Intra-firm Trade in the Presence of Uncertainty

Maxwell Tuuli*

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Abstract

This paper investigates the role of uncertainty in the choice of organizational structure adopted by a firm. Specifically, the decision to either vertically integrate or outsource production of intermediate inputs. We propose a model of incomplete contracting and unequal bargaining á la Antras and Helpman (2004), where we incorporate demand uncertainty by assuming that firms do not know the industry demand they face before making production decisions. Uncertainty is resolved after firms make a relationship-specific investment in the production of intermediate inputs. We find that, in the presence of demand uncertainty, firms engage more in vertical integration compared to when they know the industry demand with certainty. This is because by vertically integrating with an intermediate input supplier, the firm is able to adjust better to fluctuations in the demand of its final output. We also find in the theoretical model that, under uncertainty, vertical integration tendency is less strong in more capital intensive industries. This is because firms located in capital intensive industries find it more profitable to concentrate on producing the capital intensive input while they outsource the production of the intermediate input. We empirically test the predictions of the model by using industry-level data from the manufacturing sector in the US and find results consistent with the implications of the model. In particular, our point estimates suggest that a one standard deviation increase in demand uncertainty increases the share of intra-firm trade by approximately 6.4%. We interpret these results as evidence that the interaction between strategic behaviour and uncertainty influences the choice of organizational structure.

Keywords: Demand uncertainty, intra-firm trade, vertical integration, capital intensity, outsourcing
JEL classification: D21, D23, D24,F14, F23, L23

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1 Introduction

The study of the determinants of the organizational structure adopted by firms as well as the location of multinational firms in the global economy have gained a lot of traction especially in the last two decades. The pioneering work of Antras (2003) has reignited the importance of incomplete contracting and property rights in determining the boundaries of multinational firms and the international location of production as well as the pattern of intra-firm trade. The increase in the interest in the activities of multinational firms has become important because of the significant role these firms have gained over the years. For instance, in 2000, the share of intra-firm trade in the United States was estimated to account for approximately 46% of total imports (Bernard et al. 2010) with the global share averaging approximately 35% in the year 2001 (UNCTAD, 2002). This reflects the general importance of global activities in the domestic production of firms.

Improvement in communication networks and the significant reduction in trade barriers over the years have helped shape the activities of multinational firms and increase international trade. Production activities remain complex, which has culminated in several strands of literature dedicated to shedding light on these issues. Production fragmentation, for instance, has evolved with different firms opting for different forms of organizational structures. Tesla virtually manufactures all its production units around the world within the boundaries of the firm while Nike maintains a network of suppliers producing a variety of intermediate inputs for the production of its final goods. Antras and Helpman (2004, 2008) argued in a heterogenous firm framework the importance of "headquarter services" in determining the pattern of observed organizational structures.[1]

An issue that has received relatively less attention in the discussions around the organizational structure of firms is what role uncertainty plays in the decision of the firm regarding the production structure it chooses. Real options theory provides a background in understanding the behavior of firms in terms of investment. Since the choice

[1]In addition to Antras (2003) and Acemoglu et al. (2007) these papers apply the production heterogeneity model developed in the likes of Melitz (2003) and the property rights theory developed in Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995) to explore the global location and production decision of multinational firms.

between vertical integration and arm's length production involves different levels of investment and incentive structure, theories of investment under uncertainty provides a lens through which this issue can be examined.[2]

There are different incentives for vertical integration under demand uncertainty. On the one hand, vertical integration maybe regarded as a means of transferring risks from one sector of the economy to the other. By vertically integrating with an intermediate input supplier, a firm is able to adjust to changes in the demand of its final output (Carlton, 1979). However, outsourcing reduces the burden of having to manage complex production lines.[3] In perfectly competitive intermediate input markets, final good producers should be able to adjust costlessly to changes in the demand of its final output. The question regarding which of these incentives dominate may in large part be influenced by the industry in which the firm operates.

The goal of this paper is to highlight the role of uncertainty in determining the organizational structure of the firm. More specifically, we examine how demand uncertainty of the final output produced by the firm affects the decision of the firm to vertically integrate with its suppliers or engage them in an arm's length relationship.[4] To accomplish this, we introduce demand uncertainty into Antras and Helpman (2004), where firms have an idea about the distribution of demand facing the industry without knowing the exact realization of demand before making sourcing decisions. In this setup, we find that the presence of uncertainty increases intra-firm trade compared to the standard model in which demand facing the firm is known with certainty. We also find that under plausible assumptions, higher elasticity of headquarter services with respect to final output production reduces intra-firm trade in the presence of uncertainty. We combine several industry level data from the US to test the predictions of the model and find that our results are generally consistent with the model discussed. We interpret these results as a sort of copying mechanism that multinational firms em-

[2]Guiso and Parigi (1999) and Bloom et al (2007) for instance note that, in the presence of uncertainty, firms may hold back an investment decision even if a profitable opportunity presents itself. This phenomenon would be pronounced when investment is sunk and irreversible.

[3]For instance, the final good producer does not have to deal with managing the inventory of its intermediate inputs.

[4]We use vertical integration synonymously with the occurrence of intra-firm trade and arm's length relationship as outsourcing. Vertical integration confers property rights on the final good producer while outsourcing limits the exercise of control over the use of intermediate inputs by the final good producer.

ploy when facing demand uncertainty.

The analysis in this paper is related to several strands of literature dealing with the organizational structure of firms. First, it contributes to the overall discussion on international trade within firm borders and the factors influencing its outcome.[5] Helpman (1984) discusses the existence of multinational firms outside factor price equalization, with multinational firms emerging if there is an incentive to geographically separate capital intensive production activities from labour intensive production. On the other hand, Markusen (1984) and Brainard (1997) rationalize the existence of multinational firms even in the absence of factor endowment differences by arguing that multinational firms emerge in equilibrium whenever transportation cost is high and firm specific economies of scale is relatively higher compared to plant specific economies of scale.

We also follow previous studies related to property rights theory and the holdup problem with elements of firm heterogeneity. We follow the framework proposed in Antras (2003), Acemoglu et al. (2009) and Antras and Helpman (2004, 2008) that builds on the property rights theory to investigate the organizational choices of firms. While the organizational choices present in these models emerge without any form of uncertainty, our major departure in this area involves the introduction of uncertainty.[6] While this literature has roots in international trade literature, another strand of literature emphasizing uncertainty at the firm level and its effect on the boundaries of the firm flourishes. Prominent in this strand is Williamson (2000, 2002) who argues that the firm's internal organizations are able to deal with uncertainty better, especially with greater asset specificity, than when it engages in an arm's length relationship.[7] Thus, we make a contribution to this strand of literature by arguing that the presence

[5]This literature builds on contributions by Helpman (1984) and Markusen (1984). An extensive discussion of this literature can be found in Markusen and Maskus (2001).

[6]A notable research in line with this is Carballo (2014). However, his focus is the response of a firm's organizational structure to economic uncertainty, which is quite distinct from the issue examined in this paper. Also, a recent study along this area is done by Lee (2015), however, his focus is on the asymmetric effect of uncertainty on durable and non-durable goods. See also Sun and Tian (2011).

[7]Also related to this, Carlton (1979) posits that a vertically integrated firm is able to buy intermediate inputs within itself cheaper than when it engages in outsourcing in which the risks from the supplier can be transferred to the firm. Kranton and Minehart (2000) and Fossati (2012), however, discuss the links a firm may have with suppliers in a network. In the presence of substantial uncertainty, a firm with several networks of suppliers producing specialized intermediate inputs is able to reduce its risks more than a firm involved in vertical integration. This therefore offers a view in favour of outsourcing in the presence of uncertainty.

of uncertainty, by distorting the optimal amount of inputs used in production, affects the organizational choice of the firm.

There has also been increasing empirical studies on the determinants of the boundaries of firms in the international trade literature. Antras (2003) rests part of his theoretical argument on the observation that the share of intra-firm trade in the US is significantly high the higher the capital intensity of the industry. By using the share of capital in production as a proxy for headquarter services and data for 23 industries from the US Bureau of Economic Analysis (BEA), Antras (2003) finds strong evidence for the hypothesis that the share of intra-firm imports in total imports increases the higher the capital intensity of the industry. Similar empirical evidence are found by Yeaple (2006), who also provides evidence consistent with Antras and Helpman (2004). His findings are particularly interesting for US trade relations with countries for which the difference in variable cost between the two countries is significant. A recent empirical exposition by Nunn and Trefler (2013) tests several propositions by the class of models on firms' organization starting from Antras (2003) and finds evidence consistent with these models.[8] While our empirical results confirm most of these initial studies, we provide new insights by emphasizing the importance of uncertainty on the organizational structure of the firm.

The contribution of this paper is twofold. First, we introduce demand uncertainty in a standard firm organizational choice model and drive new implications on the incentive of firms to engage in vertical integration instead of outsourcing. More specifically, we find that, in the presence of demand uncertainty, firms deal with risk by engaging in vertical integration as opposed to outsourcing. We also examine the interaction between uncertainty and capital intensity in the decision of the firm to engage in vertical integration and find that for firms with higher capital intensity, the presence of uncertainty reduces intra-firm trade. Thus, this introduces another lens through which fluctuations in intra-firm trade can be interpreted.[9] Secondly, the paper provides supplementary empirical evidence on the determinants of intra-firm trade by examining

[8]Most of these studies use industry level data for the analysis, however for a firm level analysis of these issues see Kohler and Smolka (2012) and Lee (2014).

[9]Note that our focus in this paper is purely on demand uncertainty. For a discussion of other forms of uncertainty on the international trade literature see for instance Handley and Limão (2015) and Handley (2014).

the implications of the model with industry level data from the US. Using a simple form of difference in difference methodology, we find results consistent with previous studies on the issue and wide support for the implications of the model outlined.

The rest of the paper is structured as follows. Section 2 introduces the model and examines the implications for intra-firm trade. In section 3, we discuss the data and empirical strategy used and present the results. We summarize the findings and provide recommendation for further analysis in the conclusion in section 4.

2 The Model

We first present a stripped down version of the model in Antras and Helpman (2004) in which demand for final output of the firm is deterministic and then we introduce uncertainty in the demand for final output into the model and derive its implication for the organization of the firm. The need for different contractual arrangements results from different incentive compatibility and the contractual environment that arises. Firms require two intermediate inputs for the production of the final output. The final good producer produces "headquarter" services and combines with intermediate inputs from a supplier to produce the final output. Final good producers have no choice on which input to produce in-house. What is endogenously determined is the organizational structure that the firm adopts. Different organizational structures present the firm with different incentives and therefore the choice of the firm strikes a balance between the incentive and the level of input distortion arising from any particular organizational structure. We outline these choices in the following theoretical framework.

2.1 The Environment

The environment comprises two agents, households and output producers. Production requires final good producers called the firm and intermediate input suppliers. Final good producers within a particular industry have access to a market in which they operate by selling final goods produced from combining two intermediate inputs,

the headquarter services and intermediate inputs supplied by an input supplier. Firms cannot produce intermediate inputs themselves unless it contracts a supplier to produce and supplier to it. Suppliers on the other hand require factors of production in order to produce the intermediate input. We simply assume that the only factor required for the production of the intermediate input is labour with a linear production function where one unit of labour produces exactly one unit of the intermediate input.

2.1.1 Certain Demand

We assume that there are J industries operating within the economy with several firms located within each industry. Firms in each industry engage in product differentiation which affords them some market power along the lines of Dixit-Stiglitz (1977). The preferences of the representative household in the economy is given by the following utility function.

$$U = \sum_{j=1}^{J} z_j log \left[\int_0^{N_j} x_j(i)^{\alpha_j} di \right]^{\frac{1}{\alpha_j}} \tag{1}$$

we assume that z_j is the share of income spent on goods produced by industry J or alternatively the size of demand with $\sum_j z_j = 1$. We assume that α_j is between zero and 1. For each industry there are N firms operating in it where $x(i)$ is the variety of output j consumed by the individual. The elasticity of substitution between each variety in each industry is given by σ_j, which is greater than 1 and is constant in all industries with the degree of product differentiation given by $\alpha_j = \frac{\sigma_j - 1}{\sigma_j}$ where higher values indicates a less degree of product differentiation. Given the utility function and the consumption pattern of the representative household the optimal demand facing each firm located in industry j and producing variety i is given by

$$x_j(i) = z_j A_j p_j(i)^{\frac{-1}{1-\alpha_j}}; A_j = \frac{E}{\int_0^{N_j} p_j(i)^{\frac{-\alpha_j}{1-\alpha_j}} di} \tag{2}$$

Notice here that the demand parameter is constant which implies that before a firm makes its production decision it knows for sure the industry demand level and the demand it faces. E is the total expenditure in the economy and it is equivalent to the income level in the economy.

2.1.2 The Firm

The final good firm produces its variety by using intermediate inputs provided by a supplier that is specific and unique to the requirements of the firm. We assume that once the input is produced and provided by the supplier to the final good firm it has no economic value outside the relationship with the firm that requested the input. This type of assumption is often referred to as a relationship specific contract. With no contract enforceability, no outside firm can verify the quality of the input supplied. Input suppliers can either produce the input with low or high quality. If the input supplier supplies an input of low quality, the firm rejects it and the input supplier earns negative profit therefore there is no incentive for the input supplier to produce intermediate input of low quality.

We assume that the firm and the supplier enter into a non-contractible relationship which implies that the content of their agreement can not be verified by an outside party (say the courts) and decide to invest in the amount of inputs required of each of them after which the final output is produced and revenue shared according to a bargaining process. Negotiation takes the form of Nash-bargaining where the final good producer get β of the revenue and the supplier gets $1-\beta$. In addition to the variable cost required of each agent in the production process, the final good producer incurs a fixed cost depending on the organizational structure chosen by the firm. We assume there are infinite number of potential input suppliers and therefore with free entry, input suppliers earn zero profit in equilibrium. This means that the firm can offer the potential supplier a participation fee that extracts all potential profits resulting from their relationship. For final good producers, there is a large number of potential entrants in each industry where firms first pay a fixed cost of entry before drawing a productivity level consistent with the mechanism in Melitz (2003). Thus, final good producers also expect to earn a zero profit from entering into the production of any variety of the final output.

In terms of sourcing strategy, here we assume the final good producer has two options for sourcing intermediate inputs in a foreign location.[10] The firm can integrate a

[10]This is different from Antras and Helpman (2004) where the firm has essentially four different options. In this model we do not consider outsourcing and integration within the domestic economy. This

foreign supplier into its organizational setup which involves some elements of property rights for the production of the input. This kind of vertical integration implies that the firm has a level of control over the inputs produced though not fully. In the event of a break down of their relationship, the final good producer is able to salvage the inputs produced but can only generate a fraction of the revenue given by δ. However, instead of vertical integration the firm can have an arms length relationship with the input supplier which involves no elements of property rights in the form of outsourcing. We assume as in several other studies (see for instance Antras and Helpman (2004) and Grossman and Helpman (2008)) that the cost involved with monitoring and managing a bigger organization when vertical integration takes place is higher than in the case of outsourcing. Therefore, we assume that the fixed cost of vertical integration is greater than the fixed cost from outsourcing i.e $F^I > F^O$.

The setup described above implies that firms can influence the ex-post outcome of their revenue by the choice of organizational structure. As indicated above, the revenue generated by the final good producer from vertical integration is given by $\gamma = \delta + \beta(1-\delta)$ while that from outsourcing is simply given by β . The reason why the share of revenue under vertical integration is given by γ is because, the final good firm gets δ of the total revenue produced for sure whether its relationship with the intermediate input supplier breaks down or not and only has to engage in Nash-bargaining with the integrated intermediate input supplier for a fraction of the revenue generated. [11] Notice that the outside option for the supplier in both organizational structures is zero but vertically integrated firms are able to capture a part of surplus even in the event of a breakdown in relationship with the supplier. Therefore, for the vertically integrated firm, there are gains from trade resulting from the honor of the contract by both the supplier and the firm which is given by $(1-\delta)$.[12]

is a convenient simplification and also consistent with the data used in the analysis.

[11] Intermediate input suppliers have no incentive to produce low quality inputs because doing so results in zero profit. The share of revenue received by the intermediate input supplier is given by $(1-\beta)(1-\delta)$.

[12] It is important to note that since we assume all input suppliers are located in the foreign country, the size of δ is dependent of the institutional structures governing contracts in the country. In a more institutionally advanced country the size of δ is expected to be significantly high and increase the incentive for firms to be engaged in vertical integration.

2.1.3 Decision Making

There is a sequence of decisions made by the potential final good producer before final output eventually gets produced. First, all potential firms draw a productivity level, θ after paying a fixed cost of entry. After drawing a productivity level high enough to produce the final output, firms in stage two decide what sourcing strategy to adopt. Recall that in this model, both sourcing strategies take place only in the foreign market. The firm and the supplier then invest in the production of the inputs required for the production of the final output. The optimal amount of investment by each agent is dependent on the expected share of revenue that would accrue to it, which is a function of the bargaining strength of the firm. In the final stage of the game, final output is assembled by the firm and revenue shared according to the Nash-bargaining. We solve the sequence of the game by backward induction. Before the firm decides to enter into production after drawing the productivity level, it accurately projects the sequence of events, therefore we start with the firm's expected share of revenue at the final stage, which informs its level of investment and sourcing choice in the third and second stage of the game.

Stage 4. This stage is characterized by the revenue generated by the final good producer. We assume the firm produces using a simple Cobb-Douglas production function given by the equation below. We are interested in the behaviour of a representative firm, i in a representative industry, j so the solution is symmetric for each firm and industry so we drop the subscripts and proceed with a representative firm

$$x = \theta \left[\frac{h}{\eta}\right]^{\eta} \left[\frac{m}{1-\eta}\right]^{1-\eta}, 0 < \eta < 1 \tag{3}$$

Where h, m represent the quantity of headquarter services and intermediate input provided by the firm and the supplier respectively. η denotes the share of headquarter services required in the production process and is also conveniently the elasticity of x with respect to h. Using equation (2) and (3), the firm generates the following revenue from the sale of the final output

$$R = px = (zA)^{1-\alpha}\theta^{\alpha}\left[\frac{h}{\eta}\right]^{\alpha\eta}\left[\frac{m}{1-\eta}\right]^{\alpha(1-\eta)} \tag{4}$$

We see from the revenue function that firms located in industries where consumer demand is high generate higher revenue than firms facing smaller output demand.

Stage 3. This stage involves investment into the production of the intermediate input given the anticipated share of the revenue in the final stage. Given the expected share of revenue, the final good producer and the supplier choose h and m independently to maximize $\lambda R - rh$ and $(1-\lambda)R - \omega m$ respectively. Here, we use a generic parameter λ, to denote the share of revenue the goes to the final good producer and $1-\lambda$ as the share of revenue obtained by the intermediate input supplier.[13] Where r and ω denote the unit cost of headquarter services required by the firm and unit cost of labour employed by the supplier. Since we are not distinguishing in regards to the location of the input supplier, ω is constant. From the above, we obtain the optimal investment in h and m given by the following:

$$h^* = \eta z A(\alpha\theta^{\alpha})^{\frac{1}{1-\alpha}}\left(\frac{\lambda}{r}\right)^{\frac{1-\alpha(1-\eta)}{1-\alpha}}\left(\frac{1-\lambda}{\omega}\right)^{\frac{\alpha(1-\eta)}{1-\alpha}} \tag{5}$$

$$m^* = (1-\eta) z A(\alpha\theta^{\alpha})^{\frac{1}{1-\alpha}}\left(\frac{\lambda}{r}\right)^{\frac{\alpha\eta}{1-\alpha}}\left(\frac{1-\lambda}{\omega}\right)^{\frac{1-\alpha\eta}{1-\alpha}} \tag{6}$$

From the optimal values of h and m above, the lack of contractibility and contract enforcement introduces distortion to the level of investment by the firm and the supplier. There is underinvestment in both inputs by the firm and the supplier.

Stage 2. In stage two, the firm chooses an organizational structure based on its expected profit from the different sourcing strategies. In the beginning the firm makes an offer to the supplier and the supplier either accepts or rejects it. Since there are a large number of potential suppliers for the intermediate input, in equilibrium, the firm extracts all the surplus from the supplier thus offering it $t = (1-\lambda)R^* - \omega m^*$. In equilibrium the firm earns the following profit

[13]For our two types of firm structure, λ takes on different values. Under vertical integration $\lambda = \gamma$ while under arm's length production $\lambda = \beta$.

$$\Pi = R^* - rh^* - \omega m^* - F \tag{7}$$

$$= \theta^{\frac{\alpha}{1-\alpha}} \psi(\lambda, \eta) - F$$

Where

$$\psi(\lambda, \eta) = zA\alpha^{\frac{\alpha}{1-\alpha}} \left(\frac{\lambda}{r}\right)^{\frac{\alpha\eta}{1-\alpha}} \left(\frac{1-\lambda}{\omega}\right)^{\frac{\alpha(1-\eta)}{1-\alpha}} [1 - \alpha\eta\lambda - \alpha(1-\eta)(1-\lambda)] \tag{8}$$

Since we have solved a general form of the problem of the firm, we have not made a determination regarding the actual bargaining power of the firm. Therefore in the equations above depending on the ownership structure, $\lambda \in \{ \delta + \beta(1-\delta), \beta\}$. Given the above discussion, the firm assesses the profits from vertical integration and that from outsourcing and in stage 2 decides on the ownership structure that maximizes its profit.[14]

2.2 Sourcing Decision

For the firm to decide on the organizational structure a major consideration is the amount of revenue it can extract from the supplier given the organizational structure. Here, we assume that $\gamma = \delta + \beta(1-\delta) > \beta$ which implies that the bargaining power of an integrated firm is higher than when the firm is in an arm's length relationship with an independent supplier. There are various observations to be made from the analysis above, first assume that the firm can choose, depending on its organizational structure, any value of λ then the firm may choose a value of λ equal to one but doing so reduces profits to zero because the input supplier has no incentive to supply the intermediate input. Also, by choosing a value of λ equal to zero the firm generates zero profits. Taking into consideration these choices of λ and the effect on investment and output production by both the intermediate input producer and final good producer, the optimal decision of the firm would be to choose a value of λ that maximizes equa-

[14]Note that the fixed cost in this case $F \in [\ \mathrm{F}^O, F^I]$ since the ownership structure is not determined at this point.

tion (8) (i.e the slop of the profit function). Doing so provides the firm with the optimal amount of profit to be generated from engaging in the production of the final output.[15] Antras and Helpman (2004) obtain the optimal value of λ which is dependent on the elasticity of x with respect to h and also for the purpose of our analysis this optimal value $\lambda^*(\eta)$ is independent of the share of income z spent in the industry in which the firm is located.[16]

Notice that as discussed earlier, the revenue share of the final goods firm is not at its unrestricted disposal implying that it can not choose any arbitrary value of λ. If the final good producer adopts vertical integration as an organizational structure its share of revenue is given by $\gamma = \delta + \beta(1-\delta)$ else choosing outsourcing results in a revenue share of $\beta < \gamma$. Since $\lambda^*(\eta)' > 0$ we expect that there exists a value of η denoted by $\eta*$ such that $\lambda^*(\eta*) = \beta < \gamma$. This implies that for a final good firm with $\eta < \eta^*$, outsourcing intermediate input production to a supplier completely dominates vertical integration as an organizational structure. In our analysis, since we are interested in industry level analysis, $\lambda^*(\eta*)$ refers to industries that require at least $\eta*$ share of headquarter services such that outsourcing is preferred to vertical integration as an organizational structure. Thus our first model prediction, identical to the discussion in Antras and Helpman (2004), is as follows:

Proposition 1. *Given the cost structure firms face in every industry, there exists a critical value of η denoted by $\eta*$ such that firms in industries with $\eta < \eta*$ outsource while industries with $\eta > \eta*$ engage in vertical integrate with their intermediate input suppliers.*

This follows directly from the fact that industries where $\eta < \eta*$ have smaller bargaining power since the elasticity of x with respect to h is small thus making it profitable to engage an independent supplier for the production of the intermediate input than produce it in-house.

[15] In other words, this value of λ is the target level of revenue share if final good producer has unrestricted chance to chose the share of revenue it receives.

[16] Specifically, $\lambda^*(\eta) = \frac{\eta(\alpha\eta+1-\alpha)-\sqrt{\eta(1-\eta)(1-\alpha\eta)(\alpha\eta+1-\alpha)}}{2\eta-1}$ directly from Antras and Helpman (2004) and it is an increasing function of η.

2.3 The Model with Demand Uncertainty

The above discussion has mostly concentrated on a situation where the final good producer knows with certainty the demand for its final output and the model discussed above is a stripped down version of Antras and Helpman (2004). However we focused on industry characteristics as opposed to the firm level analysis. The important next step we pursue is what happens if the representative industry does not know with certainty the demand it faces. This question is important because as pointed out by Bloom (2014), uncertainty appears to vary with macro economic conditions, therefore, it is not farfetched to address the issue of how demand fluctuations in different industries affect the organizational structure of firms located in those industries.

In order to accomplish this, it is convenient to rewrite our demand function in equation (**??**) as $p_j(i) = \mu_j x_j(i)^{\alpha-1}$ where $\mu_j = (z_j A_j)^{1-\alpha}$. We characterize uncertainty with the fluctuations of the parameter μ_j which implies that there are two sources of demand uncertainty that can result, either from fluctuations in spending share of an industry, z_j or fluctuations in aggregate demand, A_j. In the following analysis we assume μ_j follows a uniform distribution on $[\bar{\mu_j} - \frac{\upsilon_j}{2}, \bar{\mu_j} + \frac{\upsilon_j}{2}]$ with $0 < \upsilon_j < 2\bar{\mu_j}$, similar to Sun and Tian (2011), which ensures that demand is positive.

With the forgoing discussion and stage game outlined in section $2.1.3$ the firm maximizes its expected profit in stage 3 compared to a deterministic case in which the firm knows the value of μ_j with certainty. For a firm that decides to engage in vertical integration in stage 3, optimal value of m is the solution to the first order condition for the intermediate input m, which is given by the following:

$$m = (1-\eta)(\alpha\mu\theta^{\alpha})^{\frac{1}{1-\alpha(1-\eta)}}(\omega)^{-\frac{1}{1-\alpha(1-\eta)}}\left(\frac{h}{\eta}\right)^{\frac{\alpha\eta}{1-\alpha(1-\eta)}} \tag{9}$$

Taking the value of m as given in the equation above and λ as the share of revenue obtained by the firm, the payoff of the firm is equal to the following:

$$\pi^I = \frac{1-\alpha(1-\eta)}{\alpha}(\alpha\mu\theta^{\alpha})^{\frac{1}{1-\alpha(1-\eta)}}(\frac{\omega}{1-\gamma})^{-\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left(\frac{h}{\eta}\right)^{\frac{\alpha\eta}{1-\alpha(1-\eta)}} - F^I \tag{10}$$

Then the expected profit of the final good producer is given by the following:

$$\Pi_I^u = \int \pi^I d\mu - rh \tag{11}$$

$$= \frac{1-\alpha(1-\eta)}{\alpha}\Delta(\alpha\theta^\alpha)^{\frac{1}{1-\alpha(1-\eta)}}(\omega)^{-\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left(\frac{h}{\eta}\right)^{\frac{\alpha\eta}{1-\alpha(1-\eta)}} - \upsilon F^I - rh \tag{12}$$

where $\Delta = \frac{1-\alpha(1-\eta)}{2-\alpha(1-\eta)}\left[\left(\bar{\mu}+\frac{\upsilon}{2}\right)^{\frac{2-\alpha(1-\eta)}{1-\alpha(1-\eta)}} - \left(\bar{\mu}-\frac{\upsilon}{2}\right)^{\frac{2-\alpha(1-\eta)}{1-\alpha(1-\eta)}}\right]$. Equation 12 enables us to find the optimal investment in h which is given by the following:

$$h = \eta\Lambda\Delta^{\frac{1-\alpha(1-\eta)}{1-\alpha}}(\alpha\theta^\alpha)^{\frac{1}{1-\alpha}}\left[r^{\alpha\eta}\omega^{\alpha(1-\eta)}\right]^{-\frac{1}{1-\alpha}} \tag{13}$$

Where $\Lambda = \left[\frac{(1-\alpha(1-\eta)(1-\gamma))(1-\gamma)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}}{1-\alpha(1-\eta)}\right]^{\frac{\alpha(1-\eta)}{1-\alpha}}$

We can then substitute equation 13 into 12 to find the expected profit that an integrated firm hopes to get in the presence of uncertainty. This is given by the following:

$$\Pi_I^u = \left(\frac{1-\alpha}{\alpha}\right)\Lambda(\alpha\theta^\alpha)^{\frac{1}{1-\alpha}}\Delta^{\frac{1-\alpha(1-\eta)}{1-\alpha}}\left[r^{\alpha\eta}\omega^{\alpha(1-\eta)}\right]^{-\frac{1}{1-\alpha}} - \upsilon F^I \tag{14}$$

$$= \psi'(\eta,\gamma,\upsilon)\theta^{\frac{1}{1-\alpha}} - \upsilon F^I \tag{15}$$

Where for simplicity $\psi'(\eta,\gamma,\upsilon) = (\frac{1-\alpha}{\alpha})\Lambda\alpha^{\frac{1}{1-\alpha}}\Delta^{\frac{1-\alpha(1-\eta)}{1-\alpha}}\left[r^{\alpha\eta}\omega^{\alpha(1-\eta)}\right]^{-\frac{1}{1-\alpha}}$

Notice that the presence of uncertainty introduces distortions to the optimal values of investment by the firm h and its optimal demand of intermediate inputs m and this in turn distorts the profit level of the firm. In the presence of uncertainty the fixed cost of integration is also affected by the uncertainty level. This can be thought of generally as the additional cost in terms of frictions to the firm for having to alter its quantity demanded of the intermediate good when it faces uncertainty.

In a bargaining process similar to the one above we can also find the expected profit of the firm that decides to outsource the production of its intermediate inputs instead of vertically integrate production. In the above, the share of revenue that accrues to the firm engaged in vertical integration is given by $\gamma = \delta + \beta(1-\delta)$, however, similar to the case without uncertainty the share of revenue that goes to the firm when it engages in outsourcing is given by β. Therefore the expected profit to the firm for outsourcing

is given by the following:

$$\Pi_O^u = \left(\frac{1-\alpha}{\alpha}\right) \Lambda'(\alpha\theta^\alpha)^{\frac{1}{1-\alpha}} \Delta^{\frac{1-\alpha(1-\eta)}{1-\alpha}} \left[r^{\alpha\eta}\omega^{\alpha(1-\eta)}\right]^{-\frac{1}{1-\alpha}} - \upsilon F^O \quad (16)$$

$$= \psi'(\eta,\beta,\upsilon)\theta^{\frac{1}{1-\alpha}} - \upsilon F^O \quad (17)$$

Where $\Lambda' = \left[\frac{(1-\alpha(1-\eta)(1-\beta))(1-\beta)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}}{1-\alpha(1-\eta)}\right]^{\frac{\alpha(1-\eta)}{1-\alpha}}$

As can be seen from the above equations, the presence of uncertainty also distorts the profit level of the firm that engages in outsourcing.

2.4 Sourcing Decision Under Uncertainty

Similar trade off exists for the firm between outsourcing and vertical integration in the presence of uncertainty. Denoting the optimal value of the share of revenue that accrues to the firm in the presence of uncertainty as $\lambda^u(\eta)$ which is an increasing function of η there exists a value of η^u such that for any firm located in an industry where $\eta < \eta^u$ it is not profitable for the firm to engage in vertical integration since $\lambda^u < \beta$. However, for firms located in industries where $\eta > \eta^u$ there exists a level of firm productivity for which expected profits from integration dominates that from outsourcing and therefore the firm would choose to engage in vertical integration. The important issue however is how the choice between vertical integration is affected by the presence of uncertainty. To see this, we compare the profits from an integrated firm without uncertainty to the expected profits of a firm facing uncertainty. Using equation 8 and 15 we assume the following:

Assumption 1: $\upsilon < \frac{\psi'(\eta,\gamma,\upsilon)}{\psi(\eta,\gamma)}$

The assumption above essentially states that the profit function of the integrated firm in the presence of uncertainty is steeper than the case in which the firm is certain about the demand it faces. This is an innocuous assumption because in the presence of demand uncertainty the variability in profits is great, and this assumption is particularly true in the case with positive demand shocks. This is analogous and intuitively similar to the assumption used in Williamson (2000, 2002,) in his discussion of trans-

action cost theory and White (1945) analysis of the automobile industry in the US. We have the following proposition.

Proposition 2. *If assumption 1 holds, then there is more vertical integration in the presence of demand uncertainty compared to the case where firms face a predetermined industry level demand.*

To see this, assumption 1 implies that the minimum productivity level required by the firm engaged in vertical integration in the absence of uncertainty to break even (i.e $\Pi_I^c = 0$) is higher than that required by the firm in the presence of uncertainty.[17] Since the presence of uncertainty distorts both expected profits from outsourcing and integration in a similar way, it implies that the productivity level at which the firm is indifferent between outsourcing and integration in the presence of uncertainty is less than the minimum productivity level for which the firm is indifferent in the absence of uncertainty. Therefore for a particular representative firm, it requires a marginally less productivity level in order to engage in vertical integration and be profitable when facing uncertainty than when demand is certain.[18] The intuition behind this result is that, if a firm vertically integrates with its intermediate input supplier it is able to manage the production of the intermediate input when there is a demand shock than when it engages a third party supplier. In the case of an independent supplier, it may be difficult to respond to demand shocks without having to pay any penalty. Also, management of inventory under vertical integration is better than under outsourcing and since fluctuations in demand invariable requires a more robust inventory management system vertical integration in the presence of demand uncertainty generates higher profit for the firm compared to a firm engaged in outsourcing.[19] Thus in the presence of uncertainty, vertical integration is more pronounced than the case where

[17]Where Π_I^c is the profit level of the vertically integrated firm in the absence of uncertainty which is a given by equation 7. By also setting $\Pi_I^u = 0$ we find the minimum productivity level required to make it profitable for a firm to participate in vertical integration in the presence of uncertainty.

[18]Notice that η has to be high enough for the existence of both vertical integration and outsourcing within a particular industry. If η is very small then only one organizational structure emerges; outsourcing. No matter the level of firm productivity, it is only able to obtain a small share of the revenue which makes outsourcing the preferred organizational structure. Since in our data within any narrowly defined industry there exist both organizational structures this condition is trivially satisfied.

[19]For example Zara, a vertically integrated clothing store, manages the seasonality and variations in its fashion lines more quickly compared to similar stores such as H&M and Gap that engages primarily in outsourcing. It is reported that Zara can introduce a new product line within three weeks whereas it can take as much as nine months for H&M to do the same.

the firm knows its demand with certainty. We represent this situation in the diagram below:

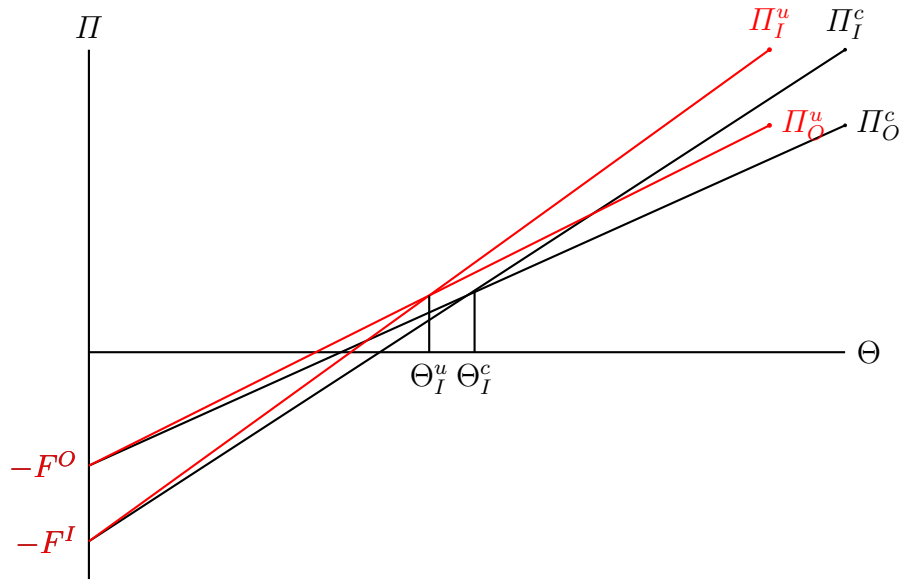

Figure 1: Vertical integration under uncertainty

The level of productivity for which the firm is indifferent between outsourcing and vertical integration in the presence of uncertainty can be found by $\Pi_I^u = \Pi_O^u$. This is given by the following:

$$\Theta_I^u = \frac{\upsilon(F^I - F^O)}{\psi'(\eta, \gamma, \upsilon) - \psi'(\eta, \beta, \upsilon)} \tag{18}$$

Where $\Theta_I^u = \theta^{\frac{\alpha}{1-\alpha}}$. This level of productivity is less than the level of productivity given by $\Pi_I^c = \Pi_O^c$.[20] Therefore holding η constant, marginally less productivity is required for the firm to engage in vertical integration. Thus in the presence of uncertainty, vertical integration is pronounced partly as a mechanism for coping and managing the distortions that arise as a result of this uncertainty.

We have looked at the case where firms located in the same industry in terms of the elasticity of headquarter services to final output production η require different levels of productivity to engage in vertical integration depending on whether uncertainty is present or not. What happens then for firms located in different industries in terms of η but have similar levels of productivity Θ and the same share if profit λ but face uncertainty? What determines the incentive to outsource or engage in vertical integration? From equation 18 we assume the following:

[20]Where Π_O^c is the profit level of the firm engaged in outsourcing in the absence of demand uncertainty which is given by a version of equation 7. This level of productivity is denoted by Θ_I^c.

Assumption 2: $\frac{\partial \psi'(\eta,\lambda,\upsilon)}{\partial \eta} < 0$

The assumption implies that for two firms with identical levels of productivity Θ and the same bargaining power λ, profit is higher for the firm located in industry η_1 given that $\eta_1 < \eta_2$. Essentially, firm 2 is producing a higher share of headquarter services which should enable it capture greater rents from vertical integration, however since it has the same revenue share as firm 1, its profit level will be lower if it engages in vertical integration than if it outsources. Thus we have the following proposition:

Proposition 3. *If assumption 2 holds, then in the presence of demand uncertainty there is less vertical integration for higher values of η.*

To see this, assume two representative firms with the same level of productivity but located in two different industries such that $\eta_1 < \eta_2$ and further assume that firm 1 is indifferent between outsourcing and vertical integration. Since $\eta_1 < \eta_2$ and if assumption 2 holds it must be the case that firm 2 outsources production of its intermediate goods since doing so results in a higher profit than vertical integration. For firm 2 to participate in vertical integration or become indifferent between vertical integration and outsourcing in the presence of uncertainty, it must be the case that the productivity level of firm 2 is greater than that of firm 1. This contradicts the fact that the two firms have same level of initial productivity. Therefore, in the presence of uncertainty a higher level of η is associated with less vertical integration. This can be illustrated in the figure below:

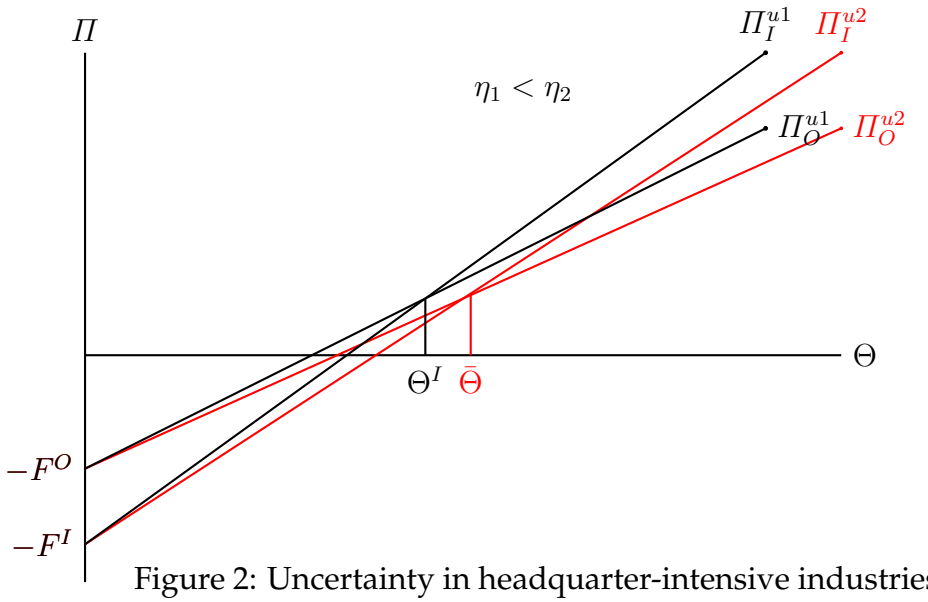

Figure 2: Uncertainty in headquarter-intensive industries

From the diagram, firm 1 is indifferent between vertical integration and outsourcing at Θ^I. We assume that firm 2 has the same level of productivity however because assumption 2 holds it implies that the profit functions faced by firm 2 is given by Π_I^{u2} and Π_O^{u2}. At this level of productivity, the profit level of firm 2 is higher if it outsources than when it engages in vertical integration. Thus firm 2 requires a higher level of productivity given by $\bar{\Theta}$ for it to be indifferent between outsourcing and vertical integration. Therefore for firms located in industries with higher headquarter services the vertical integration productivity threshold is higher. Hence, if $\bar{\eta}\in[\eta^b, 1]$, where η^b is the level of η high enough for the occurrence of both types of organizational structures, then there is more vertical integration for firms located in industries with $\eta < \bar{\eta}$ compared to those located in $\eta > \bar{\eta}$. Intuitively, in industries with higher value of η the most important input for production is the headquarter services, therefore in the presence of uncertainty the representative firm would be more interested in mitigating the risks by concentrating its effort on the provision of headquarter services while outsourcing the production of intermediate inputs to a third party since intermediate inputs is a smaller fraction of the overall inputs needed for production.

We have discussed above several implications of the decision by the firm to outsource or engage in vertical integration when it faces uncertainty regarding the demand of its final output. For any industry characterized by a small elasticity of headquarter services to final output, the decision to either outsource the production of intermediate inputs or engage in vertical integration is independent of the level of productivity of the firm and the firm will always find it profitable to outsource instead of engage in vertical integration. In the presence of uncertainty, the organizational structure is unchanged for firms with $\eta < \eta^b$. However, for industries in which $\eta > \eta^b$ uncertainty is associated with increased vertical integration. Thus firms located in the same industry would have different organizational structures depending on their level of productivity. We also suggested in our model that firms that require higher η and facing demand uncertainty would require an even higher level of productivity to be profitable and nudged into vertical integration. Therefore a higher $\bar{\eta}$ is associated with a lower level of vertical integration in the presence of uncertainty.[21]

[21] In this particular situation we are interested in the between industry effect of uncertainty on vertical

In the rest of the section, we exploit the variation in the industry level requirement of headquarter services in the production of final output to assess the impact of uncertainty on the organizational structure that govern different types of industries. Therefore we compile industry level data from different sources in the US to test the predictions of the model.

3 Empirical Evidence

The basic model discussed above provides unambiguous implication that the presence of demand uncertainty leads to increased intra-firm trade. We also find that in the presence of uncertainty, industries in which higher headquarter services are required for the production of final output reduces vertical integration. Thus while vertical integration and uncertainty are positively related, vertical integration and uncertainty are negatively related when $\bar{\eta}$ is sufficiently high. In this section we combine industry level data from different sources for the US to test the implications of the model outlined above. Specifically, we are interested in testing the following hypothesis:

Hypothesis 1: Intra-firm trade increases in industries where the share of headquarter services in total production is high (**Antras and Helpman Effect**).

As suggested in proposition 1, firms located in high capital intensive industries have a higher bargaining power which makes them able to appropriate a higher share of revenue by integrating with a supplier. This is a direct implication of Antras and Helpman (2004) and Antras (2003) provided empirical evidence that support the argument that intra-firm trade is higher in capital intensive industries.

Hypothesis 2: Uncertainty has an unambiguously positive impact on intra-firm trade.

integration for a specified value of $\bar{\eta}$. This will be precisely determined and defined using the first moments and medians in different industries in the empirical section of the paper.

This is a direct implication of the model outlined which posits that, the presence of uncertainty makes vertical integration more attractive to the firm since it is able to manage the level of uncertainty better when intermediate inputs are produced within the boundaries of the firm.

Hypothesis 3: Intra-firm trade is less in capital intensive industries in the presence of uncertainty.

In industries that are capital intensive (i.e require high headquarter services), the most important factor of production is the headquarter services. In the presence of uncertainty, final good producers would focus efforts in managing the consequences that are inherent in production by focusing on the production of head quarter services while outsourcing the production of intermediate inputs. Therefore, as outlined in the theoretical section, the presence of uncertainty reduces intra-firm trade in capital intensive industries. The next section outlines the empirical strategy and the data used in testing the hypothesis.

3.1 Empirical strategy

In order to empirically estimate the relationship between uncertainty and vertical integration, we exploit variations at the industry level of the share of headquarter services required for the production of final output. Since required headquarter services differ by industry, we study the variation in vertical integration across different industry classification using the following specification:

$$VI_{jt} = \vartheta_0 + \vartheta_1 \cdot unc_{jt} + \vartheta_2 \cdot unc_{jt} \cdot [\eta = 1 | \eta > \bar{\eta}] + X'\vartheta_3 + \varphi_c + \varphi_i + \varepsilon_{ji} \tag{19}$$

The above specification can be thought of as a simple form of a difference in difference estimation since industries are sorted into different categories depending on their level of dependence on headquarter services for final good production. VI_{jt} is a measure of vertical integration in industry j at time t and is defined as the share of intra-firm trade in a particular industry as a percentage of total imports while unc_{jt} refers to a measure

of uncertainty at the industry level in a particular year. We use a dummy variable equal 1 to denote industries with a value of η higher than a specific threshold and zero otherwise. We also include a variety of industry specific factors that are known to affect the degree of vertical integration as well as country specific variables such as the rule of law and a measure of the financial development of the country to account for the conduciveness of the business environment in a particular country which is denoted as vector X. φ_c and φ_i represent country and year fixed effects while ε_{ji} is the classical error term. We do not include industry fixed effect since we are interested in teasing out the variation in industry headquarter services requirement on vertical integration. Adding industry fixed effect will subsume these variations.

3.2 Data sources and definition

Our measure of vertical integration is given by $\frac{M_j^v}{M_j^v+M_j^o}$ which is the share of related party imports from industry j at any specific period of time and it is taken from the BEA. Related party transactions are recorded as imports between two firms with at least 6% stake in the ownership of the firm.[22] Desai et al (2004) however reports that whole ownership is common in which firms own 80% stake in foreign affiliate in 1997. This data is aggregated at the NAICS 6-digit industry level from 2002 to 2009. The time frame chosen is limited by the availability of other important independent variables in the regression.

We use two variables to capture demand uncertainty at the industry level. First, we use the dispersion of sales revenue growth at the firm level aggregated to the SIC 4-digit industry level to measure the degree of uncertainty that is characteristic of any particular industry. On average, the number of establishments used in the construction of this variable per industry is 27 plants. It is computed by taking the standard deviation of sales growth by these plants in a particular year. Generally, higher value of dispersion implies that the industry is subject to a high degree of volatility and therefore faces more uncertainty. Secondly, variations in plant level total factor productivity shocks aggregated at the industry level is used as the second measure of industry level

[22] A similar measure of vertical integration is used in studies by Nunn and Trefler (2013) and Costinot et al. (2011).

uncertainty. This second measure of uncertainty more accurately captures supply side uncertainty. Although the focus of this work is not on supply side uncertainty, this alternate measure helps in shedding light on the effect of uncertainty in general and its effect on intra-firm trade. We use data constructed by Bloom et al (2012) using datasets from the US Annual Survey of Manufactures (ASM) census for the analysis.[23]

One important variable of interest we need is the share of headquarter services in the production of final output. Several studies including Antras (2003) use the share of capital in production as a measure of capital intensity requirement at the industry level. We use data from the NBER-CES manufacturing provided at the NAICS 6-digit industry level to measure capital intensity. More specifically, we use total capital investment divided by total worker wages as our measure of capital intensity. In the baseline regression we match the NAICS 6-digit industry level to SIC 4-digit using concordance provided by NBER and define $\bar{\eta}$ as the mean of capital intensity at the SIC 4-digit industry level and define a dummy equal one if an industry has capital intensity greater than the mean in a given year.[24] We also employ other industry level variables that are related to intra-firm trade with data available form NBER. These include skills intensity, measured as the log of non-productive worker wages to total worker wages: material intensity, measured as the log of expenditure on materials divided by total worker wages. Material intensity refers to the the amount of intermediate inputs used by the firm. We also include value added output at the industry level as a measure of the productivity level of the industry. This is measured as the log of value added divided by total worker wages. These variables are expected to be positively related to intra-firm trade at the industry level. [25]

Our analysis also include country level variables to capture the fact that a business friendly environment tends to promote trade of any form. Thus following Chinn and Ito (2006) and Girma and Shortland (2004), we use one traditional measure of the level of financial development in the import country measured as the ratio of private credit by deposit and other financial institutions to GDP. A higher value of this variable is

[23]This data is freely available and can be accessed on http://www.stanford.edu/~nbloom/RUBC.zip

[24]We also define $\bar{\eta}$ as the median of industry capital intensity. Several other specifications are used for robustness checks.

[25]These variables can be found at http://www.nber.org/nberces/ Data is only available from 2002 to 2009 thus we limit out sample to these years.

often associated with greater financial deepening which is relevant for trade. We also use data from the 2013 version of the World Bank's Financial Structure database. To capture the effect of the business environment on intra-firm trade we use the rule of law index based on data developed by the world bank on worldwide Governance.[26] Table 1 provides summary statistics for the variables used in the analysis.

[**Table 1:** About here]

The table above shows summary statistics for 142 industry classification at the NAICS 6-digit level from the manufacturing sector and contains imports from 152 different countries. Not all countries record positive values for all industry groups. The choice of industry and countries of imports were limited by the availability of information.

3.3 Empirical results

3.3.1 Baseline results

This section analyzes whether uncertainty has a significant effect on the share of intra-firm trade and to what extent capital intensity requirement affect this relationship. As already explained earlier, we use the specification in equation 19 for our baseline analysis. To start with we first find the mean of capital intensity for the entire sample and generate a dummy variable equal one for industries with capital intensity greater than the overall mean and zero otherwise. Invariably we have two distinct industries in terms of capital intensity i.e those with capital intensity below the overall mean and those for which capital intensity is above the overall mean.

We show the baseline results in table 2. The first three columns report regression results using the deviations of sales at the plant level as a measure of uncertainty. As can be seen, uncertainty has an unambiguously positive relationship with intra-firm trade thus confirming the hypothesis outlined in the model. The same results are obtained using the innovations to plant level total factor productivity as a measure of

[26]The rule of law index captures agents perception and confidence in the laws in a particular country. More specifically it captures the quality of contract enforcement, property rights and the court system as well as the likelihood of crime and violence. It ranges from -2.5 to 2.5 with higher values representing better institutional quality.

industry level uncertainty. Even though uncertainty has a negative effect on intra-firm trade for industries with capital intensity greater than the overall mean in our sample these coefficients are not statistically significant. We add several industry and country level controls that are important determinants of intra-firm trade to the analysis and find broadly consistent results. Capital intensity for instance has an unambiguously positive relation with intra-firm trade which is consistent with several other studies that have looked at the relationship between capital intensity and intra-firm trade (see for instance Antras (2003) and Nunn and Trefler (2013)). Material intensity is generally negative in our regression analysis however, skills intensity even though it has positive association with intra-firm trade provide coefficient values that are barely significant at the 10% significance level. At the country, the financial development of the country has broadly economically insignificant effect on the share of intra-firm trade, the level of contract enforcement in the country which is measure by the rule of law index and can be thought of as δ in the context of our model has a positive effect on intra-firm trade which indicates that countries that have effective contract enforcement laws and principles would tend to witness more intra-firm trade compared to countries with weaker contract laws. Controlling for year fixed effect, country fixed effect or both do not change the results reported.

Our choice of the mean industry level capital intensity as our reference point can of course be questioned. In the mean time however as our baseline analysis we look more closely at the construction of this variable. As a next step we calculate the mean level of capital intensity at the SIC 4-digit industry level since each of them contain several subindustries at the NAICS 6-digit classification and generate a dummy variable equal one for industries within each SIC that has capital intensity greater than the mean and zero otherwise. Thus in this modification, we are trying to tease out the within industry variation of capital intensity requirement and its interaction with uncertainty as a determinant of intra-firm trade. The results of this modification is shown in table 3. Similar to results reported in table 2, uncertainty has a positive and significant effect on the level of intra-firm trade. A closer look at the results also points out that the presence of uncertainty within industries with capital intensity greater than the mean level

within a broadly defined industry classification has a negative and significant effect on the share of intra-firm trade. Thus within the broader industry, industries with higher capital intensity are associated with reduced intra-firm trade. This can be termed as the "across narrow industry within broader industry" effect. Across narrowly defined industries within a broader industry classification, the higher the capital intensity required the less there is intra-firm trade. The control variables have broadly consistent results similar to that in table 2.

Another dimension we would like to look at is the time varying effect of capital intensity in an industry and its effect on intra-firm trade. There is no reason to think that the intensity of capital for each industry is constant over time. To this end we find the time varying mean for each industry i.e we calculate the mean in each SIC 4-digit for each year and generate a dummy variable equal one if an industry within the SIC 4-digit industry has capital intensity greater than the mean in that year and zero otherwise. We present results of this analysis in table 4. Similar to the results discussed above, uncertainty has a positive effect on the share of intra-firm trade while uncertainty at higher capital intensity across time has a negative effect on intra-firm trade. This particular results are the strongest in terms of the the level of significance of the coefficients. All the coefficients have the correct sign and are significant at the 1% significance level except one which has the correct sign but is significant at the 5% significance level. The control variables still have broadly consistent signs with the inclusion of both year and country fixed effects having a negligible impact on the coefficients of the analysis. Using columns (3) and (6) from table 3 we graph the margins of the impact of the two different measures of uncertainty and their interaction with capital intensity on the share of intra-firm trade. We use columns (3) and (6) partly because our coefficients of interest are significant at the 1% level and also because the R^2 for these regression are higher compared to the others. Figures 2 to 5 in the appendix show these margins and as can be seen the higher the uncertainty the higher would be intra-firm trade but as capital intensity increases, uncertainty tend to be associated with less intra-firm trade.[27]

[27] We can precisely find the effect of a one standard deviation increase on the share of intra-firm trade. Using column 3 of table 3 a simple "back of the envelop" calculation finds that a one standard deviation increase in uncertainty increases intra-firm trade by about 6.4% while reducing intra-firm trade share

3.3.2 Robustness checks

We have considered three variations of separating industries into high capital intensity and low capital intensity industries and analyzing how these different variations affect the share of intra-firm trade when industries face uncertainty. We have also used two different measures of uncertainty to assess this relationship and the results from varying definitions of capital intensity and measures of uncertainty give results consistent with the theory outline. To be sure these results are not being driven by spurious variables, we subject out analysis to a buttery of other robustness checks.

Interaction with Capital Intensity: As pointed out earlier, using the mean of capital intensity may be questionable since there is really no theoretical reason to use the industry level mean of capital intensity as a way of separating industries. To address this we simply interact our measures of uncertainty with capital intensity to see if our results are altered in any significant way. Table 5 reports the results of this exercise. The results in table 5 show that interacting uncertainty with capital intensity provides results that are consistent with results obtained earlier indicating that our earlier specification is similar to the one used here. Uncertainty has a positive effect on intra-firm trade while the interaction term for uncertainty and capital intensity is negative with coefficients of similar magnitudes to those above.

Alternative Measures of η: Since we have used the industry mean of capital intensity to categorize industries a natural next step is to see if our results are robust to similar categorization. First we begin with variations of capital intensity using the median. We find the median within each SIC 4-digit classification and generate dummy variables analogous to the case when using the mean. Table 6 reports results for within industry variation in median capital intensity while table 7 provides results for within industry variation of median capital intensity across time. The results from these tables provide qualitatively similar results to those found using the mean capital intensity to categorize industries. A similar categorization is done using the $95th$ percentile of industry capital intensity. As is the case in the analysis above, the higher the capital intensity required in a particular industry the lower the share of intra-firm trade will

for industries with capital intensity greater than the industry mean by about as much as 26%.

be in the presence of uncertainty. We show this analysis in table 8. Uncertainty still has a positive effect on the share of intra-firm trade as suggested by the theoretical model and several other analysis done while industries located above the $95th$ percentile in the SIC 4-digit industry classification have a smaller share of intra-firm trade when facing uncertainty at the industry level.

Simple Falsification Test: To be able to rule out the possibility that our results are a result of random chance we undertake a simple falsification test. If our results are not random, then assuming that we have another set of data with uncertainty variables unrelated to the one used in the analysis we should at best expect results using that data set to have an insignificant effect on the share of intra-firm trade in our data set. Of course getting that kind of data can be tasking. Alternatively, we could generate random variables to mimic this artificial data set. To do this we first generate normal random numbers for our two uncertainty measure that have the same mean and standard deviation as our original data set.[28] Then using these two measure we analyze to see if there is any relationship between these randomly generated measures of uncertainty and the share of intra-firm trade. Tables 9 and 10 provide the results from this test. Table 9 uses our artificial measure of uncertainty and interact it with our measure of within industry median variation in capital intensity across time. It shows that the measure of uncertainty used has no effect on intra-firm trade. Both variables of interest are insignificant at conventional levels. Table 10 uses the randomly generated measure of uncertainty interacted with our measure of capital intensity at the industry level and find that these artificial measures of uncertainty have no significant impact on intra-firm trade while uncertainty in the presence of high capital intensity is positively related to intra-firm trade which is contrary to our theoretical model and the results in our main paper. By randomly assigning random measures of uncertainty to industries we are able to rule out the possibility that the results in our paper are driven by some random observations.

[28]We also generated random variables using other distributions such as rectangular, hypergeometric and gamma. Using these distribution gives results similar to the test using the normal distribution therefore we stick to the widely known normal distribution.

3.3.3 Extensions and Alternative Explanation

Alternative Measure of Vertical Integration: In the main analysis of the paper we used Intra-firm trade as a measure of vertical integration. In an attempt to provide further evidence on the relationship between demand uncertainty and intra-firm trade we use an alternative measure of vertical integration which measures the degree to which two industries are related and therefore the probability that firms can vertically integrate production. We use the measure proposed by Fan and Lang (2002) and refined in Acemoglu et al (2009) and Fresard et al (2014) using the Input-Ouput tables.

We use the benchmark input-output account published by the Bureau of Economic Analysis (BEA) to calculate the degree of vertical integration by an industry. Input-output tables provide useful information about the dollar value of inputs from one industry used in the production of output in another industry. The 2002 input-output accounts provide data at the six digit NAICS level which we use in the calculation of the index for the manufacturing sector, comparable to the data used earlier.

We start by using data from Compustat for all firms in the manufacturing sector at the four digit SIC code and matching these with the six digit NAICS input-output data using concordance provided by BEA. For every pair of industries, IO_i and IO_j, we follow Acemoglu et al (2009) and calculate, using the input-output tables, the dollar value of input i used in the production of a unit dollar value of output j. This value, VI_{ij} can be termed as the vertical integration coefficients which represents the opportunity for vertical integration between the two industries. We use the universe of coefficients from the data to calculate the vertical integration index at the firm level. This index is calculated as follows:

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

Where v_{fit} is the vertical integration index for firm f located in industry i at time t. N_{ft} is the set of industries in which the firm operates at time t and $|N_{ft}|$ is the number of industries in which the firm operates at time t. Next, we calculate the vertical integration index at the industry level which is expressed as follows:

$$V_{it} = \frac{1}{|N_{it}|} \sum_{i \in N_{it}} v_{fit}$$

Where V_{it} is the vertical integration index for industry i at time t. N_{it} is the set of firms located in industry i at time t and $|N_{it}|$ is the number of firms located in industry i at time t. We then use this as an alternative measure of vertical integration for our analysis.

Table 11 provides the results from using this measure of intra-firm trade. This results confirm those obtained in the previous analysis. In particular, Table 11 shows that uncertainty is positively related to vertical integration and reduces vertical integration in capital intensive industries. These results are highly significant with higher explanatory power when we use this alternative measure of vertical integration.

Demand Uncertainty and Industry Concentration: An important thought experiment is to consider an alternative way of thinking about demand uncertainty and how different industries adjust to shocks in demand. Let us assume the demand curve in equation (2) still holds. We assume, however that, the demand facing each industry is subject to demand shocks which we model simply as $x = zAp^{\frac{-1}{1-\alpha}} + \varrho$ with $E(\varrho) = 0$. If an industry is populated by n number of firms then for every non-zero realization of ϱ each firm is expected to be affected by $\frac{\varrho}{n}$ of the shock. Since every industry is populated by different values of n, in a less concentrated industry (i.e a higher value of n) we expect demand shocks to fade out as the number of firms increases:

$$\lim_{n \to \infty} \frac{\varrho}{n} = 0$$

Therefore, in less concentrated industries, demand shocks (or alternatively uncertainty about the realization of demand shocks) are likely to affect individual firms less and may not matter in the decision regarding vertical integration. However, for highly concentrated industries any shock to demand is an important factor for the few firms in the industry and therefore should play a role in determining whether a firm in this industry vertically integrates with its supplier or not. Therefore, firms in highly concentrated industries are more likely to engage in vertical integration compared to those in less

concentrated industries. For this reason we introduce a measure of industry concentration as a proxy for demand uncertainty. We use the Herfindahl-Hirschman Index (HHI) to measure industry concentration. Using data of firms in the manufacturing sector from Compustat we follow Beiner et al. (2011) and measure HHI as the sum of squared market shares of each firm in a given industry. Therefore the concentration index is measured as follows:

$$HHI_{jt} = \sum_{i=1}^{N_j} \left(\frac{sales_{ijt}}{\sum_{i=1}^{N_j} sales_{ijt}} \right)^2$$

HHI_{jt} is the measure of concentration of industry j at time t: $sales_{ijt}$ represents sales of firm i in industry j at time t. Higher values of the index represents more concentration and less competition in the industry.

Table 12 reports results using HHI as a proxy for demand uncertainty in the analysis. It shows that, very concentrated industries are associated with more intra-firm trade compared to less concentrated industries. The first row of table 12 shows all the coefficients are positive and statistically significant at the 1% significance level. Industry level concentration appears, in table 12, not to have any significant differential effect on intra-firm trade in terms of the capital intensity requirement in the industry as row 2 of table 12 shows.

4 Conclusion

This paper contributes to the current debate on the organizational structure adopted by firms by introducing demand uncertainty as a possible channel considered by multinational firms before deciding whether to engage in vertical integration or outsource production. We adapt the model in Antras and Helpman (2004) to an environment in which firms face uncertainty regarding the demand in the industry in which the firm is located. The presence of uncertainty encourages intra-firm trade as firms try to cope with the risks involved by producing intermediate inputs in-house. For particularly high capital intensive industries, the presence of uncertainty reduces vertical integration as firms tend to concentrate on the core business of the firm while outsourcing

the production of intermediate inputs that play a small part in the production of final output.

We use industry level data for the US to test the hypothesis of the model and find evidence broadly consistent with the theoretical model outlined. The findings in this paper have policy implications for both the source country and the destination country. As pointed out by Tanaka (2015), multinational firms have a pay premium for their employees. Therefore, for the destination country, when industries face demand uncertainty, in order to maintain the wage premium for workers in multinational firms, tax breaks may be required for firms with high capital intensity to mitigate the risks of reducing intra-firm trade. On the other hand, for the source country, it shows that the consequences of plant level uncertainty are not limited to the activities in the domestic economy, but may have far reaching consequences in terms of international trade.

Several issues relating to uncertainty and intra-firm trade remain to be discussed in the literature. For instance, what mechanism is at play in the relationship between uncertainty and intra-firm trade. A possible scenario is to look at how time lags between demand uncertainty and the delivery of intermediate inputs interact. In particular, if firms operate in industries where time lags are high, uncertainty may be resolved earlier and therefore presents less risks regarding the form of organizational choice. These mechanisms can be explored more accurately with access to firm level data that have idiosyncratic risk elements to firms.

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APPENDIX

Table 1: **Descriptive Statistics.**

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Intra-Firm Trade	32042	0.297	0.345	0	1
Capital Intensity	48766	0.387	0.427	0.039	5.888
Skills Intensity	48766	-0.0540	-0.424	-1.676	0.479
Materials Intensity	48766	1.802	0.649	0.214	4.529
Value Added	48766	0.500	0.102	0.188	0.794
Uncert_sales	34603	0.249	0.059	0.124	0.428
Uncert_tfp	34603	0.481	0.100	0.194	1.037
Fin. Dev.	44963	66.532	51.385	0.888	272.936
Rule of Law	48551	0.347	1.009	-2.5	1.999

As pointed out in the variables description section, we combine data from different sources. Intra-Firm Trade measures the share of imports from related parties and therefore ranges from zero to one. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law which we get from datasets provided by the world bank.

Table 2: **Baseline Regression: η is the overall mean**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.717***	0.637***	0.847***	0.270*	0.379***	0.381***
	(0.225)	(0.231)	(0.223)	(0.141)	(0.131)	(0.137)
Uncert*$[\eta = 1]$	-0.199	-0.167	-0.057	-0.047	-0.050	0.017
	(0.145)	(0.147)	(0.142)	(0.076)	(0.075)	(0.073)
Materials Intensity	-0.080**	-0.104***	-0.110***	-0.123***	-0.110***	-0.138***
	(0.035)	(0.037)	(0.036)	(0.037)	(0.036)	(0.036)
Skills Intensity	0.044	0.031	0.061*	0.004	0.014	0.024
	(0.034)	(0.034)	(0.033)	(0.033)	(0.033)	(0.032)
Value Added	-1.237***	-1.225***	-1.261***	-1.278***	-1.344***	-1.349***
	(0.175)	(0.176)	(0.171)	(0.185)	(0.184)	(0.181)
Capital Intensity	0.024***	0.025***	0.020***	0.025***	0.023***	0.019***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.174***	0.188***	-0.157	0.189***	0.175***	-0.156
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.03	0.03	0.12	0.03	0.03	0.12

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for industries with capital intensity greater than the overall **MEAN**. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 3: **Baseline Regression: η is the mean within SIC 4-digit industry**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.576**	0.611***	0.899***	0.283**	0.268*	0.416***
	(0.228)	(0.233)	(0.225)	(0.051)	(0.053)	(0.051)
Uncert*$[\eta = 1]$	-0.138	-0.205**	-0.228**	-0.073	-0.105**	-0.111**
	(0.099)	(0.102)	(0.098)	(0.051)	(0.053)	(0.051)
Materials Intensity	0.092***	0.095***	0.056**	0.081***	0.086***	0.040*
	(0.023)	(0.023)	(0.023)	(0.024)	(0.024)	(0.024)
Skills Intensity	0.032	0.019	0.052	0.005	-0.008	0.011
	(0.034)	(0.034)	(0.033)	(0.033)	(0.033)	(0.032)
Value Added	-0.865***	-0.829***	-0.936***	-0.896***	-0.844***	-0.974***
	(0.159)	(0.159)	(0.157)	(0.165)	(0.167)	(0.164)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.175***	0.186***	-0.166	0.176***	0.186***	-0.165
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.02	0.02	0.12	0.02	0.02	0.12

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for NAICS 6-digit industries located within SIC 4-digit industry with capital intensity greater than the **MEAN** in each SIC 4-digit industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 4: **Within Industry-Year Variation: η is the mean within SIC 4-digit industry by year**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.883***	0.830***	1.078***	0.440***	0.342**	0.474***
	(0.227)	(0.234)	(0.226)	(0.131)	(0.141)	(0.137)
Uncert*$[\eta = 1]$	-0.460***	-0.450***	-0.459***	-0.195***	-0.192***	-0.190***
	(0.099)	(0.099)	(0.095)	(0.051)	(0.051)	(0.049)
Materials Intensity	-0.082***	-0.099***	-0.091***	-0.101***	-0.113***	-0.110***
	(0.031)	(0.033)	(0.031)	(0.032)	(0.033)	(0.032)
Skills Intensity	0.048	0.036	0.063*	0.013	0.003	0.019
	(0.034)	(0.034)	(0.033)	(0.032)	(0.033)	(0.031)
Value Added	-1.333***	-1.311***	-1.299***	-1.374***	-1.311***	-1.323***
	(0.164)	(0.165)	(0.161)	(0.171)	(0.172)	(0.168)
Capital Intensity	0.023***	0.024***	0.019***	0.023***	0.024***	0.019***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.176***	0.189***	-0.160	0.177***	0.189***	-0.159
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.03	0.03	0.13	0.03	0.03	0.13

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for NAICS 6-digit industries located within SIC 4-digit industry in a given year with capital intensity greater than the **MEAN** in each SIC 4-digit industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Figure 1: The Marginal Effect of Uncertainty on Intra-firm Trade

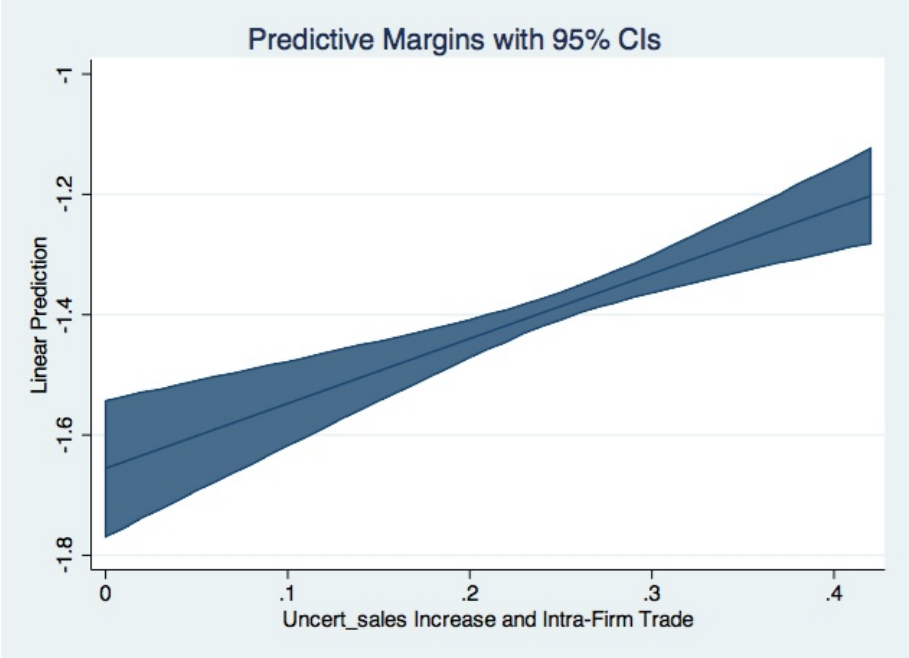

Figure 2: The Marginal Effect of Uncertainty for High Capital Intensive Industries

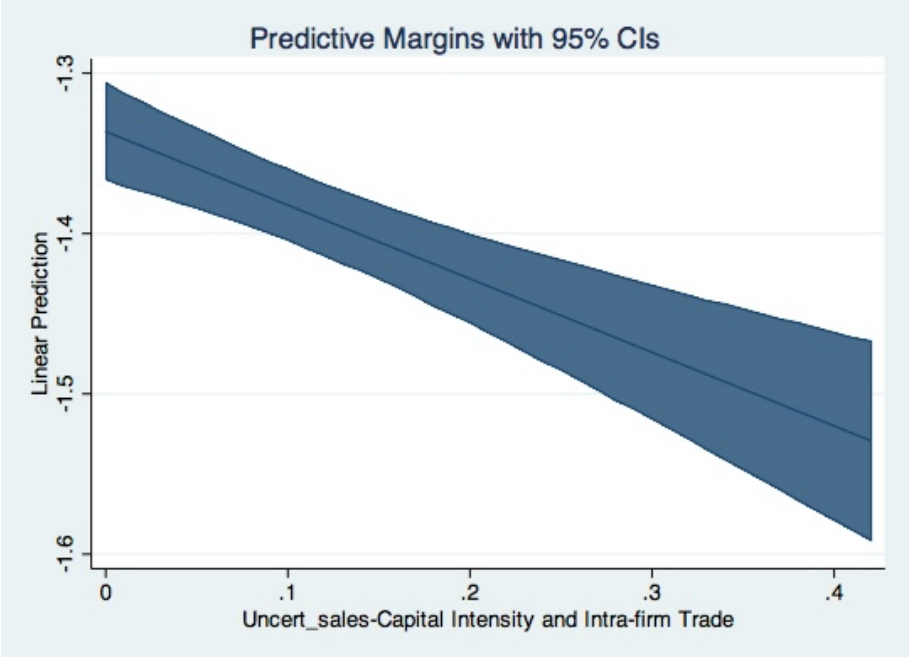

Figure 3: The Marginal Effect of Uncertainty on Intra-firm Trade

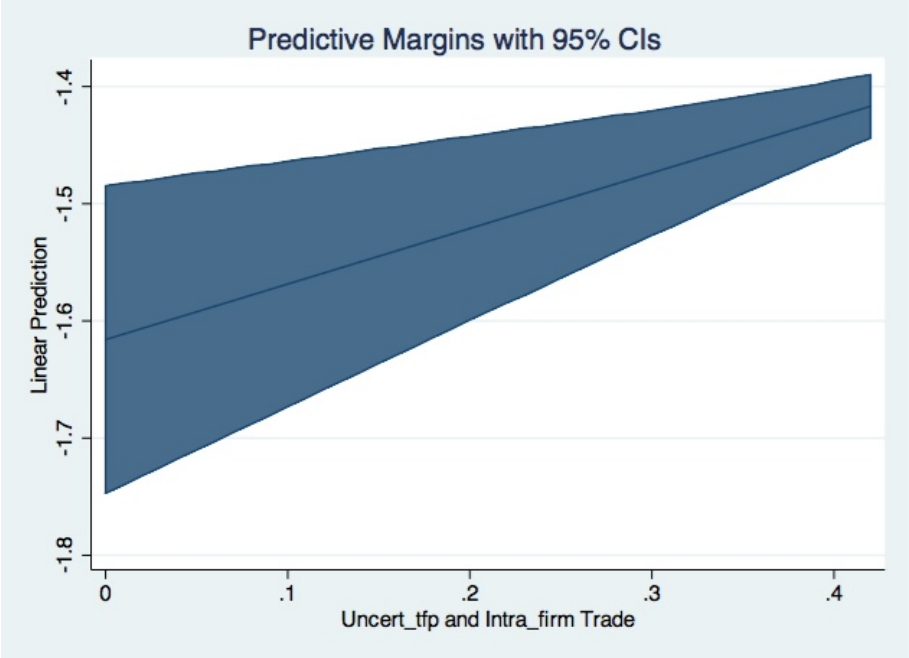

Figure 4: The Marginal Effect of Uncertainty for High Capital Intensive Industries

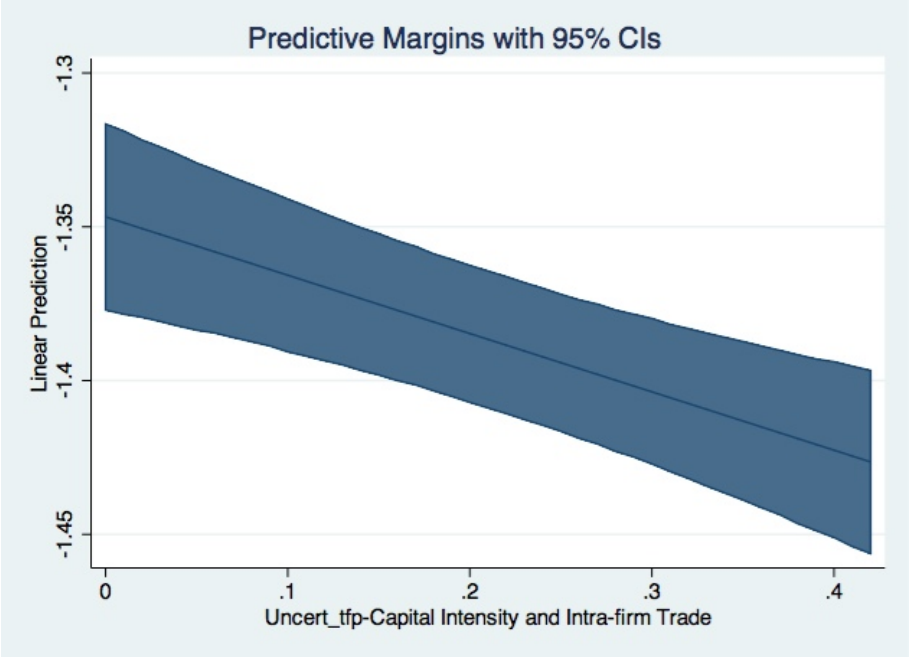

Table 5: **Interaction of Uncertainty with Capital Intensity**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.829***	0.787***	1.127***	0.501***	0.395**	0.582***
	(0.244)	(0.251)	(0.244)	(0.146)	(0.157)	(0.153)
Uncert*(Capital Intensity)	0.172	- 0.193*	- 0.282***	-0.122**	- 0.120**	-0.163***
	(0.107)	(0.108)	(0.106)	(0.055)	(0.055)	(0.054)
Materials Intensity	-0.140***	-0.167***	-0.177***	-0.174***	-0.188***	-0.204***
	(0.038)	(0.039)	(0.038)	(0.039)	(0.040)	(0.039)
Skills Intensity	0.055	0.042	0.074**	0.033	0.023	0.045
	(0.034)	(0.034)	(0.033)	(0.033)	(0.034)	(0.032)
Value Added	-1.389***	-1.375***	-1.399***	-1.508***	-1.442***	-1.499***
	(0.169)	(0.170)	(0.166)	(0.180)	(0.182)	(0.177)
Capital intensity	0.022***	0.023***	0.018***	0.021***	0.023***	0.017***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.174***	0.188***	-0.156	0.175***	0.188***	-0.155
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.03	0.03	0.13	0.03	0.03	0.13

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. We interact the level of uncertainty in an industry with capital intensity of the industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 6: **Baseline Regression: η is the median within SIC 4-digit industry**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.599**	0.625***	0.915***	0.284**	0.268*	0.419***
	(0.233)	(0.237)	(0.229)	(0.133)	(0.142)	(0.138)
Uncert*$[\eta = 1]$	-0.139	-0.189*	-0.211**	-0.054	-0.078	-0.087*
	(0.099)	(0.102)	(0.097)	(0.051)	(0.053)	(0.050)
Materials Intensity	0.095***	0.098***	0.060**	0.082***	0.087***	0.042*
	(0.023)	(0.024)	(0.023)	(0.024)	(0.024)	(0.024)
Skills Intensity	0.030	0.017	0.050	0.004	-0.010	0.010
	(0.034)	(0.034)	(0.033)	(0.033)	(0.033)	(0.032)
Value Added	-0.851***	-0.808***	-0.913***	-0.881***	-0.823***	-0.952***
	(0.158)	(0.159)	(0.156)	(0.164)	(0.166)	(0.164)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.175***	0.186***	-0.166	0.176***	0.186***	-0.165
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.02	0.02	0.12	0.02	0.02	0.12

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for NAICS 6-digit industries located within SIC 4-digit industry with capital intensity greater than the **MEDIAN** in each SIC 4-digit industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 7: **Within Industry-Year Variation: η is the median within SIC 4-digit industry by year**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	1.018***	0.953***	1.190***	0.389***	0.486***	0.515***
	(0.232)	(0.240)	(0.230)	(0.144)	(0.133)	(0.140)
Uncert*$[\eta = 1]$	-0.479***	-0.452***	-0.445***	-0.207***	-0.217***	-0.196***
	(0.103)	(0.103)	(0.098)	(0.054)	(0.054)	(0.051)
Materials Intensity	-0.075**	-0.093***	-0.085***	-0.106***	-0.093***	-0.105***
	(0.032)	(0.033)	(0.032)	(0.034)	(0.033)	(0.032)
Skills Intensity	0.040	0.027	0.055*	-0.002	0.007	0.014
	(0.034)	(0.034)	(0.033)	(0.033)	(0.032)	(0.031)
Value Added	-1.308***	-1.285***	-1.273***	-1.290***	-1.351***	-1.303***
	(0.163)	(0.164)	(0.160)	(0.172)	(0.171)	(0.168)
Capital Intensity	0.023***	0.024***	0.019***	0.024***	0.023***	0.019***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule Law	0.176***	0.190***	-0.158	0.190***	0.177***	-0.157
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.03	0.03	0.13	0.03	0.03	0.13

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for NAICS 6-digit industries located within SIC 4-digit industry in a given year with capital intensity greater than the **MEDIAN** in each SIC 4-digit industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 8: **Within Industry-Year Variation: η is the 95th percentile within SIC 4-digit industry by year**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.616***	0.619***	0.880***	0.324**	0.306**	0.439***
	(0.224)	(0.230)	(0.222)	(0.131)	(0.142)	(0.138)
Uncert*$[\eta = 1]$	-0.396***	-0.387***	-0.347***	-0.167***	-0.160***	-0.137**
	(0.114)	(0.114)	(0.110)	(0.058)	(0.058)	(0.056)
Materials Intensity	0.091***	0.091***	0.052**	0.080***	0.082***	0.036
	(0.023)	(0.023)	(0.023)	(0.023)	(0.024)	(0.024)
Skills Intensity	0.032	0.019	0.052	0.004	-0.008	0.012
	(0.034)	(0.034)	(0.033)	(0.033)	(0.033)	(0.032)
Value Added	-0.966***	-0.926***	-1.016***	-0.974***	-0.926***	-1.039***
	(0.162)	(0.163)	(0.161)	(0.168)	(0.170)	(0.168)
Fin. Dev.	-0.000	-0.000	-0.002*	-0.000	-0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.176***	0.186***	-0.169	0.177***	0.186***	-0.167
	(0.018)	(0.018)	(0.138)	(0.018)	(0.018)	(0.138)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	14254	14254	14254	14254	14254	14254
R^2	0.02	0.02	0.12	0.02	0.02	0.12

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for NAICS 6-digit industries located within SIC 4-digit industry in a given year with capital intensity greater than the **95TH PERCENTILE** in each SIC 4-digit industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 9: **Falsification: Using randomly generated values of uncertainty**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	0.240	0.234	0.262	-0.097	-0.097	-0.079
	(0.175)	(0.175)	(0.168)	(0.098)	(0.098)	(0.094)
Uncert*$[\eta = 1]$	-0.113	-0.099	-0.081	-0.078	-0.065	-0.042
	(0.083)	(0.083)	(0.079)	(0.079)	(0.079)	(0.076)
Materials Intensity	-0.109***	-0.127***	-0.117***	-0.111***	-0.129***	-0.120***
	(0.029)	(0.030)	(0.029)	(0.029)	(0.030)	(0.029)
Skills Intensity	0.062**	0.054**	0.050**	0.062**	0.054**	0.051**
	(0.026)	(0.026)	(0.025)	(0.026)	(0.027)	(0.025)
Value Added	-1.269***	-1.249***	-1.189***	-1.269***	-1.250***	-1.190***
	(0.144)	(0.145)	(0.141)	(0.144)	(0.145)	(0.141)
Capital Intensity	0.021***	0.023***	0.019***	0.021***	0.023***	0.019***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Fin. Dev.	-0.001**	-0.001***	-0.001**	-0.001**	-0.001***	-0.001**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule of Law	0.193***	0.207***	-0.107	0.192***	0.207***	-0.106
	(0.014)	(0.015)	(0.117)	(0.014)	(0.015)	(0.117)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	20334	20334	20334	20334	20334	20334
R^2	0.02	0.03	0.12	0.02	0.03	0.12

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for NAICS 6-digit industries located within SIC 4-digit industry in a given year with capital intensity greater than the **MEDIAN** in each SIC 4-digit industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 10: **Falsification: Interaction of randomly generated measures of Uncertainty with Capital Intensity**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: Intra-firm Trade	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	-0.021	0.005	0.059	-0.099	-0.099	-0.080
	(0.175)	(0.175)	(0.169)	(0.098)	(0.098)	(0.094)
Uncert*(Capital Intensity)	0.473***	0.414***	0.379***	0.469***	0.416***	0.392***
	(0.128)	(0.128)	(0.130)	(0.122)	(0.122)	(0.124)
Materials Intensity	-0.157***	-0.170***	-0.156***	-0.157***	-0.170***	-0.157***
	(0.031)	(0.032)	(0.031)	(0.031)	(0.032)	(0.031)
Skills Intensity	0.080***	0.070***	0.065**	0.079***	0.070***	0.065**
	(0.027)	(0.027)	(0.026)	(0.027)	(0.027)	(0.026)
Vallue Added	-1.366***	-1.336***	-1.269***	-1.366***	-1.337***	-1.273***
	(0.146)	(0.147)	(0.143)	(0.146)	(0.147)	(0.143)
Capital Intensity	0.018***	0.020***	0.017***	0.018***	0.020***	0.016***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fin. Dev.	-0.001**	-0.001***	-0.001**	-0.001**	-0.001***	-0.001**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Rule Law	0.194***	0.208***	-0.105	0.194***	0.208***	-0.104
	(0.014)	(0.015)	(0.117)	(0.014)	(0.015)	(0.117)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	20334	20334	20334	20334	20334	20334
R^2	0.02	0.03	0.12	0.02	0.03	0.12

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. We interact the level of uncertainty in an industry with capital intensity of the industry. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is a randomly generated variable fro the normal distribution matching the mean and standard distribution of the original data. Uncert_tfp s a randomly generated variable fro the normal distribution matching the mean and standard distribution of the original data. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 11: **Extension Regression: η is the overall mean**

Measure of Uncert	$Uncert\_sales$			$Uncert\_tfp$		
Dep Var: VI index (VI_{it})	(1)	(2)	(3)	(4)	(5)	(6)
Uncert	1.467***	1.357***	1.339***	1.061***	0.891***	1.021***
	(0.052)	(0.055)	(0.055)	(0.028)	(0.027)	(0.029)
Uncert*$[\eta = 1]$	-0.589***	-0.572***	-0.550***	-0.234***	-0.242***	-0.225***
	(0.031)	(0.031)	(0.030)	(0.013)	(0.013)	(0.013)
Materials Intensity	-0.003	0.018**	0.028***	-0.019**	-0.041***	-0.010
	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.009)
Skills Intensity	-0.007	-0.003	-0.007	-0.118***	-0.120***	-0.120***
	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Value Added	-1.026***	-1.017***	-0.969***	-1.134***	-1.066***	-1.089***
	(0.042)	(0.044)	(0.044)	(0.043)	(0.041)	(0.044)
Capital Intensity	0.015***	0.013***	0.012***	0.015***	0.017***	0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Fin. Dev.	-0.000	0.000*	0.000	0.000	-0.000**	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rule of Law	0.006	-0.002	0.034	-0.004	0.008*	0.033
	(0.004)	(0.004)	(0.028)	(0.004)	(0.004)	(0.027)
Controls:						
Year FE	N	Y	Y	N	Y	Y
Country FE	N	N	Y	N	N	Y
Obs	9358	9358	9358	9358	9358	9358
R^2	0.27	0.29	0.32	0.33	0.29	0.35

VI_{it} is the alternative measure of vertical integration calculated using input-output tables from the BEA. $[\eta = 1]$ is a dummy variable equal one for industries with capital intensity greater than the overall **MEAN**. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. Uncert_sales is the standard deviation of sales at the plant level in a particular industry while Uncert_tfp measures innovations to total factor productivity at the plant level in an industry. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance

Table 12: Concentration and Intra-firm Trade.

Dependent Variable: Intra-firm Trade	(1)	(2)	(3)
HHI	0.179***	0.167***	0.185***
	(0.044)	(0.044)	(0.042)
HHI*$[\eta = 1]$	-0.008	-0.020	-0.008
	(0.049)	(0.049)	(0.048)
Materials Intensity	-0.122***	-0.157***	-0.140***
	(0.038)	(0.040)	(0.039)
Skills Intensity	0.046	0.041	0.040
	(0.034)	(0.034)	(0.032)
Value Added	-1.214***	-1.213***	-1.144***
	(0.184)	(0.185)	(0.180)
Capital Intensity	0.021***	0.025***	0.021***
	(0.003)	(0.003)	(0.003)
Fin. Dev.	-0.001**	-0.001***	-0.002**
	(0.000)	(0.000)	(0.001)
Rule of Law	0.195***	0.211***	-0.158
	(0.017)	(0.017)	(0.136)
Obs	13893	13893	13893
R^2	0.02	0.03	0.13

Intra-Firm Trade measure the share of imports from related parties and therefore ranges from zero to one. $[\eta = 1]$ is a dummy variable equal one for industries with capital intensity greater than the overall **MEAN**. Capital Intensity is the amount of capital required for final good production and is measured as total capital investment divided by total worker wages. Skill Intensity, Materials Intensity and Value Added are measured analogously. HHI is the Herfindahl-Hirschman Index of industry concentration. These represent our two measures of industry level uncertainty. Fin. Dev. and Rule of Law are country level measures of Financial development and rule of law. Robust standard errors are in parentheses. * Indicates 10% significance, ** 5% significance, ***1% significance