Buyer Investment, Export Variety, and Intrafirm Trade

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Abstract: This paper studies a model of buyer investment and its effect on the variety and vertical structure of international trade. A distinction is made between two types of buyer investment: "flexible" and "specific", which differ in the ability of a buyer to match with a seller. The interaction of the fixed costs with the entry and pricing incentives of suppliers are analyzed. It is shown that (i) there can be multiple equilibria in the variety of products traded, and (ii) less product variety is associated with more intrafirm trade. The possibility of multiple equilibria is consistent with the observation that some similar economies, such as Taiwan and South Korea, differ substantially in their export varieties to the U.S. A cross-country empirical analysis confirms the negative correlation between export variety and intrafirm trade.

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1. INTRODUCTION

Recent literature in international trade has emphasized the importance of contractual relationships between firms, and sought to explain these contractual relations by features of the industries and host countries. For example, Antràs (2003) argues that in more capital-intensive industries, a greater share of trade is intrafirm, i.e. between a parent and its subsidiaries. Antràs and Helpman (2003) analyze a more general multi-industry, multi-country model, where the type of contracts and ownership between firms will depend on features of the industry (such as the productivity distribution of firms) as well as features of the host countries (such as factor prices). This literature expands the predictions of conventional trade theory by showing how institutional features of exporting industries, and in particular the contractual relations between firms interact with exogenous features such as factor intensities and endowments to determine trade patterns.

In this paper we shift attention from characteristics of the exporting country to the behavior of buyers in the importing country. Gary Gereffi (1994; Gereffi and Pan, 1994) uses the term "big buyers" to refer to the mass merchandisers in the United States who, he argues, have influenced the organization of production in Asia. As a specific example, consider South Korea and Taiwan. While these two economies export in many of the same broad industry categories, the details of their trade are quite different. South Korea is well-known for trying to achieve "world status" in products such as cars, microwaves, consumer electronics, dynamic random access memories (DRAMs) and other mass-produced goods. The business groups selling these goods – such as Hyundai, Samsung and Daewoo – have become household names in the U.S. and worldwide. Taiwan, by contrast, focuses more on intermediate inputs and customized products, selling auto parts and bicycles rather than cars, more customized chips than DRAMs, women's fashions as opposed to men's shirts, etc. Many of these goods are produced under OEM (original equipment manufacturer) arrangements for retailers overseas, who typically require customized designs. This is one explanation for the finding that Taiwan exports a great variety of products to the U.S. than does South Korea in many industries (Feenstra, Yang, and Hamilton, 1999).

Feenstra and Hamilton (2006) have recently argued that the differential export patterns from South Korea and Taiwan are at least in part the result of *increased demand* generated by regulatory changes in the United States. Specifically, the repeal of "fair trade laws" in the United States during the 1960s allowed for huge increase in mass-merchandising, orchestrated by the merchandisers acting as intermediaries between U.S. consumers and Asian producers. This increase in U.S. demand occurred just as Korea and Taiwan were in a position to meet that demand; but it was exercised in different market segments within the two countries. Big buyers began to look to Korea for the provision of long production runs of relatively standardized products, whereas Taiwan supplied shorter production runs of more specialized, niche products. Feenstra and Hamilton explain this differential response of buyers by appealing to the business groups found in the two countries: the large, vertically-integrated *chaebol* in South Korea, versus the smaller upstream groups in Taiwan, who provide inputs to unaffiliated firms downstream. Due to these differing market structures, they hypothesize that the exercise of international demand resulted in quite different export varieties from each country.

To examine this hypothesis formally, we propose a simple model of how buyers can influence product variety. In particular, we consider how buyer investment in input requirements can affect the variety and vertical structure of trade for intermediate goods.[1] Our basic model, described in section 2, is the familiar circle of product varieties, with upstream suppliers arranging themselves at discrete intervals. Downstream buyers have a preferred specification of the good, but can incur an investment allowing them to more easily adapt to specifications that are not their preferred. Such "flexible" investment, however, reduces

[1] The recent literature on the organization of international trade tends to focus on situations where sellers make investments, as in McLaren (2000) and Antràs (2003), so our focus on buyer investment complements that literature. Models in the theory of contracts and firms also tend to focus more on the investment incentives of the sellers, but investments by buyers have also received attention as, for instance, in the general framework of Grossman and Hart (1986), and in the empirical work of Joskow (1987), where downstream power plants can make asset-specific investments by locating closer to coal mines.

the incentives for upstream entry and results in fewer upstream varieties. This tension between upstream variety and downstream flexibility can give rise to *multiple equilibria* in the economic organization: more (or all) downstream buyers make flexible investment and upstream suppliers produce fewer varieties; or fewer (or no) downstream buyers make flexible investment and upstream suppliers produce more varieties. One interesting implication of this model is that it provides an explanation for the different export market structures of South Korea and Taiwan, if we interpret the equilibrium with fewer varieties as applying to Korea, and the equilibrium with more varieties as applying to Taiwan.

It is not the goal of this paper to explain why South Korea may be in one equilibrium and Taiwan in another, however: Feenstra and Hamilton (2006) survey literature from economics, political science and sociology, each of which, in their own way, sheds light on reasons for the differences between these countries. Our goal is more modest, and that is to identify some other feature of the organizational structure that is theoretically correlated with export variety, and then check whether such a correlation is actually observed in a sample of countries. In this way we are making incremental progress toward explaining the differing organizational structure across countries, though we stop far short of a unified explanation for such differences.

The organizational variable we shall focus on, in addition to export variety, is the vertical integration between the buyer and seller. In section 3, we allow each downstream buyer to have the additional option of making a "specific" investment that would match its preferred specification with a particular supplier's (i.e. increasing the buyer's match quality with the supplier). In an equilibrium with more varieties, a buyer can expect its input needs to be matched relatively well by a supplier, and thus there is less benefit to make the specific investment *ex ante*; the opposite is true in an equilibrium with fewer varieties. As it turns out, more buyers can potentially benefit from the specific investment in an equilibrium with few varieties. However, there is an important distinction between a buyer's flexible investment and specific investment: while the former reduces suppliers' market power, the latter increases their market power and can create the familiar hold-up problem. Vertical integration between buyers and suppliers can serve as a mechanism to overcome the hold-up problem and realize the gains from specific investment. Consequently, in an equilibrium with fewer varieties, where the gains from specific investment are higher, there is more vertical integration, or more intrafirm trade. Our key prediction, then, is that there is a negative correlation between variety and intrafirm trade.

At an aggregate level, we know that this prediction is true for South Korea and Taiwan: Zeile (2003, p. 26) reports that for U.S. imports in 1997, only 9.8% of goods coming from Taiwan were intrafirm purchases from their foreign parent groups, whereas 32.8% of goods coming from Korea were intrafirm purchases;[2] and as noted above, South Korea provides less export variety to the U.S. The goal of our empirical work in sections 4 and 5 is to explore this connection between product variety of exports and intrafirm trade for a broader sample of countries. Antràs (2003) finds that countries with more capital-intensive exports are more likely to engage in intrafirm trade across borders. Using his results as a first-stage regression, we test for the relationship between intrafirm trade and export variety using a second-stage gravity equation. That is, export variety is regressed on country variables such as GDP, population, distance to trading partners, etc., as well as intrafirm trade. We find that this variable is negatively correlated with export variety, as expected from our theory. Conclusions and directions for further research are discussed in section 6.

2. THE BASIC MODEL

There are two countries, home (H) and foreign (F). There is a continuum of M firms in H, each of which needs to purchase 1 unit of an input from F. Each home firm's input has an ideal characteristic that is represented by a point on a circle of unit perimeter length. In purchasing the input, the firm incurs an adjustment cost that is the product of τ and the distance between its ideal point and the location of its supplier along the circle. Thus τ is the unit adjustment (transportation) cost, which is a measure of how flexible the downstream

[2] For the 1992 benchmark survey, Zeile (1997, Table 6) reports that 4.5% of the goods coming from Taiwan were intrafirm purchases from their foreign parent groups, whereas 21% of the goods coming from Korea were intrafirm purchases. Evidently, the extent of intrafirm exports from both Taiwan and Korea has been growing.

firm is in its input requirement (or how easily the downstream firm can substitute its input between different suppliers). A downstream firm can invest (I) to increase the flexibility of its input requirement. In particular, we assume:

$$\tau = \begin{cases} \tau_h & if \quad I = 0 \\ \tau_l & if \quad I = k > 0 \end{cases}, \tag{1}$$

where $0 < \tau_l < \tau_h$. For instance, k could be an investment in a technology that allows greater input substitutability. Alternatively, k may be an investment that reduces transaction costs with potential suppliers, such as setting up an office in F.[3] *Ex ante*, each firm's ideal point is a random variable uniformly distributed on the circle. Downstream firms in H will also be called buyers.

There are a large number of potential suppliers (upstream firms) in the foreign country. Each of them can choose to enter the market with entry cost $f > 0$ and produce the input with constant marginal cost $c \geq 0$.

Before further discussing the model, we give an intuitive overview of our results and the underlying mechanisms, so that readers can assess the extent to which our main insights may or may not depend on the specifics of the model. What we have in mind is an environment where upstream suppliers produce differentiated goods for downstream firms. Product differentiation allows the upstream suppliers to price above marginal cost, and the ensuing economic rents are equal to the entry cost in a free-entry equilibrium. When downstream firms invest to reduce their marginal transportation cost, they become more flexible in input requirements, which leads to lower equilibrium upstream prices. As a result, there will be fewer upstream suppliers (and hence fewer varieties) in equilibrium. This creates an interesting tension between upstream variety and downstream flexibility, where the incentive for a downstream firm to invest in reducing τ is higher if the number of upstream varieties is lower, whereas the incentive for the marginal supplier to enter is lower if τ is lower. This tension, which has not been formulated in the literature before, is the source of potential

[3] The investment could also be on the organization/marketing of production. If the downstream firms are retailers, for instance, by investing in large discount stores (shopping malls) and adopting mass retailing, the downstream firms may desire more standardized products with lower costs.

multiple equilibria in product varieties: a high-variety equilibrium where no downstream buyer makes flexibility investment; a low-variety equilibrium where all downstream firms invest in flexibility; and a medium-variety equilibrium where only some buyers invest in flexibility.

We next detail the timing of our game as follows:

- Stage 1. Potential suppliers simultaneously make entry decisions, and choose locations on the circle if entry occurs.
- Stage 2. Each downstream firm in H decides whether to invest k to increase its flexibility in dealing with different suppliers.[4]
- Stage 3. The downstream firms' locations (ideal points) on the circle are realized. The suppliers who have entered the market, observing downstream firms' locations and whether they have invested k, simultaneously bid prices to the downstream firms.
- Stage 4. Each downstream firm accepts the offer with the lowest purchasing cost (price plus adjustment cost), and the input is produced.[5]

We start our analysis by considering the situation where $n \geq 2$ suppliers are located on the circle with equal distance from each other.[6] Without loss of generality, we let supplier 1 be located at the bottom of the circle and number suppliers and buyers in the clockwise order. A buyer's location is characterized by x_i, which means that the buyer is located immediately ahead of supplier i and its distance from i is x_i.

Given any $\tau \in \{\tau_h, \tau_l\}$, any x_i will effectively face two competing suppliers, i and $i+1$ for $i = 1, ..., n-1$, or n and 1 for $i = n$. Supplier $i's$ marginal customer, on the side ahead

[4] Our results in the basic model would also hold if the entry decisions of potential suppliers were made after or simultaneously with downstream firms' investment decisions. Our analysis for the extended model in the next section, however, will depend on the assumption that the entry decisions of potential suppliers are made in stage 1.

[5] The downstream firms are assumed to value the input sufficiently high so that the input is always purchased in equilibrium.

[6] Throughout the paper, we will consider only pure strategies, and our solution concept is subgame-perfect Nash equilibrium.

of i, is $x_i = \frac{1}{2n}$. If $x_i < \frac{1}{2n}$, supplier i has a competitive advantage in serving x_i and will supply x_i at price p_i, where

$$p_i + \tau x_i = c + \tau \left(\frac{1}{n} - x_i \right). \tag{2}$$

The Bertrand-Nash equilibrium price of firm i for buyer x_i is:

$$p_i(x_i) = \max \left\{ c,\ c + \tau(\frac{1}{n} - 2x_i) \right\}. \tag{3}$$

If portion $\alpha \in [0, 1]$ of buyers have τ_h (investing no k), and portion $1 - \alpha$ of buyers have τ_l (investing k), we assume that each portion will be uniformly distributed on the circle, same as the entire buyer population. Supplier i's equilibrium profit, taking into account the potential buyers on its other side as well, is thus

$$\begin{aligned}\pi_i &= M \left[2\alpha \int_0^{\frac{1}{2n}} \left(c + \tau_h(\frac{1}{n} - 2x_i) - c \right) dx_i + 2(1-\alpha) \int_0^{\frac{1}{2n}} \left(c + \tau_l(\frac{1}{n} - 2x_i) - c \right) dx_i \right] - f \\ &= M \frac{1}{2n^2} \left(\alpha \tau_h + (1-\alpha) \tau_l \right) - f.\end{aligned}$$

In a free-entry (zero-profit) equilibrium, we have

$$\hat{n} = \sqrt{M \frac{\hat{\tau}}{2f}}, \tag{4}$$

where $\hat{\tau} \equiv \alpha \tau_h + (1-\alpha)\tau_l$. We assume $M \geq \frac{8f}{\tau_l}$, which ensures $\hat{n} \geq 2$.

A buyer's expected price when there are n suppliers is

$$2n \int_0^{\frac{1}{2n}} p_i(x_i)\, dx_i = 2n \int_0^{\frac{1}{2n}} \left(c + \tau(\frac{1}{n} - 2x_i) \right) dx_i = c + \frac{\tau}{2n}. \tag{5}$$

The buyer's expected cost of purchasing the input when there are n suppliers is

$$2n \int_0^{\frac{1}{2n}} \left(p_i(x_i) + \tau x_i \right) dx_i = 2n \int_0^{\frac{1}{2n}} \left(c + \tau(\frac{1}{n} - 2x_i) + \tau x_i \right) dx_i = c + \frac{3\tau}{4n}. \tag{6}$$

Our focus on an upstream market structure in which all suppliers have the same distance from each other is justified by the following result:

Lemma 1 *In equilibrium, all suppliers must be equally distanced from each other.*

Proof. See the appendix. ■

We are now ready to establish the main result of the basic model. Define

$$\overline{k} \equiv \frac{3}{4}\frac{\tau_h - \tau_l}{n_l}, \qquad \underline{k} \equiv \frac{3}{4}\frac{\tau_h - \tau_l}{n_h}, \tag{7}$$

$$\alpha_m \equiv \frac{\tau_l}{(\tau_h - \tau_l)}\left(\left(\frac{\overline{k}}{k}\right)^2 - 1\right) \in (0,1) \text{ for } k \in \left(\underline{k},\ \overline{k}\right), \tag{8}$$

$$\tau_m \equiv \alpha_m \tau_h + (1-\alpha_m)\tau_l, \tag{9}$$

$$n_j \equiv \sqrt{\frac{M\tau_j}{2f}} \qquad \text{for } j = h, m, l. \tag{10}$$

Then, since $\tau_l < \tau_m < \tau_h$, we have $n_l < n_m < n_h$.

Proposition 1 *For the basic model:*

(1) If $k > \overline{k}$, the unique equilibrium is $I^* = 0$ $(\tau^* = \tau_h)$ for all buyers and $n^* = n_h$.

(2) If $k < \underline{k}$, the unique equilibrium is $I^* = k$ $(\tau^* = \tau_l)$ for all buyers and $n^* = n_l$.

(3) If $\underline{k} \leq k \leq \overline{k}$, there are three and only three equilibria: (i) $I^* = 0$ $(\tau^* = \tau_h)$ for all buyers and $n^* = n_h$; (ii) $I^* = k$ $(\tau^* = \tau_l)$ for all buyers and $n^* = n_l$; and (iii) for $\underline{k} < k < \overline{k}$, $I^* = 0$ $(\tau^* = \tau_h)$ for α_m buyers while $I^* = k$ $(\tau^* = \tau_l)$ for $(1-\alpha_m)$ buyers, and $n = n_m$.

Proof. See the appendix. ■

Thus, F can have multiple equilibrium market structures in its exports. To see the implications of this result for cross-country comparisons in our empirical work later, we may imagine for a moment that there are two foreign countries, exporting to H two upstream products. We suppose that each exporting country specializes in a different product for export to H.[7] Our multiple-equilibrium result in Proposition 1 implies that the equilibrium number of suppliers in two exporting countries can be rather different, even if the two

[7] Though non-specialization is also an equilibrium, it is easy to conceive of additional factors that can make specialization the likely equilibrium outcome. For instance, if a downstream firm needs to first incur a (small) fixed "entry" cost to choose the country from which to procure the input, such as the cost of gathering country-specific information, specialization will become the *unique* equilibrium. With multiple exporting countries, we shall thus focus on the equilibrium where each upstream product is produced only in one country. In reality, there can be multiple upstream products in one country. Our model can still be applied even if there is not complete specialization or if there is specialization only for some products.

countries and the underlying industry conditions for the two products are similar: one may have a relatively small number of large suppliers, each producing a large quantity; and another may have a larger number of smaller suppliers, each producing a smaller quantity. This provides a possible explanation of the different market structures of export sectors in South Korea and Taiwan, if we interpret the equilibrium with fewer suppliers as applying to Korea, and the equilibrium with more suppliers as applying to Taiwan.[8]

While the circle model is well known in the product differentiation literature, ours has two distinctive features: namely, τ can be changed through investment and the locations of buyers are observed by sellers in price competition. These features seem especially natural in the intermediate-goods market, where the identities of buyers are usually known by suppliers, and where a buyer is likely to be able to invest in technologies or to make arrangements that affect the cost to change suppliers.[9] We could obtain similar results if the locations of the downstream firms were not observable (so that a supplier must charge the same price to all buyers), but our framework is analytically more convenient.[10]

We can shed some light on the welfare property of the equilibrium choice of I. The expected procurement cost of any downstream firm is given by

$$z = \begin{cases} c + \frac{3\tau_h}{4n_h} & if \quad I^* = 0 \text{ for all buyers and } n^* = n_h \\ c + \frac{3\tau_h}{4n_m} = c + \frac{3\tau_l}{4n_m} + k & if \quad \alpha_m \text{ buyers choose } I^* = k \text{ and } n^* = n_m \\ c + \frac{3\tau_l}{4n_l} + k & if \quad \text{all buyers choose } I^* = k \text{ and } n^* = n_l \end{cases} . \tag{11}$$

Corollary 1 *In equilibrium, buyers' choice of I^*, or whether to make the input flexibility investment, minimizes their procurement cost if*

$$\text{either } k \leq \frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l} \text{ or } k > \bar{k}.$$

[8] However, as we have already said in Section 1, it is beyond the scope of this paper to explain why a country may end up with a particular equilibrium, which is discussed by Feenstra and Hamilton (2006) and is an interesting issue for future research.

[9] The considerations here are related to the approach in Chen (2006), who studies the incentives for, and effects of, marketing innovations by producers of final goods that increase their abilities to gather consumer information or reduce consumer transaction costs.

[10] In the intermediate-goods market, it is common for suppliers to negotiate with individual buyers and charge different prices to different buyers.

Otherwise $I^* = k$ can occur in equilibrium but buyers' procurement costs are not minimized.

Proof. See the appendix. ■

Interestingly, while the ability to invest in the flexibility of input requirements can benefit the buyers, sometimes it also makes them worse off. Such investment intensifies competition among any given number of suppliers and reduces the rents needed to cover their entry costs. For fear of this, there will be less entry of suppliers, resulting in less variety in the intermediate-goods market and less competition there, which makes it indeed desirable for the buyers to invest in input flexibility. The inefficiency arises since the flexible investment by the buyers has a negative externality on the suppliers, which the buyers do not internalize. In equilibrium, the suppliers correctly anticipate this and reduce entry. The problem is that buyers cannot collectively commit not to invest k. Such commitment, for instance, would not be possible if contracting for k is not feasible.

3. SPECIFIC INVESTMENT AND VERTICAL STRUCTURE

In our basic model, the upstream and downstream firms are by assumption independently owned. We now extend the basic model to allow the vertical structure in international trade to be determined endogenously, so that in equilibrium some firms may be vertically integrated. The main idea here is to allow a buyer the additional option to make an *ex ante* (specific) investment that would improve its match quality with a particular supplier. When the number of suppliers is large, the buyer can expect its input needs to be matched relatively well by a supplier, and thus there is relatively low expected benefit to make the specific investment. On the other hand, when the number of suppliers is low, a buyer expects to incur more substantial adjustment cost to meet its input requirement, making the specific investment more worthwhile. Under the assumption that the cost of the specific investment differs across the buyer population (follows a continuous distribution), the marginal buyer who would choose the specific investment is determined by the condition that its cost and benefit from the investment are equalized; and there will be more buyers who can potentially benefit from the specific investment if there are fewer suppliers. However, the specific investment would subject the buyer to the increased market power of the supplier towards whom the buyer has made the specific investment,[11] making vertical integration a desirable organizational arrangement to overcome the hold-up problem and to provide the investment incentive. Consequently, when there are fewer suppliers, there will be more vertical integration, or more intrafirm trade.

Having provided an overview of our idea and the results for the extended model, we now turn to the specifics of the game. We modify stage 2 of the basic model so that, at stage 2, a sequence of events occur in the following order: First, each buyer learns to which supplier it is closest (or, equivalently, which one of the segments of length $\frac{1}{2n}$ on the circle it belongs to), even though the buyer's precise location is not realized until Stage 3. We shall call an upstream firm the favored supplier of the downstream firms to which it is closest. Second, each buyer chooses whether to vertically integrate with its favored supplier.[12] Third, each buyer can invest s to position its ideal point at the location of its favored supplier,[13] where s is the realization of a continuous random variable with c.d.f. $G(s)$ on support $[\underline{s}, \overline{s}]$, s is independent of the buyer's (to be realized) distance from her favored supplier,[14] and $0 < \underline{s} \leq \frac{\tau_h}{4n_h} < \frac{\tau_l}{4n_l} + k < \overline{s}$.[15] The buyer also decides whether to invest k as it chooses s.

[11] Notice that the flexible investment in the basic model has the opposite property that it reduces suppliers' market power. It will become clear shortly that in equilibrium a buyer will not duplicate the two investments (i.e., will invest at most one of the two).

[12] We assume that vertical integration can possibly occur only if at least one party strictly benefits from it, even though for simplicity we assume that there is no additional cost associated with vertical integration. We can easily add a cost for vertical integration and reduce s by this cost, without changing the result of our analysis.

[13] This is a crude way of introducing the idea that a buyer can invest to increase her match quality with a supplier, for instance, through adjusting its input requirement, adopting a particular technology, providing specific employee training, or marketing efforts promoting the supplier's product.

[14] Our results could still hold if there is some positive correlation between s and the distance, but the analysis would be much more complicated. What we have in mind is a situation where the downstream firm faces uncertainty in its match quality with the favored supplier, and the investment of s can be made only before the uncertainty is resolved.

[15] The assumption that $\frac{\tau_h}{4n_h} < \frac{\tau_l}{4n_l} + k$ will not be needed if we are only concerned with multiple equilibria for the same industry. For comparisons of different industries, this assumption ensures that k is not too

Everything else in this extended model is the same as in the basic model.[16]

It is immediately clear that, if neither vertical integration nor investment in s occurs, the analysis and the equilibrium of the game will be exactly the same as in the previous section. In particular, since the expected procurement cost for any buyer on any of the segments of length $\frac{1}{2n}$ is the same, knowing which segment it belongs to will not change the buyer's decision on whether or not to invest k.

Our analysis of the extended model has three cases to consider:

Case 1. $n^* = n_l$

If in equilibrium $n^* = n_l$, then the expected procurement cost of a buyer without investing s (but investing k) is $c + \frac{3\tau_l}{4n_l} + k$, and its favored supplier expects to receive from it

$$2n_l \int_0^{\frac{1}{2n_l}} \left(p_i\left(x_i\right) dx_i - c\right).$$

If

$$s + c < c + \frac{3\tau_l}{4n_l} + k - 2n_l \int_0^{\frac{1}{2n_l}} \left(p_i\left(x_i\right) dx_i - c\right) = c + \frac{\tau_l}{4n_l} + k,$$

or

$$s < \frac{\tau_l}{4n_l} + k \equiv s_l, \tag{12}$$

then investing s (and not investing k) will lead to a higher joint surplus between this pair of buyer and supplier. However, if the buyer invests s, it will be subject to the well-known hold-up problem since the supplier has not committed to its price. Because the buyer making the specific investment will be further away from other suppliers, it expects to pay a higher price *ex post*. Thus, absent of vertical integration, s will not be invested. Vertical integration can solve this hold-up problem and realize the potential gains from the specific investment.

small relative to $\left(\sqrt{\tau_h} - \sqrt{\tau_l}\right)$. It can be easily verified that $\underline{k} > \frac{1}{4}\left(\frac{\tau_h}{n_h} - \frac{\tau_l}{n_l}\right)$.

[16] Notice, in particular, that upstream suppliers set their prices at stage 3, after the buyers' precise locations are realized, while the vertical integration decision is made before the realization of buyers' locations. This timing assumption captures the idea that there is uncertainty at the time the vertical integration decision is made, and vertical integration can be a response to a potential hold-up problem.

With vertical integration, for convenience we assume that the downstream firm makes a take-it-or-leave-it offer to the upstream firm, and we allow two possible processes of vertical integration between downstream firms and their favored supplier: first, one downstream firm purchases the upstream firm while the other integrating downstream firms sell their businesses to the upstream firm, resulting in a vertically integrated firm that is owned by a buyer; second, all vertically integrating downstream firms sell their businesses to their favored supplier, resulting in a vertically integrated firm that is owned by the supplier.[17] Under either assumption, vertical integration will not change the expected earnings of the upstream firms and hence not the equilibrium number of upstream producers, because the upstream firm's expected payoff from each merging downstream firm will be

$$\tilde{\pi}_i = \int_0^{\frac{1}{2n}} \left(p_i\left(x_i\right) - c\right) 2n dx_i = \int_0^{\frac{1}{2n}} \left(c + \tau_l \left(\frac{1}{n_n} - 2x_i\right) - c\right) 2n_l dx_i = \frac{\tau_l}{2n_l},$$

which is the same as its expected earnings from any downstream firm who is within the $\frac{1}{2n_l}$ distance and who does not invest s (but invests k, consistent with $n^* = n_l$).

Therefore, if in equilibrium $n^* = n_l$, a mass of $MG\left(s_l\right)$ buyers will vertically integrate with suppliers, or $MG\left(s_l\right)$ amount of $H's$ imports from F will be intrafirm imports.

Case 2: $n = n_m$

If in equilibrium $n = n_m$, which can occur for any $k \in \left(\underline{k},\ \overline{k}\right)$, the expected procurement cost of a downstream firm without investing s is

$$c + \frac{3\tau_h}{4n_m} = c + \frac{3\tau_l}{4n_m} + k.$$

An upstream firm's expected payoff from each merging downstream firm will be

$$\tilde{\pi}_i = \int_0^{\frac{1}{2n}} \left(\alpha_m \left(c + \tau_h \left(\frac{1}{n_m} - 2x_i\right)\right) + (1 - \alpha_m)\left(c + \tau_l \left(\frac{1}{n_m} - 2x_i\right)\right) - c\right) 2n_m dx_i = \frac{\tau_m}{2n_m},$$

[17] For our purpose, we do not consider the issue of how ownership rights should be assigned within a firm. We simply assume that vertical integration solves, or at least alleviates, the hold-up problem. However, the property rights approach (e.g., Grossman and Hart, 1986) has suggested that the ownership rights should be assigned to the party that makes the investment, which, in our case here, is the buyer.

Vertical integration (together with investing s by a downstream firm) will occur if and only if

$$s + c < c + \frac{3\tau_l}{4n_m} + k - \left(\frac{\tau_m}{2n_m}\right) = c + \frac{3\tau_l}{4n_m} + k - \frac{\tau_m}{2n_m},$$

or

$$s < \frac{3\tau_l - 2\tau_m}{4n_m} + k \equiv s_m. \tag{13}$$

Therefore, if in equilibrium $n^* = n_m$, a mass of $MG(s_m)$ buyers will vertically integrate with suppliers, or $MG(s_m)$ amount of $H's$ imports from F will be intrafirm imports. Note that

$$s_m = \frac{3\tau_l - 2\tau_m}{4n_m} + k = \frac{3\tau_h - 2\tau_m}{4n_m} \tag{14}$$

for any $k \in \left(\underline{k},\ \overline{k}\right)$.

Case 3: $n = n_h$

Finally, if in equilibrium $n = n_h$, the expected procurement cost of a downstream firm without investing s is

$$c + \frac{3\tau_h}{4n_h}.$$

Vertical integration (together with investing s by a downstream firm) will occur if and only if

$$s + c < c + \frac{3\tau_h}{4n_h} - \left(2n_h \int_0^{\frac{1}{2n_h}} p_i(x_i)\, dx_i - c\right) = c + \frac{\tau_h}{4n_h},$$

or

$$s < \frac{\tau_h}{4n_h} \equiv s_h. \tag{15}$$

Therefore, if in equilibrium $n^* = n_h$, a mass of $MG(s_h)$ buyers will vertically integrate with suppliers, or $MG(s_h)$ amount of $H's$ imports from F will be intrafirm imports.

Equilibrium of the Extended Model

Summarizing the discussion above and using results from Proposition 1, we can characterize the equilibrium in the extended model as follows:

Proposition 2 *In equilibrium of the extended model:*

(1) If $k > \bar{k}$, the unique equilibrium is: $n^* = n_h$; $MG(s_h)$ buyers vertically integrate with suppliers and invest only s, while the rest of buyers remain vertically separated and invest neither s nor k.

(2) If $\frac{1}{4}\left(\frac{\tau_h}{n_h} - \frac{\tau_l}{n_l}\right) < k < \underline{k}$, the unique equilibrium is: $n^* = n_l$; $MG(s_l)$ buyers vertically integrate with suppliers and invest only s, while the rest of buyers remain vertically separated and invest only k.

(3) If $\underline{k} \leq k \leq \bar{k}$, there are three equilibria: the two equilibria characterized above, and a third equilibrium (for $\underline{k} < k < \bar{k}$) where $n^* = n_m$; $MG(s_m)$ buyers vertically integrate with suppliers and invest only s, while the rest of buyers remain vertically separated, α_m portion of them investing nothing and $1 - \alpha_m$ portion of them investing only k.

Proposition 2 provides the basis for an interesting relationship between product variety and intrafirm trade in equilibrium. Notice that if $\underline{k} \leq k \leq \bar{k}$, we have $s_l > s_m > s_h$ since

$$\begin{aligned} s_l &= \frac{\tau_l}{4n_l} + k = \frac{3\tau_l - 2\tau_l}{4n_l} + k > \frac{3\tau_l - 2\tau_m}{4n_m} + k = s_m, \\ s_m &= \frac{3\tau_h - 2\tau_m}{4n_m} > \frac{3\tau_h - 2\tau_h}{4n_h} = \frac{\tau_h}{4n_h} = s_h. \end{aligned}$$

If $k < \underline{k}$ or $k > \bar{k}$, we have $s_l > s_h$ since

$$s_l - s_h = \frac{\tau_l}{4n_l} + k - \frac{\tau_h}{4n_h} = k - \frac{1}{4}\left(\frac{\tau_h}{n_h} - \frac{\tau_l}{n_l}\right) > 0.$$

We have thus established the following:

Corollary 2 *Corresponding to the possible equilibrium numbers of product varieties $n_l < n_m < n_h$, the amounts of vertical integration, or of intrafirm trade, are respectively $MG(s_l) > MG(s_m) > MG(s_h)$. That is, more product varieties are associated with lower intrafirm trade.*

Notice that the negative correlation between variety and intrafirm trade holds whether the parameter values of our model allows a unique equilibrium or multiple equilibria.[18] Our

[18]Note that if H imports from several F countries, then other factors that affect variety may need be controlled in order to make across-country comparisons. For instance, an F country that is closer to H or

assumption that the downstream firms appropriate all the gains from vertical integration significantly simplifies the analysis. Under this assumption the upstream firms will receive the same payoff in this extended model as in the basic model (with or without vertical integration), so the incentive for entry in the upstream market is not changed; as a result, there is no change for the conditions on k for the equilibrium number of suppliers. If the upstream firms' payoffs increase as a result of vertical integration, there will be additional upstream entry in equilibrium; this will complicate the analysis, but will not change the qualitative nature of our results. In particular, since the gains from investing s (and hence from vertical integration) continue to be higher when the number of suppliers is lower, there will again be more vertical integration when there are fewer upstream product varieties.

Corollary 2 offers a testable prediction about product variety and intrafirm trade, which will be the focus of our empirical analysis in the next two sections.

4. EMPIRICAL SPECIFICATION AND DATA

To test the hypotheses developed above, we extend the data from Antràs (2003), who used Bureau of Economic Analysis (BEA) data to construct intrafirm imports to the U.S. in manufacturing industries for 1992. U.S. intrafirm imports from, say, Canada, are measured relative to total Canada exports to the U.S. to obtain a measure of vertical integration. Antràs runs regression across countries and across firms, though the data do not allow both dimensions to be distinguished at the same time. The first question we need to address is which dimension is most appropriate to our analysis.

While our model of sections 2 and 3 is best suited towards analyzing different industries, the hypothesis that greater product variety is associated with less vertical integration across industries would be very difficult to evaluate using trade data. The reason is that the classification of goods in trade data (called the Harmonized System, HS) has a great many categories in some industries, like textiles and apparel, or footwear, but very few classifi-

that is larger may export more variety to H while at the same time also allow lower s for the buyers in H, causing more vertical integration (intrafirm trade). Such considerations will be important for our empirical analysis later.

cations in other industries, like automobiles. More categories arise when they are needed to implement tariffs and quotas, as occurred under the Multifiber Agreement in textiles and apparel products, while fewer categories are needed when the trade policies are more uniform. This rather arbitrary categories of goods in the HS does not mean that shirts, pants, or shoes have more or less product variety than cars, trucks or motorcycles, but only that the trade policies differ across industries. It would not be appropriate to evaluate the number of HS product categories in each industry to evaluate the extent of its variety, so using trade data does not give any consistent metric by which the variety can be compared across different industries.

But this problem does not arise if we instead consider the product variety of countries. In that case it is easy to count that, within most industries, Taiwan exports in more HS categories to the U.S. than does South Korea (Feenstra, Yang and Hamilton, 1999). So we can get a consistent measure of export variety from Taiwan as compared to South Korea, or more generally, of any country in their exports to the U.S. The measurement of export variety we use is better than a simple count of HS categories, and as shown in Feenstra (1994) and discussed in the Appendix, is the theoretically accurate measure of variety for a CES aggregator function. This measure of variety has been utilized recently by Broda and Weinstein (2006), who analyze the increasing variety of imports coming into the U.S. Hummels and Klenow (2005) also use the same measure of trade variety and call it the "extensive margin" of exports (as contrasted with the "intensive margin," which would be the quantity of exports rather than variety). We will construct the extensive margin of exports for a broad sample of countries exporting to the U.S., over 1989 to 2004.[19]

The evidence from South Korea and Taiwan is that their differences in export variety are similar across industries. That is, Taiwan has greater export variety to the U.S. in nearly all industries. We believe that the same is true when comparing other countries: the extent of export variety tends to be a characteristic of countries that is similar across industries. To check this, we have computed our measure of export variety to the U.S. using seven

[19] The measure of product variety that we use, from Feenstra and Kee (2007), is consistent across countries and time; see the appendix.

broad industry groups: agriculture, textiles and garments, wood and paper, petroleum and plastics, mining and metals, machinery and transport equipment, and electronics. For each industry and country, we have computed export variety to the United States over 16 years (1989-2004). In Table 1, we report the matrix of correlations of export variety across different industries in year 1997.[20] The correlations of export variety between each industry and the aggregate economy are all above 0.8 (column 1). The export varieties of the seven industries are also highly correlated with each other: all correlations are above 0.5 and most of them are over 0.7. If a country has a large number of export varieties in one industry, it is very likely that it also has a large number of export varieties in other industries.

Furthermore, we have also checked more disaggregate data using 3 digit and 4 digit ISIC categories (International Standard Industrial Classification). To be more concrete, we first calculate the export variety at ISIC 3 or ISIC 4 industry level respectively, then we take average over all varieties to get a variety mean value for each country. The correlations between this variety mean across industries and our aggregate export variety are 0.983 and 0.977, respectively, for 3 digit and 4 digit ISIC. This confirms that using country's overall export variety will reflect the product variety within individual industries, and not just a tendency for some countries to specialize in more industries than others.

Given the country-level measure of export variety, we utilize the county-level data on intrafirm imports from Antràs (2003). We broaden Antràs' sample by also using data on U.S. multinationals' intrafirm imports from their foreign affiliates, which are now available from the BEA. This way we will extend our data from a single year (1992, as used by Antràs) to a 16-year time series. The BEA reports data on imports shipped by overseas affiliates to their U.S. parents, and imports shipped to U.S. affiliates by their foreign parent groups. Unlike Antràs, we focus on the former since the BEA collect data on the latter only in their benchmark surveys, which just cover 3 years (1992, 1997 and 2002). Also unlike Antràs, we do no restrict ourselves to manufacturing industries, but use intrafirm sales to either manufacturing or to wholesale industries, again allowing for a larger sample.

[20] We also check the matrix of correlations of export variety across industries for each single year from 1989 to 2004. They all have similar patterns, so we choose to report the result of a middle year, 1997.

In order to test the relationship between export variety and intrafirm trade it is important to control for other factors that influence variety. Simple proximity of a country to the U.S., as well as sheer size of a country, will both lead to higher variety. We can control for these factors by estimating a gravity equation where the dependent variable is export variety to the U.S., by partner country, and including control variables for country size, distance, etc., as well as including intrafirm trade on the right. Since intrafirm trade is endogenous, we use instruments that come from the Antràs regression, i.e. countries' capital and labor endowments. Under this approach the dependent variable (export variety) is measured for much broader set of countries than is intrafirm trade, where we only have the countries reported by the BEA. So this approach allows for a broader country sample than used by Antràs, though we will need to take into account in the estimation that many countries do not have BEA data reported on intrafirm trade, as we shall do in the next section.

5. EMPIRICAL RESULTS

We begin by replicating the results of Antràs (2003), but for a broader sample of years, from 1989 to 2004. In Table 2 the dependent variable is the intrafirm imports to the U.S., in both manufacturing and wholesale industries, measured as a percentage of total U.S. imports from that foreign country, as calculated from the BEA's country-level data. The explanatory variables used are the same as in Antràs (2003): regression (1) uses the capital-labor ratio of each country; regression (2) adds the labor stock; regression (3) adds the human capital-labor ratio; regression (4) adds the corporate tax rate; regression (5) adds overall economic freedom; and the last regression adds indexes of openness to trade from PWT 6.2. In all regressions, we include a year dummy to control for the yearly fixed effects. Since we are using a broader sample of years in regressions, we need to update our data as compared to Antràs (2003): in our regressions, capital and labor data as well as the export variety are from Feenstra and Kee (2007) and are over 16 years; the human capital abundance is adopted from Hall and Jones (1999); the corporate tax is from "the world tax database" (corporate tax: top tax rate) at the University of Michigan, Ross School of Business; economic freedom index is adopted from Gwartney et al (2007);[21] finally we use the openness index (in current price) from Penn World Table 6.2. Because of the endogeneity of this openness index, we also use gravity-style instruments including GDP per capita, population, proximity, and several indicator variables.

As shown in Table 2, the capital-labor ratio, which is the key variable suggested by Antràs' model, retains its positive and significant sign as the number of observations are expanded from his sample. Countries' openness and overall economic freedom both have significantly positive impacts on intrafirm trade, while the corporate tax, labor endowment and human capital abundance have significantly negative effects.

To evaluate the correlation between export variety and intrafirm trade, in Table 3 we report estimates of a gravity equation for nearly 130 countries selling to the United States, pooling data for years 1989-2004. Adding intrafirm trade share as a regressor to the gravity equation raises two empirical issues. The first issue is that many countries do not report any intrafirm trade with the U.S. in the BEA surveys. We presume that these countries have minimal intrafirm trade, and then construct the ratio of intrafirm trade to total foreign country exports as:

$$\text{Intrafirm trade ratio} = \begin{cases} \ln(\text{U.S. intrafirm imports/Foreign exports}) \text{ if reported by BEA} \\ \delta_t \text{ if U.S. intrafirm imports are not reported by BEA in year } t \end{cases}.$$

Under this formulation, δ_t denotes the natural log of the (U.S. intrafirm imports/Foreign exports) ratio for exporting countries not reporting to the BEA.

In order to include δ_t in our estimation, it is convenient to break up the intrafirm trade ratio into two distinct variables, as follows:

$$\text{Intrafirm trade ratio} = \begin{cases} \ln(\text{U.S. intrafirm imports/Foreign exports}) \text{ if reported by BEA} \\ 0 \text{ if U.S. intrafirm imports are not reported by BEA in year } t \end{cases},$$

and,

$$\text{Missing intrafirm indicator} = \begin{cases} 0 \text{ if U.S. intrafirm imports are reported by BEA in year } t \\ 1 \text{ if U.S. intrafirm imports are not reported by BEA in year } t \end{cases}.$$

[21] Gwartney et al (2007) reports the economic freedom index each 5 years before 2000, so we use 1990 value for 1989-1994, 1995 value for 1995-1999; and then we use the annual freedom index for 2000-2004.

Now the parameter δ_t becomes the estimated coefficient on the missing intrafirm indicator variable.

In column (1) of Table 3, we report the OLS regression of the gravity equation using the log of export variety as the dependent variable, and including the intrafirm trade ratio and missing intrafirm indicator as defined above as explanatory variables. The coefficient of intrafirm trade is negative, but very small in magnitude and insignificantly different from zero. The coefficient of the missing intrafirm trade indicator is also negative, and highly significant. Notice that we measure (U.S. intrafirm imports/Foreign country exports) as a percentage, so Canada appears as about 45 instead of 0.45, for example. The negative estimate of δ_t should be interpreted as an estimate of (U.S. intrafirm imports/Foreign country exports) for the missing countries that is less than one percent, so its natural log is negative. Other explanatory variables, including GDP per capita as well as population in each partner country, along with distance to the U.S. (all in natural logs), are all significant at the 1% level. We also add several indicator variables as controls: a common border with the U.S.; OECD member; OPEC member; and having English as the primary language.[22] All except the common border and OPEC membership indicators are highly significant.[23]

The second issue raised by including intrafirm trade is that this regressor is endogenous. In column (2) of Table 3, we correct for the endogeneity of the intrafirm imports by using instruments shown in Table 2 (except for openness): the capital-labor ratio, labor endowment, human capital-labor ratio, corporate tax rate and overall economic freedom for each country. These are the same variables used by Antràs regression (2003), where we update the available data when possible since we are extending our data set to include a 16-year time series instead of a single year (1992) as in Antràs. To check the effectiveness of our instruments, we use first stage F statistics of the regressions which equals 22.94. All of our following regressions pass the Stock-Yogo weak identification test at 5% maximal IV

[22] These indicator variables as well as distance are obtained from Feenstra, Markusen and Rose (2001).

[23] Surprisingly, the indicator variable for OECD membership is negative and significant. This may be offsetting the larger positive coefficient on the English language indicator, which might be over-predicting the impact of common language for those English-speaking OECD countries.

relative bias level (the critical value = 18.37).

When constructing the first-stage value of the intrafirm trade ratio, we use instruments only for those observations that have positive intrafirm imports. That is, we construct the variable:

$$\text{Predicted Intrafirm trade ratio} = \begin{cases} \text{Predicted value of } \ln(\text{U.S. intrafirm imports/Foreign exports}) \\ 0 \text{ if U.S. intrafirm imports are not reported by BEA in year } t \end{cases}.$$

The predicted value of ln(U.S. intrafirm imports/Foreign country exports) is obtained from a regression like that shown in column (5) of Table 2. That regression has 638 observations, reflecting intrafirm trade for roughly 40 countries reported by the BEA in each of the 16 years. We then add the zero value for the other (2104 – 638) = 1466 observations included in the gravity equation.

Using the predicted intrafirm trade ratio, along with the missing intrafirm indicator, the results are shown in column (2) of Table 3. The intrafirm trade ratio is still negative, and is now significantly different from zero. This confirms our hypothesis that intrafirm trade is negatively correlated with product variety, after controlling for other factors. Notice, however, that the negative coefficient on intrafirm trade is sensitive to the fact that we have also included the missing intrafirm indicator variable in the gravity equation: if that indicator variable is dropped, then the coefficient of the intrafirm trade ratio switches from negative to positive. The fact that the indicator variable is highly significant shows that countries with negligible intrafirm trade with the U.S. have distinctly lower export variety in their sales to the U.S. than otherwise. By including the missing intrafirm indicator variable, we are partially controlling for this strong selection effect.

In the remaining regressions reported in Table 3, we follow the IV method used in column 2 but consider narrower measures of export variety as a robustness check, constructed for the seven industry groups shown in Table 1 (columns 3-9). So we are changing the dependent variable to be measured at the industry level, but making no changes in the independent variables. All those industry-level regressions show quite similar sign, magnitude and significance patterns as the results in the regression using aggregate export variety (column 2): intrafirm trade by U.S. multinationals is negatively correlated with the industry varieties exported by each country to the U.S., while the missing trade indicator remains significantly negative, implying those countries with negligible intrafirm trade with the U.S. have even much smaller export variety to the U.S.[24]

Finally, we use the mean value of ISIC 3-digit industry varieties as the dependent variable. The result, reported in the last column of Table 3, further confirms the prediction of our theoretical model.[25] Both of the coefficients on intrafirm trade and the missing trade indicator are smaller in magnitude, but still remain negative and highly significant.

As an alternative to the results in Table 3, we have also experimented with a gravity regression which is similar to column (1) of Table 3 but does not include intrafirm trade variable nor the missing trade indicator. The residuals from this regression are then used as an explanatory variable in the Antràs regressions that have intrafirm trade as the dependent variable. The motivation for using unexplained export variety as a regressor, rather than total export variety, is the same as our motivation for using similar countries like South Korea and Taiwan as a comparison: we want to control for other factors that would jointly influence export variety and intrafirm trade, but that are outside of the model we have presented. This modified Antràs regression, when using aggregate variety, gives a negative coefficient on the export variety residual, though not significant. When the regression is run on each of the 7 industries, all but industry 4 (petroleum and plastics) confirm our theoretical hypothesis that export variety residual is *negatively* correlated with intrafirm trade. For two out of seven sectors, the coefficients on the variety residual are significantly negative. We conclude that the negative relationship between export variety and intrafirm trade, suggested by our theory, is borne out more strongly in the empirical approach reported in Table 3, than in the alternative approach described above.[26]

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[24] Since intrafirm trade and its instruments do not vary by industry, so our weak instruments test gives the same first stage F-statistics (F(5, 610)=22.94), which is greater than the Stock-Yogo critical value at the 5% level.

[25] We also use the mean value of ISIC 4-digit industry varieties as the dependent variable. The result is similar and is available upon request.

[26] Results from this alternative approach are available on request. Chen and Feenstra (2005) contains an analysis that uses this approach but with a smaller sample size.

6. CONCLUDING REMARKS

This paper has studied a simple model of buyer investment and its effect on the variety and vertical structure of international trade. The model distinguishes between two types of buyer investment: “flexible" and "specific", which differ in the ability of a buyer to match with a seller. An analysis of these two types of investment, and of their interactions with the entry and pricing incentives of suppliers, yields two major insights. First, the tension between upstream variety and downstream flexibility can give rise to multiple equilibria in the variety of products traded. While our empirical analysis does not explicitly address the issue of multiple equilibria, this theoretical result is consistent with the observation that Taiwan and South Korea, despite the similarities in their underlying economies, have very different structures of export varieties to the U.S. Second, since the potential gains from specific investment is higher with less product variety, and since vertical integration can serve as a mechanism to overcome the hold-up problem under specific investment, less product variety is associated with more intrafirm trade. This implication of our theory is supported by the result from our formal empirical analysis.

Our argument that investments by buyers can influence the product variety and more generally the market structure of exports raises important policy and development issues. Should exporting countries encourage such buyer investments, perhaps by the establishment of trade fairs inviting participants from foreign countries? Both South Korea and Taiwan have engaged in such activities to promote exports, which have the potential for a social gain when the amount of trade is too small initially (Rauch and Watson, 2004, 2006). Within the context of our model, such activities could reduce the investment cost (k or s) that buyers must incur in order to meet their input requirements more easily or to raise match quality with suppliers, when procuring inputs from the exporting country. As a result, buyers would have lower procurement costs from the exporting country, which can increase the country's exports and economic growth if demand for the country's exports is determined endogenously. It would be desirable in future research to extend our model so that parameter M (demand for a country's exports) is indeed determined endogenously. Such a framework would enable us to examine the willingness of buyers to make investments when faced with a range of heterogeneous sellers in different countries, and to better understand the welfare and policy implications of buyer investment.

There are other interesting directions for future research. One possibility is to further expand our model to allow a consideration of the internal organization of the firms involved in intrafirm trade, such as how the control rights are allocated within a firm. Another possibility is to allow the downstream firms the additional possibilities of producing or purchasing the intermediate goods internally or domestically (which would be a channel to endogenize M in our model). It would also be interesting to consider the effects of downstream competition on the vertical organization of international trade. These extensions could potentially shed new light on how the institutional arrangements between firms influence the patterns of trade and international outsourcing.

APPENDIX

Proofs

Proof of Lemma 1. We consider the two cases where $n = 2$ and $n \geq 3$ separately.

Case 1: $n = 2$. We denote supplier i by *Ui.* Suppose first that U2's distance from U1 is $y \leq \frac{1}{2}$ clockwise. For any consumer x_1 and x_2 of given τ, the equilibrium prices of U2 are

$$\begin{aligned} p_2(x_1) &= \max\{c,\ c+\tau(2x_1-y)\}, \\ p_2(x_2) &= \begin{cases} c+\tau y & if \quad 0 \leq x_2 \leq \frac{1}{2}-y \\ \max\{c,\ c+\tau(1-y-2x_2)\} & if \quad \frac{1}{2}-y < x_2 \leq \frac{1-y}{2} \end{cases}. \end{aligned}$$

U2's profit is the same as U1's and is equal to

$$\begin{aligned} \pi(y) &= M\int_{\frac{y}{2}}^{y}(c+\hat{\tau}(2x_1-y)-c)\,dx_1 + M\int_0^{\frac{1}{2}-y}(c+\hat{\tau}y-c)\,dx_2 \\ &\quad + M\int_{\frac{1}{2}-y}^{\frac{1-y}{2}}(c+\hat{\tau}(1-y-2x_2)-c)\,dx_2 = -\frac{1}{2}My^2\hat{\tau}+\frac{1}{2}My\hat{\tau}, \end{aligned}$$

where recall $\hat{\tau} = \alpha\tau_h + (1-\alpha)\tau_l$. Thus

$$\pi'(y) = -M\hat{\tau}y + \frac{1}{2}M\hat{\tau},$$

and hence in equilibrium y must be $y^* = \frac{1}{2}$. Similar $y^* = \frac{1}{2}$ if we assume $y \geq \frac{1}{2}$.

Case 2: $n \geq 3$. Suppose that the distance of supplier $i+1$ to i is y, and its distance to supplier $i+2$ is $l - y$. It suffices to show that in equilibrium $y = \frac{l}{2}$, since this would imply that there can be no equilibrium where suppliers are not located in equal distance to each other, and furthermore by letting $l = \frac{2}{n}$ it is an equilibrium for firms to locate in equal distance to each other.

With reasoning similar to that in Case 1, we can assume $y \leq \frac{l}{2}$ and write the equilibrium profit of supplier $i+1$ as

$$\begin{aligned} \pi_{i+1}(y) &= M \int_{\frac{y}{2}}^{y} (c + \hat{\tau}(2x - y) - c)\, dx + M \int_{0}^{\frac{l}{2}-y} (c + \hat{\tau} y - c)\, dx \\ &\quad + M \int_{\frac{l}{2}-y}^{\frac{l-y}{2}} (c + \hat{\tau}(l - y - 2x) - c)\, dx = -\frac{1}{2} M y^2 \hat{\tau} + \frac{1}{2} M \hat{\tau} l y. \end{aligned}$$

Thus

$$\pi'_{i+1}(y) = -M y \hat{\tau} + \frac{1}{2} M \hat{\tau} l,$$

and hence in equilibrium $y^* = \frac{l}{2}$. *Q.E.D.*

Proof of Proposition 1. First, from Lemma 1, suppliers will locate in equal distance from each other in equilibrium.

Second, if $I = 0$ and hence $\tau = \tau_h$ for all buyers, then $n = n_h$ from the derivation of $\hat{n}$ given in equation (1) and the definition of n_h. Thus it is an equilibrium for all buyers to choose $I^* = 0$ with $n^* = n_h$ if and only if, given n_h, no buyer can benefit from investing k, or

$$c + \frac{3\tau_h}{4n_h} - \left(c + \frac{3\tau_l}{4n_h} + k\right) \leq 0,$$

or $k \geq \frac{3}{4}\frac{\tau_h - \tau_l}{n_h} \equiv \underline{k}$.

Third, if $I = k$ and hence $\tau = \tau_l$ for all buyers, then $n = n_l$ from the derivation of $\hat{n}$ given in equation (1) and the definition of n_l. Thus it is an equilibrium for all buyers to choose $I^* = k$ with $n^* = n_l$ if and only if, given n_l, no buyer can benefit from investing 0, or

$$\frac{3\tau_l}{4n_l} + k \leq \frac{3\tau_h}{4n_l}.$$

That is, $k \leq \frac{3}{4}\frac{\tau_h - \tau_l}{n_l} \equiv \overline{k}$.

Fourth, since $n_l < n_h$, we can divide k into the three mutually exclusive intervals. If $k > \overline{k}$, it is an equilibrium for all buyers to choose $I^* = 0$ with $n^* = n_h$; and there can be no other equilibrium for the following reason: If there were another equilibrium, some buyers must choose $I = k$ at this equilibrium, and thus the equilibrium number of firms would be $\tilde{n} \in [n_l, n_h)$. But then any buyer choosing $I = k$ cannot be optimizing since for $k > \overline{k}$,

$$\left(c + \frac{3\tau_h}{4\tilde{n}}\right) - \left(c + \frac{3\tau_l}{4\tilde{n}} + k\right) = \frac{3}{4}\frac{\tau_h - \tau_l}{\tilde{n}} - k < \frac{3}{4}\frac{\tau_h - \tau_l}{\tilde{n}} - \overline{k} \leq \frac{3}{4}\frac{\tau_h - \tau_l}{n_l} - \overline{k} = 0.$$

Thus, if $k > \overline{k}$, the unique equilibrium is $I^* = 0$ for all buyers and $n^* = n_h$. An analogous argument establishes that, if $k < \underline{k}$, the unique equilibrium is $I^* = k$ for all buyers and $n^* = n_l$.

Finally, to establish Part (3) of the proposition, we notice that (i) and (ii) follow immediately from the second and third steps above. It is also clear that there can be no other equilibrium where all buyers choose $I = k$ or none does. Thus, our proof will be complete if (iii) holds and it gives the only equilibrium where some buyers invest k and others do not. Notice that if in equilibrium some buyers invest k and others do not, the buyers must have the same expected procurement cost from investing k or 0; that is

$$\frac{3\tau_h}{4n} = \frac{3\tau_l}{4n} + k.$$

On the other hand, for any α, free entry in the upstream market requires that in equilibrium

$$n^2 = M\frac{1}{2f}\left(\alpha\tau_h + (1-\alpha)\tau_l\right).$$

These two simultaneous equations are uniquely solved by $\alpha = \alpha_m \equiv \frac{\tau_l}{(\tau_h - \tau_l)}\left(\left(\frac{\overline{k}}{k}\right)^2 - 1\right)$ and $n = n_m \equiv \sqrt{\frac{M\tau_m}{2f}}$, where $\alpha_m = 0$ if $k = \overline{k}$, $\alpha_m = 1$ if $k = \underline{k}$, and $0 < \alpha_m < 1$ for $\underline{k} < k < \overline{k}$. Therefore it is indeed an equilibrium that $I^* = 0$ for α_m buyers, $I^* = k$ for $(1 - \alpha_m)$ buyers, and $n = n_m$; and there can be no other equilibrium where some buyers invest k and others do not. *Q.E.D.*

Proof of Corollary 1. If buyers were able to act jointly in committing to an I in the beginning of the game, then it would be optimal for them to choose $I = 0$ if

$$c + \frac{3\tau_h}{4n_h} \leq c + \frac{3\tau_l}{4n_l} + k,$$

or $k > \frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l}$, and to choose $I = k$ if

$$k \leq \frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l}.$$

And, since $c + \frac{3\tau_h}{4n_m} > c + \frac{3\tau_h}{4n_h}$ due to $n_m < n_h$, it would not be optimal for some buyers to choose $I = k$ and the others to choose $I = 0$. Notice that

$$\underline{k} - \left(\frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l}\right) = \frac{3}{4}\frac{\tau_h - \tau_l}{n_h} - \left(\frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l}\right) = \frac{3\tau_l}{4}\left(-\frac{1}{n_h} + \frac{1}{n_l}\right) > 0.$$

Therefore, if the procurement cost is lower with $I = k$, or $k \leq \frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l}$, we must also have $k < \underline{k}$ and hence in equilibrium $I^* = k$. But if the procurement cost is lower with $I = 0$, or $k > \frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l}$, it is still possible that in equilibrium $I^* = k$. This inefficient "over-investment" by the buyers occurs as the unique equilibrium outcome if $\frac{3\tau_h}{4n_h} - \frac{3\tau_l}{4n_l} < k < \underline{k}$, and can occur as one of the equilibria if $\underline{k} \leq k \leq \bar{k}$. If $k > \bar{k}$, then $I^* = 0$, which also minimizes the procurement cost. *Q.E.D.*

Measurement of Product Variety in Trade

The measure of export variety we use is derived from a CES utility function by Feenstra (1994), and has been employed recently by Hummels and Klenow (2005), who call it the "extensive margin," and by Broda and Weinstein (2006). Suppose that the set of exports from countries h and F are denoted by J_{it}^h and J_{it}^F in industry i and year t. These sets can differ, but must have some product varieties in common. Denote this common set by $J \equiv \left(J_{it}^h \cap J_{it}^F\right) \neq \varnothing$. From Feenstra (1994), an inverse measure of export variety from country h that is consistent with a CES aggregator function is:

$$\lambda_{it}^h(J) = \frac{\sum_{j \in J} p_{it}^h(j) q_{it}^h(j)}{\sum_{j \in J_{it}^h} p_{it}^h(j) q_{it}^h(j)} \tag{A1}$$

Notice that $\lambda_{it}^{h}(J) \leq 1$ in (A1) due to the differing summations in the numerator and denominator. This term will be strictly less than one if there are goods in the set J_{it}^{h} that are *not found* in the common set J. In other words, if country h is selling some goods in period t that are *not sold* by country F, this will make $\lambda_{it}^{h}(J) < 1$. The more unique goods that are exported by country h and not country F, the lower is the value of $\lambda_{it}^{h}(J)$, so it is an inverse measure of country h's export variety. The ratio, $[\lambda_{it}^{F}(J)/\lambda_{it}^{h}(J)]$, therefore measures the export variety of country h relative to country F. It increases with the variety of goods exported from country h, and decreases with the variety of goods exported from country F.

We shall measure the ratio $[\lambda_{it}^{F}(J)/\lambda_{it}^{h}(J)]$ using exports of countries to the United States, according to the 10-digit Harmonized System (HS) classification. To measure this ratio, we need a consistent comparison country F. For this purpose, we shall use the *worldwide exports* from all countries to the U.S. as the comparison. Furthermore, we take the union of all products sold in any year, and we average real export sales of each product over years. Denote this comparison country by F, so that the set $J_{i}^{F} = \cup_{h,t} J_{it}^{h}$ is the *total set of varieties* imported by the U.S. in sector i over all years, and $p_{i}^{F}(j)q_{i}^{F}(j)$ is the *average real value of imports* for product j (summed over all source countries and averaged across years). Then comparing country $h = 1, \ldots, H$ to country F, it is immediate that the common set of goods exported is $J \equiv J_{it}^{h} \cap J_{i}^{F} = J_{it}^{h}$, or simply the set of goods exported by country h. Therefore, from (A1) we have that $\lambda_{it}^{h}(J) = 1$, and export variety by country h is measured by:

$$\Lambda_{it}^{h}(J) \equiv \frac{\lambda_{it}^{F}(J)}{\lambda_{it}^{h}(J)} = \frac{\sum_{j \in J_{it}^{h}} p_{i}^{F}(j) q_{i}^{F}(j)}{\sum_{j \in J_{i}^{F}} p_{i}^{F}(j) q_{i}^{F}(j)} \tag{A2}$$

Notice that the measure of export variety in (A2) changes over time or across country *only* due to changes in the set of goods sold by that country, J_{it}^{h}, which appears in the numerator on the right. The denominator is constant across countries and time. Therefore, (A2) is a measure of product variety of exports that is consistent across countries and over time. Summary statistics for the measure of export variety in (A2) are provided in Feenstra and Kee (2007, Table 1).

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Table 1: Correlation matrix of export variety across seven sectors, in 1997

	Aggregate	Agriculture	Textiles and garments	Wood and paper	Petroleum and plastics	Mining and metals	Machinery and transport equipment	Electronics
Aggregate	1.00							
Agriculture	0.86	1.00						
Textiles and garments	0.84	0.78	1.00					
Wood and paper	0.97	0.85	0.86	1.00				
Petroleum and plastics	0.81	0.72	0.56	0.75	1.00			
Mining and metals	0.93	0.80	0.71	0.88	0.77	1.00		
Machinery and transport	0.95	0.78	0.73	0.90	0.72	0.95	1.00	
Electronics	0.96	0.76	0.79	0.93	0.67	0.84	0.89	1.00

Notes: Export variety is constructed as described in the Appendix.

Table 2: Intrafirm trade and factor intensity: replicating Antràs (2003)

	Dependent variable: Imports by U.S. parents, relative to total foreign country exports, 1989-2004					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Ln(K/L)	0.293**	0.204**	0.324**	0.320**	0.185**	0.173**
	(5.71)	(4.74)	(4.40)	(4.51)	(2.75)	(2.61)
Ln(L)		-0.187**	-0.201**	-0.186**	-0.166**	-0.122**
		(4.99)	(5.49)	(5.30)	(4.94)	(2.89)
Ln(H/L)			-0.945*	-0.915*	-1.761**	-1.431**
			(2.22)	(2.20)	(4.89)	(3.57)
Corporate tax				-3.441**	-1.870**	-1.800**
				(4.44)	(2.74)	(2.63)
Economic Freedom					0.465**	0.356**
					(8.90)	(4.53)
openness						0.003*
						(2.40)
Constant	-2.388**	1.861*	1.034	2.071*	0.985	0.604
	(2.85)	(2.16)	(1.10)	(2.17)	(1.15)	(0.69)
Observations	649	649	641	641	638	615
R-squared	0.07	0.11	0.12	0.15	0.26	0.29

Robust t statistics in parentheses, * significant at 5%; ** significant at 1%

Notes: The dependent variable is different from Antràs (2003): it includes both manufacturing and wholesale intrafirm imports; but it only includes imports by U.S. parents from their foreign affiliates. The instruments we use for openness are GDP per capita, population, proximity, and dummy variables for common language, common border, OECD membership and OPEC membership.

Table 3: Gravity equation for U.S. imports

	Dependent variable: export variety									
	aggregate		Industry 1	Industry 2	Industry 3	Industry 4	Industry 5	Industry 6	Industry 7	ISIC3 mean
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
GDP per capita	0.467**	0.486**	0.495**	0.732**	0.706**	0.863**	0.702**	0.778**	0.802**	0.279**
	(40.22)	(40.54)	(14.45)	(22.07)	(23.80)	(23.98)	(22.00)	(21.24)	(24.11)	(31.70)
Population	0.236**	0.225**	0.389**	0.369**	0.376**	0.378**	0.453**	0.305**	0.262**	0.149**
	(16.87)	(15.74)	(16.72)	(14.40)	(15.07)	(13.63)	(16.87)	(11.04)	(10.45)	(16.10)
Distance to U.S.	-0.160**	-0.144**	-0.865**	-0.542**	-0.418**	-0.165*	-0.193**	-0.152*	-0.133	-0.02
	(4.53)	(3.99)	(15.18)	(7.71)	(6.73)	(2.20)	(2.67)	(2.02)	(1.80)	(0.83)
Common border	0.09	0.482**	-0.603**	-0.085	-0.051	1.124**	0.686**	0.891**	0.530**	0.462**
	(1.00)	(5.06)	(4.04)	(0.53)	(0.32)	(6.31)	(4.03)	(4.47)	(2.82)	(8.09)
OECD member	-0.204**	-0.238**	-0.398**	-0.930**	-0.565**	-0.744**	-0.175*	0.199*	-0.399**	0.005
	(6.09)	(6.87)	(5.22)	(11.42)	(8.20)	(8.97)	(2.12)	(2.13)	(4.91)	(0.17)
OPEC member	-0.131	-0.13	-0.556**	-0.949**	-0.944**	1.153**	-0.407**	-0.450*	-0.390*	-0.152*
	(1.46)	(1.41)	(3.42)	(5.26)	(4.72)	(8.23)	(2.65)	(2.54)	(2.34)	(2.46)
English Language	0.401**	0.436**	1.002**	0.493**	0.823**	0.388**	0.732**	0.789**	0.650**	0.249**
	(11.28)	(12.02)	(15.45)	(5.95)	(11.97)	(4.22)	(9.33)	(9.10)	(8.16)	(10.33)
Intrafirm trade ratio	-0.027	-0.242**	-0.244**	-0.386**	-0.343**	-0.381**	-0.358**	-0.494**	-0.409**	-0.108**
	(1.77)	(11.59)	(6.13)	(9.79)	(9.55)	(8.16)	(8.97)	(10.29)	(9.48)	(6.20)
Missing intrafirm	-0.496**	-0.913**	-0.999**	-1.024**	-1.104**	-1.264**	-1.328**	-1.943**	-1.649**	-0.629**
indicator	(9.36)	(13.98)	(9.93)	(8.93)	(9.58)	(10.34)	(11.47)	(14.53)	(13.86)	(12.98)
Constant	-3.162**	-2.860**	0.147	-2.952**	-4.553**	-8.587**	-8.602**	-7.060**	-5.965**	-1.322**
	(11.13)	(9.91)	(0.26)	(5.19)	(8.30)	(12.56)	(13.85)	(10.21)	(8.63)	(6.76)
Observations	2166	2104	2042	2019	2043	1939	1915	1921	1962	2104
R-squared	0.64	0.64	0.46	0.4	0.49	0.5	0.56	0.57	0.52	0.69

Robust t statistics in parentheses, * significant at 5%; ** significant at 1%

Notes: All variables except indicators are measured in natural logs. Column (1)-(2) are using aggregate export variety as dependent variable, column (10) is using variety mean of ISIC 3-digit industries, while the rest columns are using individual industry varieties. Column (1) is estimated with OLS, while other columns use instruments for positive intrafirm imports. Instruments used include the capital-labor ratio, labor endowment, human capital-labor ratio, corporate tax rate and overall economic freedom.