DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 15-08

Asymmetric effect of uncertainty on intrafirm trade in the durable and the nondurable industries

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October 2015

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Job Market Paper

October 2015

Abstract

I investigate demand uncertainty as a determinant of the 'make-or-buy' problem of multinational firms. Under uncertainty, firms face trade-offs between outsourcing and vertical integration: while outsourcing requires less initial investment and allows easier entry and exit, vertical integration offers a better management and communication system. I argue that the relationship between uncertainty and the choice of sourcing mode depends on the durability of the final goods that a firm produces. Under uncertainty, firms in the durable industries prefer vertical integration, which offers a better management ability. In the nondurable industries, however, the inelastic demand makes firms less sensitive to uncertainty when they choose between outsourcing and vertical integration. The effect of uncertainty, therefore, is weaker in the nondurable industries. I show these relationships based on the simple model of Grossman and Helpman (2002). US industry-level intrafirm trade data exhibit consistent results: The more uncertain an industry's demand is, the more intrafirm trade there is in the durable industries, but this relationship is not found in the nondurable industries. This study offers a theoretical model and empirical evidence of uncertainty as a determinant of the firm boundaries.

Keywords: uncertainty, outsourcing, vertical integration, multinational, durable good
JEL Classification Numbers: D20, F14, F23, L23.

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I would like to thank Martin Boileau, Thibault Fally, Keith Maskus, James Markusen, Terra McKinnish, Hyunbae Chun, as well as seminar and conference participants at Sogang University, European Trade Study Group, Midwest International Trade Meeting, and Western Economic Association Annual Meeting for helpful comments. All remaining errors are mine.

1 Introduction

As Ronald Coase wrote in 1937, expecting the future wants of consumers and producing accordingly before the demand is realized is a fundamental problem that firms face. They often need to make decisions on the quantity and price of their production before they know the market demand. This gap between production decisions and the realization of demand affects, among other things, firms' choice of boundaries, i.e. whether to supply required intermediate goods from integrated producers (vertical integration) or in arm's length (outsourcing),[1] because the two choices have tradeoffs in dealing with the uncertainty. This paper investigates the effect of demand uncertainty on firms' choice of vertical integration versus outsourcing in an open economy.

The tradeoffs between outsourcing and vertical integration under demand uncertainties[2] are as follows. On the one hand, outsourcing requires smaller initial sunk costs and allows easier entry and exit of the market. Real option literature finds that uncertainties make firms more cautious about investment (Guiso and Parigi, 1999; Bloom et al., 2007). Outsourcing, therefore, is attractive under uncertainty, especially when investment is irreversible and intermediate goods are customized. On the other hand, vertical integration offers a secure supply of intermediate goods even when the demand of the final goods or the supply of the intermediate goods undergo shocks. A better management ability, such as effective communication systems or inventory management, helps firms to securely supply intermediate goods. Transaction cost economics (TCE), therefore, claims that vertical integration fares better than arm's length transactions under uncertainty.

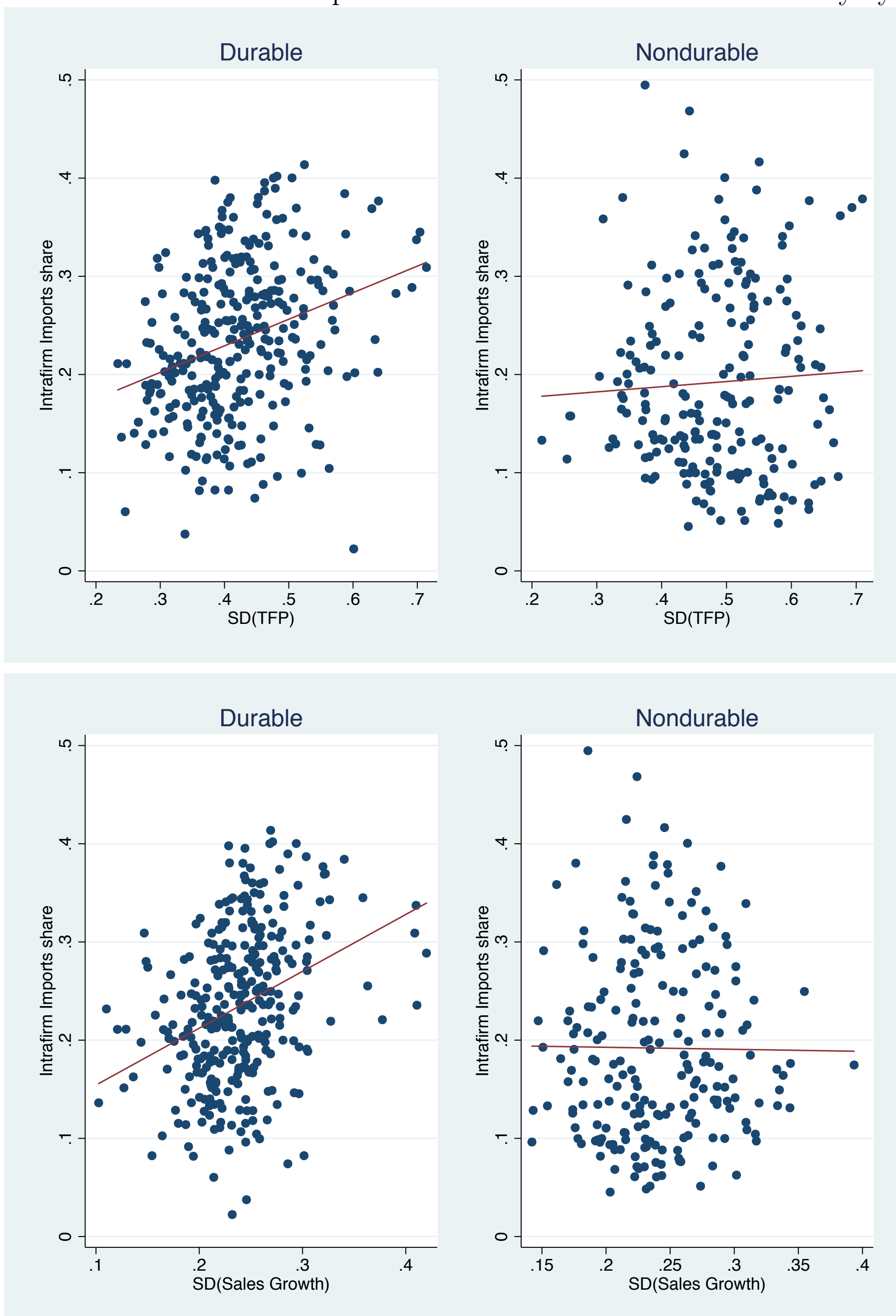
In the data, the claim of TCE holds only in the durable industries. Figure 1 plots the level of vertical integration measured by the share of US intrafirm imports[3] and the

[1] It is important to define the two organizational forms to understand their tradeoffs. I follow the general definitions of industrial organization literature: vertical integration means 'the unification of control rights' (Gibbons, 2005, p.203) when a downstream party owns an upstream party. Outsourcing means when an upstream party supplies intermediate goods under contract without the ownership or the control of downstream party on the upstream.

[2] My use of demand uncertainty is close to the context of microeconomic uncertainty, resulting from changes in preference, for example. See Bloom et al. (2012) for recent discussions on the concepts and definitions of uncertainty.

[3] I use the related-party transactions data from US Census Bureau as proxy of intrafirm trade. A transaction is defined to be between 'related-party' if one party has more than 6% (10%) of ownership of the other party in case of imports (exports).

Figure 1: The share of intrafirm import transactions and demand uncertainty by durability



Notes: Intrafirm imports share is the share of related party imports out of all imports in the US. For the variable of demand uncertainty, the top panel uses the standard deviation of plant level TFP shocks and the bottom panel uses the standard deviation of plant level sales growth in 4-digit NAICS manufacturing industries. Uncertainty variables are from Bloom et al. (2012). All variables span 2002 through 2009, and were measured on a yearly basis.

demand uncertainty measured by the standard deviation of plant-level total factor productivity (TFP) shocks (top) and sales growth (bottom). On both top and bottom of the left panels, which represent the durable industries, the relationship between uncertainty and the choice of vertical integration is positive. In the nondurable industries on the right panels, however, intrafirm imports share is insensitive to uncertainty. The choice of sourcing modes is consistent with TCE, which claims that vertical integration fares better than outsourcing under uncertainty, in the durable industries but not in the nondurable industries.

Why does durability affect the relationship between uncertainty and the choice of vertical integration? I argue that it is because of the very nature of demand for durable and nondurable goods. Durable goods (such as cars and electronics) tends to have more elastic demand than nondurable goods (such as food, beverage, and clothing).[4] Elastic demand implies a larger change in consumption in response to a shock. As uncertainty increases, therefore, integration is more attractive to firms in the durable industries because it offers better ability to stabilize prices and profits. Firms in the nondurable industries, however, face a lower impact of uncertainty on consumption and their choice of firm boundaries is not as sensitive as firms in the durable industries.

One may dispute that uncertainty itself is higher in the durable industries. In data used in Figure 1, however, the average standard deviation of TFP shocks is significantly lower in the durable industries than in the nondurable industries at the 1 percent level.[5] What causes the asymmetry in the durable and the nondurable industries, therefore, is not the absolute size of uncertainty but the sensitivity of response. Another possible reason behind the asymmetry is the different lengths of the gap between production and sales in the durable and the nondurable industries. Durable goods are generally more complicated and seem to require more stages of production to get finished products. This would imply longer gaps between production and sales, (which is also called 'lead time' in the management literature,) and more uncertainty. However, while durable industries are more skill- and R&D-intensive,[6]

[4]It is a well-known fact in macroeconomics that the fluctuation of durable consumption is much larger than nondurable consumption along with business cycles. See Baxter (1996), for example. This paper, however, focuses on the static equilibrium of firm boundaries, rather than the change of firm boundaries along with business cycles.

[5]See Table 3 in section 3 for details.

[6]Again, see Table 3 in section 3 for details.

their average number of production stages is statistically significantly shorter than the nondurable industries according to a measure by Fally (2012). Whether the lead time is longer for durable goods, therefore, is unclear. Thus, I claim that the elasticity of demand is the key reason behind the asymmetric effect of uncertainty on the durable and the nondurable industries.

Before describing the model, I note that it is important to study the demand uncertainty as a determinant of firm boundaries in an international setting, especially in the US. It is because the volume of international intrafirm transactions is much larger than the domestic intrafirm transactions in the US. In 2012, 53% of all imports was through related-party transactions in the US manufacturing industries. Less than 1% of domestic US firms, however, have physical intrafirm transactions according to Atalay et al. (2014). While trade economists have actively studied the determinants of intrafirm trade,[7] the effect of uncertain demand was not explored much in the literature.[8] I also note that the sourcing decisions are made at the firm level, but the equilibrium of the model is discussed at the industry level because the industry equilibrium is proved to have a single pervasive mode of production.

I develop a model that describes the effect of demand fluctuation on the choice of outsourcing versus vertical integration. Based on a simplified version of the Grossman and Helpman (2002), I introduce uncertain demand as in Carlton (1979), which yields the lag between the time of production and the time of actual sales. Firms experience profit losses

[7] The literature of the make-or-buy problem of multinational firms has mainly two strands. One emphasizes the non-rivalry and the non-excludability of knowledge and shows that the choice of production mode depends on the importance of the knowledge-capital (Ethier and Markusen, 1996; Horstmann and Markusen, 1987; Glass and Saggi, 2002). The other strand of the literature is based on the firm theory, especially the property-right approach by Grossman and Hart (1986) and Hart and Moore (1990) where the tension between incentive and holdup problem plays the central role in determining the mode of production. Known determinants in this literature include capital-intensity (Antràs, 2003), the product cycle (Antràs, 2005), financial constraints of firms (Carluccio and Fally, 2012), and tariffs (Díez, 2013). Nunn and Trefler (2013) support this view by providing empirical evidence using the data of US manufacturing industries. Costinot et al. (2011) use adaptation firm theory to show that the routineness of the tasks is related to the boundaries of firms, and Chen et al. (2012) combines the two views above and provide a more comprehensive approach.

[8] One exception is Carballo (2014), who studies the effect of overall uncertainty on firms' sourcing options and responses to economic crises. There is, however, a large literature on the effect of uncertainty on the boundary of firms outside of international trade. The strength of firm system under uncertainty is consistently emphasized in transaction cost economics (Williamson, 1985, 2000, 2002): internal organization (vertical integration) has better adaptability to high uncertainty than arm's length production, especially when asset specificity is greater. Carlton (1979) assumes that in-house production of intermediate goods offers cheaper prices whereas buying additional amount from arm's length transmits the risk of unsold goods. He shows that final-good producers always choose some degree of vertical integration and cover the inputs for 'low-probability demand' from the market.

when expected and realized demands are different. When realized demand is higher than expected, firms lose potential sales, which causes extra costs (for example, compensation to disappointed customers to keep the firm's reputation.) When realized demand is lower than expected, firms lose the production costs of leftover goods.[9] Under this setting, the model provides valid trade-offs of the two sourcing options: outsourcing requires lower initial fixed costs, and integration offers a better adaptability to uncertainties.

The prediction of the model depends on the durability of the products. The model shows that, in the durable industries, vertical integration is more profitable under uncertainty as long as the compensation to customers are positive and marginal cost of vertical integration is higher than outsourcing. Note that higher marginal costs of vertical integration also imply a higher adaptability under uncertainty than outsourcing. This result shows that the corporate-level adaptability is more important than savings in the initial investment under uncertainty in the durable industries. This prediction, however, does not hold in the nondurable industries. Uncertainty affects the equilibrium prices and the profitability of sourcing modes of both integrated and outsourcing firms. In the nondurable industries, however, inelastic demand implies that the resulting sales under uncertainty is more stable than under the durable industries. Firms in the nondurable industries, therefore, have less incentive to choose vertical integration and invest in the management system.

I confront the predictions of the model using US 6-digit NAICS industry-level intrafirm trade data in the manufacturing sector. Specifically, I use the difference-in-differences method with panel fixed effects to estimate the influence of the uncertainty of final goods on the sourcing options for intermediate goods in the durable and nondurable industries. The measure of sourcing mode is the share of intrafirm imports,[10] and the measures of uncertainty are standard deviation of TFP shocks and sales growths as used in Figure 1. The empirical results show that the intrafirm imports are positively and significantly correlated with demand uncertainty in durable industries but not in the nondurable industries, as Figure 1

[9] Note that I do not consider the inventory management for simplicity of the model. See the companion paper Lee (2015) for the intrafirm trade model with inventory.

[10] Note that, due to the data availability, the sourcing mode variable is binary in the theoretical model but is continuous in the empirical analysis.

illustrates.

The baseline estimation results indicate that the durable industries increase the share of intrafirm imports by 68.2 percentage points more than nondurable industries in response to one standard deviation increase in the dispersion of sales growth. This result implies that as uncertainties increase, the benefit of better management and the securement of the input supplies under uncertainty outweighs the benefit of lower sunk cost in the durable industries. The results are robust to other estimation strategies and alternative measures of demand uncertainty and sourcing options.

This paper unveils a new empirical regularity regarding the asymmetric patterns of international sourcing modes in the durable and the nondurable industries under uncertainty, and explains the asymmetry based on the traditional lens of the transaction cost economics. The finding that the effect of uncertainty on the sourcing modes depends on the durability of final goods provides a rationale for why the predictions about uncertainty and firm boundaries in the literature are mixed.[11] Also, this paper is one of a few studies about the effect of uncertainty on the international trade of intermediate goods. While Carballo (2014) focuses on how macroeconomic uncertainty affects sourcing decisions of firms, this paper focuses on the industry-equilibrium modes of firm boundaries under microeconomic uncertainty.

The next section describes the general equilibrium model, and section 3 discusses the empirical analysis. Section 4 presents extensions and robustness analysis. Section 5 concludes.

2 A Simple Model

The theoretical model in this section is based on a simplified version of Grossman and Helpman (2002). I incorporate the demand uncertainty to the model of outsourcing versus

[11] The literature has mixed predictions on the relationship between uncertainty and the choice of organization. Simon (1951) and Williamson (1975) analyze the adaptability of market and firm to the unexpected circumstances and emphasize the benefits of integrated organizations under uncertainty. Carlton (1979) provides a theory of firm with uncertain demand and shows that firms have an incentive to at least partially integrate the input-supplier for more volatile demand. This theory is empirically tested by Lieberman (1991): using the data of chemical-products industries, he shows that both demand variability (of the final good) and transaction costs are important determinants of vertical integration. Some theoretical studies (Blair and Kaserman, 2014; Fossati, 2012) report the opposite result where firms choose more outsourcing when there are more demand uncertainties, since the benefit of flexibility of outsourcing due to lower sunk cost is more emphasized.

vertical integration in industry equilibrium. First I describe the model with certain demand, then compare it with uncertain demand to show the effect of uncertainty on the choice of sourcing mode in the durable and the nondurable industries.

2.1 Certain demand

There are J industries in the economy: each industry produces differentiated varieties in a monopolistically competitive fashion as in Dixit-Stiglitz. The preference of the representative consumer is:

$$u = \sum_{j=1}^{J} \mu_j \log \left[\int_0^{N_j} y_j(i)^{\alpha_j} di \right]^{1/\alpha_j}. \tag{1}$$

Industry j produces N_j differentiated varieties, and C_j is the representative consumer's composite consumption in industry j. I assume that $\sum_{j=1}^{J} \mu_j = 1$ where μ_j is the proportion of expenditure on or the size of demand for industry j. The elasticity of substitution among the differentiated varieties σ_j is constant in industry j; $\alpha_j = \frac{\sigma_j - 1}{\sigma_j}$ represents the degree of product differentiation where higher α_j indicates less differentiation (and higher substitutability.) The consumption of variety i in industry j is $y_j(i)$. As is well known, this utility function yields the following demand function for the differentiated variety i:

$$y_j(i) = \mu_j A_j p_j(i)^{-1/1-\alpha_j}; \quad A_j = \frac{E}{\int_0^{N_j} p_j(i)^{-\alpha_j/1-\alpha_j} di}, \tag{2}$$

where E is the total expenditure, which is equivalent to the total wage of the economy.

In industry j, there are three types of firms: vertically integrated firms (v-firm), specialized final good producers (s-firm), and specialized input producers (m-firm). Since the firm structure of every industry is symmetric, I drop the industry index j from here. Vertically integrated firms produce final goods using in-house produced intermediate goods. Specialized final-good producers outsource intermediate goods to specialized input producers. Integrated firms and specialized final good producers have identical production functions for final goods. Both integrated firms and specialized final good producers have the ability to transform one unit of intermediate good into one unit of final good. The ability to produce intermediate goods, however, depends on the type of firms. The marginal cost of producing one unit of intermediate good is one unit of labor for specialized input producers, and λ unit of labor for integrated firms where $\lambda > 1$. Integrated firms are assumed to require a higher marginal cost of producing intermediate goods because their level of specialization is lower than independent producers and their size of the firm requires higher bureaucracy costs. While larger institutions spend more operation costs, they offer better management, communication, and adaptability under uncertainties.

Each firm requires fixed costs for entry: the fixed costs of vertically integrated firms, specialized input producers, and specialized final-good producers are k_v, k_m, and k_s unit of labor, respectively, for all varieties. I assume that $k_s + k_m \leq k_v$: entering as a vertically integrated firm requires higher fixed costs than the sum of the two specialized firms because a firm needs to acquire (or merge with) another firm to be vertically integrated.

Once entering the market, one supplier (m-firm) produces $x(i)$ units of specialized input, then the partnered final-good producer (s-firm) produces $y(i) = x(i)$ units of final goods. The revenue from the final good sales is $p(i)x(i)$, and the two firms bargain over the revenue with ω share to the supplier and $1 - \omega$ to the final-good producer. If the negotiation fails, both parties receive zero revenue. Suppliers may choose between high- and low-quality inputs, but if they choose low-quality inputs, there will be no transactions, and the m-firm loses all the costs that already incurred. Thus, m-firms always produce high-quality inputs and choose the quantity $x(i) = \mu A(\alpha\omega)^{1/1-\alpha}$ to maximize the expected profit. Combining this supply with the demand in equation (2) yields the equilibrium price under outsourcing:

$$p_O = \frac{1}{\alpha\omega}, \tag{3}$$

with the quantity of final-goods equal to

$$y_O = \mu A(\alpha\omega)^{1/1-\alpha}. \tag{4}$$

The equilibrium price and quantity yields the following expected profit of a supplier:

$$\pi_m = (1 - \alpha)\omega\mu A(\alpha\omega)^{\alpha/1-\alpha} - k_m. \tag{5}$$

Knowing this, the final-good producer imposes transfer $T = \pi_m$ to suppliers. Thus, the expected profit from outsourcing when entering the market is:

$$\pi_O = (1 - \omega)\mu A(\alpha\omega)^{\alpha/1-\alpha} - k_s + T = (1 - \omega\alpha)\mu A(\alpha\omega)^{\alpha/1-\alpha} - k_o \tag{6}$$

where $k_o = k_s + k_m$.

Vertically integrated firms also choose the quantity, $x(i) = y(i)$ to maximize their profit. Combined with the market demand, the equilibrium price of vertically integrated firms is:

$$p_V = \frac{\lambda}{\alpha} \tag{7}$$

with the quantity of final-goods equal to

$$y_V = \mu A \left[\frac{\alpha}{\lambda}\right]^{1/1-\alpha}. \tag{8}$$

Thus, the expected profit of a vertically integrated firm is:

$$\pi_V = (1 - \alpha)\mu A \left[\frac{\alpha}{\lambda}\right]^{1/1-\alpha} - k_v. \tag{9}$$

In summary, the sequence of events is as follows: 1) Entry: All three types of firms enter the market paying the fixed costs. 2) Non-frictional match: Every specialized firm is matched with the other type of specialized firm. 3) Production 1: both integrated and specialized firms produce intermediate goods 4) Bargaining: Specialized firms bargain over the expected profits. 5) Production 2: Production and sales of final goods.

In the industry equilibrium, all firms make zero profits because of free-entry. For outsourcing firms to break even, from equation (6),

$$A_O = \frac{k_o}{(1-\omega\alpha)(\alpha\omega)^{\alpha/1-\alpha}} \tag{10}$$

and for integrated firms to break even, from equation (9),

$$A_V = \frac{k_v}{(1-\alpha)(\alpha/\lambda)^{\alpha/1-\alpha}}. \tag{11}$$

If an industry is in an equilibrium with pervasive outsourcing, an integrated firm would benefit if $A_O \geq A_V$. Conversely, if an industry is in an equilibrium with pervasive integration, an outsourcing firm would benefit if $A_V > A_O$. Thus, each industry has a single mode equilibrium: pervasive vertical integration if $A_O \geq A_V$, and pervasive outsourcing if $A_V > A_O$. Also, as the ratio of the break-even demand level,

$$\frac{A_V}{A_O} = \frac{(1-\alpha\omega)}{(1-\alpha)}(\omega\lambda)^{\alpha/1-\alpha}\frac{k_v}{k_o} \tag{12}$$

increases, outsourcing is more likely. Outsourcing, therefore, is more likely when the fixed costs of integration is relatively higher than the fixed costs of outsourcing (k_v/k_o), the marginal cost of integration (λ) is higher, or the bargaining share of supplier (ω) is higher.

2.2 Uncertain demand

Now consider a mean-preserving spread of the certain demand in the previous section. Suppose that the demand μ_j fluctuates binarily keeping $\sum_j \mu_j = 1$: the proportion of expenditure of the representative consumer in industry j takes the value of μ_{jH} with probability γ_j and μ_{jL} with probability $1-\gamma_j$ where $\mu_{jH} > \mu_{jL}$. The expected demand of industry j is $\mu_{je} = \gamma_j\mu_{jH} + (1-\gamma_j)\mu_{jL}$. Again, I drop the j subscript from here because the discussion is symmetric in every industry. I assume that final good producers know only the distribution of market demand, and they need to decide their quantity and price of production before they know which demand level is realized. Thus, the choice of quantity is always equal to the expected demand as below.

$$E[y] = \mu_e A p^{-1/1-\alpha}. \tag{13}$$

The expected profit of a vertically integrated firm is a weighted average of the two possible levels of demand:

$$E[\pi_V] = \gamma[\mu_e y' p - \mu_e y' \lambda - (\mu_H - \mu_e) y' c - k_v] + (1-\gamma)[\mu_L y' p - \mu_e y' \lambda - k_v], \tag{14}$$

where $y' = Ap^{-1/1-\alpha}$. The first term in the right hand side of equation (14) shows that, when the realized market demand is high, the firm experiences shortage. The variable cost of production is $\mu_e y' \lambda$ (the amount of production times the marginal cost of production) and the amount of lost demand is $(\mu_H - \mu_e)y'$: I assume that the lost profit is proportional to the lost demand since firms need to offer a positive compensation ($c > 0$) to the lost customers not to lose their reputation. When the realized market demand is low, the firm sells $\mu_L y'$ but it still needs to pay the full cost of production, $\mu_e y' \lambda$. The equilbrium price under integration that maximizes the profit is:

$$p'_V = \frac{\mu_e \lambda + \gamma c(\mu_H - \mu_e)}{\alpha[\gamma \mu_e + (1-\gamma)\mu_L]}. \tag{15}$$

Notice that this price is identical to the case of certain demand in equation (7) if the demand is known ex ante. The expected demand is, therefore, $y_V = \mu_e A p_V'^{-1/1-\alpha}$.

The expected profit of a specialized intermediate-good producer is

$$E[\pi_m] = \gamma[\omega \mu_e y' p - \mu_e y' - (\mu_H - \mu_e) y' c - k_m] + (1-\gamma)[\omega \mu_L y' p - \mu_e y' - k_m], \tag{16}$$

which yields the optimal price of outsourcing equal to

$$p'_O = \frac{\mu_e + \gamma c(\mu_H - \mu_e)}{\omega \alpha[\gamma \mu_e + (1-\gamma)\mu_L]}. \tag{17}$$

Again, p'_O is identical to the case of certain demand in equation (3) when demand is known ex ante. The expected demand is $y_O = \mu_e A p_O'^{-1/1-\alpha}$. The resulting expected profit of an outsourcing firm is the profit of the final-good producer plus the transfer from the intermediate-good supplier:[12]

$$\pi'_O = \pi'_s + T = Ap_O^{-1/1-\alpha}\left(\frac{1-\omega\alpha}{\omega\alpha}\right)(\mu_e + \gamma c(\mu_H - \mu_e)) - k_o. \tag{18}$$

The expected profit of an integrated firm is

$$\pi'_V = Ap_V^{-1/1-\alpha}\left(\frac{1-\alpha}{\alpha}\right)(\mu_e\lambda + \gamma c(\mu_H - \mu_e)) - k_v. \tag{19}$$

Equations (18) and (19) yield the ratio of break-even demands under uncertainty:

$$\frac{A'_V}{A'_O} = \frac{(1-\alpha\omega)}{(1-\alpha)}(p'_V/p'_O)^{\alpha/1-\alpha}\frac{k_v}{k_o}, \tag{20}$$

where $\frac{p'_V}{p'_O} = \omega\frac{\mu_e\lambda + \gamma c(\mu_H - \mu_e)}{\mu_e + \gamma c(\mu_H - \mu_e)}$.

2.3 Choice under uncertainty

The effect of demand uncertainty on the choice of organization can be shown by comparing the ratio of break-even demands of integration and outsourcing in equations (12) and (20). Again, note that the uncertain demand in section 2.2 is the mean-preserving spread of the certain demand in section 2.1. I define a latent variable Θ as double ratios of break-even demands under certain and uncertain demand to analyze the effect of uncertain demand on the choice of production modes:

$$\begin{aligned}\Theta \equiv \quad \frac{A_V/A_O}{A'_V/A'_O} &= \left[\frac{p_V/p_O}{p'_V/p'_O}\right]^{\alpha/1-\alpha} \\ &= \left[\lambda\frac{\mu_e + \gamma c(\mu_H - \mu_e)}{\mu_e\lambda + \gamma c(\mu_H - \mu_e)}\right]^{\frac{\alpha}{1-\alpha}}.\end{aligned} \tag{21}$$

[12]Specifically, the profit of an outsourcing firm (π'_s) and the transfer (T') are as below.

$$\begin{aligned}\pi'_s &= [\gamma\mu_e + (1-\gamma)\mu_L](1-\omega)Ap_O^{-\alpha/1-\alpha} - k_s \\ T' &= \pi'_m = [\gamma\mu_e + (1-\gamma)\mu_L]\omega Ap_O^{-\alpha/1-\alpha} - [\mu_e + \gamma c(\mu_H - \mu_e)]Ap_O^{-1/1-\alpha} - k_m\end{aligned}$$

Vertical integration is more likely to be the equilibrium mode of production when uncertainty is introduced if the break-even ratio falls or $\Theta \geq 1$. Some calculations show that $\Theta \geq 1$ if and only if $\lambda \geq 1$. Since the model is assumed that $\lambda > 1$, the model predicts that vertical integration is more likely under uncertain demand.

I can understand this result in two ways. First is the price mechanism. Under uncertainty, as equation (21) shows, the price ratio as well as the break-even ratio of demands of integration and outsourcing are smaller compared to the case of certain demand ($\Theta \geq 1$). This implies that vertical integration is more profitable under uncertainty because integration price becomes relatively cheaper. In a monopolistically competitive setting, higher price means less profit. Specifically, the price of final goods increases when demand is more uncertain, regardless of the mode of production ($p_O < p'_O$ and $p_V < p'_V$). But the outsourcing price goes up relatively more than integration price ($p_V/p_O \geq p'_V/p'_O$) as long as $c > 0$ and $\lambda > 1$ are assumed.

The second way to understand is through the transaction cost economics which gives the consistent prediction. As I assumed earlier in the description of the model, the marginal cost reflects the required management costs under uncertainty: $\lambda > 1$ implies that integrated firms have lower level of specialty and pay higher level of management costs to produce intermediate goods than independent firms. Under uncertain demand, however, the benefits of integration outweigh the benefits of outsourcing. Integrated firms possess better ability to handle the problems of over- and under-production using their superior communication system, inventory management, and faster decision makings that are free from contractual bindings.

Now I turn to discuss the asymmetric effect of demand uncertainty on institutional choices in the durable and the nondurable industries. The model sheds light on this topic through the price elasticity of demand, which distinguishes the durable industries from the nondurable industries. Durable goods have a higher price elasticity of demand compared to nondurable goods: consumers may delay their purchases of cars and electronic products[13] but continue to spend on food and beverages. I assume that a higher price elasticity of demand directly

[13] Bloom (2014) calls this 'real option' of consumption.

implies a higher elasticity of substitution α. (See appendix for details.) Also, Θ in equation (21) increases a α increases. Therefore, the positive relationship between the choice of vertical integration and demand uncertainty is stronger in the durable industries where demand is more elastic. In the nondurable industries where demand is inelastic, such positive relationship is muted because Θ is closer to zero. Demand uncertainty encourages the choice of vertical integration in an industry where consumers sensitively respond to changes in prices. In the next section, I test these predictions of the model.

3 Empirical Evidence

The model in the previous section describes the effect of demand uncertainty on the industry equilibrium mode of production. The equilibrium mode of sourcing intermediate goods under uncertainty depends on the durability of the products that an industry produces: vertical integration is more likely to be the equilibrium mode in the durable industries, and outsourcing is more likely in the nondurable industries. I test this prediction in this section using an industry level measure of vertical integration in the U.S., which is the share of intrafirm imports out of total imports.

3.1 Specification

The purpose of the empirical analysis is to test the prediction about uncertainty and the organization of firms using the U.S. intrafirm imports data. Since the choice between outsourcing and vertical integration under demand uncertainty depends on the durability of the products of an industry, the difference-in-differences method is suitable for the data analysis. Specifically, I estimate the following equation:

$$VI_{ict} = \beta_0 + \beta_1 Unc_{it} + \beta_2 (Unc_{it}) \times (Dur_i) + X'_{1it}\bar{\beta}_3 + X'_{2c}\bar{\beta}_4 + \alpha_c + \alpha_t + \epsilon_{ict}, \qquad (22)$$

where i, c, and t index industries, countries, and period, respectively. VI_{ict} is the measure of vertical integration, which is the share of intrafirm imports out of all imports in industry i from country c to the U.S. in period t. Unc_{it} is the US industry i's demand uncertainty in period t. Dur_i is the durability dummy variable. The coefficient of the interaction term of uncertainty and durability variables, β_2, indicates whether the durable industries change the sourcing mode more sensitively compared to the nondurable industries. The empirical analysis would be consistent with the theoretical model if β_2 is positive and significant. X_{1it} is a vector of industry-level control variables that consists of the size, external financial dependence, market structure (differentiation), capital-, skill-, material-, and R&D-intensity.[14] X'_{2c} is a vector of country-level controls that includes the rule of law. I include country and year fixed effects in the estimation to capture unobserved variations.[15]

3.2 Data sources and variable descriptions

The measure of vertical integration is the share of intrafirm imports out of all imports in industry i in period t. I use the related party imports data of the U.S. from 2002 to 2009[16] classified by NAICS 6-digit industry from the U.S. Census Bureau.[17] Every import transaction to the U.S. is categorized as a related or non-related import. The share of intrafirm imports is related party imports divided by the total imports in industry i in period t from country c.[18] I use the average of two years' observations as one period t's value, resulting in four periods in total.

To capture uncertainty at the industry level, I use the within-industry dispersion of plant-level sales growth. Higher dispersion of sales across plants within an industry indicates frequent changes in sales and in turn the difficulty in predicting the amount of sales or demand in the industry, or higher demand uncertainty. I use the standard deviation of real sales growth of all plants in industry i in period t. This data is in SIC 4-digit industries in 2002-2009 from the Annual Survey of Manufactures of the U.S. Census.[19] The data contain

[14]Note that all these control variables vary across time except for the R & D-intensity due to data limitation.

[15]I do not include industry fixed effects to leave the industry variation.

[16]This data is available from 2002 to 2012, but the uncertainty variable is available until 2009. So I use data from 2002 to 2009.

[17]The related-party import is defined as the import transactions between two parties, either of which has 6 percent or more of ownership or voting right. However, whole ownership is most common (80% in 1997) among foreign affiliates of US firms (Desai et al., 2004). Also, because either the US or the foreign party may have the ownership of the other according to this definition, this intrafirm share measure includes both backward and forward vertical integration.

[18]Nunn and Trefler (2013) and Costinot et al. (2011) use similar measure of intrafirm share in their cross-sectional analysis.

[19]This data is available at http://www.stanford.edu/ nbloom/RUBC_industry.zip

27.1 establishments on average per SIC 4-digit industry-year pair, and this size allows enough variation in the data.

The information on durability is directly from the NAICS code, which categorizes all manufacturing industries into durable and nondurable goods manufacturing in NAICS 3-digit level. Table 1 lists all 3-digit manufacturing industries in NAICS by durability. The durability variable in our analysis is defined "1" for durable industries and "0" for nondurable industries.

Table 1: NAICS 2002 manufacturing industries by durability

Durable Goods Manufacturing	
321	Wood Product Manufacturing
327	Nonmetallic Mineral Product Manufacturing
331	Primary Metal Manufacturing
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
334	Computer and Electronic Product Manufacturing
335	Electrical Equipment, Appliance, and Component Manufacturing
336	Transportation Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Manufacturing
Nondurable Goods Manufacturing	
311	Food Manufacturing
312	Beverage and Tobacco Product Manufacturing
313	Textile Mills
314	Textile Product Mills
315	Apparel Manufacturing
316	Leather and Allied Product Manufacturing
322	Paper Manufacturing
323	Printing and Related Support Activities
324	Petroleum and Coal Products Manufacturing
325	Chemical Manufacturing
326	Plastics and Rubber Products Manufacturing

Source: U.S. Census Bureau, U.S. Bureau of Labor Statistics.

I control for other determinants of the intrafirm share of imports. Since higher capital-intensity leads to more in-house production (Antràs, 2003), I include this variable to the specification of the regression. I also include skill-intensity and material-intensity in the set of control variables in keeping with Heckscher-Ohlin theory. For these three variables, I use yearly NBER-CES manufacturing industry database in 6-digit NAICS from 2002 to

2009: capital-intensity is the log of the investment over total wage; material-intensity is the log of material cost over total wage; skill-intensity is the log of wage to skilled workers over total wage. Since the choice of vertical integration and the size of industries can be positively correlated, I control for the size of industries using the share of value added of an industry out of GDP. The dependence on external source of financing is related to the choice of sourcing mode (Acemoglu et al., 2009). So I include external financial dependence, which is defined as capital expenditures minus cash flow from operations divided by capital expenditures (Rajan and Zingales, 1998, p.564). I include a country-level control variable, rule of law, since it is a source of comparative advantage in international trade (Nunn, 2007).[20]

Since the intrafirm imports share data categorizes all non-intrafirm imports into outsourcing, it does not tell us whether outsourcing is in the form of a long-term contract or spot market. So l use Rauch index, which categorizes NAICS 6-digit industries into differentiated goods, reference priced goods and goods traded on organized exchanges. If standardized goods are outsourced (the two latter cases), spot market is more likely, and if differentiated goods are outsourced, long-term contract would be more likely. I code differentiated good as "1" and others as "0".[21] I interact the Rauch index with R & D-intensity to control for the market structure and product complexity. I draw the U.S. R & D intensity variable in 2005 from Nunn and Trefler (2013).[22]

3.3 Descriptive statistics

Table 2 reports the number of observations, mean, and standard deviation of the variables. I have unbalanced panel data that covers 349 6-digit NAICS manufacturing industries for 4 periods (years 2002-2009). Among the 236 countries that US manufacturing industries are importing from, only 5 countries have zero intrafirm import transactions. Table 3 compares the average industrial characteristics by durability.[23] The share of intrafirm imports in

[20]Data on the rule of law variable is from the website of Nathan Nunn at http://scholar.harvard.edu/files/nunn/files/qje_contracts_final1.zip.

[21]Among 150 industries, however, 140 are differentiated markets and only 10 are either reference priced or traded on organized exchanges.

[22]This data is available at http://scholar.harvard.edu/files/nunn/files/incomplete_contracts.zip.

[23]Petroleum and coal products manufacturing (NAICS 324) is excluded in nondurable industries, but including them does not make any meaningful difference in the results of the mean-comparison analysis.

Table 2: Descriptive statistics

Category	Variable	N. of Obs.	Mean	Std. Dev.
By industry, country, and year	Intrafirm import share	134,751	0.247	0.330
By industry and year	SD (sales growth)	1,465	0.236	0.059
	SD (TFP shocks)	1,465	0.436	0.115
	Capital intensity, log	1,946	-1.818	0.746
	Skill intensity, log	1,942	-0.937	0.332
	Material intensity, log	1,946	1.229	0.646
	Share of value added	1,946	0.037	0.069
	External Financial Dependence	1,415	3.413	83.964
By industry	Durability	349	0.610	0.488
	R & D intensity	155	0.018	0.045

Number of countries: 236
Number of 6-digit manufacturing industries: 349
Number of years: 8 (2002-2009)

Figure 2: The share of intrafirm import transactions by durability

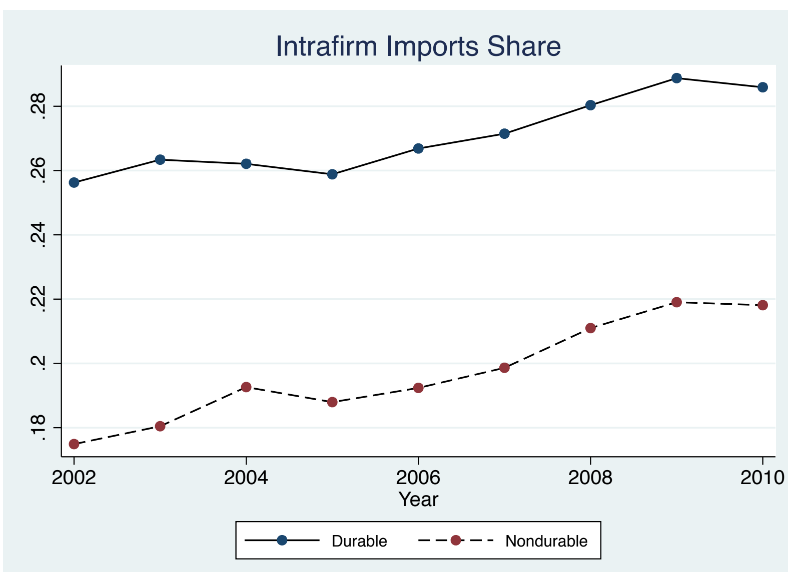


Table 3: Industrial characteristics by durability

	Durable		Nondurable		Mean Comparison
Variable	Obs.	Mean	Obs.	Mean	ΔMean
Intrafirm import share	82,131	0.278	52,620	0.200	0.078***
		(0.341)		(0.308)	(0.002)
SD (sales growth)	900	0.240	563	0.231	0.009***
		(0.059)		(0.058)	(0.003)
SD (TFP shocks)	900	0.416	563	0.471	-0.055***
		(0.106)		(0.121)	(0.006)
Capital intensity, log	1,184	-2.009	762	-1.520	-0.489***
		(0.608)		(0.838)	(0.033)
Skill intensity, log	1,180	-0.891	762	-1.007	0.116***
		(0.358)		(0.273)	(0.015)
Material intensity, log	1,184	1.034	762	1.530	-0.496***
		(0.545)		(0.675)	(0.028)
Share of value added	1,184	0.031	762	0.045	-0.014***
		(0.043)		(0.096)	(0.003)
External Financial Dependence	889	1.231	526	7.102	-5.872
		(100.741)		(42.428)	(4.618)
R & D intensity	119	0.022	35	0.006	0.016**
		(.004)		0.013	(.008)

Notes: Standard deviations are in parentheses in mean columns. Standard errors from the two-group mean-comparison tests are in parentheses in the last column. ΔMean is defined as 'Mean(durable) - Mean(nondurable).' Ext. Fin. Dep. denotes external financial dependence. *** denote significance at 1% level.

durable industries is 7.8 percentage point higher on average, and the difference is statistically significant at 1 percent level. As Figure 2 shows, this pattern that durable industries have higher level of vertical integration is consistently found in all years of the sample. The two measures of demand uncertainty, which are the standard deviation of plant-level sales growths and TFP shocks by industry, have different signs in mean comparison. In durable industries, the standard deviation of sales growth is significantly higher than nondurable industries, but the standard deviation of TFP shocks is significantly lower than nondurable industries on average. This difference suggests that overall demand uncertainty is not necessarily larger in thedurable industries.

I compare other variables known to be the determinants of the vertical integration by durability. Durable industries are more skill and R & D intensive. Interestingly, however, nondurable industries are larger (when measured by the share of value added out of GDP), more capital and material intensive. These variables are known to positively affect the sourcing option of firms, but nondurable industries have overall lower intrafirm imports share. Thus, I submit that the effect of uncertainty and skill-intensity are stronger in the nondurable industries when it coms to choosing the sourcing method. I examine these relationship in detailed analysis in the following sections.

3.4 Results

I test the model following the specification in equation (22). First, I report the results when I do not consider the effect of durability on the relationship between demand uncertainty and the share of intrafirm imports. In column (1) in Table 4, I do not include the interaction term of demand uncertainty and durability. The coefficient of demand uncertainty, which is measured by the standard deviation of plant-level sales growth in each industry, is positive and significant. In column (2), I include the interaction term of demand uncertainty and durability, incorporating the difference-in-differences method in the analysis. The regression results show that the effect of demand uncertainty on the share of vertical integration is significantly different in durable and nondurable industries. According to β_2 in column (2), the effect of one standard deviation increase in demand uncertainty has 23.5

Table 4: Vertical integration and demand uncertainty - Baseline analyses

Dependent variable	Intrafirm Share (6-digit)			
Measure of *Unc*	SD(sales growths)		SD(TFP shocks)	
	(1)	(2)	(3)	(4)
Unc	0.397***	0.135	0.225***	0.0934
	(0.0980)	(0.123)	(0.0611)	(0.0599)
(Unc)×*(Dur)*		0.235***		0.156***
		(0.0551)		(0.0270)
Capital Intensity	0.0109	0.0181	0.00814	0.0187
	(0.0121)	(0.0128)	(0.0115)	(0.0121)
Skill Intensity	0.0226	0.0251	0.0154	0.0173
	(0.0201)	(0.0210)	(0.0203)	(0.0208)
Material Intensity	-0.000558	0.00421	-0.0121	-0.00928
	(0.0123)	(0.0122)	(0.0139)	(0.0136)
Share of VA	0.109	0.121*	0.170**	0.180***
	(0.0768)	(0.0685)	(0.0860)	(0.0693)
Ext. Fin. Dep.	-6.87e-05***	-6.08e-05***	-7.78e-05***	-6.81e-05***
	(1.83e-05)	(1.67e-05)	(2.05e-05)	(1.65e-05)
(R & D intensity) ×(Rauch)	0.164	0.0844	0.150	-0.00231
	(0.145)	(0.153)	(0.159)	(0.160)
Obs	21,962	21,962	21,962	21,962
R-squared	0.192	0.194	0.193	0.191

Notes: *Unc* denotes demand uncertainty and *Dur* denotes durability. * denote significance at 10% level. ** denote significance at 5% level. *** denote significance at 1% level. Robust standard errors are clustered by industries and years. Country and year fixed effects are included.

percentage point higher impact on the increase of the share of vertical integration in the durable industries than in the nondurable industries. The coefficient of uncertainty (β_1) is positive but insignificant. This suggests that, in nondurable industries, the effect of demand uncertainty has insignificant effect on the intrafirm imports share.

I have similar results in columns (3) and (4) when the measure of demand uncertainty is the standard deviation of plant-level TFP shocks in each industry. While the dispersion of sales growth across plants in an industry captures changes in demand, supply may also affect the sales growth. The dispersion of TFP shocks across plants in each industry is measured by the standard deviation of residuals of the autoregressive establishment-level TFP. Since the innovations to establishment level TFP contain demand shocks, I use this variable as an alternative of the dispersion of sales growth. Again, I draw the variable from Bloom et al. (2012) and it is built using the same data source as the sales growth variable, which is the Annual Survey of Manufacturing. The coefficients of uncertainty and the interaction of uncertainty and durability (β_1, β_2) are consistent with columns (1) and (2) with slightly smaller magnitude.

The control variables in the above regressions have mixed impacts on the share of vertical integration. The coefficients of capital intensity, skill intensity, and material intensity are insignificant in columns (1) through (4) in Table 4. The signs of the coefficients of capital and skill intensities are positive, which is consistent with the literature (Antràs, 2003; Nunn and Trefler, 2013). The coefficients of material intensity is mostly negative. The share of value added of the industry in GDP, which measures the size of industries, are positive and mostly significant. The coefficients of external financial dependence are close to zero. Market differentiation is negatively correlated with vertical integration.

The results confirm the prediction of the model in the previous section that the higher demand uncertainty increases the choice of vertical integration in durable industries. Demand uncertainty is a more relevant problem regarding the choice of sourcing options in the durable industries. The positive relationship between demand uncertainty and vertical integration in durable industries suggests that the benefit of firm-level ability of management in an integrated institution under uncertainty outweighs the cost of initial investment required to build it. The regression results also show that the effect of uncertainty is weaker for nondurable industries, supporting the results in the model.

Table 5: Vertical integration and demand uncertainty - Alternative measures

Dependent variable	Intrafirm Share (4-digit)		VI Index (6-digit)	
Measure of *Unc*	Volatility	Volatility	SD(sales)	SD(TFP)
	(1)	(2)	(3)	(4)
Unc	1.115**	-1.949	0.00542	0.0449
	(0.441)	(1.845)	(0.0840)	(0.0279)
(Unc)×(Dur)		2.966*	0.0683	0.0349
		(1.632)	(0.0511)	(0.0231)
Obs	16,617	16,617	211	211
R-squared	0.219	0.220	0.117	0.137

Notes: * denote significance at 10% level. ** denote significance at 5% level. *** denote significance at 1% level. Robust standard errors are clustered by industries and years. In columns (1) and (2), country and year fixed effects are included in the regressions. In columns (3) and (4), only year fixed effects are included since 'Vertical Relatedness' does not have country dimension. All control variables in the baseline analysis are included.

4 Extensions and robustness analysis

I present the regression results with another measure of demand uncertainty in Table 5, which is the industrial volatility. I use this variable as an alternative measure since the fluctuations of industry productions can partly capture the demand uncertainty. Following Bergin et al. (2009), I use the monthly production worker employment data from Current Employment Survey (CES) in the Bureau of Labor Statistics from 2002 to 2009. Since the CES industry identifier is unique and often combines several 5- or 6-digit NAICS industries, I match the industry classification of CES with 4-digit NAICS. I seasonally adjust, log, and HP-filter the data. Then I take the standard deviation of the data by 2 years, which means one period's volatility is based on the standard deviation of 24 observations.

The coefficient estimates with this alternative variable of demand uncertainty is in

Table 6: Vertical integration and demand uncertainty - Poisson distribution

Dependent variable	Intrafirm Share (6-digit)		Intrafirm Share (4-digit)	VI index (6-digit)	
Measure of *Unc*	SD(sales)	SD(TFP)	Volatility	SD(sales)	SD(TFP)
	(1)	(2)	(3)	(4)	(5)
Unc	0.383	0.275	-8.126	0.363	0.134
	(0.449)	(0.222)	(7.517)	(0.504)	(0.234)
(Unc)×(Dur)	0.864***	0.566***	11.98*	0.842***	0.549***
	(0.210)	(0.0999)	(6.828)	(0.297)	(0.143)
Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	-	-
Log pseudolikelihood	-12258.672	-12255.198	-8590.5806	-152.72681	-152.73101
Observations	21,962	21,962	16,617	285	285

Note: * denote significance at 10% level. ** denote significance at 5% level. *** denote significance at 1% level. Robust standard errors are clustered by industries and years. In columns (1) to (3), country and year fixed effects are included in the regressions. In columns (4) and (5), only year fixed effects are included since 'Vertical Relatedness' does not have country dimension. All control variables in the baseline analysis are included.

columns (1) and (2) in Table 5. Column (1) does not include the interaction term of uncertainty and durability, and the results are similar to the baseline analyses, where the coefficient of uncertainty is positive and significant. Interestingly, the coefficient of uncertainty in column (2), where the interaction term is included, is negative. This result suggests that, in nondurable industries, outsourcing is prevalent as volatility increases. However, the coefficient is not significant. The coefficient of the interaction term (β_2) is positive and significant, which is consistent with the baseline analyses. Therefore, the results in both Table 4 and Table 5 show that uncertainty is significantly and positively related with higher intrafirm share of the durable industries, but it does not significantly affect intrafirm share of the nondurable industries.

I also use an alternative measure of vertical integration that calculates the probability that firms in an industry have vertically integrated operations as in Fan and Lang (2000) and Acemoglu et al. (2009). This variable shows how much dollar value of inputs the firm can procure from the firm's own operations to produce one dollar's worth of an output. Thus, this variable is an approximation of vertical integration based on input-output table and the information of the industries at which firms operate. To compute this measure, I first use the benchmark input-output table in 2002 from the U.S. Bureau of Economic Analysis (BEA). The input-output requirement table reports the dollar value of each input industry i to produce one dollar's worth of the output industry j, IO_{ij}, for all 435 industries in the U.S. The industry classification in the input-output table (IO code) is based on 2002 NAICS but aggregated at various digit-levels. For example, transportation and warehouse industries are matched with 3-digit NAICS code while many manufacturing industries are matched with 5- or 6-digit NAICS code. Using the concordance table from BEA,[24] I match the NAICS code with the IO code. I drop government and special industries since they are not included in NAICS. I also exclude wholesale and retail trade following Fan and Lang (2000) and construction since they are defined only at NAICS 2-digit level. Then I combine this information with Compustat's segment data that reports the multiple industries in which each U.S. public firm is operating. The vertical integration index for firm f primarily operating in industry i in year t is defined as

$$VI_{fit} = \frac{1}{|N_{ft}|} \sum_{j \in N_{ft}} IO_{ij} \tag{23}$$

where N_{ft} is the set of industries in which firm f is active in time t and $|N_{ft}|$ denotes the number of these industries (Acemoglu et al., 2009, pp.1264-1265). Since a firm may operate in more than two industries, I take the average of the VI's of each industry that a firm belongs to. Then the industry level measure of vertical integration is

$$VI_{it} = \frac{1}{|N_{it}|} \sum_{f \in N_{it}} VI_{fit}, \tag{24}$$

where N_{it} denotes the set of firms operating in industry i in year t and $|N_{it}|$ is the number of firms in industry i in year t.

The regression results with the VI index as a measure of vertical integration are in columns (3) and (4) in Table 5. The demand uncertainty variable is the standard deviation

[24] The table is available in the appendix of the article "U.S. Benchmark Input-Output Accounts, 2002" in Survey of Current Business in Oct. 2007.

of sales in column (3) and of TFP in column (4). Since the number of observations in these two analyses is smaller, I use 1-year period values instead of 2-year average values. The signs of coefficients β_1 and β_2 are consistent with the baseline analyses, but they are not as significant. Thus, the relationship of demand uncertainty and vertical integration is not clear when the VI index is used as a measure of vertical integration. However, poisson regressions below give significant results.

Table 6 reports the estimation results with poisson regression. I use this method as a robustness check because the dependent variable is a share ranging from 0 to 1. The dependent variable is intrafirm imports share and the VI index in columns (1) to (3) and in columns (4) and (5), respectively. The results are mostly similar to the baseline analyses, but β_2's are significant even when the VI index is used as the dependent variable.

5 Conclusion

This paper investigates the demand uncertainty as a determinant of the boundaries of firms. Based on the simplified model of Grossman and Helpman (2002), I show the positive relationship between vertical integration and demand uncertainty in the durable industries and the insignificant relationship in the nondurable industries. Under uncertainty, the importance of adaptability of internal structures (integration) outweighs the flexibility of market transactions (outsourcing) in the durable industries. This effect is weaker in the nondurable industries, however, because inelastic demand lessens the effect of uncertatinty. This prediction is tested using the US intrafirm trade in manufacturing industries, and the results are consistent with the model and robust to alternative measures of important variables and regression methods.

In the future, it will be interesting to test the theory using data from other countries that have active domestic intrafirm transactions unlike the US. With such data, one can compare the trade-offs of sourcing intermediate goods from domestic and international suppliers under outsourcing and vertical integration. Also, it is important to find a better way to divide demand uncertainty from supply uncertainty. While it is difficult to find a measure of pure demand uncertainty, an innovative method (such as what Handley (2014) used to obtain policy uncertainty) will help comparing the impact of demand and supply uncertainties.

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Appendix

A Relationship between price elasticity of demand and elasticity of substitution

In section 2, I directly connect the price elasticity of demand to the elasticity of substitution. Such connection is based on the calculations below. The price elasticity of demand (PED) in the model is

$$\begin{aligned}\text{PED}(i) &= \frac{\partial y(i)}{\partial p(i)} \cdot \frac{p(i)}{y(i)} \\ &= \frac{1}{1-\alpha}\left(\frac{\alpha p(i)^{-\alpha/1-\alpha}}{P} - 1\right),\end{aligned}$$

where $P \equiv \int_0^N p(i)^{-\alpha/1-\alpha} di$. In the equilibrium, whether it is pervasive outsourcing or pervasive integration, the elasticity of substitution has a positive relationship with the price elasticity of demand in the most ranges of α, given that the number of varieties is big enough. Specifically, the partial derivative of the PED with respect to α is positive as long as N is big enough:

$$\frac{\partial PED(i)}{\partial \alpha} = \frac{1}{(1-\alpha)^2}\left(\frac{\alpha}{N} - 1\right) + \frac{1}{1-\alpha}\frac{1}{N} > 0$$

Given that the median elasticity of substitution yields $\alpha \approx 0.8$ according to Imbs and Méjean (2014) and the average number of plants in an industry in the data used in this paper is 27, the positive relationship always holds in the model.