of the variety, industry and location of intermediate-input production. It is straightforward to check that, in this probabilistic framework, expected imports are twice as large as in the previous section, i.e., $M^{N,S} = 2s^N s^S (rK + wL)$, while expected intrafirm imports are identical to those in the case of nontradable final goods, i.e., $M_{i-f}^{N,S} = s^N n_Y^S p_Y y$. It thus follows that the share of intrafirm imports in total imports will be one-half of that in equation (26). Therefore, all the claims in Lemma 4 and Proposition 2 remain valid in this alternative set-up. This example illustrates that in order to eliminate the prediction relating the share of intrafirm imports and relative capital abundance, one needs to introduce *ad hoc* correlations in the cross-country distribution of final-good varieties.³³

B. Technical Know-How and North-South Trade Consider yet an 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, the North, that possess the know-how to produce varieties of final-goods. The remaining countries, the South, do not have this know-how and thus export only intermediate inputs and import only final goods. Denote the former set by $\mathcal{N} \subseteq J$ and the latter by $\mathcal{S} \subseteq J$. The final good is traded at arm's length at a negligible but positive cost. Since production of final varieties is costless, this implies that countries belonging to \mathcal{N} will only trade intermediate inputs between themselves (it follows that if $\mathcal{S} = \emptyset$, the pattern of trade would be identical to the one discussed above). In order to service the Southern markets for final goods, countries in the North will import varieties of intermediate input in excess of the amount needed to satisfy their domestic demand. Assume that these *excess* imports are not biased towards any particular industry, in the sense that these excess imports constitute the same fraction of the exporter's production in each industry.

Since countries in \mathcal{S} import only final-good varieties, the bilateral share of intrafirm imports in total imports is trivially 0 for all $s \in \mathcal{S}$. Conversely, a given country

³³For instance, if the locations of intermediate and final-good production were perfectly correlated, then $P_k^j(i|j') = 0$ for all $j \neq j'$, and the share of intrafirm imports would be zero for all countries.

$n \in \mathcal{N}$ will only import intermediate inputs. In particular, given an exporting country $j \in J$, imports from j will be comprised of those intermediates required for domestic consumption of final goods and those required to service Southern countries. Denote by η_n^j the share of j 's production that is imported to service Southern countries. Then total imports from j will be $(s^n + \eta_n^j)s^j E$, with their intrafirm component being $(s^n + \eta_n^j)n_Y^S p_Y y$. When taking the ratio, the terms in η_n cancel, and the share of intrafirm imports in total imports is again given by an expression identical to equation (26). Conditional on the importing country belonging to \mathcal{N} (which is surely the case for the United States), Proposition 2 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, unless η_n^j is negatively correlated with the size of country n , the second statement in Lemma 4 will also still apply.

4 Econometric Evidence

In this section, I use data on intrafirm and total U.S. imports to test more formally the empirical validity of the main results of the paper. I 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 show that the clear correlation in Figure 1 does not seem to be driven by the omission of other relevant variables. Next, I move on to the relationship between relative factor endowments and the share of intrafirm imports. The link predicted by Proposition 2 is confirmed even after controlling for additional factors that could reasonably be expected to affect this share. Furthermore, as predicted by the theory, the size of the exporting country is shown not to have an independent effect on the share of intrafirm imports. Finally, I analyze the determinants of the total volume of intrafirm imports and show that, consistently with Lemma 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 discuss the specifications and the data I use to test the hypotheses.

4.1 Specification

Cross-Industry Tests 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 $\beta_k > \widehat{\beta}$, a prediction that does not seem to be borne by the data. Imagine, however, that the model provides a valid description of the world, but the statistician disaggregates the industry data under a criterion different from the one dictated by preferences or technology. In particular, instead of the sectors Y and Z in the model, the statistician disaggregates the data into M industries. Denote by $n_Y^j(m)$ the measure of firms in country j that produce varieties of intermediate inputs of sector Y and that are included in industry $m \in M$ by the statistician. Let $n_Z^j(m)$ be the analogous measure for sector Z . The statistician will report an average capital intensity in industry m and country j equal to:³⁴

$$k^j(m) = \frac{n_Y^j(m)K_Y + n_Z^j(m)K_Z}{n_Y^j(m)L_Y + n_Z^j(m)L_Z}. \quad (27)$$

On the other hand, letting j be the rest of the world, the statistician will record U.S. imports in industry m amounting to $s^{US}(n_Y^j(m)p_{Yy} + n_Z^j(m)p_{Zz})$, of which $s^{US}n_Y^j(m)p_{Yy}$ will be reported as intrafirm imports and $s^{US}n_Z^j(m)p_{Zz}$ as imports at arm's length. The share of intrafirm imports in industry m will therefore be:

$$S_{i-f}^{US,j}(m) = \frac{n_Y^j(m)p_{Yy}}{n_Y^j(m)p_{Yy} + n_Z^j(m)p_{Zz}}. \quad (28)$$

Combining equations (27) and (28) yields

$$S_{i-f}^{US,j}(m) = \frac{k^j(m) - K_Z/L_Z}{(1 - qL_Y/L_Z)k^j(m) + qK_Y/L_Z - K_Z/L_Z}, \quad (29)$$

where $q = p_{Zz}/p_{Yy}$. It is straightforward to check that the recorded share of intrafirm imports in industry $m \in M$ is an increasing function of the recorded average capital intensity in that industry.³⁵ The model can thus deliver the smooth pattern in Figure

³⁴I drop the superscript j when the theory dictates that a certain variable will be identical in all countries. This is the case, for instance, of L_Y , which in the model is given by equation (18).

³⁵In particular, $S_{i-f}^{US,j}(m)$ increases with $k^j(m)$ as long as $K_Y/L_Y > K_Z/L_Z$, which is true in the model since $\widetilde{\beta}_Y > \widetilde{\beta}_Z$.

1.³⁶

In the econometric results below, I report estimates from regressions of the form:

$$\ln \left(S_{i-f}^{US,ROW} \right)_m = \theta_1 + \theta_2 \ln (K/L)_m + W'_m \theta_3 + \epsilon_m, \quad (30)$$

where $(S_{i-f}^{US,ROW})_m$ is industry m 's share of intrafirm imports in total U.S. imports from the rest of the world, $(K/L)_m$ is the average capital-labor ratio in the exporting industry, W_m is a vector of controls, and ϵ_m is an error term, which is assumed to be orthogonal to the regressors. The vector W_m is included to control for other possible industry-specific determinants of vertical integration. Since I observe the share $(S_{i-f})_m$ in four different years, I also include industry effects in some of the regressions. In light of Proposition 1, I hypothesize that $\theta_2 > 0$.

Cross-Country Tests The second hypothesis that I test is that, in the cross-section of countries, the share of intrafirm imports in total imports is higher, the higher the capital-labor ratio of the exporting country. Equation (26) actually provides a closed-form solution for this relationship. Denoting the importing country by US and the exporting country by j , and applying a log-linear approximation to (26) leads to the following specification:³⁷

$$\ln \left(S_{i-f}^{US,j} \right) = \gamma_1 + \gamma_2 \ln (K^j/L^j) + \gamma_3 \ln (L^j) + W'_j \gamma_4 + \epsilon_j, \quad (31)$$

where $S_{i-f}^{US,j}$ 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 , L^j is population in country j , W_j is a vector of controls, and ϵ_j is an orthogonal error term. 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. $\gamma_2 = (1 - \sigma_L) \sigma_L / (1 - \sigma_L - \widetilde{\beta}_Z)$. This implies that the elasticity of the share of intrafirm imports to the capital-labor ratio should not be lower than the labor share in the economy. Furthermore, from the last statement in Proposition 2, we should not expect γ_3 to be significantly different from zero.

³⁶As pointed out by a referee, the smooth pattern in Figure 1 could also be the result of idiosyncratic preferences by firms concerning the outsourcing decision. An explicit modelling of such firm-level heterogeneity would, however, greatly complicate the general-equilibrium analysis.

³⁷In particular, I log-linearize (26) around $K^j/L^j = K/L$, and obtain $\ln S_{i-f}^{US,j} \Big|_{K^j/L^j=K/L} \simeq \ln(\mu) + \frac{(1-\sigma_L)\sigma_L}{1-\sigma_L-\widetilde{\beta}_Z} (\ln K^j/L^j - \ln K/L)$.

The third test I conduct consists in running a regression analogous to (31) but with the log of *total* intrafirm imports (instead of its share in total imports) in the left-hand side. In particular, I consider the specification:

$$\ln \left(M_{i-f}^{US,j} \right) = \omega_1 + \omega_2 \ln \left(K^j / L^j \right) + \omega_3 \ln \left(L^j \right) + W_j' \omega_4 + \varepsilon_j. \quad (32)$$

In view of Lemma 4, both ω_2 and ω_3 should be positive. Furthermore, it is easy to show that the model imposes the restrictions $\omega_2 > \gamma_2$ and $\omega_3 = 1$.³⁸ In words, the total volume of intrafirm imports should be more responsive to the capital-labor ratio of the exporting country than its share in total imports, while its elasticity with respect to the size of the exporting country should be one.

4.2 Data

Dependent Variables 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; and (ii) imports shipped to U.S. affiliates by their foreign parent group. The series were obtained from the direct investment dataset available from the Bureau of Economic Activity (BEA) website. The BEA suppresses data cells in order to avoid disclosure of individual firm data. This limits the scope for testing the hypotheses of the paper in a fully satisfactory manner. For reasons discussed in Appendix A.4, I end up running equation (30) for a panel consisting of 23 manufacturing industries and four years: 1987, 1989, 1992, and 1994. As for equations (31) and (32), 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 82% for drugs in 1994, for an overall average of 21.2%. In the cross-section of countries, the share

³⁸Notice that (25) can be written as $M_{i-f}^{US,j} = s^{US} (rK + wL) \frac{L^j}{K} \left(\frac{(1-\tilde{\beta}_Z)(1-\sigma_L) \frac{K^j}{L^j} - \tilde{\beta}_Z \sigma_L \frac{K}{L}}{\beta_Y - \tilde{\beta}_Z} \right)$. Log-linearizing this expression around $K^j/L^j = K/L$ yields:

$$\ln M_{i-f}^{US,j} \Big|_{K^j/L^j=K/L} \simeq \text{constant} + \ln L^j + \frac{(1-\sigma_L)(1-\tilde{\beta}_Z)}{1-\sigma_L-\tilde{\beta}_Z} (\ln K^j/L^j - \ln K/L).$$

ranges from an almost negligible 0.1% for Egypt up to 64.1% for Switzerland, for an overall average of 22.4% (see Table 2).

Table 2. Share of Intrafirm Imports in total U.S. Imports (%)

by Industry (avg. 1987-94)				by Country (1992)			
DRU	65.5	FOO	13.9	CHE	64.1	ESP	15.5
OCH	40.9	PAP	12.7	SGP	55.4	AUS	15.5
VEH	39.8	FME	12.6	IRL	53.7	JPN	14.2
ELE	37.3	STO	11.8	CAN	45.1	ISR	12.4
COM	36.7	INS	11.1	NDL	42.2	HKG	11.2
CHE	35.9	TRA	10.7	MEX	41.7	PHL	8.4
CLE	35.7	PLA	9.1	PAN	35.8	ITA	8.1
RUB	23.9	PRI	6.1	GBR	33.2	ARG	5.1
AUD	23.8	LUM	4.1	DEU	31.9	COL	4.6
OEL	18.9	OMA	2.6	MYS	30.1	OAN	4.6
IMA	17.3	TEX	2.3	BEL	27.3	VEN	1.4
BEV	15.1			BRA	25.9	CHL	1.3
				FRA	21.6	IDN	1.3
				SWE	16.8	EGY	0.1

Note: see Appendix A.5 for a list of industries and countries.

Industry Variables Most right-hand side variables in the cross-industry regressions are taken from the NBER Manufacturing Industry Productivity Database.³⁹ Capital intensity is measured as the ratio of the total capital stock to total employment in the corresponding exporting industry.⁴⁰ To control for other potential determinants of internalization, I run equation (30) including other industry characteristics one at a time. First, I allow for the possibility that the integration decision might be determined by the human-capital intensity of the production process. To the extent that final-good producers also contribute to their suppliers' costs related to the acquisition of human capital (e.g., by financing training programs), a model identical to the one developed above with human capital H replacing K would indeed predict an effect of human-capital intensity. Furthermore, if physical capital and

³⁹The SIC classification used in the NBER Manufacturing Database was converted to BEA industry categories using a concordance table available from the BEA and reproduced in Table A.1.

⁴⁰This presupposes that U.S. industry capital intensities are similar to those in the rest of the world. In a world with factor price equalization this would naturally be the case. In a more general set-up, the much weaker assumption of no factor intensity reversals is sufficient to ensure that the same qualitative results would be obtained by using the source country factor intensity data.

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 Manufacturing dataset. A completely analogous argument could be used to defend the inclusion of some measure of the importance of R&D and advertising in the production process. R&D intensity and advertising intensity are defined, respectively, as the ratio of R&D expenditures to sales and advertising expenditures to sales, and are obtained from a 1977 FTC survey.⁴¹ I also control for the possibility that the integration decision may be driven by the size of scale economies at the plant level, as measured by average capital stock per establishment.⁴² Finally, the decision to integrate could also be related to the importance of suppliers' production in the overall value chain. A rough way of proxying for this is to control for the share of value added in total industry sales, as reported in the NBER manufacturing dataset.

Country Variables The main right-hand side variables in equations (31) and (32), including the capital-labor ratio of the exporting country and its total population, are taken from the cross-section of country variables for the year 1988 constructed by Hall and Jones (1999). In the present paper, I have adopted 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 instead 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). Other authors have stressed the importance of fiscal and institutional factors in determining the attractiveness of foreign direct investment in a given country. Countries with relatively lower corporate taxes and relatively better institutional environments should, in principle, be more prone to hosting affiliates of U.S. firms. In the regressions below, I use data on average corporate tax rates from a Price Waterhouse survey, as well as the index of institutional quality for the year 1990 reported in Gwartney et al. (2002). Within

⁴¹This measure has been widely used in the literature (e.g., Cohen and Klepper, 1992, Brainard, 1997).

⁴²This variable was constructed combining the capital stock figures from the NBER dataset with data on the number of establishments published by the U.S. Census Bureau in its County Business Patterns series.

the institutional factors, I also attempt to distinguish between the effect of a country's degree of openness to FDI and that of its degree of openness to international trade. Indices of openness to FDI and to trade are obtained from survey data reported in the World Competitiveness Report (1992). Table 3 reports descriptive statistics for all variables included in the regressions.

4.3 Results

Intrafirm Trade and Factor Intensity The top panel of Table 4 presents random effects estimates of equation (30). Column I includes no controls in the regression and is therefore the econometric analog to Figure 1. The coefficient on $\ln(K/L)_m$ 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 1% increase in K/L increases the share of intrafirm imports by around 0.95%. Column II includes human-capital intensity in the regression. As expected, this leads to a reduction of the estimate of θ_2 , which, however, remains highly significant. The coefficient on $\ln(H/L)_m$ is positive but not statistically significant. In column III, the ratio of R&D expenditures to sales is also included in the regression and is found to have a very significant effect on the share of intrafirm imports. The estimate of θ_2 in column III is lower than that implied by Figure 1, but it still implies that a 1% increase in K/L , should lead to a 0.78% increase in the share of intrafirm imports. The inclusions of advertising intensity in column IV, of the size of economies of scale in column V, and of value-added intensity in column VI do not overturn any of the qualitative results. None of these variables seems to affect significantly the share of intrafirm imports, while capital intensity and R&D intensity remain significant at the 1% level.

Table 3. Descriptive Statistics

	Obs	Mean	St. dev.	Min	Max
$\ln\left(S_{i-f}^{US,ROW}\right)_m$	92	-1.90	0.92	-4.74	-0.19
$\ln(K/L)_m$	92	4.26	0.57	3.21	5.73
$\ln(H/L)_m$	92	-0.69	0.60	-1.78	0.60
$\ln(R\&D/Sales)_m$	92	-4.20	1.00	-6.07	-2.47
$\ln(ADV/Sales)_m$	92	-4.27	1.10	-6.63	-2.24
$\ln(Scale)_m$	92	1.63	0.92	0.06	3.48
$\ln(VAD/Sales)_m$	92	-0.66	0.18	-1.13	-0.32
$\ln\left(S_{i-f}^{US,j}\right)$	28	-2.08	1.44	-6.67	-0.45
$\ln(K/L)_j$	28	10.54	0.86	8.13	11.59
$\ln(L)_j$	28	16.03	1.20	13.63	18.16
$\ln(H/L)_j$	28	0.82	0.19	0.47	1.10
<i>CorpTax_j</i>	28	0.32	0.08	0.15	0.44
<i>EconFreedom_j</i>	28	6.36	1.22	4.19	8.24
<i>OpFDI</i>	26	7.83	1.23	4.73	9.57
<i>OpTrade</i>	26	6.70	1.22	3.52	8.67
$\ln\left(M_{i-f}^{US,j}\right)$	28	6.36	2.64	-1.39	10.49

Table 4. Factor Intensity and the Share $S_{i-f}^{US,ROW}$

Dep. var. is $\ln\left(S_{i-f}^{US,ROW}\right)_m$	<i>Random Effects Regressions</i>					
	I	II	III	IV	V	VI
$\ln(K/L)_m$	0.947*** (0.187)	0.861*** (0.190)	0.780*** (0.160)	0.776*** (0.162)	0.703*** (0.249)	0.723*** (0.253)
$\ln(H/L)_m$		0.369 (0.213)	-0.002 (0.188)	-0.038 (0.200)	-0.037 (0.206)	-0.081 (0.221)
$\ln(R\&D/Sales)_m$			0.451*** (0.107)	0.470*** (0.114)	0.452*** (0.128)	0.421*** (0.140)
$\ln(ADV/Sales)_m$				0.055 (0.094)	0.059 (0.097)	0.035 (0.107)
$\ln(Scale)_m$					0.068 (0.179)	0.100 (0.190)
$\ln(VAD/Sales)_m$						0.403 (0.657)
R^2	0.50	0.55	0.72	0.73	0.73	0.73
No. of obs.	92	92	92	92	92	92
	<i>Fixed Effects Regressions</i>					
	I	II	III	IV	V	VI
$\ln(K/L)_m$	0.599** (0.299)	0.610** (0.300)	0.610** (0.300)	0.610** (0.300)	0.943** (0.412)	1.058** (0.410)
p-value Wu-Hausman test	0.14	0.27	0.62	0.64	0.52	0.19

Note: Standard errors in parenthesis (*, **, and *** are 10, 5, and 1% significance levels)

Consistency of the random effects estimates requires the industry effects to be uncorrelated with the other explanatory variables. One might worry that the omission of some relevant industry variables might lead to biases in the random effects estimates. As a robustness check, the bottom panel of Table 4 reports the fixed effects estimates of θ_2 together with the p-value of a Wu-Hausman test for exogeneity of the industry effects.⁴³ The fixed effects estimates of θ_2 are all significantly different from zero at the 5%-significance level. Furthermore, the point estimates are not too different from their random effects counterparts and the null hypothesis of exogeneity of the industry effects cannot be rejected at reasonable significance levels.

Intrafirm Trade and Factor Abundance Table 5 reports OLS estimates of equation (31) 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 significantly different from zero and, as predicted by the theory, the point estimate of the elasticity is necessarily higher than any plausible labor share in the world. Column II confirms the claim in Proposition 2 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 coefficient of $\ln(L)_j$ is actually negative but statistically indistinguishable from zero. Column III introduces the measure of human-capital abundance in the regression. Contrary to what might have been expected (c.f., Zhang and Markusen, 2001), the estimated coefficient on $\ln(H/L)_j$ is negative, although again insignificantly different from zero. Conversely, the effect of physical-capital abundance remains significantly positive at the 1% level. As shown in column IV and V, controlling for the average corporate tax rate and the index of institutional quality does not overturn the results. The coefficients on both $CorpTax_j$ and on $EconFreedom_j$ are not significantly different from zero, while the estimate of γ_2 remains significantly positive at the 5% level. Finally, column VI suggests that the insignificance of the institutional variable in column V might be due to the counterbalancing effects of different policies. In particular, the share of intrafirm trade is negatively affected by the degree of openness to FDI but positively

⁴³The R&D and advertising intensity variables are purely cross-sectional and are thus dropped in the estimation. This explains that the estimates in columns II, III and IV are all identical.

(although insignificantly) affected by the degree of openness to trade. Overall, the significant effect of the capital-labor ratio of the exporting country on the share of intrafirm imports appears to be very robust.⁴⁴

Table 6 presents the OLS estimates of equation (32). Columns I and II confirm that the theoretical predictions in Lemma 4 are borne by the data. Both the capital-labor ratio of the exporting country and its size seem to have a significant positive effect on the volume of U.S. intrafirm imports. Consistently with the theory, the elasticity of $M_{i-f}^{US,j}$ with respect to K^j/L^j is estimated to be higher than the elasticity of $S_{i-f}^{US,j}$ with respect to K^j/L^j . Furthermore, the elasticity of $M_{i-f}^{US,j}$ with respect to L^j is, as predicted, not significantly different from one. As reported in columns III and IV, controlling for human capital abundance and for the average corporate tax rate has a negligible effect on the coefficients. The inclusion of the institutional index in column V leads to a substantial fall in the estimated elasticity of intrafirm imports to the capital-labor ratio, but the effect remains significant at the 5% level. Finally, column VI includes separate measures of openness to FDI and openness to trade. The results indicate that controlling for the capital-labor ratio of the exporting country, intrafirm imports are negatively affected by its openness to FDI. This may seem puzzling, but the model can shed light on this finding. Recall from section 2.3 that the attractiveness of integration is decreasing in the share ϕ of ex-post surplus accruing to final-good producers. If a higher openness to FDI corresponds to a larger bargaining power for foreign final-good producers, then *on this account* the model is consistent with the coefficient on $OpFDI$ being significantly negative.⁴⁵ Importantly, the effect of the capital-labor in column VI continues to be significant at the 1% level, while the effect of size is only marginally insignificant at the 10% level.

⁴⁴Including $OpFDI$ and $OpTrade$ reduces the number of observation to 26, since no data on these variables is available for Egypt and Panama. I re-ran the regressions in columns I, through V, without these two countries and obtained very similar results.

⁴⁵Note, 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.

Table 5. Factor Endowments and the Share $S_{i-f}^{US,j}$

Dep. var. is $\ln(S_{i-f}^{US,j})$	I	II	III	IV	V	VI
$\ln(K/L)_j$	1.141*** (0.289)	1.110*** (0.299)	1.244*** (0.427)	1.239*** (0.415)	1.097** (0.501)	1.119** (0.399)
$\ln(L)_j$		-0.133 (0.168)	-0.159 (0.164)	-0.158 (0.167)	-0.142 (0.170)	0.017 (0.220)
$\ln(H/L)_j$			-1.024 (1.647)	-0.890 (1.491)	-1.273 (1.367)	-0.822 (1.389)
<i>CorpTax_j</i>				-0.601 (3.158)	0.068 (3.823)	1.856 (2.932)
<i>EconFreedom_j</i>					0.214 (0.213)	
<i>OpFDI_j</i>						-0.384* (0.218)
<i>OpTrade_j</i>						0.292 (0.273)
R^2	0.46	0.47	0.48	0.50	0.50	0.43
No. of obs.	28	28	28	28	28	26

Note: Robust standard errors in parenthesis (*, **, and *** are 10, 5, and 1% sig. levels)

Table 6. Factor Endowments and the volume $M_{i-f}^{US,j}$

Dep. var. is $\ln(M_{i-f}^{US,j})$	I	II	III	IV	V	VI
$\ln(K/L)_j$	2.048*** (0.480)	2.192*** (0.458)	2.188*** (0.716)	2.154*** (0.663)	1.650** (0.762)	2.096*** (0.695)
$\ln(L)_j$		0.607** (0.229)	0.608** (0.268)	0.614** (0.271)	0.670** (0.243)	0.700 (0.419)
$\ln(H/L)_j$			0.031 (3.289)	0.953 (3.316)	-0.406 (2.992)	0.708 (3.052)
<i>CorpTax_j</i>				-4.135 (5.294)	-1.763 (5.955)	-0.647 (5.295)
<i>EconFreedom_j</i>					0.795 (0.443)	
<i>OpFDI_j</i>						-1.006** (0.474)
<i>OpTrade_j</i>						0.674 (0.560)
R^2	0.44	0.52	0.52	0.53	0.60	0.49
No. of obs.	28	28	28	28	28	26

Note: Robust standard errors in parenthesis (*, **, and *** are 10, 5, and 1% sig. levels)

5 Conclusions

This paper began by unveiling two systematic patterns in the intrafirm component of international trade. Traditional trade theory is silent on the boundaries of firms. Existing contributions to the theory of the firm tend to be partial-equilibrium in scope and have ignored the international dimensions of certain intrafirm transactions. Building on two workhorse models in international trade and the theory of the firm, I have developed a simple model that can account for the novel facts identified in the introduction. By combining a Grossman-Hart-Moore view of the firm with a Helpman-Krugman view of international trade, I have constructed a model that determines both the pattern of international trade and the boundaries of firms in a unified framework.

Nevertheless, much remains to be done. Future empirical investigations are likely to unveil new distinct features of the volume of intrafirm trade that cannot be accounted for by the simple model developed here. On the one hand, the Grossman-Hart-Moore theory enhances our understanding of only a subset of the determinants of ownership structure. Holmström and Milgrom (1994) have emphasized that, in many situations, issues related to job design and the cost of measuring performance are more relevant when choosing between inside or outside procurement.⁴⁶ It would be interesting to investigate the implications of such a view of the firm for the volume of intrafirm trade. On the other hand, in determining trade patterns, I have resorted to a very simple trade model. Future work should help us to understand potential channels by which technological differences, transport costs or international factor-price differences can affect the organization and location of international production. In Antràs (2002), I have started to deal with some of these issues in a dynamic, Ricardian model of North-South trade featuring endogenous product cycles as well as endogenous organizational cycles. In particular, the model gives rise to a new version of the product cycle, in which manufacturing is shifted to the South first within firm boundaries, and only at a later stage to independent firms in the South.

⁴⁶Baker and Hubbard (2002) find that ownership patterns in the trucking industry reflect the relevance of each of these two strands in the literature.

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A Appendix

A.1 Proof of Lemma 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

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

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

A.2 Proof of Lemma 2

From simple differentiation of (11), it follows that $\partial\Theta(\cdot)/\partial\beta_k > 0$ if and only if

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

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

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

From simple differentiation of this expression, it follows that $\vartheta'(\delta) > 0$ if and only if $(1 - \alpha\rho)^2 - (2 - \alpha)(1 - \alpha)(1 - \rho)\rho > 0$ for some $\rho \in (0, 1)$. But it is simple to check that this is in fact true all $\alpha, \rho \in (0, 1)$, and therefore $\vartheta(\delta) > \vartheta(0) = 0$. Notice that Assumption 1 is not necessary for this result. QED.

A.3 Proof of Proposition 1

From equation (11) and the definition of $\bar{\phi}$, note that we can write

$$\Theta(0, \cdot) = \frac{1 - \alpha(1 - \bar{\phi})}{1 - \alpha(1 - \phi)} \left(\frac{1 - \bar{\phi}}{1 - \phi} \right)^{\frac{\alpha}{1-\alpha}} < 1$$

and

$$\Theta(1, \cdot) = \frac{1 - \alpha\bar{\phi}}{1 - \alpha\phi} \left(\frac{\bar{\phi}}{\phi} \right)^{\frac{\alpha}{1-\alpha}} > 1.$$

The inequalities follow from $\bar{\phi} > \phi$ and the fact that $(1 - \alpha x)x^{\frac{\alpha}{1-\alpha}}$ is an increasing function of x for $\alpha \in (0, 1)$ and $x \in (0, 1)$. The rest of the Proposition is a direct implication of Lemma 2. 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 suppresses data cells in order to avoid disclosure of individual firm data. The unsuppressed 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, and; (ii) imports shipped to U.S. affiliates by their foreign parent group, by industry of affiliate.^{47,48} The sum of these two elements was constructed at the finest level of disaggregation available, focusing on manufacturing industries and excluding natural-resource industries (in particular, petroleum, ferrous metals and non-ferrous metals).⁴⁹ 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

⁴⁷The BEA defines a foreign parent group as consisting of (1) the foreign parent, (2) any foreign person, proceeding up the foreign parent’s ownership chain, that owns more than 50 percent of the person below it, up to and including the ultimate beneficial owner, and (3) any foreign person, proceeding down the ownership chain(s) of each of these members, that is owned more than 50 percent by the person above it.

⁴⁸The conceptually correct disaggregation for case (ii) would have been by the industry of the exporter (i.e. of the foreign parent group). Unfortunately, these series are not available. Intrafirm imports of type (i) constitute, however, more than two-thirds of all intrafirm imports. More importantly, a similar pattern to that in Figure 1 emerges when the analysis is restricted to intrafirm imports of type (i).

⁴⁹Patterns of ownership in natural-resource sectors are likely to be determined by factors, such as national sovereignty, from which I abstract in the model.

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.⁵⁰ 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.

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.

As pointed out by a referee, a significant portion of intrafirm trade involves final goods that are shipped from a manufacturing plant to an overseas wholesale affiliate which then distributes the good in the foreign country. Unfortunately, the BEA dataset does not distinguish between imports of intermediate inputs and imports of final goods, so that the latter cannot be subtracted from intrafirm imports. As pointed out by the same referee, however, this is not necessarily a problem for the empirical work as an analogous theoretical model can also be interpreted in the context of a supplier-distributor relationship.

⁵⁰This is only done for two observations. The results are robust to imputing alternative values between 0 and \$500,000.

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