Vertical Specialization in Multinational Firms*

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Abstract: In the recent decades, growth of overall world trade has been driven in large part by the rapid growth of trade in intermediate inputs. This input trade results in part from multinational firms choosing to outsource input processing to their foreign affiliates, thereby creating global production networks in which each actor is vertically specialized. In this paper, we use firm-level data on U.S. multinationals to examine trade in intermediate inputs between parent firms and their foreign affiliates. We estimate affiliate demand for imported inputs as a function of host-country trade costs, factor prices, and other variables. Among our main findings are that affiliate demand for imported inputs for further processing decrease in direct proportion to host-country tariffs, host-country wages for less-skilled labor (both in absolute terms and relative to wages for more-skilled labor), and host-country corporate income tax rates. Consistent with recent theory, these results suggest that vertical specialization within multinational firms rises as trade barriers between countries fall and as factor-price differences between countries widen.

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“Vertical Specialization in Multinational Firms”
Executive Summary

In recent decades, growth of overall world trade has been driven in large part by the rapid growth of trade inside multinational firms. Much of this trade results from multinationals choosing to outsource input processing to their foreign affiliates, thereby creating global production networks in which each actor is vertically specialized and linked via trade. Many commentators have raised concern about these networks, claiming that they tend to reduce parent activity in the United States. This perspective assumes that affiliate and parent activity in global production networks are necessarily substitutes for each other, with foreign expansion resulting in little more than parents exporting jobs to foreign locales.

Economic theory suggests that one force behind the spread of global production networks is falling trade barriers between the United States and low-wage countries in Asia, Latin America, and other emerging regions. The logic is that low import tariffs in these economies allows multinational firms to reduce costs by moving product assembly and other input processing abroad. The result is a vertical production network in which skill and capital-intensive tasks are performed in the United States and labor-intensive tasks are performed in low-wage countries. While this hypothesis accords with anecdotal evidence, there has been little systematic empirical analysis of how host-country trade costs, wages, and tax rates contribute to vertical specialization in multinational firms. In this paper we provide such an analysis using firm-level data on U.S. multinationals. From a standard cost-minimization framework, we derive the demand for imported inputs for further processing by foreign affiliates of U.S. parents, and then estimate the sensitivity of this demand to host-country tariffs, factor prices, taxes, and other variables suggested by theory. Having comprehensive data on the foreign activities of U.S. multinationals allows us to address several important estimation issues that complicate the analysis.

We have several important findings. One is a prominent role for tariffs in vertical specialization. We find that imported intermediate inputs are strongly negatively correlated with host-country tariffs. Our preferred estimates imply that a one-percent fall in tariffs leads to a three-to-five percent increase in the quantity of intermediate inputs imported by foreign affiliates. Small reductions in trade barriers appear to produce large increases in input trade. A second finding is that vertical specialization is sensitive to host-country labor costs. Imported-input demand is decreasing in host-country wages for low-skilled workers and increasing in host-country wages for high-skilled workers. This suggests that U.S. multinationals have their affiliates specialize in input processing in countries where low-skilled labor is abundant and high-skilled labor is scarce. A third finding is that the extent of vertical specialization is greater where corporate income tax rates are lower. This suggests that higher corporate taxes are a disincentive for vertical production networks, which often involve not just affiliate imports of inputs from their parents but also affiliate exports of processed goods back to their parents.

We emphasize that these results do *not* suggest that parent and affiliate activity in vertically specialized global production networks are substitutes. Instead, host-country forces such as low tariffs and labor costs stimulate parent production of inputs for export to affiliates for further processing. The patterns we uncover are consistent with parent and affiliate activity worldwide being complements, with all stages of networks rising and falling in concert.

1. Introduction

Two key features of the current process of globalization are increased trade in intermediate inputs and increased flows of foreign direct investment (FDI). For the last several decades, growth of overall world trade has been driven in large part by the rapid growth of trade in intermediate inputs. There are now several empirical studies that document this development. Finger (2001) finds that trade in inputs has grown much faster than trade in final goods, and he estimates that intermediates now account for 30% of world trade in manufactures.[1] Hummels, Ishii, and Yi (2001) identify *vertical specialization* – production arrangements in which a good is made via multiple stages located in multiple countries—as an important aspect of intermediate-input trade.[2] They calculate that from 1970 to 1990, the increase in exports associated with vertical specialization accounted for one-third of world export growth.

Multinational enterprises appear to mediate a large fraction of world trade in inputs. U.S. multinationals, for example, account for over half of total U.S. exports (Slaughter, 2000). Within manufacturing, the majority of this trade is in intermediates. In 1999, 92.4% of exports by U.S. parent firms to their manufacturing affiliates located abroad were inputs for further processing (Borga and Zeile, 2002). This input trade is one element of global production networks, in which multinationals outsource input processing to their foreign affiliates and the affiliates export their output to final consumers or to other plants for yet more processing.

Theory offers many explanations for the spread of vertical specialization in global production networks, such as falling trade barriers or low host-country wages. But little empirical work has gone beyond documenting facts about this process to provide a theoretically informed, micro-

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[1] See also Feenstra (1998) and Campa and Goldberg (1997).

[2] This phenomenon has been given various names, including de-localization, disintegration of production, fragmentation, global production sharing, foreign outsourcing, and slicing up the value chain. See Helleiner (1973), Balassa (1978), Findlay (1978), Sanyal (1983), Feenstra (1998), and Hummels et al. (2001).

level empirical analysis of the relative importance of these explanations. In this paper we provide such an analysis using firm-level data on U.S. multinationals.

Our data come from legally mandated confidential surveys conducted by the U.S. Bureau of Economic Analysis (BEA) of all U.S. multinationals. For majority-owned foreign affiliates in manufacturing in 1994, we have a direct measure of vertical specialization: imports from U.S. parent firms of intermediate inputs for further processing. We use a standard cost-minimization framework to derive the demand for imported inputs by foreign affiliates, and we then estimate the sensitivity of this demand to host-country tariffs, factor prices, taxes, and other variables suggested by theory. Our estimation combines the BEA surveys with data on host-country policies and characteristics from outside sources. Having comprehensive data on the foreign activities of U.S. multinationals allows us to address several important estimation issues, such as the absence of data on transaction prices between parent firms and their affiliates.

Our work is relevant to several bodies of literature on the causes and consequences of vertical specialization in global production networks. The first is research on the impact of declining trade barriers. Many of the studies cited above mention falling political and natural trade barriers as a likely explanation of vertical specialization. In an important recent paper, Yi (2002) argues that standard models of trade in final goods cannot account for how the modest observed declines in trade barriers could have produced the dramatic observed growth in world trade. Yi shows theoretically how vertical specialization allows declining trade barriers to trigger magnified and non-linear decreases in production costs and thus dramatic increases in world trade flows. We examine this hypothesis by estimating the sensitivity of demand for imported intermediate inputs to host-country tariffs.

The second body of literature to which our paper relates is empirical work on theories of multinational enterprises. Theory tends to view multinationals as the result of either horizontal expansion, in which firms save on trade costs associated with exporting by setting up production facilities in destination markets, or vertical expansion, in which firms fragment production stages across countries to arbitrage international differences in factor prices.[3] Several recent empirical studies have tested these alternative theories using aggregate BEA data—e.g., total sales of U.S. foreign affiliates by country. These studies generally find that affiliate sales are higher in countries with higher tariffs and transport costs on U.S. goods, but not in countries with larger skill differences relative to the United States (Brainard, 1997; Maskus and Markusen, 1999; Carr, Markusen, and Maskus, 2001; Blonigen, Davies, and Head, 2002).[4] These results are usually interpreted as evidence in favor of horizontal FDI and against vertical FDI.

But aggregate data on multinationals may yield noisy indicators of whether FDI is horizontal or vertical in nature. A more detailed view of multinational operations might produce a more complete picture of what motivates FDI. Hanson, Mataloni, and Slaughter (2001), for instance, find that import processing and export production by affiliates of U.S. multinationals is more common in low-wage countries than in high-wage countries.[5] In this paper, we assess whether vertical specialization by U.S. foreign affiliates responds to cross-country variation in factor prices, as would be consistent with vertical FDI.

The third body of literature to which our work relates is that on the labor-market consequences of the globalization of production. Trade in intermediate inputs is one means through which firms in high-wage countries can outsource labor-intensive tasks to low-wage

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[3] On the former, see Markusen (2002) and Markusen and Venables (1998, 2000). On the latter, see Helpman (1984), Helpman and Krugman (1985), and Yeaple (2001).

[4] Other results contradict this view. Yeaple (2001) finds that the impact of host-country education on affiliate sales is weaker for less-skill-intensive industries, suggesting that multinationals in less-skill-intensive industries prefer less-skill-abundant countries.

countries, in line with comparative advantage. Feenstra and Hanson (1997, 1999) find that increased intermediate-input trade is associated with increases in the relative demand for—and thus the relative wage of—skilled labor in both the United States and Mexico. Other evidence suggests that trade in intermediates has contributed to similar labor-market outcomes in Asia and Europe (see survey in Feenstra and Hanson, 2002). That vertical specialization can substantially influence labor markets makes understanding its determinants important.

Our empirical analysis yields a number of results. One is a prominent role for tariffs in vertical specialization. We find that imported intermediate inputs are strongly negatively correlated with host-country tariffs. Our preferred estimates, which appear robust to a range of estimation choices, imply an elasticity of between –3.0 and –5.0: a one-percent fall in tariff markups leads to a three-to-five percent increase in the quantity of imported intermediate inputs. This high sensitivity of vertical specialization to tariffs is consistent with Yi's (2002) model in which small changes in tariffs produce large changes in input trade.

A second finding is the sensitivity of vertical specialization to host-country labor costs. Imported-input demand is decreasing in host-country wages for low-skilled workers and increasing in host-country wages for high-skilled workers. The responsiveness of vertical specialization to wages is at odds with much of the empirical work on multinationals that uses aggregate data. Consistent with vertical FDI, we find that foreign affiliates do more processing of imports the lower are low-skilled wages relative to high-skilled wages.

A third finding is that the extent of vertical specialization also depends on other host-country policies and characteristics. Imported-input demand is decreasing in host-country corporate tax rates, increasing in the presence of host-country export-processing zones, and decreasing in the

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[5] See Barba Navaretti, Haaland, and Venables (2002) for similar evidence on European multinationals. Again using aggregated data, Shatz (2000) studies the exporting behavior of U.S. multinationals.

market size of the host country. Many of these forces have received little attention in previous research. For example, many studies have examined how taxes affect aggregate FDI flows (Hines, 2001), but not on how they affect the composition of FDI.

Our paper has four additional sections. In Section 2 we present our empirical framework. In section 3 we discuss the data and present summary statistics. In Section 4 we report our estimation results. And in Section 5 we conclude.

2. Empirical Framework

In this section, we develop an empirical framework for how U.S. multinationals organize the operations of their foreign affiliates. Our focus is on affiliate operations at a given point in time. We assume that U.S. parent firms have previously developed knowledge capital of some kind—through creating patents, copyrights, trademarks, and other intangible assets—and have chosen in which countries to locate affiliates. The remaining decision is how affiliates should organize production. For simplicity, consider two production stages: input manufacturing and input processing. Input manufacturing often may involve producing sophisticated componentry, and so is likely to be relatively skill and capital intensive. Input processing often involves little more than assembly, and so is likely to be relatively labor intensive.

Consider two alternative strategies for FDI. A strategy of vertical specialization would have foreign affiliates import inputs from their U.S. parents and then process these inputs into final products. By locating labor-intensive input processing abroad and capital-intensive input production in the United States, this strategy would allow the multinational to take advantage of international differences in factor prices. But, given the need to ship inputs between countries, it results in high transport costs. A strategy of vertical integration would have foreign affiliates both produce and process inputs. In this case, the parent relocates the entire production process to its foreign affiliates. This strategy minimizes transport costs, since there is no need for affiliates to import inputs, but it also prevents the multinational from taking full advantage of factor-price differences across countries.

In practice, firms are likely to choose a strategy somewhere between the two extremes of complete vertical specialization and complete vertical integration. This choice may depend on the factors just identified, such as trade and labor costs. It may also depend on other host-country policies and characteristics. Next, we derive an empirical model that allows us to capture the relative importance of these various forces.[6]

2.1 An Empirical Model

Consider a foreign affiliate of a U.S. parent firm. Let the short-run cost function for the affiliate be C(**w**,K,Y). Here, **w** is a vector of prices for variable factors; this includes wage rates for labor used in input production, wage rates for labor used in input processing, the price of manufacturing inputs imported from the parent, and the price of headquarter services imported from the parent. Variables K and Y represent affiliate capital stock and total output, respectively.

There are two items to note about this cost structure. The first is its short-run nature. This follows from our data being a cross-section rather than a panel of affiliates.[7] The second is that we are assuming the affiliate cost function is separable from that of the U.S. parent firm. This

[6] Notice that under the strategy of either vertical specialization or vertical integration, the foreign affiliate must ship final outputs to end users. This implies that, given the presence of a foreign affiliate in a particular country, the destination market for affiliate sales does not affect the choice between the affiliate being vertical specialized or vertically integrated. See Hanson, et al (2001) for evidence on the export-versus-local sales decision of foreign affiliates.

[7] Data on foreign affiliates of U.S. parents do exist for some earlier years. We have not added these years to our sample because we lack corresponding data on some key regression variables. It is unlikely that adding additional years would greatly enhance the estimation. The primary variation in wages, tariffs, and tax rates, and other variables is across countries and not across time (at least over horizons of a decade or less). An advantage of having additional years of data would be to control for affiliate fixed effects, but this would come at the potential cost of losing much of the systematic variation in our regressors. As we discuss below, with our one year of data we are able to control for parent-by-industry fixed effects in the estimation.

allows us to examine the activity choices of affiliates in isolation, and is appropriate so long as input production and input processing are technologically separable activities. We acknowledge that within a multi-affiliate firm, the same affiliates of a given U.S. parent are likely to use similar production technology and may face common prices for inputs or services imported from the parent. We allow for this possibility in the estimation.

To derive an estimating equation, we need to select a functional form for costs. A convenient choice is the translog form, which Diewert (1974) introduced and Kohli (1978, 1991) used initially in the international-trade literature. In our case, this function can be written as

$$\begin{aligned}\ln C = \alpha_0 + \sum_{h=1}^{H} \alpha_h \ln w^h + \beta_k \ln K + \tfrac{1}{2}\sum_{h=1}^{H}\sum_{j=1}^{H} \gamma_{hj} \ln w^h \ln w^j \\ + \tfrac{1}{2}\beta_{kk} \ln K^2 + \sum_{h=1}^{H} \phi_{hk} \ln w^h \ln K\end{aligned} \tag{1}$$

where w^h denotes the prices of the optimally chosen variable inputs h=1,…,H, and K denotes the quantity of fixed capital. For notational simplicity, in equation (1) we assume that the affiliate production technology is constant-returns to scale, such that output does not appear on the right-hand side. In the empirical analysis we will test this restriction.[8]

The usefulness of the translog function comes from computing its first derivatives, $\partial \ln C/\partial \ln w^h = (\partial C/\partial w^h)(w^h/C)$. By Shepard's Lemma, $\partial C/\partial w^h$ equals the demand for input h. It follows that $(\partial C/\partial w^h)(w^h/C)$ equals the share of factor h in total costs, which we denote by the cost-share s^h. Differentiating equation (1) with respect to $\ln w^h$ yields the following expression,

$$s^h = \alpha_h + \sum_{j=1}^{H} \gamma_{hj} \ln w^j + \phi_{hk} \ln K\,, \tag{2}$$

[8] To preview our results, we find evidence consistent with affiliate technology being constant returns to scale. That affiliates exhibit constant returns in no way implies that parents do as well. Given the importance of R&D and other fixed-cost activities in parent operations, we expect their technology to be subject to increasing returns.

for h=1,…,H. The expression in (2) relates the demand for input h, measured as its share in total costs, to prices of variable inputs and quantities of fixed inputs. This set of equations is the basis for our empirical work. We estimate the cost-share equation for a single input, imported intermediate inputs for further processing. This cost share measures the degree of vertical specialization in foreign affiliates. The higher are imported inputs in total costs, the more specialized is the affiliate in processing inputs and the less vertically integrated its operations.[9]

Denoting the share of imported intermediate inputs in total costs by s^m, our estimating equation for affiliate a in industry i belonging to U.S. parent p and located in host-country c is,

$$\begin{aligned} s^m_{aipc} &= \alpha_{ip} + \gamma_{ms} \ln w^s_c + \gamma_{mu} \ln w^u_c + \gamma_{mm} \ln p^m_{ipc} + \gamma_{mo} \ln p^{hq}_{ipc} \\ &\quad + \phi_{mk} \ln K_{aipc} + \varepsilon^m_{aipc} \end{aligned} \tag{3}$$

where α_{ip} is a parent- and industry-specific constant term (discussed below); w^s_c is the price of skilled labor in country c; w^u_c is the price of unskilled labor in c; p^m_{ipc} is the price of imported intermediate inputs from parent p in industry i and country c; p^{hq}_{ipc} is the price of headquarter services imported from parent p in industry i and country c; K_{aipc} is the affiliate capital stock; and ε^m_{aipc} is an disturbance term reflecting errors in measuring imported inputs and total costs.

After estimating equation (3) it is straightforward to calculate elasticities of substitution between factors and own-price elasticities of factor demand. The own-price elasticity of demand for factor m, imported intermediate inputs, is given by,

[9] Given data limitations, it is problematic to estimate cost shares for other variable inputs. To do so would require data on the affiliate employment of labor by different skill types *separately* for input production and for input processing. Our data only report aggregate employment by skill type for an affiliate. Thus, we do not know whether an affiliate that hires skilled labor produces inputs, processes inputs, or both. One potential advantage of estimating other cost-share equations would be the ability to impose cross-equation parameter restrictions in (2) implied by the symmetry of cross-price derivatives and by the fact that an exhaustive set of cost shares must sum to one.

$$PED_{mm} = \frac{\gamma_{mm} + s^m(s^m - 1)}{s^m} \tag{4}$$

The cross-price elasticity of demand between inputs m and h is given by,

$$PED_{mh} = \frac{\gamma_{mh} + s^m s^h}{s^m} \tag{5}$$

An advantage of the translog framework is that it does not impose restrictions on the pair-wise elasticities of substitution between inputs. This generalizes from more-restrictive technologies such as Cobb-Douglas or CES (in which all elasticities equal one or a constant, respectively).

2.2 Estimation Issues

Several important estimation issues merit attention. A first is that we do not have data on p^m_{ipc} or p^{hq}_{ipc}, the transaction prices that affiliates pay for inputs and services they import from their parents. This data limitation is hardly surprising. There is little price data for trade flows anywhere, let alone for individual businesses operating in hundreds of countries and industries. We are able to address this problem by exploiting the structure of the BEA data; specifically, the fact that most foreign affiliates share a U.S. parent with at least one other affiliate.

Suppose that p^m_{ipc} can be expressed in log terms as the sum of two parts: the f.o.b. price in the United States for that import, and any host-country wedge between that U.S. price and p^m_{ipc} that is due to trade barriers or transport costs. For example, a U.S. parent that manufactures electrical appliances may obtain tungsten in the United States for all its light-bulb affiliates abroad, but different affiliates may pay different prices based on different trade frictions. In the simplifying case where import tariffs are the only source of this price wedge, we can write p^m_{ipc} as follows,

$$\ln p^m_{ipc} = \ln p^m_{ip} + \ln(1 + \tau_{ic}) \tag{6}$$

where p_{ip}^{m} is the f.o.b. price of the input in the United States and τ_{ic} is the *ad valorem* tariff rate that country c levies on imports in industry i.

We have data on τ_{ic} (and other trade costs), but not on p_{ip}^{m}. We do, however, observe the activities of multiple affiliates that operate in the same industry and that share the same parent. If the parent charges its affiliates in the same industry the same f.o.b. price for inputs, then taxes and trade barriers such as τ_{ic} will be the only source of variation in p_{ipc}^{m} across affiliates in the same industry belonging to the same parent. We can then measure p_{ipc}^{m} in two parts: (a) a full set of parent-by-industry dummy variables, α_{ip}, which captures the unobservable f.o.b. price, p_{ip}^{m}; and (b) host-country trade costs, which we measure using data on host-country industry tariffs, non-tariff barriers, and transportation costs, and distance from the United States.

Allowing for parent-by-industry fixed effects, rather than just parent effects, allows for the fact that many multinationals are multi-product firms whose affiliates span diverse industries. Thus, a parent firm's light-bulb affiliates can face different imported-input prices from its refrigerator affiliates. These parent-by-industry controls also address differences in vertical specialization due to technological primitives or firm business practices (e.g., vertical specialization may be inherently less feasible in food industries with highly perishable inputs).

By the same logic just discussed, we also control for unobservable headquarter service prices, p_{ipc}^{hq}. The parent-by-industry controls, α_{ip}, capture any unobserved components of service prices that parents charge to all affiliates in the same industry; measures of trade costs capture country- and/or industry-specific components. Affiliates may import from parents a wide range of headquarter services, such as use of patents, copyrights, and trademarks, analysis of market conditions, or advice about management strategy. Parents may receive payment for these services through either fees or repatriated earnings. The price parents charge may vary across affiliates due to transport costs (e.g., more-remote affiliates may be more costly to service), in a manner similar to imported manufacturing inputs. This price may also vary across affiliates due to host-country corporate income taxes (e.g., higher tax rates may make repatriated earnings less attractive), and so we include this variable as a regressor.

An important aspect of measuring both p^{m}_{ipc} and p^{hq}_{ipc} is transfer pricing. It is commonly asserted that multinationals price intra-firm transactions—i.e., set p^{m}_{ipc} and p^{hq}_{ipc} –such that firm-wide pre-tax profits accrue to affiliates in low-tax jurisdictions (e.g., Clausing, 2001; Grubert and Mutti, 1991). We have no direct data on transfer pricing, but our treatment of p^{m}_{ipc} and p^{hq}_{ipc} summarized in (6) should control for at least some of any unobservable transfer-pricing motives. The parent-by-industry controls remove differences in the average propensity to transfer price across U.S. parents, which may result from variation in their foreign-tax-credit status with the Internal Revenue Service (IRS). And the inclusion of corporate income tax rates controls for transfer-pricing motivations that vary across host-countries.

A second estimation issue is that we do not observe any prices for any intermediate inputs that affiliates may purchase locally. In principle, the price for local inputs should be an additional regressor in equation (3). In practice, these prices may be well captured by our just-discussed measures for p^{m}_{ipc} and p^{hq}_{ipc}. If local input prices are set on the world market, and so equal to world input prices plus trade costs, then including as regressors parent-by-industry dummy variables and trade costs controls for their presence.

A third estimation issue is the source of variation in wages facing affiliates. In equation (3) the wages w^{u}_{c} and w^{s}_{c} are assumed to vary only across countries. This would be the case if affiliates are price-takers in labor markets and if there were one national market for each distinct skill group. In practice, wages may vary across other dimensions as well. Certain multinationals may tend to pay more or less in all their affiliates (e.g., higher-quality multinationals with more-advanced technologies may pay wage premia). Wages may vary by industry, consistent with the large amount of empirical evidence in many countries on inter-industry wage differentials. In the empirical analysis, we use as a baseline measure wages at the country level and experiment with alternative wage measures at the industry or affiliate level.

A fourth estimation issue is that there may be factors beyond the regressors already discussed that influence how foreign affiliates organize their activities and that therefore should be included in equation (3). For example, recent research suggests the level of inward FDI may vary with a country's overall legal and political environment—in particular, with policies regarding FDI and exchange rates. To control for this possibility, in some specifications we include as regressors measures of a country's investment and exchange-rate policies and of the quality of its financial, legal, and political institutions.

A final estimation issue involves the regressand. In our data, the dependent variable s^{m}_{aipc} takes a value of zero for many affiliates. This may be due to the technological infeasibility of separating input production and processing, which would result in an affiliate strategy of complete vertical integration. One approach to this problem would be to include in (3) measures of the technological separability of production as regressors and then estimate (3) as a Tobit. However, such measures are not readily available. The parent-by-industry dummy variables could proxy for these technology variables, but the presence of a large number of unobserved fixed effects complicates use of the Tobit. With few observations per dummy variable category (i.e., small numbers of affiliates of the same parent firm and in the same industry), there is the risk that Tobit estimates of parameter coefficients would be inconsistent (Wooldridge, 2002).

Instead, we address zero observations in the dependent variable in two ways. First, we drop from the sample affiliates in industries in which imports of inputs for further processing are rare.[10] The excluded industries—e.g., food processing, petroleum refining, pulp and paper, newspaper, soap and cleansers—appear to be primarily ones in which either there is a single stage of production or technology or transport costs make it prohibitively expensive to geographically separate input production and input processing. Second, we check the consistency of our OLS estimates of (3) by using a Tobit with a more-aggregate set of dummy variable categories. Fewer parent-industry combinations increase the number of observations per category and thus improves the consistency of Tobit parameter estimates.

2.3 Summary of Estimation Strategy

To summarize our estimation strategy, our goal is to explain the variation in imported intermediate inputs across foreign affiliates that are in the same industry and that share the same U.S. parent. In controlling for parent-by-industry fixed effects, we identify the responsiveness of input processing imports to wages, tariffs, tax rates, and other factors by using information on the cross-country variation in these variables. The regression coefficients, in combination with sample data on cost shares, yield estimates of the elasticities of parent outsourcing to affiliates with respect to factor prices, trade barriers, and other policies.

Our baseline estimating equation can now be written as follows:

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[10] The cutoff we apply is an industry mean of imported inputs for further processing as a share of total sales of less than 5%.

$$s_{aipc}^{m} = \alpha_{ip} + \gamma_{ms} \ln w_c^s + \gamma_{mu} \ln w_c^u + \gamma_{mm} \left[\ln(1+\tau_{ic}) + \ln(1+f_{ic}) \right]$$
$$+ \gamma_{mm} \ln(1-t_c) + \phi_{mk} \ln K_{aipc} + \beta X_c + \varepsilon_{aipc}^{m} \tag{7}$$

where, among the new variables relative to (3), τ_{ic} is the host-country industry *ad valorem* tariff rate; f_{ic} is the host-country industry *ad valorem* freight rate (i.e., transport cost); t_c is the host-country corporate tax rate; and X_c are measures of other host-country policies and characteristics. We report results for OLS and Tobit estimators, with standard errors that allow for both arbitrary forms of heteroskedasticity and correlations in disturbances within parent-industry groups. The standard errors associated with the coefficient estimates in (7) are used to calculate standard errors for the elasticities of interest using the Delta method (Wooldridge, 2002).

3. Data Description and Summary Statistics

3.1 Data Sources

The primary data for this project are for the operations of U.S. multinationals, both of their U.S.-based parents and their foreign affiliates. These data come from legally mandated confidential surveys conducted by the U.S. BEA. A U.S. multinational consists of one U.S. parent plus one or more foreign affiliates. A parent is an individual or a group such as a trust, corporation, or partnership that controls a business enterprise incorporated in the United States that has at least one foreign affiliate. A foreign affiliate is a foreign business enterprise (incorporated or unincorporated) in which there is U.S. direct investment; that is, it is a foreign business enterprise in which the U.S. parent has at least a 10-percent equity stake.

We use data from the 1994 "benchmark" survey, which covers the entire population of U.S. multinationals in that year. Less data are collected for minority-owned affiliates, so we use the sample of majority-owned affiliates (i.e., those in which the U.S. entity has at least a 50% equity stake) in manufacturing, of which there were 6,955 in 1994 (out of 8,014 total manufacturing affiliates linked to 1,456 U.S. parent enterprises). This sample of majority-owned affiliates spanned 52 manufacturing industries and 105 host countries.

For our regression analysis in equation (7), the dependent variable s^{m}_{aipc} is the share in total affiliate costs of imports from the United States of intermediate inputs for further processing. Total costs are proxied by total revenues, i.e., total affiliate sales adjusted for inventory changes.[11] Imported inputs capture imports both from U.S. parents and from non-parent U.S. entities.[12] We use two affiliate-level regressors of (log) quantities: capital stock and output (see note 7). Affiliate capital stocks K_{aipc} are measured as net property, plant, and equipment valued at historical cost. Total output is measured as total revenues.

Turning to other regressors, we do not observe the true marginal prices for labor w^{u}_{c} and w^{s}_{c} facing each affiliate. We approximate these marginal prices using wage unit values (compensation divided by employment) constructed from the United Nations' Industrial Statistics Database. We measure the unskilled wage, w^{u}_{c}, as the wage unit value in that country's apparel sector, which in most countries is among the most labor-intensive and lowest-wage industries. We measure the skilled wage, w^{s}_{c}, as the wage unit value in a set of that countries' high-wage, skill-intensive industries (chemicals, electronics, electrical machinery).

As discussed in Section 3.2, for robustness we also try a number of wage unit values constructed directly from the BEA data. Manufacturing affiliates are required by the BEA to report wage bills and employment separately for non-production and production workers, an

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[11] Firms responding to BEA surveys are, for the most part, instructed to denominate financial information in U.S. dollars valued in the prices and exchange rates of the year covered by the data.

[12] Approximately 90-95% of imports from the United States by foreign affiliates of U.S. multinationals are from parent firms. Even where affiliate imports come from an entity other than the parent, the parent may still have arranged the transaction. With

occupation classification that tends to separate more-skilled from less-skilled workers. So for each affiliate we construct wage unit values for non-production and production workers. We use these own-affiliate wage measures and also construct "outside" wage measures defined for each affiliate as the average wage paid by all other affiliates in the same country or country and industry. These outside wages may address the potential problem of endogeneity in affiliate-level wages, in that variation in affiliate wages may reflect variation in both in true prices for given labor quality and in labor quality itself.

Each foreign affiliate is classified in a single industry of primary business based on the distribution of sales across industries that it is required to report. For our 1994 data, the BEA uses an internal industry definition, the BEA International Surveys Industry (ISI) codes, that are closely related to the 1987 3-digit U.S. Standard Industrial Classification (SIC) codes. A foreign affiliate generally represents the consolidation of the U.S. direct investor's business operations in a host country in a single three-digit industry.[13] Controlling for parent-industry fixed effects require us to exclude from the sample any affiliates that are the sole affiliate of a parent/industry. This exclusion does not appear to be too severe. In 1994, for our initial sample of 8,014 manufacturing affiliates, this requires dropping 778 affiliates. The median number of affiliates per U.S. parent is 4, with a maximum of 146. There were 1,456 U.S. parent firms.

Our primary trade-cost measures are tariffs, non-tariff barriers (NTBs), and transportation costs. Tariffs are from the United Nations' TRAINS (Trade Analysis and Information System) CD-ROM. The original source data are classified by country and by 6-digit Harmonized System

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this in mind, the measure of affiliate imports we use is all U.S. imports, including imports from parent and non-parent entities. Estimation results from using just imports from parents are nearly identical to those we report below.

[13] The only exception to this rule is that foreign affiliate in the same host country, but in different three-digit industries, may be consolidated if they are integral parts of the same business operation. Industry classification follows a three-step procedure. First, the affiliate is classified in the one-digit industry that accounts for the largest percentage of its sales. Second, within that one-digit industry it is classified in the two-digit industry that accounts for the largest percentage of its sales. Third, within that two-digit industry it is classified in the three-digit industry that accounts for the largest percentage of its sales.

product codes.[14] Aggregation of the data from a 4-digit SIC basis to a 2/3-digit ISI basis was obtained by weighting the disaggregated data by the value of U.S. exports to the country. Data on NTBs also come from TRAINS. The original source data for these were at the 4-digit SIC level, which we then concorded to BEA industries as just described. This information is categorical, indicating presence or absence of NTBs tracked by TRAINS.

The transportation-cost data were generated from data files in Feenstra (1996), which report for each industry in each year imports in terms of both c.i.f. values and customs values.[15] For each observation we constructed transportation costs as (imports c.i.f. value - imports customs value) as a share of the customs value of imports. The original source data are classified on a 4-digit 1987 SIC basis; they were aggregated to a 2/3-digit ISI basis by weighting the disaggregated data by the value of total imports by the host country. Tariffs, NTBs, and transportation costs are all bilateral for the host country vis a vis the United States and all vary by country as well as industry as described. Distance and adjacency to the United States are two other possible proxies for trade barriers that we also include in our analysis. The adjacency indicator accounts for any trade barriers specific to Canada and Mexico (e.g., NAFTA).

We have two sources of data for corporate income tax rates. From Grubert (2001), we have country-level measures from the IRS Statistics of Income Division. Constructed from IRS tax returns of U.S. multinationals, these measure average effective tax rates facing these businesses. From the University of Michigan World Tax Database, we have statutory corporate income tax rates that measure maximum marginal tax rates facing these businesses. Because average and marginal tax rates may influence firms differently, we report results using both measures.

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[14] These data, plus a translation of them to a 1987 4-digit U.S. SIC basis were obtained from Jon Haveman.

[15] The c.i.f. value is the price of the goods plus packing costs, insurance, and freight charges to the port of entry. The customs value is the value of the goods at the port of export.

The remaining regressors capture additional host-country policies and characteristics. To measure market size in the host-country, we use Hanson and Xiang's (2002) measure of market potential, which defines market size in a country to be national GDP plus a distance-weighted sum of GDP in neighboring countries. We include an indicator variable for English as the primary language. We also include several policy-related regressors. One is an indicator for the presence of export-processing zones (EPZs). Collected from PriceWaterhouseCoopers, this variable captures a range of host-country export incentives. Using data from Shambaugh (2002), we also construct an indicator for whether the host country fixes the value of its currency to the U.S. dollar. Recent research (e.g., Frankel and Rose, 2002) finds that bilateral trade is stimulated by currency unions; we generalize from this evidence to examine whether host-country exchange-rate policy matters along the more-general fixed-versus-float margin. We use a measure of "country risk" from Business Environment Risk Intelligence, which is related to overall economic policy and the resulting political and economic risks (e.g., of wars and strikes). A final policy regressor is a collection of "economic freedom" measures collected by the Heritage Foundation and *The Wall Street Journal*. We average country index scores for respect for property rights, extent of government regulation, and prevalence of black-market activities, with higher scores indicating *less* economic freedom.

For the sample used to estimate our initial specifications of equation (7), Table 1 reports summary statistics for our regressand and several of our important regressors. For the average affiliate in our sample, 11% of its total costs are accounted for by imports from the United States of intermediate inputs for further processing. Average host-country/industry tariff and transportation-cost rates are both slightly over 5%. The mean marginal and average corporate tax rates are higher, at 34.4% and 25.7%. The mean less-skilled wage is only about one-half the average more-skilled wage. 17.3% of the affiliate observations are in either Canada or Mexico, and 31.0% of them are located in an English-speaking country.

3.2 Preliminary Evidence

Before showing regression results, Table 2a first shows patterns of vertical specialization by broad industry and country groups in our data. Each cell of this table reports the mean share of imported inputs for further processing as a share of total costs (proxied by total revenues). Means are weighted by affiliate total output.

Vertical specialization appears to be most prominent in regions that have both low trade costs and/or low labor costs vis a vis the United States. Mexico is the most obvious example. It is a low-wage country and in 1994 benefited not just from adjacency to the United States but from low trade barriers arising from the North American Free Trade Agreement (NAFTA). Canada is another example. While a high-wage country, it has even lower trade costs than Mexico. Canada's major production centers are located quite near industrial regions of the United States and it signed a free trade agreement with the United States in 1989, five years before NAFTA was implemented. Vertical specialization is also relatively common in East Asia. While distant from the United States, the region has moderate labor costs and open markets, at least in key export industries such as electronics. Consistent with theory, poor candidates for vertical specialization include regions with high labor costs and moderate to high trade costs (OECD Europe, OECD Japan) and regions with low labor costs but relatively closed markets (Other Latin America, which is dominated by the Mercosur countries of Argentina and Brazil; Other Asia, which is dominated by India; Africa; and the Middle East).

Apart from regional patterns, certain industries appear to be good candidates for vertical specialization. These include machinery, transportation equipment, and electronics, of which the largest sub-industry is computers. Several common features of manufacturing in these industries may make them amenable to global outsourcing. One is that production tends to involve distinct stages—design, component production, final assembly—that are physically separable. Firms need not perform these tasks in the same location, and so can locate different stages in different countries. Another feature is that production stages exhibit different factor intensities, with design activities and component production being more skill-intensive and assembly activities being more labor-intensive. To the extent that factor costs vary across countries, firms may have an incentive to locate labor-intensive activities in labor-abundant countries.

The broad sectoral and regional patterns evident in Table 2a hide variation across U.S. multinationals in the extent to which they choose to have their affiliates be vertically specialized. There may be important differences in business strategy across multinationals that make affiliates of, say, one semiconductor manufacturer more vertically specialized than affiliates of another. To control for differences in vertical specialization that are specific to the U.S. parent, in Table 2b we report the mean of imported inputs for processing (as a share of total revenues) as the deviation from the mean across affiliates of the same parent. Positive entries indicate cases where, across affiliates of the same parent, there is greater vertical specialization. Canada and Mexico stand out as cases where vertical specialization is especially strong.

In the regression analysis, we aim to uncover which factors drive the aggregate variation visible in Tables 2a and 2b. As a preview, Figure 1 plots the affiliate share of imported inputs in total revenues against the host-country/industry tariff rate facing that affiliate (or, more precisely, the log of one plus the tariff). Our discussion in Section 2 predicts a negative correlation between these two variables. Even without controlling for host-country labor costs and other factors, the unconditional correlation is indeed negative: the line of best-fit for a simple OLS regression of imported inputs on tariffs has a coefficient estimate of –0.721 (with a standard error of 0.073). We now turn to our more-systematic analysis.

4. Estimation Results

4.1 Main Results

Our baseline estimates of equation (7) use a relatively parsimonious set of regressors, upon which we then expand. Table 3 reports these baseline estimation results, which are OLS coefficient estimates with standard errors that allow for both arbitrary forms of heteroskedasticity and correlations in disturbances within parent-industry groups. Column 1 reports results using the statutory maximum marginal tax rate; column 2 replaces this regressor with the effective average tax rate. Each row reports coefficient estimates (and standard errors in parentheses). Both specifications also include 786 parent-by-industry dummy variables.

There are three notable results in Table 3. First is the role of tariffs. Imported intermediate inputs as a share of affiliate costs are strongly negatively correlated with host-country tariffs. Recall from Section 2.2 that host-country tariffs are a potentially important determinant of the price of imported intermediate inputs that affiliates face. Our estimates indicate that affiliates do in fact respond to tariff-induced changes in imported-input prices. The coefficient estimates from column 1 of Table 3 imply (from equation (4), using sample-average cost shares) that the own-price elasticity of demand for imported inputs is –2.747 (standard error of 0.860): a one-percent fall in input prices related to the markup due to tariffs leads to a nearly three-percent increase in the quantity of imported intermediate inputs.

This sensitivity of vertical specialization to tariffs is consistent with Yi's (2002) model in which small changes in tariffs produce large changes in production costs and thus input trade. Again, Yi hypothesizes that the dramatic growth in world trade does not accord with modest tariff declines if trade is in just final goods. Actual tariff declines can explain actual trade growth only with trade in intermediate inputs. Our empirical evidence is consistent with this theory.

A second notable finding in Table 3 is the sensitivity of vertical specialization to host-country labor costs. Imported-input demand is decreasing in host-country wages for low-skilled workers and increasing in host-country wages for high-skilled workers, with all coefficient estimates significant at standard levels. The coefficient estimates from column 1 of Table 3 imply (from equation (5), using sample-average cost shares) that the cross-price wage elasticities of demand for imported inputs are –0.237 (standard error of 0.082) for less-skilled labor and 0.367 (standard error of 0.091) for more-skilled labor. A one-percent fall in less-skilled wages leads to about a quarter-percent increase in the quantity of imported intermediate inputs, while a one-percent fall in more-skilled wages leads to about a third-percent decline in that quantity.

This responsiveness of vertical specialization to wages is at odds with much of the empirical work on multinationals that uses aggregate data. Consistent with models of vertical FDI, we find that foreign affiliates do more processing of imports the lower are low-skilled wages relative to high-skilled wages. This accords with intuition: imports for further processing and less-skilled labor, which is predominantly employed in production occupations, are expected to be complementary inputs. This difference in findings is likely due to our focus not on aggregate multinational operations but rather on a particular aspect—intra-firm trade of intermediate inputs—that accords more closely with theories of vertical FDI. Our evidence suggests that in reality, individual multinationals may span a range of activities and therefore may display both vertical and horizontal characteristics.

The third notable result of Table 3 is the important role played by other host-country policies and characteristics, many of which have received little attention in previous research. Important among these is host-country corporate taxes: imported-input demand is significantly lower in countries with higher corporate tax rates (either statutory marginal or effective average). This role for effective tax rates is consistent with anecdotal evidence (e.g., Hanson, 2001) that many governments give generous tax breaks to foreign firms that engage in export processing within their borders—an activity that very often involves vertically specialized affiliates that import large amounts of intermediate inputs. Many studies have examined how taxes affect aggregate FDI (Hines, 2001), but not on how they affect the composition of FDI.

Demand for imported intermediate inputs is higher for affiliates in Canada or Mexico, consistent with these countries enjoying lower trade costs with U.S. firms. Demand is lower the higher is the affiliate's capital intensity. This accords with the presumed complementarity between imported-input processing and less-skilled labor discussed above. There is a large amount of empirical evidence that capital and less-skilled labor tend to be substitutes (Hamermesh, 1993). Demand for imported inputs declines with distance, but this effect attenuates as distance grows. Table 3 shows no obvious role for affiliate output, which is consistent with production in affiliates being constant returns to scale. The correlation between either transport costs and English and imports of intermediates is statistically insignificant.

4.2 Additional Results

Table 4 expands the set of regressors. Relative to Table 3, the specifications in Table 4 drop as regressors output and transportation costs (because their estimated coefficients were not statistically different from zero in Table 3 and remained so in unreported other specifications) and the statutory marginal tax rate (because results on this variable are qualitatively quite similar to those for the effective average tax rate). Columns 1 and 2 each introduce a different set of regressors; column 3 combines them all.

Important correlations from Table 3 generally remain in Table 4. For example, in column 1 the coefficient estimate on tariffs imply that own-price elasticity of demand for imported inputs is –4.443 (standard error of 0.987); the analogous wage estimates imply cross-price elasticities of demand for imported inputs of –0.171 (standard error of 0.087) for less-skilled labor and 0.353 (standard error of 0.097) for more-skilled labor.

Column 1 of Table 4 adds five additional policy variables. Affiliate reliance on imported intermediate inputs is higher in host countries with export-processing-zone policies. This is consistent with evidence that export processing often involves vertically specialized affiliates. The results for NTBs are puzzling: imported intermediates as a share of affiliate costs are positively correlated with NTBs. To the extent that NTBs are trade barriers that raise the real cost of imports, the opposite correlation might be expected. We suspect that problems with the NTB data may matter here. NTBs do not measure whether quantitative restrictions on trade bind, but rather whether governments have the option of imposing them. Other studies have found, controlling for tariffs, perverse effects of NTBs, as well. There is no consistently significant effect for any of the remaining three policies in column 1: value-added tax rates; fixed exchange rates with the U.S. dollar; and a measure of policy openness to FDI.

One other correlation of note in column 1 is that affiliate imported intermediate inputs are higher the higher is the materials share of sales in the United States for that affiliate's industry. This U.S. materials share may reflect the technological feasibility of an industry to have its constituent activities organized in global production networks.

Column 2 of Table 4 adds three new country-level indicators of broad policies and the market environment. Affiliate reliance on imported intermediate inputs is lower in countries situated in regions with larger market potential. This is consistent with horizontal theories of FDI, in which multinationals located in markets with larger local demand are more oriented towards producing for local consumers and less oriented towards producing for global vertical production networks. Affiliate reliance on imported intermediate inputs is higher in host countries with higher levels of economic freedom. This is consistent with the idea that global production networks are, by definition, intricate structures for which businesses prefer locations with clearer property rights and less regulation. Finally, there is no clear correlation between vertical specialization and our measure of country risk.

The final column of Table 4 combines all new regressors from the first two. The magnitude and significance of coefficient estimates is mostly unchanged in this larger specification. We take this collective evidence from Table 4 to arrive at our "preferred specification" that eliminates several regressors whose estimated coefficients were consistently not statistically different from zero.

Results for this preferred specification appear in the first column of Table 5. All coefficient estimates have the same sign as in earlier tables, and all differ from zero at or near standard significance levels. For this preferred specification, the implied own-price elasticity of demand for imported inputs is –4.799 (standard error of 0.985): a one-percent fall in input prices related to the markup due to tariffs leads to a nearly five-percent increase in the quantity of imported intermediate inputs. The implied cross-price wage elasticities of demand for imported inputs are –0.287 (standard error of 0.086) for less-skilled labor and 0.399 (standard error of 0.088) for more-skilled labor. Thus, the inclusion of additional controls raises the absolute value of the estimates for our elasticities of interest.

The next column of Table 5 estimates the same specification using Tobit rather than OLS. We needed to sharply reduce the number of fixed effects in this specification: from 786 parent-industry fixed effects to just eight industry effects. Many of the coefficient estimates retain the same sign and pattern of significance—e.g., on tariffs and wages. But other estimates do change magnitude (or even sign for corporate taxes) and significance. This apparent instability of the Tobit estimates was confirmed in unreported results where we experimented with a larger number of dummy variables. As discussed in Section 2, there are concerns about the sensitivity of these Tobit estimates to the nature of included fixed effects. Nevertheless, the broad patterns appear to match those of the OLS estimates.

The final column of Table 5 estimates our preferred specification where we replace our parent-industry controls with a full set of 105 country controls. The cost of these country controls is the need to exclude all variables that vary across countries only. The benefit is that this allows a check whether the estimates for the tariff regressor are affected by unobserved, country-specific factors. For instance, countries with lower tariffs may also enact other policies that are attractive to firms engaged in export processing. The results in column 3 suggest that this is not the case. Even with a full set of country controls, the coefficient on the tariff (and other industry-varying regressors) is virtually unchanged.

Beyond what is reported in Table 5, we have experimented with other specifications. One uses alternative measures of key regressors. We constructed industry tariffs and transportation costs using arithmetic rather than trade-weighted averages. We also measured wages a number of different ways using wage data collected directly by the BEA—e.g., the production and non-production wage unit values paid by each affiliate (see discussion in Section 2). The coefficient estimates were qualitatively unchanged for these different measurement options of our key regressors. A second alternative specification defines imported inputs for further processing to be those purchased from the parent firm, directly (thus excluding imported inputs purchased from third parties or from countries other than the United States). This change in the definition of the dependent variable has virtually no impact on our results. This is hardly surprising, since, as discussed earlier, imports of inputs from parent firms constitute the vast majority of total imported intermediates by affiliates.

5. Conclusion

In this paper, we examine trade in imported inputs for further processing between U.S. multinational parents and their affiliates in foreign countries. These shipments of intermediate inputs provide a direct measure of vertical specialization within multinationals. Theory suggests that input processing by foreign affiliates may be determined by host-country trade costs and factor prices, among other variables. Our results broadly support this prediction.

Among our main findings are that affiliate demand for imported inputs decreases in direct proportion to host-country tariffs, host-country wages for less-skilled labor (absolutely and relative to host-country wages for more skilled labor), and host-country corporate income tax rates. Demand for inputs is also affected by other host-country policies and characteristics, including the presence of export processing zones and the size of the host-country market.

The sensitivity of multinational trade in intermediate inputs to tariffs that we find is consistent with Yi (2002), who shows that in the presence of vertical specialization small changes in tariffs can produce large changes in trade flows. The responsiveness of vertical specialization to the wages of less-skilled and more-skilled labor is consistent with theories of vertical FDI, in which multinationals go abroad to take advantage of international differences in factor prices. More generally, our results suggest that multinationals tailor the nature of their foreign operations in response to local market conditions. They appear to make affiliates more oriented toward producing for local consumers (and so more vertically integrated) in countries with higher wages, higher tariffs, and larger markets, and they appear to make affiliates more oriented toward processing inputs imported from abroad (and so more vertically specialized) in countries with lower wages, lower tariffs, and smaller markets.

Our results also suggest that other host-country policies influence vertical specialization, sometimes in unexpected ways. Lower corporate income tax rates appear to be associated with greater vertical specialization. While both theory and empirical work have shown that lower corporate taxes in a country are generally associated with greater FDI inflows, there has been little work on whether taxes affect how multinationals organize their foreign operations. These results we consider to be directions for future research.

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Table 1: Summary Statistics

Variable	Mean (s.d.)
Imported-Input Share	0.110
	(0.176)
More-Skilled Wages	28.647
($, Thousands)	(17.173)
Less-Skilled Wages	14.804
($, Thousands)	(7.927)
Tariff Rate	0.054
(ad valorem)	(0.052)
Transportation Costs	0.049
(ad valorem)	(0.141)
Tax Rate, Marginal	0.344
	(0.056)
Tax Rate, Average	0.257
	(0.098)
Distance to United States	7,078.673
(Kilometers)	(4068.928)
Adjacent to United States	0.173
	(0.378)
English Speaking	0.310
	(0.463)
No. Observations	4,285

Notes: Each cell reports the variable mean and, in parentheses, its standard deviation. These statistics are for the sample used in the baseline estimates reported in Table 2. See text for details on variable definitions and construction.

Source: Authors' calculations using data from the U.S. Bureau of Economic Analysis and other sources.

Table 2a: Imported Intermediate Inputs, by Industry and Region for 1994

Region Industry	Canada	Mexico	Other Lat.Am.	OECD Europe	OECD Asia	East Asia	Other Asia	Africa	Middle East	World
Chemicals	18.92	12.35	9.44	4.90	9.87	15.51	8.57	--	--	7.62
Metals	19.23	23.13	--	--	7.88	13.79	--	15.51	4.14	8.24
Machinery	37.19	44.24	9.95	8.20	7.42	8.62	6.06	4.79	10.98	10.98
Electronics	20.16	40.82	21.14	9.83	17.89	26.98	1.49	13.34	4.39	17.44
Transportation	50.36	45.67	3.36	2.33	5.11	6.21	--	--	--	21.39
Other Mfg	18.15	13.29	--	--	11.82	7.27	--	2.33	8.89	8.89
Total	38.66	36.70	8.45	5.64	10.41	15.24	4.46	11.79	4.48	13.59

Notes: This table shows means by one-digit industry and geographic region of the share of imported inputs for further processing in total revenues for foreign affiliates of U.S. multinational enterprises. Means are weighted by affiliate total output. The Other Europe region is excluded from the table due to disclosure restrictions (there are few affiliates per industry in the region). The same applies to entries that read, "--." The sample is 4,285 majority-owned foreign affiliates of U.S. multinationals that belong to a parent that has as least two foreign affiliates. The year is 1994.

Source: Authors' calculations using data from the U.S. Bureau of Economic Analysis.

Table 2b: Imported Intermediate Inputs, Deviations from Parent Means

Region Industry	Canada	Mexico	Other Lat.Am.	OECD Europe	OECD Asia	East Asia	China	Other Asia	Africa	Middle East	World
Chemicals	7.89	3.52	-0.26	-4.05	-2.03	3.78	-4.85	0.69	0.12	-5.26	-1.93
Metals	11.54	14.94	1.44	-2.48	-0.58	5.36	1.48	-6.27	-4.66	3.44	1.24
Machinery	25.16	29.02	-0.38	-2.55	-3.08	-8.00	-6.64	-1.47	7.5	-22.54	-0.97
Electronics	3.61	23.18	5.96	-3.25	6.17	11.11	7.53	-11.73	0.11	-12.87	3.28
Transportation	28.22	20.62	-10.57	-14.93	-15.65	-16.13	--	-15.1	-2.19	--	1.97
Other Mfg	6.61	4.35	-0.93	-4.27	-2.79	0.76	-1.42	-8.95	-2.55	-7.74	-2.11
Total	21.01	17.55	-2.73	-6.4	-2.11	-0.06	0.65	-4.29	-0.89	-12.69	0.08

Notes: This table shows the mean share of imported inputs for further processing in total revenues for foreign affiliates of U.S. multinationals minus the mean share for all foreign affiliates that share the same U.S. parent. Entries are weighted by total affiliate output. See notes to Table 2a for other details on table definitions, data sources, and sample definition.

Table 3: Estimation Results, Baseline Specifications

Regressor	(1)	(2)
More-Skilled Wages	0.028	0.029
	(0.010)	(0.010)
Less-Skilled Wages	-0.037	-0.036
	(0.009)	(0.009)
(1 + Tariff Rate)	-0.204	-0.205
	(0.094)	(0.095)
(1 + Transport Costs)	-0.020	-0.010
	(0.031)	(0.030)
(1 – Marginal Tax Rate)	0.080	
	(0.027)	
(1 – Average Tax Rate)		0.058
		(0.024)
Distance	-0.220	-0.250
	(0.102)	(0.104)
Distance^2	0.015	0.017
	(0.006)	(0.006)
Adjacency	0.184	0.194
	(0.030)	(0.031)
English Speaking	0.010	0.007
	(0.007)	(0.007)
Capital Stock	-0.007	-0.007
	(0.003)	(0.003)
Output	0.001	0.001
	(0.005)	(0.005)
Controls	Parent-Industry	Parent-Industry
No. of Observations	4,285	4,285
R-squared	0.46	0.46

Notes: Cell entries are OLS parameter estimates (and standard errors) for equation (7). Each column estimates a specification of (7) using the regressors of that column. All specifications also include 786 parent-by-industry dummy variables. All variables are in logarithms except the dichotomous variables Adjacency and English Speaking. See text for equation (7) and details on variable definitions and construction.

Table 4: Estimation Results, Expanded Specifications

Regressor	(1)	(2)	(3)
More-Skilled Wages	0.027	0.029	0.036
	(0.011)	(0.010)	(0.010)
Less-Skilled Wages	-0.030	-0.046	-0.049
	(0.010)	(0.010)	(0.011)
(1 + Tariff Rate)	-0.392	-0.133	-0.376
	(0.109)	(0.113)	(0.130)
(1 – Average Tax Rate)	0.068	0.015	0.038
	(0.029)	(0.028)	(0.033)
Distance	-0.255	-0.039	-0.179
	(0.139)	(0.116)	(0.154)
Distance^2	0.016	0.003	0.010
	(0.008)	(0.007)	(0.009)
Adjacency	0.113	0.179	0.106
	(0.035)	(0.033)	(0.042)
English Speaking	0.009	-0.006	-0.001
	(0.007)	(0.010)	(0.010)
Capital Stock	-0.007	-0.007	-0.007
	(0.002)	(0.002)	(0.002)

Notes: See continuation of this table on next page.

Table 4: Estimation Results, Expanded Specifications

Regressor	(1)	(2)	(3)
U.S. Materials Share of Sales	0.073		0.071
	(0.047)		(0.045)
Non-Tariff Barriers	0.031		0.021
	(0.011)		(0.012)
Export-Processing Zones	0.068		0.074
	(0.017)		(0.021)
(1 – Value-Added Tax Rate)	0.098		-0.047
	(0.053)		(0.071)
Fixed Exchange Rate w/ U.S.	0.017		0.004
	(0.015)		(0.020)
FDI Openness	-0.005		0.006
	(0.007)		(0.007)
Market Potential		-0.045	-0.053
		(0.014)	(0.016)
Country Risk		0.000	0.001
		(0.000)	(0.001)
Economic Freedom		-0.038	-0.032
		(0.010)	(0.010)
Controls	Parent-Industry	Parent-Industry	Parent-Industry
No. of Observations	4,274	4,095	4,085
R-squared	0.47	0.48	0.48

Notes: Cell entries are OLS parameter estimates (and standard errors) for equation (7). Each column estimates a specification of (7) using the regressors of that column. All specifications also include 786 parent-by-industry dummy variables. All variables are in logarithms except the dichotomous variables Adjacency, English Speaking, Non-Tariff Barriers, Export-Processing Zones, and Fixed Exchange Rates. See text for equation (7) and details on variable definitions and construction.

Table 5: Estimation Results, Robustness Checks

Regressor	(1)	(2)	(3)
More-Skilled Wages	0.032	0.070	
	(0.010)	(0.013)	
Less-Skilled Wages	-0.043	-0.097	
	(0.010)	(0.013)	
(1 + Tariff Rate)	-0.431	-0.641	-0.433
	(0.109)	(0.134)	(0.164)
(1 – Average Tax Rate)	0.049	-0.015	
	(0.025)	(0.032)	
Distance	-0.236	-0.131	
	(0.114)	(0.122)	
Distance^2	0.014	0.006	
	(0.007)	(0.007)	
Adjacency	0.095	0.070	
	(0.034)	(0.028)	
Capital Stock	-0.006	-0.001	-0.007
	(0.002)	(0.002)	(0.002)
U.S. Materials Share of Sales	0.070	0.038	0.072
	(0.047)	(0.018)	(0.046)
Non-Tariff Barriers	0.026	0.024	0.022
	(0.011)	(0.011)	(0.013)
Export-Processing Zones	0.081	0.128	
	(0.016)	(0.019)	
Market Potential	-0.034	-0.088	
	(0.011)	(0.013)	
Economic Freedom	-0.026	-0.072	
	(0.006)	(0.010)	
Controls	Parent-Industry	Industry	Country
No. of Observations	4,238	4,238	4,314
R-squared	0.48	0.29	0.48

Notes: Cell entries are parameter estimates (and standard errors) for equation (7). Columns 1 and 3 use OLS, column 2 uses Tobit. Column 1 includes 786 parent-by-industry dummy variables; column 2 includes eight industry controls; and column 3 includes 105 country controls. Each column estimates a specification of (7) using the regressors of that column. All variables are in logarithms except the dichotomous variables Adjacency, Non-Tariff Barriers, and Export-Processing Zones. See text for equation (7) and details on variable definitions and construction.

Figure 1: Raw Correlation between Imported Inputs and Tariffs