Three Essays on Intrafirm Trade

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THREE ESSAYS ON INTRAFIRM TRADE

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A thesis submitted to the Faculty of the Graduate School of the University of Colorado in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Department of Economics

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This thesis entitled:

Three Essays on Intrafirm Trade

By Sooyoung Lee

has been approved for the Department of Economics

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Professor Martin Boileau, Chair

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Professor Keith Maskus

Date: _________________________________

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.
I study the determinants and effects of how multinational firms source intermediate goods. The first chapter studies the choice of multinational firms between outsourcing and vertical integration and its evolution. I develop a dynamic model where the buyer’s trust towards her supplier evolves over time depending on the supplier’s performance. In the long term when trust is high, ownership is allocated to the party that can contribute the most to the performance of the relationship. In the short term, however, limited trust can lead to alternative sourcing modes, resulting in switches of ownership as trust accumulates over time. Empirical results using US intrafirm imports data exhibit that the share of intrafirm imports decreases as the number of years of transaction rises, suggesting the evolution from vertical integration to outsourcing as trust accumulates in US manufacturing industries.

In the second chapter, I investigate demand uncertainty as a determinant of the international ‘make-or-buy’ problem. I show that the choice of sourcing mode under uncertainty depends on the durability of the goods. The impact of uncertainty is bigger in durable industries because the gap between production decisions and actual sales is longer. A simple model based on Grossman and Helpman (2002) shows that vertical integration (outsourcing) is more likely to be the industry equilibrium under uncertain demand in the durable (nondurable) industries. US industry-level intrafirm trade data exhibit consistent results.

The third chapter studies the impact of sourcing modes on international trade in recessions. During the recent recession in 2008-09, intrafirm trade fell less and adapted more swiftly to changes in demand than the arm’s length trade. I present a two-country general equilibrium model to explain the heterogeneous responses of intermediate goods trade depending on the sourcing mode. Based on the theoretical and empirical evidence, the model assumes that vertically integrated firms manage the inventory more effectively than outsourcing firms at added costs. The model economy is able to replicate the resilience of the intrafirm trade, predicting that arm’s length and intrafirm import collapse by 30.8 and 18.7 percent of the steady state level in response to an aggregate demand shock.
Dedicated to my parents
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Chapter 1

A Dynamic Model of Trust and Firm Boundaries

1.1 Introduction

As the volume and importance of the international trade of intermediate goods increase, many trade economists have studied the make-or-buy problem of multinational firms. The international choice of outsourcing (buy) versus vertical integration (make) can be more complicated because the trading partner is in the foreign country and the information on the reputation or the reliability of the partner is difficult to get from the first. Lack of such information, or trust, can make the multinationals choose suboptimal modes of organization. This paper studies whether the modes of production of the multinational firms evolve over time because of better knowledge on the trading partners obtained from experiences.

There are a few explanations for the evolution of the choice between vertical integration and outsourcing\(^1\). The first example is the life-cycle theory by George J. Stigler. Based on information that Adam Smith wrote, Stigler (1951) proposed that the trend of vertical integration of an industry shows an U-shaped life-cycle (p.190): from integration to outsourcing.

\(^{0}\)This chapter is a cowork with Thibault Fally.

\(^{1}\)Among many possible forms of contracts, we consider two forms: (backward) vertical integration, where the downstream party (buyer) owns the upstream party (supplier), and outsourcing, where the buyer does not have ownership of the supplier. This setting is consistent with Acemoglu et al. (2010).
to integration as an industry ages and as its size changes. But as the Fisher-GM case shows, for example, the possibility that the production mode can change from one to the other even in an existing pair of a buyer and a supplier in the short term. Another explanation is by Antràs (2003), who shows that the more capital-intensive a product is, the more integration is chosen. Thus, as in Antràs (2005), new goods are produced under integration, and as the production procedures get standardized, outsourcing takes place more. But again, the Fisher-GM case hints that the switch of a production mode can happen without any change in the capital-intensity.

This paper suggests a new rationale for the evolution of the mode of production, which is trust that accumulates in the relationship of a buyer (downstream party) and a supplier (upstream party). In the short term, when the buyer has little information on the type of the seller (whether good or bad), she may choose a suboptimal ownership structure to avoid possible hold-up problems. However, as the buyer observes the performance of the supplier over time, the buyer can adjust her ownership structure to be optimal. Thus, the accumulated trust through experience can help overcome the initial barriers of achieving the optimal regime.

We show this mechanism using a continuous dynamic model of trust and firm boundaries. We combine the principal-agent model with the property-right approach and incomplete

---

2The main reason behind this theory is the change of the size of an industry: A new industry usually integrates input-suppliers since they are likely to be small and it is hard to find suppliers with required specialty for the new material in the new industry. As the industry grows, its demand for inputs will increase enough to create profitable input markets so that the industry will outsource more. In declining industries, vertical integration will dominate again since their demand for the intermediate goods are lowered.

3General Motors (GM) supplied their car bodies from Fisher bodies through outsourcing, but after 5 years of the contract, GM vertically integrated Fisher bodies. See Klein (2000) for details.

4Early literature of the choice of outsourcing versus integration in international trade literature emphasizes the importance of the knowledge-capital as a determinant since the knowledge is not only non-rival but also nonexcludable in vertical production chains. (Markusen, 1995; Markusen and Venables, 1999; Ethier and Markusen, 1996; Glass and Saggi, 2002) Recent literature has more emphasis on the tradeoffs of holdup problems and incentives, and shows that the important determinants of the production mode include the institutional quality of the sourcing country (Nunn, 2007), the supplier’s financial constraints (Carluccio and Fally, 2012) and the routineness of the job (Costinot et al., 2011). See Antràs and Rossi-Hansberg (2008) and Antràs and Yeaple (2013) for the survey of organizations and trade. Chen et al. (2012) provide a combined approach of the earlier and recent literature. See Aghion and Holden (2011) for the survey on incomplete contracts and the theory of firm.

5We assume that the buyer has all bargaining power.
contracts. A buyer (principal) needs to hire a supplier (agent) for her project and both the supplier and the buyer need to exert effort to succeed in their project. We assume that there are two types of suppliers in the economy where bad ones always exert minimal effort and good ones choose between high and low effort levels, by comparing marginal costs and marginal benefits. The type of the supplier a buyer gets is unknown in the beginning. The buyer forms her belief in the type of the supplier she is paired with through a Bayesian-style, trust-accumulation process depending on the results (either success or failure) of each project they work on together. The project requires initial fixed costs to buy an asset, and the mode of production is defined by who owns the asset: integration if the buyer owns the asset, and outsourcing if the supplier owns it.

The results of optimization pin down the threshold of trust level, above which the buyer switches production mode from one to the other. Depending on the optimal regime, the buyers choose to switch from outsourcing to integration or vice versa. Outsourcing offers the leverage effect since the agent has to buy the asset, and thus reduces the cost of asymmetry. Vertical integration offers the substitution effect since the principal substitutes her high effort for low effort under integration. Thus the long-term optimal regime depends on whose effort (between the supplier and the buyer) is more important for the success of their project. We also show that trust accumulates faster under outsourcing than integration since good agents have more incentives to exert higher efforts, and they are distinguished from bad ones faster under outsourcing. The results from our model are consistent with the predictions of the property-right approach (or more broadly, transaction cost economics) in that the arm’s length production increases the incentive of suppliers.

We test the findings in the model using the recent U.S. intrafirm imports data across manufacturing industries from 2002 to 2011. We investigate whether the intrafirm imports share in each US industry from a foreign country evolves as the number of years of transactions grows over time. The important assumption is that the number of years of transactions in our data, which we call ‘age’ of buyer-supplier pairs, represents the trust of the buyer
toward the supplier. Also, we assume that continued transactions in a pair indicate less ‘failure’ of the projects and thus higher ‘trust’. This assumption is possible because we control for other variables that can influence intrafirm imports in a pair, such as skill-intensity, capital-intensity, material-intensity, and size of industry. In addition, we include the external financial dependence variable of each industry, which is constructed following Rajan and Zingales (1998). The external financial dependence represents the size of fixed cost we have in the model since the ability or willingness to buy the fixed costs depends on how much one needs to use external sources to finance her investment.

The regressions of the age on intrafirm trade show that the age has negative effects on intrafirm trade, indicating that accumulated trust through experience is significantly associated with the switches of the production mode from integration to outsourcing. According to the lessons from the dynamic model, we can interpret this result that the level of effort of suppliers are more important than that of buyers in manufacturing industries. Also, higher fixed costs of production is strongly correlated with higher share of intrafirm imports, and this effect is larger as age increases. Interestingly, the capital-intensity of industries has no significant relationship with the share of intrafirm. We suggest that the importance of capital-intensity is smaller when the trading party is less developed countries, since many of the new trading partners of the US manufacturing industries are less developed countries. The skill-intensity has a positive and significant correlation with the share of intrafirm imports, and the share of intrafirm trade increase when the importing countries are more developed.

This paper contributes to the literature of firm theory by providing a theoretical framework of the dynamic choice of integration versus outsourcing, and by suggesting a significant determinant of the choice of the firm boundaries. Also, this study sheds light on the evolution of the internal organization of international fragmentations. While there are studies about the effect of trust or reputation applied to exporting such as Araujo and Ornelas (2007) and Cagé and Rouzet (2015), the studies on trust and the sourcing mode of
international fragmentation is rare. Our study emphasizes that, when it comes to solving the international make-or-buy problem, the costs of information asymmetry between the two parties of transactions often outweighs the benefits of higher motivation from outsourcing.

The following section extensively lays out the dynamic trust model. Section 3 describes the data and the matching of important variables in the model and the data. Section 4 shows the estimation results and section 5 concludes.

1.2 The model

In this section, we develop a dynamic principal-agent model in continuous time with incomplete contracts. As in the property-right approach of the firm, ownership of assets affects outside options and each party’s incentives. In addition, the perceived probability that the supplier is good (“trust”) evolves over time with the performance of the supplier.

1.2.1 Setup

Trust We consider one principal (or buyer) and one agent (or supplier) who needs to partner up to carry out a project. The agent can be of a good type or a bad type. The principal does not observe the type of agent directly, but updates her belief on the type of the agent depending on the success or failure of the project. Trust is denoted $x_t$ and is defined as the perceived probability that the supplier is good (from the principal’s point of view). Initial trust is exogenous and given by $x_0$. We define $\theta_t = \frac{x_t}{1-x_t}$ as the odds of having a good supplier, and $\theta_0$ is the initial value of this odds ratio.

Success and failure When the project is successful between time $t$ and $t+dt$ it yields a flow of revenues $Rdt$. Revenues $R$ are fixed and exogenous. The project is also subject to failure, which is the key endogenous variable of the model. In case of failure, we assume
in the baseline model that everyone dies\textsuperscript{6} and the flow of revenues stops. If this happens, everyone gets utility zero (normalization). Failure can be due to the agent’s mistake or the principal’s mistake. This setting, where failure can arise at different stages on the supply chain, is inspired from Kremer (1993) and Costinot et al. (2012). The probability of failure of the good agent between periods $t$ and $t + dt$ is given by $r_t dt$ (Poisson rate of failure $r_t$) and the probability of success is $1 - r_t dt$. For the bad agent, the probability of failure is a constant, $\bar{r} dt > r_t dt$ and the probability of success is $1 - \bar{r} dt$. The probability of failure of the principal between periods $t$ and $t + dt$ is $m_t dt$. For infinitesimally small $dt$, the overall probability of failure of the project is given by the sum $(m_t + r_t) dt$. We thus define $\mu_t = m_t + r_t$ the overall Poisson rate of failure.\textsuperscript{7}

**Evolution of trust** The belief of the principal on the type of supplier is updated continuously depending on the success of the project. Bayesian update on the perceived probability that the agent is good follows e.g. Araujo and Ornelas (2007). Define event A as ‘the agent is good’ and event B as ‘the project of the principal and agent succeed’. Then the probability that the agent is good, conditional on success is:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}.$$

Between times $t$ and $t + dt$, the probability of success when the agent is good is $P(B|A) = 1 - m_t dt - r_t dt$; the probability of having a good agent $P(A)$ is $x_t$; and the probability of success $P(B)$ is the probability that the agent is good times the probability of success when the agent is good plus the probability that the agent is bad times the probability of success when the agent is bad. Thus, given $x_t$, as long as there is no failure between $t$ and $t + dt$,

\textsuperscript{6}This assumption allows us to avoid dealing with the evolution of trust in case of failure and simplifies the model without altering the intuition and the main mechanisms. Here we see a failure as a rare event. This is, for instance, what happens when a supplier has provided a defect component for an aircraft or for a car series which ends up being recalled.

\textsuperscript{7}Details follow in subsection D.
the evolution of trust is given by:

\[
x_{t+dt} = \frac{x_t(1 - m_t dt - r_t dt)}{x_t(1 - m_t dt - r_t dt) + (1 - x_t)(1 - m_t dt - \bar{r}dt)}.
\]

Using the first-order approximation with \( dt \) being infinitesimally small and defining \( \Delta r_t = \bar{r} - r_t \), we obtain the following expressions for the evolution of trust:

\[
\frac{dx_t}{dt} = x_t(1 - x_t)\Delta r_t
\]

Written in terms of the odds ratio of having a good agent, \( \theta_t = \frac{x_t}{1 - x_t} \), we have:

\[
\frac{d\theta_t}{dt} = \theta_t \Delta r_t. \tag{1.1}
\]

In particular, if the probability \( r_t = r \) of failure by the supplier is constant over the time interval \([0, t]\), then \( \Delta r = \bar{r} - r \) is constant, and \( \theta_t = \theta_0 \exp(\Delta r . t) \). Generally, \( \theta_t = \theta_0 \exp(\int_0^t \Delta r_s ds) \).

Trust accumulates faster when \( \Delta r_t \) is larger, which means there is a larger difference in the probability of success between good and bad agents. As a good agent exerts higher effort, he can distinguish himself from bad types faster. Note that, however, this is a stochastic process, which does not actually reveal the type of the agent to the end.

**Failure rate** The overall rate of failure \( \mu_t = r_t + m_t \) is endogenous to how much effort each party puts into the project. The probability of failure of the good agent \( r_t \) is associated with instantaneous cost \( g(r_t) \) such that the cost of effort between \( t \) and \( t + dt \) is \( g(r_t) dt \). Since it is less costly to have higher rates of failure, \( g'(r) < 0 \). In the baseline model we assume the cost of effort is linear:

\[
g(r) = \frac{(r_H - r)c}{r_H - r_L} \quad \text{for} \quad r \in [r_L, r_H],
\]

---

\(^8\text{See appendix for more details.}\)
where \( c > 0 \) is a positive exogenous parameter and \( r_L < r_H \). Linearity in the cost of effort will induce corner solutions. If the marginal gain in reducing the failure rate is smaller than the marginal cost, then the good agent chooses a high failure rate \( r_t = r_H \) by providing low effort. If the marginal gain is larger than marginal cost, then he chooses a low failure rate \( r_t = r_L \) by providing high effort. We define \( \Delta_L \equiv \bar{r} - r_L \) and \( \Delta_H \equiv \bar{r} - r_H \) to reflect the difference in failure rates between good and bad agents when the failure rate is low or high.

When the failure rate is low, \( \Delta r_t = \Delta_L > \Delta_H \) and trust accumulates faster than when the agent chooses a high failure rate (by providing little effort). In turn, the bad agent never provides any effort and cannot affect the failure rate. The bad agent has zero cost and enjoys a private benefit \( \tau dt \) during a period of time \( dt \) as long as he survives.

Finally, the principal can affect the overall rate of failure by reducing \( m_t \). The cost of reducing the rate of failure to \( m \) is given by:

\[
h(m) = \left( \frac{m_H - m}{m_H - m_L} \right)c \quad \text{for} \quad m \in [m_L, m_H],
\]

where \( m_L < m_H \) are exogenous parameters; \( m_H \) refers to higher probability of failure and \( m_L \) refers to lower probability of failure. If the marginal gain in reducing the failure rate is smaller than the marginal cost, the principal chooses a high failure rate \( m_t = m_H \) by providing low effort. If the marginal gain in reducing the failure rate is larger than the marginal cost, then he chooses a low failure rate \( m_t = m_L \) by providing high effort.

In the baseline model, we further assume that the revenue of a successful project is greater than the cost of effort of a single party \((R > c)\) while the revenue is smaller than the cost of effort of both parties \((2c > R)\), which implies that it is not profitable for both parties to jointly exert a high effort.

**Incomplete Contracts** We assume that contracts are incomplete (i.e., cannot be enforced by a third party). Any party can break up the relationship at any time. When they break up, the principal can be rematched with a random supplier, whose probability of being good
is $x_0$. The supplier does not enter the relationship unless he expects non-negative benefits. Furthermore, we assume that the implicit contract is renegotiable at any time and that the principal has full bargaining power \textit{ex ante} as well as \textit{ex post}.

\textbf{Asset ownership and outside options}  We suppose that production requires an asset (fixed cost) of value $F > 0$. In keeping with the property-right approach of the firm, “Outsourcing” refers to the case where the agent owns the asset, while “integration” refers to the case where the principal owns the asset. If the relationship is broken (but there is no failure), the party who owns the asset can retrieve the full value $F$ and the other party retrieves nothing. For example, the principal retrieves nothing under outsourcing if the relationship is broken. In case of failure, both parties die and the asset is destroyed. Hence, $F$ is a fixed cost but not a sunk cost unless the project fails. This setting creates larger incentives for the owner of the asset to make the project successful.

$F$ is assumed to be smaller than $\frac{1}{\mu}(R - c)$ when the failure rate $\mu$ is equal to $r_L + m_H$ or $r_H + m_L$, which means that the project is profitable when either the agent or the principal provide a high effort level. We denote by $\bar{V}$ the value for the principal of being matched with a random supplier (with a probability $x_0$ of being good). The outside option for the principal is therefore $\bar{V}$ under outsourcing and $\bar{V} + F$ under integration. The agent has an outside option $0$ under integration and $F$ under outsourcing.

\textbf{Payments}  Principal makes a take-it-or-leave-it offer that consists of the following streams of payments:

- A flow of payment $b_t dt$ between $t$ and $t + dt$.

- And potentially a transfer $T$, from supplier to principal, initially and whenever there is a change of regime, such as switching ownership. $T$ can be negative, positive, or null.

Here we need not specify a fixed wage vs. a bonus since the wage would be paid only in the case of continued success. Also, by assuming that the success of the project is not
verifiable by a third party, a contract cannot specify any compensation in case of severance.

1.2.2 Participation constraints and Bellman equations

**Participation Constraints** We need to distinguish the initial participation constraint at the time of signing the contract and participation at later stages. Since contracts are incomplete, any party can break the contract at any time, and thus participation has to be ensured at any time. We define $V_G(\theta)$ the value of the relationship for the good agent given the trust level.\(^9\) $V_B(\theta)$ and $V_P(\theta)$ are defined as the value of the relationship for the bad agent and the principal given $\theta$, respectively. The initial participation constraint of the good agent under outsourcing is given by:

$$V_G(\theta_0) - T_O - F \geq 0,$$

and under integration:

$$V_G(\theta_0) - T_I \geq 0,$$

where $T_O$ and $T_I$ refers to the initial transfers under outsourcing and integration respectively.

Afterwards, the good agent stays as long as $V_G(\theta) \geq F$ under outsourcing and $V_G(\theta) \geq 0$ under integration. Given that the Principal has all the bargaining power (*ex ante* and *ex post*), and given that he cannot commit not to renegotiate, the participation constraint of the good agent is always binding. This implies:

$$V_G(\theta) = 0$$  \hspace{1cm} (1.2)

under integration, and:

$$V_G(\theta) = F$$  \hspace{1cm} (1.3)

under outsourcing. At $\theta = \theta_0$, these two equalities imply that $T_O \leq 0$ and $T_I \leq 0$.

\(^9\theta\) is the only relevant state variable.
For the principal, if we have outsourcing, participation implies that the value of the relationship plus the initial transfer is larger than her outside option $\bar{V}$:

$$V_P(\theta_0) + T_O \geq \bar{V}.$$  

If the Principal’s outside option is to be rematched with a random supplier (with odds of being good equal to $\theta_0$), then $\bar{V} = V_P(\theta_0)$ and this inequality implies that $T_O \geq 0$. Hence, given the inequality above obtained from the agent’s initial participation constraint we can conclude that $T_O = 0$. Similarly, if we have integration, participation of the principal implies:

$$V_P(\theta_0) + T_I - F \geq \bar{V}.$$  

Since integration implies that the Principal pays the fixed cost, a costless rematch implies $\bar{V} = V_P(\theta_0) - F$. Given the agent’s participation constraint, we obtain that $T_I = 0$.

**Bellman equation for a good supplier**  In this model, the only relevant state variable is the amount of trust accumulated, i.e. the perceived odds $\theta_t$ that the supplier is good.\(^\text{10}\)

Below, we thus write the value function and the Bellman equation in terms of $\theta$.

We first examine the value of the relationship $V_G(\theta)$ for the good agent. Suppose that trust has reached a level $\theta_t = \theta$ at time $t$. If the supplier does not fail, the amount of trust accumulated at time $t + dt$ becomes $\theta + \theta \Delta r dt$, as described in equation (1.1). Hence, with a probability $1 - \mu dt$ ($\mu$ being the overall failure rate taking the principal’s mistakes into account), the good agent can expect a value $V_G(\theta + \theta \Delta r dt)$ from the relationship at time $t + dt$. Between $t$ and $t + dt$, the agent receives a payment $b dt$ and faces a cost of effort.

\(^{10}\)In the baseline model, trust is monotonically increasing with time unless the supplier fails and the project is interrupted. Hence, it is equivalent to write the problem in terms of time or trust. In a more general where trust may decrease as a response to a failure without interrupting the relationship, the only relevant state variable is trust.
\( g(r) dt \). Dropping the time subscripts, we obtain the following Bellman equation:

\[
V_G(\theta) = [b - g(\theta)]dt + (1 - \mu dt) V_G(\theta + \theta \Delta r dt).
\]

which can be rewritten:\(^{11}\)

\[
b - g(\theta) - \mu V_G(\theta) + \theta \Delta r \frac{\partial V_G}{\partial \theta} = 0. \tag{1.4}
\]

Note also that we do not explicitly introduce a discount rate. Having a positive discount rate is equivalent to having a higher failure rate.

The good agent choose the failure rate, \( r \), as follow: With incomplete contract and asymmetric information, the agent’s failure rate cannot be observed or specified in the contract. The only incentive for the good agent to invest in reducing the failure rate is the expected value associated with the continuation of the relationship. Hence, \( r \) satisfies the first order condition:

\[-g'(r) = V_G(\theta).\]

Thus if \( V_G(\theta) \geq \frac{c}{r_H - r_L} \), the agent chooses a low failure rate \( (r = r_L) \) by providing high effort. If \( V_G(\theta) < \frac{c}{r_H - r_L} \), the agent chooses a high failure rate \( (r = r_H) \) by providing low effort.

Given the participation constraints described in section 2.2.1, the value of the relationship for the agent is determined by the value of assets owned by the agent. Under integration, \( V_G(\theta) = 0 \), implying that the agent provides a low effort under integration (with a high failure rate \( r_H \)). Under outsourcing, the supplier has ownership over the assets and \( V_G(\theta) = F \). This implies that the agent provides a high effort under outsourcing if:

\[ F > \frac{c}{r_H - r_L}. \]

\(^{11}\)In particular, when the payment \( b \) and the failure rates \( r \) and \( \mu \) are constant, \( V_G \) takes a simple form: \( V_G(\theta) = \frac{b - g(\theta)}{\mu} \).
In the remainder of the paper we will assume that the fixed cost is large enough, so that this inequality is satisfied. Hence the failure rate of the good agent is low under outsourcing \((r = r_L)\). This setting provides a simple dynamic version of the property-right theory of the firm. The results above are consistent with property-right approach where outsourcing increases the supplier’s incentives to provide high effort.

We can also derive payments under outsourcing and integration. Under integration, the participation constraint for the agent is \(V_G = 0\), which implies that payments \(b\) equal the cost of providing a low effort. The payments is normalized to zero:

\[
b = g(r_H) = 0.
\]

Under outsourcing, the participation constraint for the agent is \(V_G = F\). It implies that payments \(b\) equal:

\[
b = g(r_H) + \mu F,
\]

where \(\mu\) is the failure rate if the agent is good (which also depends on the failure rate of the principal).

**Bellman equation for a bad supplier** In comparison, the bad agent has the following value function (defining \(\bar{\mu} = m + \bar{r}\) as the failure rate when the agent is bad):

\[
V_B(\theta) = [b + \tau]dt + (1 - \bar{\mu}dt) V_B(\theta + \theta \Delta r dt).
\]

The differences lie in the benefits \(\tau\) and the higher failure rate \(\bar{\mu}\). After solving the model, we can verify that the bad agent will engage in the relationship and mimic a good agent. Note that, when contracts are complete, the principal can ask the agent for a down payment in exchange of higher payments \(b\) in the future as long as the project is successful. When the down payment is large enough, the bad supplier has no incentive to mimic a good supplier and does not engage in the relationship. However, when contracts are incomplete, the down
payment that can be paid by the supplier cannot exceed $F$ under outsourcing (0 under integration). Hence it is possible that the bad agent mimics the good agent and engages in the relationship even if the project is not profitable for the principal. The principal would still participate if the probability of having a bad supplier is low enough.

**Bellman equation for the buyer (principal)** In turn, the value function for the principal depends on expected failure rates, revenues, payments to the supplier, and the cost of providing effort $h(m)$. If we denote $\tilde{\mu}(\theta) \equiv \frac{\bar{\mu}}{\theta + 1} + \frac{\mu^\theta}{\theta + 1}$ the expected overall rate of failure, we obtain:

$$V_p(\theta) = [R - b - h(m)]dt + (1 - \tilde{\mu}(\theta))dtV_p(\theta + \theta \Delta rdt),$$

which can be rewritten:

$$R - b - \tilde{\mu}(\theta)V_p(\theta) + \theta \Delta r \frac{\partial V_p}{\partial \theta} = 0$$

### 1.2.3 Ownership structure

**Outsourcing vs. integration with rigid ownership**

In this subsection, we start by assuming that the choice of ownership is made once and for all and cannot evolve over time with trust. Still, trust matters and the ownership structure depends on the initial level of trust $\theta_0$.

**Integration** Under integration, the value of the relationship for a good agent is equal to zero ($V_G = 0$). As derived in the previous section, payments exactly compensate the cost of providing low efforts (normalized to zero). If the principal chooses to put a high effort, the initial value of the relationship for the principal is given by:

$$(R - c) \left[ \frac{\theta_0}{1 + \theta_0 \mu_I} + \frac{1}{1 + \theta_0 \bar{\mu}_I} \right],$$

---

12Because the principal can always break up the relationship and hire an alternative supplier.
where we define $\mu_I = r_H + m_L$ the overall failure rate under integration if the agent is good and $\bar{\mu}_I = \bar{r} + m_L$ if the agent is bad. If the principal makes no effort, the value of the relationship for the principal is:

$$R \left[ \frac{\theta_0}{1 + \theta_0 r_H + m_H} + \frac{1}{1 + \theta_0 \bar{r} + m_H} \right].$$

We assume that $r_H + m_H$ is sufficiently large such that the former expression is larger than the latter, which implies that the principal exerts a high effort under integration. Hence, net of initial costs, the value of the relationship for the Principal is given by:

$$V_P(\theta_0) - F = \left( \frac{R - c}{\mu_I} \right) \left( \frac{\theta_0}{1 + \theta_0} \right) + \left( \frac{R - c}{\bar{\mu}_I} \right) \left( \frac{1}{1 + \theta_0} \right) - F.$$

(1.5)

**Outsourcing** As shown in the previous section, the good agent’s effort is maximal under outsourcing and the failure rate is constant and low ($r_t = r_L$). Reciprocally, if $2c > R$, this also implies that the effort by the principal is minimal under outsourcing and that the principal’s failure rate is high: $m = m_H$. In this case, the failure rate equals $\mu_o = r_L + m_H$ under outsourcing if the agent is good and equals $\bar{\mu}_o = \bar{r} + m_H$ if the agent is bad. Hence, the value of the relationship for the Principal is given by:

$$V_P(\theta_0) = \left( \frac{R - c}{\mu_o} - F \right) \left( \frac{\theta_0}{1 + \theta_0} \right) + \left( \frac{R - c}{\bar{\mu}_o} - \frac{\mu_o}{\bar{\mu}_o} F \right) \left( \frac{1}{1 + \theta_0} \right).$$

(1.6)

Note that, when the agent is bad, the overall failure rate is higher under integration than under outsourcing ($\bar{\mu}_I > \bar{\mu}_o$) because the failure rate for the agent is maximal and the failure rate for the principal is lower under integration.

**Optimal ownership structure** Comparing these values for the principal under integration in equation (1.5) and outsourcing in equation (1.6), we can deduce the optimal ownership structure chosen by the principal. Then, four cases arise:
A) Outsourcing is always preferred to integration if:

\[ \frac{1}{\mu_o} - \frac{1}{\mu_I} > 0 \quad \text{and} \quad \frac{1}{\mu_I} - \frac{1}{\mu_o} < \frac{\Delta r_L}{\mu_o} \frac{F}{R - c}. \]

B) Integration is always preferred to outsourcing if:

\[ \frac{1}{\mu_I} - \frac{1}{\mu_o} > 0 \quad \text{and} \quad \frac{1}{\mu_I} - \frac{1}{\mu_o} > \frac{\Delta r_L}{\mu_o} \frac{F}{R - c}. \]

Otherwise, it depends on whether the initial level of trust \( \theta_0 \) (odds ratio of having a good supplier) is above or below \( \Theta \) where \( \Theta > 0 \) is defined by:

\[ \Theta = \frac{\frac{1}{\mu_I} - \frac{1}{\mu_o} - \frac{\Delta r_L}{\mu_o} \frac{F}{R - c}}{\frac{1}{\mu_o} - \frac{1}{\mu_I}}. \] (1.7)

When \( \Theta > 0 \), two cases arise:

C) If \( \frac{1}{\mu_o} > \frac{1}{\mu_I} \), outsourcing is better than integration only for high level of initial trust:
\[ \theta_0 > \Theta. \]

D) If \( \frac{1}{\mu_I} > \frac{1}{\mu_o} \), integration is better than outsourcing only for high level of initial trust:
\[ \theta_0 > \Theta \] (see appendix for more details).

**Full trust** When the principal already knows that the agent is good with a probability 1 (i.e. when \( \theta_0 = +\infty \)), the value of the relationship under integration is:

\[ \frac{R - c}{\mu_I} - F, \]

while, under outsourcing, it equals

\[ \frac{R - c}{\mu_o} - F. \]

Hence, when the agent is known to be good, outsourcing is preferred to integration when the failure rate under outsourcing \( \mu_O = r_L + m_H \) is smaller than the failure rate under
integration $\mu_I = r_H + m_L$. In other words, when there is no asymmetry of information between the agent and the principal, outsourcing is preferred to integration when the agent can contribute more to reducing the failure rate of the project:

$$r_H - r_L > m_H - m_L,$$

for the same cost $c$.

**Outsourcing vs. integration with flexible ownership structure**

Here we assume that the ownership structure is flexible over time and may depend on the level of trust. The best ownership structure in the long term depends on whether the failure rate in outsourcing is lower than under integration ($\mu_o < \mu_I$). In the short term, however, the optimal ownership structure depends on other parameters such as the size of fixed costs $F$ and the failure rate of the bad agent.

The threshold value $\Theta$ plays also an important role in determining the trust level where the ownership structure may switch from outsourcing to integration or vice versa. The denominator of $\Theta$ determines the optimal ownership structure in the long term (i.e. when trust is high): when $\frac{1}{\mu_I} > \frac{1}{\mu_o}$, integration is preferred to outsourcing in the long term. When $\frac{1}{\mu_o} > \frac{1}{\mu_I}$, outsourcing is better then integration in the long term when the principal knows that the agent is good. In turn, the numerator of $\Theta$ determines the optimal ownership structure in the short term. When the numerator is negative, i.e. when the fixed cost is large ($\frac{F}{c - F} > \frac{1}{\mu_I}$), outsourcing is the optimal ownership structure in the short term when trust is low. When this inequality is not satisfied, integration is the optimal ownership structure in the short term. Hence, no-switch condition is as below.

**No-switch condition** If $\Theta < 0$, the choice between outsourcing and integration does not depend on the level of trust. When $\Theta > 0$, the optimal ownership depends on trust and may change over time.
The precise trust thresholds at which ownership changes hands can be described as follows:

**Proposition 1** (1) Assuming that $\Theta > 0$ and $\frac{1}{\mu_I} > \frac{1}{\mu_O}$, the switch of ownership from outsourcing to integration occurs at the trust level $\theta^*_I > 0$, where $\theta^*_I = \frac{\mu_O}{\mu_O - \Theta} > 0$.

(2) Assuming that $\Theta > 0$ and $\frac{1}{\mu_o} > \frac{1}{\mu_I}$, the switch of ownership from integration to outsourcing occurs at the trust level, $\theta^*_o$, where $\theta^*_o = \frac{\mu_I}{\mu_I - \Theta} > 0$.

**Proof.** See appendix. ■

**Lessons and comparative statics**

Parameter $\Theta$ defined in equation (1.7) is the key variable of the model. When $\Theta > 0$, the optimal ownership structure depends on trust. When $\Theta < 0$, the optimal ownership structure does not depend on trust. We thus focus on cases where the denominator and the numerator have the same sign. This sign determines the direction of switch: outsourcing followed by integration (both negative), or integration followed by outsourcing (both positive).

- For the same cost $c$ of providing high efforts (whether high effort is provided by the supplier or the buyer), ownership in the long term is simply determined by whether the failure rate $\mu_o$ under outsourcing is smaller or larger than the failure rate $\mu_I$ under integration when the agent is known to be good.

- In the short term (or in the initial periods), outsourcing is better when fixed costs $F$ are higher compared to ex post gains $R - c$:

  i) when the ownership structure is chosen once and for all (rigid ownership structure), outsourcing is more likely than integration when $\frac{F}{R-c}$ is high;

  ii) The switching trust level (under flexible ownership structure) favors outsourcing and delay the switch to integration when $\frac{F}{R-c}$ is high.
Under outsourcing, the fixed cost provides leverage and reduces the cost of asymmetry of information by empowering the agent.

- The gains from this leverage effect are larger when the asymmetry of information is large, i.e. when $\Delta r_L$ is large. Hence a larger difference between good and bad agents tends to favor outsourcing.

- When the agent is bad, the failure rate is lower under integration: $\bar{\mu}_I < \bar{\mu}_o$. In other words, the effort by the Principal can provide a substitute to the effort provided by the agent when he is more likely to be bad. Hence, when trust is low, this substitution effect (effort provided by the Principal) favors integration, while the leverage effect creates an advantage to outsourcing.

- Finally, the evolution of trust is endogenous and depends on the ownership structure. Outsourcing is associated with a larger difference between the good and bad agent’s failure rate $\Delta r_L$, hence trust accumulates faster. Integration is associated with a smaller difference between the good and bad agent’s failure rate $\Delta r_H < \Delta r_L$, hence trust accumulates at a slower pace.

### 1.3 Data

In this section, we describe the data and variables for the empirical test of the model in the previous section. We construct the important variables of the model such as vertical integration, outsourcing, trust, and fixed cost. One caveat is that, while the theoretical model is at the firm level, the unit of the data analysis is at the industry level due to the limitation of data. The industry level data used in this paper, however, still convey meaningful results that confirm the lessons of the model.
1.3.1 Intrafirm trade

The related-party trade data from U.S. Census Bureau contain the information of dollar amounts of US imports across countries and industries. Specifically, the data categorizes all imports into either related-party or non-related-party transactions\textsuperscript{13}: the definition of “related-party” by the Census Bureau is that one party of the transaction has more than 6% of ownership of the other party. We can construct the intrafirm imports variable using the ratio of related-party imports among all imports:

\[ II_{ic} = \frac{IM_{ic}^r}{IM_{ic}^r + IM_{ic}^{nr}} \times 100. \]

\( II_{ic} \) denotes the ratio of intrafirm imports in industry \( i \) from country \( c \). \( IM_{ic}^r \) and \( IM_{ic}^{nr} \) denote related-party imports and non-related-party imports in industry \( i \) from \( c \), respectively.

We use intrafirm imports for “vertical integration” and interfirm imports for “outsourcing”. Unlike the theoretical model we presented in the previous section, however, the mode of production in data is continuous. Thus, we focus on changes in intrafirm imports rather than the level of intrafirm imports since it is ambiguous to define the percentage points of intrafirm trade under which we call outsourcing. For example, the intrafirm imports of the packing-accessories industry (NAICS 332115) from Indonesia in 2003 was 57.2% of all imports in this industry-country pair. In 2004, this pair’s intrafirm imports decreased to 44.7%. Then we say that this pair is changing toward more outsourcing or less vertical integration.

1.3.2 Age as trust

We measure trust of the buyer toward the supplier by defining the ‘age’ of the relationship of the industry-country pair. We assume that the continuation of the relationship of the U.S. buyer and the foreign supplier indicates that the buyer is satisfied with the relationship

\textsuperscript{13}Only 0.027\% of all imports are not reported whether they are from related or non-related parties.
enough not to break it. Thus, the trust increases as the number of years of transaction between the buyer and the supplier increases.

We define the age variable as the sum of the number of years that have positive transactions.

\[ A_{ic} = \sum_{t=2002}^{2011} I_{ict} \]

\( A_{ic} \) denotes the age of an industry-country pair, and \( I_{ict} \) is an indicator variable, where \( I_{ict} = 0 \) if there is no import transactions in sector \( i \) from country \( c \) in year \( t \), and \( I_{ict} = 1 \) otherwise. Thus, the minimum age of an industry-country pair is 0, indicating the pair does not have any import transactions during the sample period. The maximum age is 10, indicating the pair has had non-zero import transactions in all periods. We use the pairs that are still active in 2011 to have the maximum possible variations in age. Also, we only count consecutive years of transactions, with the exception of one year rest. For example, if a pair has positive transactions in years 2008, 2009, and 2011, then the age the the pair is 3. But if a pair has non-zero transactions in years 2007, 2008, and 2011, then we drop this pair since it has more than two years of rest of the transactions and age is not defined.

We further narrow down our focus of the samples using the following criteria.

**First criterion** We focus on the trust that accumulates in *new* industry-country pairs, to see the effect of the accumulating trust on the sourcing option. Therefore, we keep the pairs whose age is less than 10: if a pair has positive transactions at all sample period, we cannot determine whether the pair is new or not. Also, we drop pairs whose age are zero, since these pairs does not have any transactions at all periods.

**Second criterion** The theoretical model predicts that the principal-agent pairs that have lower initial trust may experience switches of the sourcing mode. In order to focus on the samples that are more likely to experience switches in the sourcing mode, we drop the pairs that have no change in the share of intrafirm trade in all periods. Specifically, we drop the
Table 1.1: Distribution of age and intrafirm trade

<table>
<thead>
<tr>
<th>Age</th>
<th>Sample 1</th>
<th></th>
<th>Sample 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N Average $II_{ic}$</td>
<td>N Average $II_{ic}$</td>
<td>Share</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1,134 0.24</td>
<td>54 0.50</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>378 0.22</td>
<td>111 0.48</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>243 0.23</td>
<td>125 0.39</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>194 0.24</td>
<td>113 0.35</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>174 0.24</td>
<td>113 0.34</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>205 0.21</td>
<td>124 0.33</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>330 0.24</td>
<td>252 0.33</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>461 0.23</td>
<td>378 0.28</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1,741 0.21</td>
<td>1,433 0.25</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4,857</td>
<td>2,703</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Sample 1 is chosen based on the selecting criterion 1, and Sample 2 is chosen based on the selecting criterion 2. ‘Share’ indicate the percentage of the number of Sample 2 pairs out of the number of Sample 1 pairs.

Pairs that are 100 percent outsourcing (i.e. intrafirm share is zero) at all sample periods or 100 percent vertically integrated (i.e. intrafirm share is 1) at all sample periods; 43 percent (1 percent) of Sample 1 is 100 percent outsourcing (vertical integration). As the statistics in Table 1.1 show, the average share of intrafirm trade of the new pairs is between 0.21 to 0.24. Non-related party trade is prevalent in the data. The non-related party transactions include final goods transactions such as spot markets. On the other hand, if a sample choses 100 percent intrafirm trade at all periods, then the make-or-buy problem maybe irrelevant to the pair.

Table 1.1 shows the average share of intrafirm imports by age. The first two columns show the statistics for the sample chosen by the first criterion, which we call Sample 1. We have 4,857 pairs in this sample. In this sample, the share of intrafirm trade is similar across age, ranging from 0.21 to 0.24. The remaining columns show the statistics for Sample 2, for which we applied the second criterion explained above. Sample 2 is a subset of Sample 1, and it gives us 2,703 pairs. The numbers in ‘Share’ column indicate the percentage of the

---

14 Among 90,090 possible pairs (385 Naics 6-digit industries multiplied by 234 foreign countries that the US is importing from), age is defined for 68,766 pairs. After eliminating pairs according to the criteria 1, we have 4,857 pairs.
number of Sample 2 out of the number of Sample 1.

We can observe two interesting features in Sample 2. First, younger pairs have higher average share of intrafirm imports. The average share of intrafirm trade is 0.50 for the first year pairs, but it decreases linearly as age increases. This relationship between age and the intrafirm imports share is consistent with the propositions at the theoretical section: the length of the relationship affects the sourcing mode. Also, the share of Sample 1 out of Sample 2 increases as pairs age. This increase implies that as pairs age, more pairs have mix of intrafirm and interfirm imports. Most pairs (95 percent) start the transactions with full integration or full outsourcing, but the pair’s sourcing mode evolves over time resulting in that most pairs (82 percent) transact in the mix of outsourcing and integration.

### 1.3.3 Fixed costs and other variables

The theoretical model in the previous section emphasizes the role of fixed costs of projects: fixed costs affect the value of the relationship and outside options to both the principal and the agent. It, therefore, is important to model fixed costs in empirical analysis. We model fixed costs of projects using the external financial dependence variable, which was first used by Rajan and Zingales (1998). The external financial dependence is used as a proxy of fixed costs under the following assumption: the bigger the required investment is, the larger the size of external financial dependence. We assume that the industries that require more initial investment need to borrow more money to invest.\(^{15}\)

The external financial dependence variable is defined as the ratio of investment minus cash flow to investment, or:

\[
E_i \equiv \frac{(\text{capital expenditure}) - (\text{cash flow from operation})}{(\text{capital expenditure})}. 
\]

\(^{15}\)Since we focus on industries of a single country, the US, we do not need to control the financial development level. The level of financial market development of foreign countries that the US industries are importing from may affect the mode of production (as in Carluccio and Fally (2012), for example) but the country fixed effects in the specification alleviate the problem.
This variable measures the amount of investment that are financed from external sources, not from a firm’s cash flow. The source of this variable is Compustat US yearly data, which is at firm level. We aggregate the variable into the NAICS 6-digit industry level, and use the average of the years 2002-2011.

We also use the information on industries and countries as control variables of the empirical analysis. Capital-, skill-, and material-intensity variables are from NBER-CES database. Note that all intensities are logged variables. Institutional quality variable by country is from Nunn (2007). Industrial value added variable is from Bureau of Economic Analysis (BEA.)

### 1.3.4 Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample 1</th>
<th></th>
<th></th>
<th>Sample 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>N</td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Pair information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrafirm Imports</td>
<td>4857</td>
<td>0.22</td>
<td>0.37</td>
<td>2,703</td>
<td>0.30</td>
<td>0.39</td>
</tr>
<tr>
<td>Age</td>
<td>4857</td>
<td>5.58</td>
<td>3.35</td>
<td>2,703</td>
<td>7.44</td>
<td>2.27</td>
</tr>
<tr>
<td>Industry information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External financial dependence</td>
<td>4251</td>
<td>1.40</td>
<td>13.09</td>
<td>2,355</td>
<td>1.36</td>
<td>13.35</td>
</tr>
<tr>
<td>Capital-intensity</td>
<td>4857</td>
<td>-1.85</td>
<td>0.64</td>
<td>2,703</td>
<td>-1.87</td>
<td>0.65</td>
</tr>
<tr>
<td>Material-intensity</td>
<td>4857</td>
<td>1.10</td>
<td>0.61</td>
<td>2,703</td>
<td>1.09</td>
<td>0.62</td>
</tr>
<tr>
<td>Skill-intensity</td>
<td>4857</td>
<td>-0.90</td>
<td>0.31</td>
<td>2,703</td>
<td>-0.88</td>
<td>0.31</td>
</tr>
<tr>
<td>GDP share of Value Added</td>
<td>4857</td>
<td>0.05</td>
<td>0.09</td>
<td>2,703</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Country information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional Quality</td>
<td>3161</td>
<td>0.52</td>
<td>0.19</td>
<td>1,890</td>
<td>0.55</td>
<td>0.20</td>
</tr>
<tr>
<td>OECD</td>
<td>3227</td>
<td>0.14</td>
<td>0.35</td>
<td>1,908</td>
<td>0.20</td>
<td>0.40</td>
</tr>
</tbody>
</table>

381 industries, 225 countries | 379 industries, 189 countries

Table 1.2 gives the descriptive statistics of the data. Since Sample 2 is a subset of Sample 1 that is more likely to experience evolution of sourcing mode, the number of observations is smaller in Sample 2: 55.6 percent of Sample 1 belongs to Sample 2. Sample 1 and Sample 2 are mainly different with regards to pair information. First, the average share of intrafirm
imports in Sample 2 is 8 percentage point higher than in Sample 1. This is because most of the dropped pairs from Sample 1 are always 100 percent outsourcing. Thus, the share of intrafirm imports in Sample 2 is higher. Also, the average age in Sample 2 is 1.86 years higher than in Sample 1. This means that the dropped pairs from Sample 1 are relatively new relationships. The summary statistics of the two samples are also different in country information. Institutional quality and OECD membership on average are higher in Sample 2 than in Sample 1. Higher institutional quality or economic development in Sample 2 suggests that vertical integration is more prevalent.

1.4 Estimation and results

1.4.1 Specification of the regression equation

We test the relationship between the percentage of intrafirm imports and the age of a pair to see how the production mode evolves over time. Equation (1.8) shows the regression equation.

\[ I_{ic} = \alpha_c + \beta_1 A_{ic} + \beta_2 E_i + \beta_3 A_{ic} E_i + \beta_4 (K/L)_i + \beta_5 (S/L)_i + \beta_6 (M/L)_i + \beta_7 G_{Si} + \beta_8 I_{Qc} + \epsilon_{ic} \]

\( I_{ic} \) is the percentage of intrafirm imports of industry \( i \) from country \( c \) to the United States; \( A_{ic} \) is the age of the industry-country pair; \( E_i \) is the external financial dependence of industry \( i \); \( (K/L)_i \), \( (S/L)_i \), and \( (M/L)_i \) are capital-, skill-, and material-intensity of industry \( i \), respectively; \( G_{Si} \) is the share of value added of the US GDP of industry \( i \); \( I_{Qc} \) is the institutional quality of country \( c \); \( \alpha_c \) denotes country fixed effects.

In equation (1.8), the share of intrafirm imports in an industry from a foreign country is explained by the age of the pair, fixed costs, and their interactions. The interaction term measures whether the effect of age on the intrafirm trade is different depending on the size of the fixed costs for the production in an industry. Controlling for the intensities of industry
1.4.2 Results

The results of the regression in equation (1.8) are presented in Table 1.3. The sample pairs consist of 4,857 new industry-country pairs whose age is between 1 and 9. Column (1) shows that the basic relationship between the number of years of transactions of a pair (age) and the share of intrafirm imports has a negative but weakly significant. Column (2) shows the similar results with the country fixed effects. With regards to our model, the negative relationship between age and vertical integration implies that new pair start with more of vertical integration and then switches toward outsourcing. The direction of switch in the results, from integration to outsourcing, suggests that the leverage effects of outsourcing outweigh the substitution effect of integration in the long term. Outsourcing may not be achieved in the short term due to asymmetric information, but the pair can switch to the optimal regime, as buyer’s trust in the supplier increases. Also, the model tells us that the effort level of the supplier is more important than that of the buyer in the manufacturing sectors.

Column (3) reports that the external financial dependence variable is strongly and negatively correlated with the share of intrafirm imports even when the country fixed effects are included. This correlation suggests that as the size of fixed costs of production increases, firms will choose more outsourcing than vertical integration. Buyers (downstream parties) would prefer to have their suppliers pay the fixed costs when they are higher. Column (4) includes age, external financial dependence, and the interaction term of the two variables. The signs and significance of the first two variables are similar to column (3), and the interaction term has positive coefficient. This means that the relationship of the age and the intrafirm trade of a pair gets stronger when the fixed costs of proaction is higher.

When we include the industry characteristics as in column (5), the results become even stronger. The coefficient of the external financial dependence is significant at 5% level, and
Table 1.3: The share of intrafirm imports and age: Sample 1

<table>
<thead>
<tr>
<th>Independent variable: share of intrafirm imports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>FC</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(Age) × (FC)</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Capital-intensity</td>
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<tr>
<td></td>
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<tr>
<td>Skill-intensity</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Material-intensity</td>
</tr>
<tr>
<td>GDP share of VA</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Institutional quality</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>OECD membership</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Country fixed effects        No  Yes  Yes  Yes  Yes  No  No
Obs                           4,857 4,857 4,251 4,251 4,251 2,726 2,790
R-squared                     0.001 0.109 0.116 0.117 0.120 0.005 0.006

FC denotes the fixed costs, measured by the external financial dependence variable. ***, **, and * indicate significance at the 10%, 5%, and 1% levels. Robust standard errors are in parentheses. All standard errors are clustered by industry.
that of the age is significant at 1% level with the inclusion of the country fixed effects. Interestingly, the coefficient of capital-intensity is insignificant, which is different from the results of Antràs (2003) and Nunn and Trefler (2013). We suggest that the capital-intensity is less important for the choice of organization of firm because, as we explained earlier, the sample of our analysis consists of new relationships. The partner countries of these new pairs are less developed countries than old partners, as the summary statistics in Table 1.2 show. Note that the coefficient of skill-intensity is positive and significant at 5% level. Skill-intensive industries choose more vertical integration than outsourcing. This result supports the view of Chen et al. (2012) that the non-rivalry of the knowledge capital is the important factor of the choice of the vertical integration of multinational firms. The coefficient of material-intensity is positive, but insignificant.

Columns (6) and (7) present the regression results without the country fixed costs, but with the institutional quality and OECD membership variables, respectively. The coefficients of both institutional quality and OECD membership of countries are positive and significant. This means that the share of intrafirm imports are higher when the partner county is more developed. Note, however, that the coefficients of the external financial dependence become insignificant when we include the country characteristics instead of country fixed effects. This is partly because of the loss of the number of observations since we do not have the data for the country characteristics for all countries. (We are missing the institutional quality information for some of the new trade partners of the US.)

Table 1.4 reports the similar regression results using Sample 2, which consists of the industry-country pairs that are more likely to experience the change in the sourcing mode. In all columns, the results are stronger than the results from using Sample 1: the coefficients of age variable are 1) still negative in every specification, 2) 5 times larger on average in size compared to Sample 1, and 3) significant at 1 percent level. Therefore, when we focus on the switching group, the effect of experience or trust is much stronger.

There are two possible concerns on the results worth discussing further. First is that the
Table 1.4: The share of intrafirm imports and age: Sample 2

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.0217***</td>
<td>-0.0223***</td>
<td>-0.0221***</td>
<td>-0.0229***</td>
<td>-0.0229***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00361)</td>
<td>(0.00388)</td>
<td>(0.00388)</td>
<td>(0.00412)</td>
<td>(0.00405)</td>
<td></td>
</tr>
<tr>
<td>FC</td>
<td>-0.000822**</td>
<td>-0.000509</td>
<td>-0.000478</td>
<td>0.00664*</td>
<td>0.00623*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000324)</td>
<td>(0.00153)</td>
<td>(0.00154)</td>
<td>(0.00366)</td>
<td>(0.00360)</td>
<td></td>
</tr>
<tr>
<td>(Age) × (FC)</td>
<td>4.20e-06</td>
<td>-2.47e-07</td>
<td>-0.000819**</td>
<td>-0.000772*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000178)</td>
<td>(0.000181)</td>
<td>(0.000181)</td>
<td>(0.000400)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital-intensity</td>
<td>0.00111</td>
<td>0.00688</td>
<td>0.00687</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0184)</td>
<td>(0.0199)</td>
<td>(0.0196)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skill-intensity</td>
<td>0.00857</td>
<td>0.0126</td>
<td>0.0148</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(0.0333)</td>
<td>(0.0319)</td>
<td>(0.0308)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material-intensity</td>
<td>-0.000145</td>
<td>0.0206</td>
<td>0.0210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0182)</td>
<td>(0.0193)</td>
<td>(0.0190)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP share of VA</td>
<td>-0.0501</td>
<td>-0.0112</td>
<td>-0.0353</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0787)</td>
<td>(0.140)</td>
<td>(0.130)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional Quality</td>
<td>0.0553</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0466)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OECD membership</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0327</td>
<td>(0.0234)</td>
</tr>
</tbody>
</table>

FC denotes the fixed costs, measured by the external financial dependence variable. ***, **, and * indicate significance at the 10%, 5%, and 1% levels. Robust standard errors are in parentheses. All standard errors are clustered by industry.
changes of the share of intrafirm imports at the industry level may not necessarily mean that the firms in the industry-country pair switch from one production mode to the other. Since we focus on the new trading relationships, however, the average value of import transactions are only 1/27 the size of the older relationships: the average total import of all industry-country pairs of our Sample 1, which includes Sample 2, is 2.12 million dollars, while that of all observed industry-country pairs is 58 million dollars. Thus, the number of firms contained in each industry-country pair is small and the results in the data can reasonably represent the evolution of firm boundaries according to the accumulation of trust.

Table 1.5: Heckman sample selection model

<table>
<thead>
<tr>
<th>Independent variable: Intrafirm trade share</th>
<th>Independent variable: Selection to Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>FC</td>
</tr>
<tr>
<td>-0.0229***</td>
<td>-0.00179*</td>
</tr>
<tr>
<td>(0.00423)</td>
<td>(0.00193)</td>
</tr>
<tr>
<td>FC</td>
<td>Capital-intensity</td>
</tr>
<tr>
<td>0.00625</td>
<td>-0.0843**</td>
</tr>
<tr>
<td>(0.00419)</td>
<td>(0.0381)</td>
</tr>
<tr>
<td>Age×FC</td>
<td>Skill-intensity</td>
</tr>
<tr>
<td>-0.000772*</td>
<td>0.491***</td>
</tr>
<tr>
<td>(0.000499)</td>
<td>(0.0819)</td>
</tr>
<tr>
<td>Constant</td>
<td>OECD</td>
</tr>
<tr>
<td>0.444***</td>
<td>0.862***</td>
</tr>
<tr>
<td>(0.0827)</td>
<td>(0.0820)</td>
</tr>
<tr>
<td>Obs</td>
<td>Obs</td>
</tr>
<tr>
<td>2,790</td>
<td>2,790</td>
</tr>
</tbody>
</table>

Selection Effect

<table>
<thead>
<tr>
<th>sigma</th>
<th>rho</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3667142</td>
<td>-0.0381322</td>
</tr>
<tr>
<td>(-0.0067227)</td>
<td>(0.2597611)</td>
</tr>
<tr>
<td>lambda</td>
<td></td>
</tr>
<tr>
<td>-0.0139836</td>
<td></td>
</tr>
<tr>
<td>(0.0953368)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: FC denotes the fixed costs, measured by the external financial dependence variable. ***, **, and * indicate significance at the 10%, 5%, and 1% levels. Robust standard errors are in parentheses.

The second concern is that the composition of Sample 2 may not be random and bias the results in Table 1.4. We, thus, apply the Heckman sample selection method to address this concern. Table 1.5 reports the results: the first two columns in the top panel exhibit the

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16We adopt the specification in the last columns of Table 1.3 and Table 1.4, where OECD membership variable is used.
three important coefficients of the model. The coefficients of fixed costs and the interaction term are less significant compared to using OLS, but the coefficient of age variable is still negative and significant at 1 percent level.

The third and forth columns show the coefficients of selection model. The probit estimation, in which the dependent variable is whether an observation is selected for Sample 2 or not, shows that lower capital-intensity, higher skill-intensity, and OECD membership increase the probability to belong to the switching group. The lower panel exhibits estimated standard error for the regression model (sigma) and the correlation coefficient between the unobservables in the regression model and the selection model (rho). Using these coefficients and the average of the inverse Mills ratio, we can conclude that the OLS results are biased upward by 9.2 percent. The bias, however, is insignificant: the likelihood-ratio test for the joint independence of the equations cannot reject the hypothesis that rho is 0, implying that the unobservables are not correlated. Therefore, the estimation results from using Sample 2 in Table 1.4 is valid.

1.5 Concluding Remarks

This chapter attempts to investigate whether the choice of the mode of supplying intermediate-goods, between outsourcing and vertical integration, depends on the trust inside the relationship of a downstream party and an upstream party. We present a continuous dynamic principal-agent model of trust where the principal accumulates the trust in the agent through experiences. The model shows the trade-offs between the leverage effect and the substitution effect of two regimes. The optimization results exhibits that, as trust level reaches the threshold to switch, the buyer can choose to switch to the optimal regime of supplying intermediate-goods, which once was not profitable due to asymmetric information and fixed costs. Also, outsourcing mode reveals the type of the agent faster since good agents have

We utilize the information on the difference in Sample 1 and Sample 2 in Table 1.2 to choose the explanatory variables for the probit estimation.
higher incentives to distinguish themselves from bad ones. This model is consistent with the property-right approach in that the party who can affect the result of the production more has the ownership, and that the supplier gets a higher incentive under outsourcing than under integration. We show that trust can help the principal and the agent in the relationship to overcome asymmetric information and to achieve the optimal regime. We test this model using the disaggregated US industry-level intrafirm imports data and confirm the predictions of the model that the modes of supplying intermediate-goods do change over time as trust accumulates.
Chapter 2

Asymmetric Effect of Demand Uncertainty on Intrafirm Trade in the Durable and Nondurable Industries

2.1 Introduction

As Ronald Coase wrote in 1937, expecting the future wants of the consumer and producing accordingly before the demand is realized is a fundamental problem that firms face. They often need to make decisions on the quantity and price of their production before they know the market demand. This gap between production decisions and the realization of demand affects firms’ choice of boundaries, whether to supply required intermediate goods from integrated producers (vertical integration) or in arm’s length (outsourcing). Such gap, however, tends to be longer in the durable industries than in the nondurable industries: in turn, the optimal choice of firm boundaries under uncertainty may depend on the durability of the final goods. This paper investigates the effect of demand uncertainty on multinational firms’ choice of vertical integration versus outsourcing in the durable and nondurable industries.

Firms face the following tradeoffs between outsourcing and vertical integration under demand uncertainties.\(^1\) On the one hand, outsourcing requires smaller initial sunk costs and

\(^1\)It is important to define the two organizational forms to understand their tradeoffs. I follow the
allows easier entry and exit of the market. Real option literature finds that uncertainties make firms more cautious about investment even when they have a chance (Guiso and Pagirig, 1999; Bloom et al., 2007). Thus outsourcing is attractive under uncertainty, especially when investment is irreversible and intermediate-goods are customized. On the other hand, vertical integration offers a secure supply of intermediate goods even when the demand of the final goods or the supply of the intermediate goods undergo shocks. Better communication systems and inventory management help firms to securely supply intermediate goods. Therefore, vertical integration fares better than arm’s length transactions under uncertainty. This is why transaction cost economists claim that vertically integrated firms handle uncertainty better.

It is important to study the demand uncertainty as a determinant of firm boundaries in an international setting because the volume of intrafirm transactions in international trade is much larger than domestic trade. In 2012, 53% of all imports was through related-party transactions in the US manufacturing industries. However, less than 1% of domestic US firms have physical intrafirm transactions, according to Atalay et al. (2012). While trade economists have actively studied the determinants of intrafirm trade, the effect of uncertain
general definitions of industrial organization literature: vertical integration means ‘the unification of control rights’ (Gibbons, 2005, p.203) when a downstream party owns an upstream party. Outsourcing means when an upstream party supplies intermediate goods under contract without the ownership or the control of downstream party on the upstream.

2I use the related-party transactions as proxy of intrafirm trade. A transaction is defined to be between ‘related-party’ if one party has more than 6% (10%) of ownership of the other party in case of imports (exports). Source data is from the website of the US Census Bureau: http://sasweb.ssdb.census.gov/relatedparty/.

3The literature of the make-or-buy problem of multinational firms has mainly two strands. One emphasizes the non-rivalry and the non-excludability of knowledge and shows that the choice of production mode depends on the importance of the knowledge-capital (Ethier and Markusen, 1996; Horstmann and Markusen, 1987; Glass and Saggi, 2002). The other strand of the literature is based on the firm theory, especially the property-right approach by Grossman and Hart (1986) and Hart and Moore (1990) where the tension between incentive and holdup problem plays the central role in determining the mode of production. Known determinants in this literature include capital-intensity (Antrás, 2003), the product cycle (Antrás, 2005), financial constraints of firms (Carluccio and Fally, 2012), and tariffs (Díez, 2013). Nunn and Trefler (2013) support this view by providing empirical evidence using the data of US manufacturing industries. Costinot et al. (2011) use adaptation firm theory to show that the routineness of the tasks is related to the boundaries of firms, and Chen et al. (2012) combines the two views above and provide a more comprehensive approach.
demand was not explored much in the literature.\textsuperscript{4}

I develop a simple model that describes the effect of demand fluctuation on the choice of outsourcing versus vertical integration. Based on a simplified version of the Grossman and Helpman (2002) model, I introduce uncertain demands which yield the lag between the time of production and the time of actual sales.\textsuperscript{5} Firms experience profit losses when expected and realized demands are different. When realized demand is higher than expected, firms lose potential sales, which causes extra costs (for example, compensation to disappointed customers to keep the firm’s reputation). When realized demand is lower than expected, firms lose the production costs of leftover goods.\textsuperscript{6} Under this setting, the model provides valid trade-offs of the two sourcing options: outsourcing costs less initial fixed costs, and integration offers better adaptability to uncertainties.

The prediction of the model depends on the durability of the products. The model shows that, in durable industries, vertical integration is more profitable under uncertainty as long as the compensation to customers are positive and marginal cost of vertical integration is higher than outsourcing. Note that higher marginal cost of vertical integration implies higher

\textsuperscript{4}One exception is Carballo (2014), who studies the effect of overall uncertainty on firms’ sourcing options and responses to economic crises. There is, however, a large literature on the effect of uncertainty on the boundary of firms outside of international trade. The strength of firm system under uncertainty is consistently emphasized in transaction cost economics (Williamson, 1985, 2000, 2002): internal organization (vertical integration) has better adaptability to high uncertainty than arm’s length production, especially when asset specificity is greater. Carlton (1979) assumes that in-house production of intermediate goods offers cheaper price whereas buying additional amount from arm’s length transmits the risk of unsold goods. He shows that final-good producers always choose some degree of vertical integration and cover the inputs for ‘low-probability demand’ from the market. Lambrecht et al. (2010) indicate the similar type of mixed equilibrium as in Carlton (1979) is efficient when economy fluctuations: on top of the use of vertically integrated facility, cutting back outsourcing in recessions and raise outsourcing in booms. Parmigiani (2007) also suggests that the concurrent sourcing is the optimal under demand uncertainty, using the survey data to managers. Instead of mixed equilibrium or spot market transactions of standardized inputs, Kranton and Minehart (2000) and Fossati (2012) focus on ‘links’ to external sellers that produce specialized goods. Procuring intermediate goods from these network requires investment of downstream firms. The results exhibit that networks are more efficient than vertical integration under considerable uncertainty. These lines of research suggest that neither pure vertical integration nor pure spot market is optimal: mix or hybrid mode would do better under uncertainty.

\textsuperscript{5}The lag between production and sales is an important assumption in Carlton (1979), but the mechanisms and tradeoffs of the two regimes are different in this paper: he assumes that specialized firms have better ability to adjust to the uncertainties, but I assume that vertically integrated firms can adapt to the unknowns better, as in Williamson (2000, 2002).

\textsuperscript{6}Note that I do not consider the inventory management for simplicity of the model. See the next chapter for the intrafirm trade model with inventory.
adaptability under uncertainty than outsourcing at the same time. This result shows that corporate-level adaptability is more important than saving in an initial investment under uncertainty in durable industries. This prediction, however, does not hold for the nondurable industries. I argue that the main reason is the smaller gap between production and sales in nondurable industries. This gap tends to be larger in durable industries. Desai et al. (2007) shows that recent examples of over-production (such as *Shrek 2* DVD by DreamWorks Animation, Chinese cell phone makers) and under-production (such as iPods by Apple, large LCDs for televisions) are all durable goods. The shorter time gap between production decision and sales reduces the effect of demand uncertainty on the decision of outsourcing versus vertical integration in nondurable industries. In other words, in response to the same amount of the demand uncertainty, durable goods industries should adjust their degree of vertical integration more sensitively than in the nondurable industries. I investigate the prediction of the model using US 6-digit NAICS industry-level manufacturing data. Specifically, I use the difference-in-differences method with panel fixed effects to estimate the influence of the final-good demand variability on the intrafirm imports share in durable and nondurable industries. The measure of demand uncertainty that I use is the dispersion of sales growth across plants in an industry. Higher dispersion of sales growth within an industry means more difficulty of expecting the future sales or demand in the industry. The empirical results show that the intrafirm imports are positively and significantly correlated with demand uncertainty in durable industries but not in nondurable industries. This contrast is clear in Figure 2.1, which have plots of the demand uncertainty and the share of intrafirm imports by durability. For the demand uncertainty, the top (bottom) panel uses standard deviation of plant level sales growth (TFP shocks) in 4-digit NAICS manufacturing industries in the US. While I observe a positive relationship between the demand uncertainty and integration in durable industries in both panels, the demand uncertainty is either not correlated or negatively correlated with intrafirm imports share in nondurable industries. Note that these figures do not control for any other industry- or country-specific characteristics. Our baseline estimation results
Figure 2.1: The share of intrafirm import transactions and demand uncertainty by durability

Notes: For the variable of demand uncertainty, the top panel uses the standard deviation of plant level sales growth and the bottom panel uses the standard deviation of plant level TFP shocks in 4-digit NAICS manufacturing industries.
indicate that durable industries increase the share of intrafirm imports by 68.2 percentage points more than nondurable industries in response to one standard deviation increase in dispersion of sales growth. This result implies that as uncertainties increase, the benefit of better management and the securement of the inputs under uncertainty outweighs the benefit of lower sunk cost in durable industries and vice versa in nondurable industries.

This paper contributes to the literature of the make-or-buy problem by providing the theory and evidence of demand uncertainty as a determinant of vertical integration. The literature has mixed predictions on the relationship between uncertainty and the choice of organization. Simon (1951) and Williamson (1975) analyze the adaptability of market and firm to the unexpected circumstances and emphasize the benefits of integrated organizations under uncertainty. Carlton (1979) provides a theory of firm with uncertain demand and shows that firms have an incentive to at least partially integrate the input-supplier for more volatile demand. This theory is empirically tested by Lieberman (1991): using the data of chemical-products industries, he shows that both demand variability (of the final good) and transaction costs are important determinants of vertical integration. Some theoretical studies (Blaire and Kaserman, 1983; Fossati, 2012) report the opposite result where firms choose more outsourcing when there are more demand uncertainties, since the benefit of flexibility of outsourcing due to lower sunk cost is more emphasized. This paper provides a rationale for the mixed results by showing that the length of the gap between production and sales (or durability of products) affects the relationship of uncertainty and integration.

2.2 A Simple Model

Our model is based on a simplified version of Grossman and Helpman (2002). I incorporate the demand uncertainty to the model of outsourcing versus vertical integration in industry equilibrium. First I describe the model with certain demand, then compare it with uncertain demand to see the effect of uncertainty on the choice of sourcing mode in durable
and nondurable industries.

### 2.2.1 Certain demand

The economy consists of two sectors: sector 1 produces differentiated goods in standard Dixit-Stiglitz monopolistic competition and sector 2 produces homogenous goods in perfect competition. The preference of the representative consumer is:

\[
u = \mu \log C_1 + (1 - \mu) \log C_2; \quad C_1 \equiv \left[ \int_0^N y(i)^\alpha \, di \right]^{1/\alpha},
\]

\[
0 < \alpha < 1, \quad \alpha = (\sigma - 1)/\sigma,
\]

where \( C_1 \) is the composite consumption of the differentiated goods in sector 1 and \( C_2 \) is consumption on homogenous goods; \( \sigma \) is the constant elasticity of substitution between products in sector 1, and higher \( \alpha \) means less degree of product differentiation. \( N \) denotes the number of differentiated varieties produced in sector 1. The consumption of variety \( i \) in sector 1 is given by \( y(i) \); the share of spending in sector 1 is \( \mu \). As is well known, this utility function yields the following demand function for the differentiated goods:

\[
y(i) = \mu A p(i)^{-1/1-\alpha}; \quad A = \frac{E}{\int_0^N p(i)^{-\alpha/(1-\alpha)} \, di},
\]

where \( E \) is the total expenditure, which is equivalent to the total wage of the economy. Demand for homogenous goods is \( C_2 = (1 - \mu) E/p_2 \), where \( p_2 \) is the price of homogenous goods.

In sector 1, final good production requires one unit of a specialized component. There is no other variable input required but fixed costs of entry and searching. Final goods are produced by either specialized final-good producers or vertically integrated firms. Specialized suppliers need one unit of labor to produce one input, and integrated firms need \( \lambda \) unit. I assume that \( \lambda \) reflects the two aspects of the marginal cost of integrated firms. First is the
level of specialization or efficiency of producing intermediate goods, which tends to be lower for integrated firms. This increases $\lambda$. The second is the bureaucracy costs of integrated firms. While larger institutions require more operation costs, they offer better management, communication, and adaptability under uncertainties at the same time. I assume that the higher the impact of uncertainties to the firm, the larger the size of bureaucracy costs of a firm. Thus, the marginal cost of integrated firms can be either greater or less than the marginal cost of outsourcing firms ($\lambda \geq 1$ or $\lambda < 1$).

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

Once entering the market, one supplier (m-firm) produces $x_i$ units of specialized input, then the partnered final-good producer (s-firm) produces $y(i) = x_i$ final goods. The revenue from sales of the final goods is $p_i x_i$, and the two firms bargain over the revenue with $\omega$ share to the supplier and $1 - \omega$ to the final-good producer. If the negotiation fails, both parties receive zero revenue. Suppliers may choose between high-quality and low-quality inputs, but if they choose low-quality inputs, there will be no transactions, and the m-firm loses all the costs that already incurred. Thus, m-firms always produce high-quality inputs and choose the quantity $x_i = \mu A(\alpha \omega)^{1/1-\alpha}$ to maximize the expected profit. Combining this supply with the demand in equation (3.4) yields the equilibrium price under outsourcing:

$$p_O = \frac{1}{\alpha \omega}, \quad (2.3)$$

with the quantity of final-goods equal to

$$y_O = \mu A(\alpha \omega)^{1/1-\alpha}. \quad (2.4)$$
This gives the following expected profit of a supplier:

\[ \pi_m = (1 - \alpha) \omega \mu A(\alpha \omega)^{\alpha/1-\alpha} - k_m. \] (2.5)

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

\[ \pi_O = (1 - \omega) \mu A(\alpha \omega)^{\alpha/1-\alpha} - k_s + T = (1 - \omega \alpha) \mu A(\alpha \omega)^{\alpha/1-\alpha} - k_o \] (2.6)

where \( k_o = k_s + k_m \).

Vertically integrated firms choose the quantity, \( x_i = y_i = \mu A(\alpha/\lambda)^{1/1-\alpha} \) with the marginal cost of production \( \lambda \) to maximize the profit. Combined with the market demand, the price under vertical integration is:

\[ p_v = \frac{\lambda}{\alpha} \] (2.7)

with the quantity of final-goods equal to

\[ y_V = \mu A \left[ \frac{\alpha}{\lambda} \right]^{1/1-\alpha}. \] (2.8)

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

\[ \pi_V = (1 - \alpha) \mu A \left[ \frac{\alpha}{\lambda} \right]^{1/1-\alpha} - k_v. \] (2.9)

In summary, the sequence of events is as follows: 1) Entry - Firms enter the market, and they pay a portion of the fixed costs. 2) Non-frictional match - Every specialized firm is matched with the other type of specialized firm. 3) Production of intermediate goods 4) Bargaining over the expected profits (outsourcing firms). 5) Production and sales of final goods.

In the industry equilibrium, all firms make zero profits because of free-entry. For out-
sourcing firms to break even, from equation (2.6),

\[ A_O = \frac{k_o}{(1 - \omega \alpha)(\alpha \omega)^{\alpha/1-\alpha}} \]  

(2.10)

and for integrated firms to break even, from equation (2.9),

\[ A_V = \frac{k_v}{(1 - \alpha)(\alpha/\lambda)^{\alpha/1-\alpha}}. \]  

(2.11)

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

\[ \frac{A_V}{A_O} = \frac{(1 - \alpha \omega)(\omega \lambda)^{\alpha/1-\alpha} k_v}{k_o} \]  

(2.12)

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

### 2.2.2 Uncertain demand

Now consider a mean-preserving spread of the certain demand in the previous section. Suppose that the demand in sector 1 of the economy fluctuates binarily: the share of sector 1 takes the value of \( \mu_H \) with probability \( \gamma \) and \( \mu_L \) with probability \( 1 - \gamma \) where \( \mu_H > \mu_L \). The expected value of the demand share of sector 1 is \( \mu_e = \gamma \mu_H + (1 - \gamma) \mu_L \). Also suppose that although the producers of the final goods in sector 1 know this market demand, they need to decide their quantity and price of production before the demand is realized. Then
the choice of quantity is always equal to the expected demand as below.

\[ E[y] = E[\mu]Ap^{-1/1-\alpha} = \mu_e Ap^{-1/1-\alpha} \equiv \mu_e y'. \] (2.13)

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

\[ E[\pi_V] = \gamma[\mu_e y'p - \mu_e y'\lambda - (\mu_H - \mu_e)y'c - k_v] + (1 - \gamma)[\mu_L y'p - \mu_e y'\lambda - k_v]. \] (2.14)

The first term in the right hand side of equation (2.14) shows that, when the realized market share is high, the firm can sell only what they already produced. The variable cost of production is equal to the amount of production (expected demand) times the marginal cost of production. The amount of lost demand is \((\mu_H - \mu_e)y': I assume that the profit is lost proportional to the lost demand since firms need to offer some compensation \((c > 0)\) to the customers not to lose their reputation. When the realized market demand is low, the firm sells \(\mu_L y'\) but it still needs to pay the full cost of production, \(\mu_e y'\lambda\). The price level that maximizes the profit level is:

\[ p'_V = \frac{\mu_e \lambda + \gamma c (\mu_H - \mu_e)}{\alpha[\gamma \mu_e + (1 - \gamma) \mu_L]}. \] (2.15)

Notice that this price level is identical to the case in certain demand in equation (2.7), if the demand is known ex ante. The expected demand is, therefore, \(y_e = \mu_e Ap_V^{-1/1-\alpha}\).

The expected profit of a specialized intermediate-good producer is

\[ E[\pi_m] = \gamma[\omega \mu_e y'p - \mu_e y' - (\mu_H - \mu_e)y'c - k_m] + (1 - \gamma)[\omega \mu_L y'p - \mu_e y' - k_m], \] (2.16)
which yields the optimal price of outsourcing equal to

\[ p_O' = \frac{\mu_e + \gamma c(\mu_H - \mu_e)}{\omega \alpha [\gamma \mu_e + (1 - \gamma) \mu_L]}, \quad (2.17) \]

which is, again, identical to the case in certain demand in equation (2.3) when demand is known ex ante. The expected demand is \( y_O = \mu_e A p_O'^{-1/1-\alpha} \).

Then the expected profit of an outsourcing firm is the profit of final-good producers plus the transfer from intermediate-good suppliers.\(^7\)

\[ \pi_O' = \pi_s' + T = A p_O'^{-1/1-\alpha} \left( \frac{1 - \omega \alpha}{\omega \alpha} \right) (\mu_e + \gamma c(\mu_H - \mu_e)) - k_o \quad (2.18) \]

The expected profit of an integrated firm is

\[ \pi_V' = A p_V'^{-1/1-\alpha} \left( \frac{1 - \alpha}{\alpha} \right) (\mu_e \lambda + \gamma c(\mu_H - \mu_e)) - k_v. \quad (2.19) \]

Equations (2.18) and (2.19) yield the ratio of break-even demand under uncertainty:

\[ \frac{A_V'}{A_O'} = \frac{(1 - \alpha \omega)}{(1 - \alpha)} \left( \frac{p_V' / p_O'}{A_O'^{-1/1-\alpha} k_v / k_o} \right) \quad (2.20) \]

where \( \frac{p_V'}{p_O'} = \frac{\omega \mu_e \lambda + \gamma c(\mu_H - \mu_e)}{\mu_e + \gamma c(\mu_H - \mu_e)}. \)

### 2.2.3 Choice under uncertainty

By comparing the ratio of break-even demands in integration and outsourcing in equations (2.12) and (2.20), I can see the effect of demand uncertainty on the choice of organization.

Again, note that the uncertain demand in section 2.2.2 is the mean-preserving spread of the uncertainty in expected demand.\(^7\)

\[ \pi_s' = [\gamma \mu_e + (1 - \gamma) \mu_L](1 - \omega) A p_O'^{-1/1-\alpha} - k_s \]

\[ T' = \pi_m' = [\gamma \mu_e + (1 - \gamma) \mu_L] \omega A p_O'^{-1/1-\alpha} - [\mu_e + \gamma c(\mu_H - \mu_e)] A p_O'^{-1/1-\alpha} - k_m \]

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certain demand in section 2.2.1. I define $\Theta$ as below to analyze the difference in break-even demands level under certain and uncertain demand:

$$\Theta \equiv \frac{A_V}{A_O} = \frac{A'_V}{A'_O} = \left[ \frac{p_V}{p_O} \right]^{\alpha/(1-\alpha)}$$

$$= \left[ \frac{\lambda \mu_e + \gamma c(\mu_H - \mu_e)}{\mu_e \lambda + \gamma c(\mu_H - \mu_e)} \right]^{\frac{\alpha}{1-\alpha}}. \tag{2.21}$$

The break-even ratio falls when uncertainty is introduced if $\Theta \geq 1$, which implies that vertical integration becomes more likely. Some calculations show that $\Theta \geq 1$ if and only if $\lambda \geq 1$: vertical integration is more likely to be the equilibrium choice under uncertainty in an industry where the marginal cost of production is higher in integrated firms than outsourcing firms. Conversely, outsourcing is more likely to be the equilibrium choice under uncertainty in an industry where the marginal cost of production is lower in integrated firms than outsourcing firms.\(^8\)

This seemingly contradictory prediction conveys a valid implication. As I assumed earlier in the description of the model, the marginal cost reflects the required management costs under uncertainty. Suppose there are two manufacturing industries that face the same size of demand uncertainty. In one industry where integrated firms pay relatively higher marginal costs due to their management cost ($\lambda \geq 1$), the benefit from paying such costs outweighs the flexibility of exit and entry that outsourcing offers. The same amount of uncertainty affects the profits of the firms in this industry more than the other, and they pay more costs to adapt to the uncertainty, and it pays off when a bad event (that decreases the industry’s demand) actually hits the industry. In another manufacturing industry where integrated firms have lower marginal cost ($\lambda < 1$) than outsourcing firms, the benefit of flexibility of outsourcing regarding exit and entry of the market outweighs the benefit of better adaptability under uncertainty. Since the same amount of uncertainty affects the profits of the firms in this

\(^8\)Note that Carballo (2014) focuses on the effect of uncertainty on the decision of firms to entry and exit the market. This paper focuses on the profitability of staying integrated or outsourcing under uncertainty compared to certain demand.
industry less, having an integrated structure does not pay off under uncertainty.

I apply this implication to durable and nondurable industries. The time gap between production decision and sales tends to be longer in durable than in nondurable industries. This, in turn, means that the impact of the same amount of uncertainties affect the firms’ sourcing decisions more in durable industries. In durable industries, where $\lambda \geq 1$ is more likely to be the case, I can understand this result in two ways. First is the price mechanism. As equation (20) shows, the break-even ratio of demands of integration and outsourcing decreases under uncertainty ($\Theta \geq 1$) when the price ratio of integration and outsourcing goes down. This implies that vertical integration is more profitable under uncertainty because integration price becomes relatively cheaper. In this monopolistically competitive market, higher price means less profit. Specifically, the price of final goods increases when demand is more uncertain, regardless of the mode of production ($p_O < p'_O$ and $p_V < p'_V$). But the outsourcing price goes up relatively more than integration price ($p_V/p_O \geq p'_V/p'_O$) as long as I assume $c > 0$ and $\lambda \geq 1$. The second way to understand is through the transaction cost economics which gives the consistent prediction. In our model, vertical integration is assumed to have higher marginal cost because of higher costs of bureaucracy and less specialty of integrated firms. Higher cost of governance, however, means that integration offers higher adaptability to uncertainties. Thus, this result in which higher marginal cost is connected to higher profit emphasizes the traditional view of the new institutional economics. In nondurable industries, where $\lambda < 1$ is more likely to be the case, the mechanism works in the opposite way. The prediction of transition cost economics is not applied in these industries.

To summarize, the model on the demand uncertainty and vertical integration gives us the following testable implications. First, in durable industries, vertical integration is more likely to be the prevalent mode of production in equilibrium under demand uncertainty. Second, in nondurable industries, outsourcing is more likely to be the equilibrium mode of production under demand uncertainty. I present an empirical analysis of the implications.
above in following sections.

2.3 Empirical Evidence

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

2.3.1 Specification

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

$$V I_{ict} = \beta_0 + \beta_1 U n c_{it} + \beta_2 (U n c_{it}) \times (D u r_i) + X'_{1it} \beta_3 + X'_{2it} \beta_4 + \alpha_c + \alpha_t + \epsilon_{ict},$$

(2.22)

where $i, c,$ and $t$ index industries, countries, and period, respectively. $V I_{ict}$ is the measure of vertical integration, which is the share of intrafirm imports out of all imports in industry $i$ from country $c$ to the U.S. in period $t$. $U n c_{it}$ is the US industry $i$’s demand uncertainty in period $t$. $D u r_i$ is the durability dummy variable. The coefficient of the interaction term of uncertainty and durability variables, $\beta_2$, indicates whether the durable industries change the sourcing mode more sensitively compared to nondurable industries. The empirical analysis would be consistent with the theoretical model if $\beta_2$ is positive and significant. $X'_{1it}$ is a vector
of industry-level control variables that consists of the size, external financial dependence, market structure (differentiation), capital-, skill-, material-, and R&D-intensity.\(^9\) \(X'_{2c}\) is a vector of country-level controls that includes the rule of law. I include country and year fixed effects in the estimation to capture unobserved variations.\(^{10}\)

### 2.3.2 Data sources and variable descriptions

The measure of vertical integration is the share of intrafirm imports out of all imports in industry \(i\) in period \(t\). I use the related party imports data of the U.S. from 2002 to 2009\(^{11}\) classified by NAICS 6-digit industry from the U.S. Census Bureau.\(^{12}\) Every import transaction to the U.S. is categorized as a related or non-related import. I divide related-party imports by the total imports in industry \(i\) in period \(t\) from country \(c\) to calculate the share of intrafirm imports.\(^{13}\) I use the average of two years’ observations as one period \(t\)’s value, resulting in four periods in total.

To capture the demand uncertainty at the industry level, I use the within-industry dispersion of plant-level sales growth. Higher dispersion of sales across plants within an industry indicates frequent changes in sales and in turn the difficulty in predicting the amount of sales or demand in the industry, or higher demand uncertainty. I use the standard deviation of real sales growth of all plants in industry \(i\) in period \(t\). This data is in SIC 4-digit industries in 2002-2009 from the Annual Survey of Manufactures of the U.S. Census.\(^{14}\) The data contain 27.1 establishments on average per SIC 4-digit industry-year pair, and this size allows

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\(^9\)Note that all these control variables vary across time except for the R & D-intensity due to data limitation.

\(^{10}\)I do not include industry fixed effects to leave the industry variation.

\(^{11}\)This data is available from 2002 to 2012, but the demand uncertainty variable is available until 2009. So I set the periods of study from 2002 to 2009.

\(^{12}\)The related-party import is defined as the import transactions between two parties, either of which has 6 percent or more of ownership or voting right. However, whole ownership is most common (80% in 1997) among foreign affiliates of US firms (Desai et al., 2004). Also, because either the US or the foreign party may have the ownership of the other according to this definition, this intrafirm share measure includes both backward and forward vertical integration.

\(^{13}\)Nunn and Trefler (2013) and Costinot et al. (2011) use similar measure of intrafirm share in their cross-sectional analysis.

\(^{14}\)This data was constructed for Bloom et al. (2012) and is available at http://www.stanford.edu/~nbloom/RUBC_industry.zip
enough variation in the data.

The information on durability is directly from the NAICS code, which categorizes all manufacturing industries into durable and nondurable goods manufacturing in NAICS 3-digit level. Table 2.1 lists all 3-digit manufacturing industries in NAICS by durability. The durability variable in our analysis is defined “1” for durable industries and “0” for nondurable industries.

Table 2.1: NAICS 2002 manufacturing industries by durability

<table>
<thead>
<tr>
<th>Durable Goods Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>321 Wood Product Manufacturing</td>
</tr>
<tr>
<td>327 Nonmetallic Mineral Product Manufacturing</td>
</tr>
<tr>
<td>331 Primary Metal Manufacturing</td>
</tr>
<tr>
<td>332 Fabricated Metal Product Manufacturing</td>
</tr>
<tr>
<td>333 Machinery Manufacturing</td>
</tr>
<tr>
<td>334 Computer and Electronic Product Manufacturing</td>
</tr>
<tr>
<td>335 Electrical Equipment, Appliance, and Component Manufacturing</td>
</tr>
<tr>
<td>336 Transportation Equipment Manufacturing</td>
</tr>
<tr>
<td>337 Furniture and Related Product Manufacturing</td>
</tr>
<tr>
<td>339 Miscellaneous Manufacturing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nondurable Goods Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>311 Food Manufacturing</td>
</tr>
<tr>
<td>312 Beverage and Tobacco Product Manufacturing</td>
</tr>
<tr>
<td>313 Textile Mills</td>
</tr>
<tr>
<td>314 Textile Product Mills</td>
</tr>
<tr>
<td>315 Apparel Manufacturing</td>
</tr>
<tr>
<td>316 Leather and Allied Product Manufacturing</td>
</tr>
<tr>
<td>322 Paper Manufacturing</td>
</tr>
<tr>
<td>323 Printing and Related Support Activities</td>
</tr>
<tr>
<td>324 Petroleum and Coal Products Manufacturing</td>
</tr>
<tr>
<td>325 Chemical Manufacturing</td>
</tr>
<tr>
<td>326 Plastics and Rubber Products Manufacturing</td>
</tr>
</tbody>
</table>


I control for other determinants of the intrafirm share of imports. Since higher capital-intensity leads to more in-house production (Antràs, 2003), I include this variable to the specification of the regression. I also include skill-intensity and material-intensity in the set of control variables in keeping with Heckscher-Ohlin theory. For these three variables,
I use yearly NBER-CES manufacturing industry database in 6-digit NAICS from 2002 to 2009: capital-intensity is the log of the investment over total wage; material-intensity is the log of material cost over total wage; skill-intensity is the log of wage to skilled workers over total wage. Since the choice of vertical integration and the size of industries can be positively correlated, I control for the size of industries using the share of value added of an industry out of GDP. The dependence on external source of financing is related to the choice of sourcing mode (Acemoglu et al., 2009). So I include external financial dependence, which is defined as capital expenditures minus cash flow from operations divided by capital expenditures (Rajan and Zingales, 1998, p.564). I include a country-level control variable, rule of law, since it is a source of comparative advantage in international trade (Nunn, 2007).

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

2.3.3 Descriptive statistics

Table 2.2 reports the number of observations, mean, and standard deviation of the variables. I have an unbalanced panel that covers 349 6-digit NAICS manufacturing industries for 4 periods (years 2002-2009). Among the 236 countries that US manufacturing indus-

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15 Data on the rule of law variable is from the website of Nathan Nunn at http://scholar.harvard.edu/files/nunn/files/qje_contracts_final1.zip.
16 Among 150 industries, however, 140 are differentiated markets and only 10 are either reference priced or traded on organized exchanges.
17 This data is available at http://scholar.harvard.edu/files/nunn/files/incomplete_contracts.zip.
Table 2.2: Descriptive statistics

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

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

Figure 2.2: The share of intrafirm import transactions by durability
Table 2.3: Industrial characteristics by durability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Durable</th>
<th>Nondurable</th>
<th>Mean Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs.</td>
<td>Mean</td>
<td>Obs. Mean</td>
</tr>
<tr>
<td>Intrafirm import share</td>
<td>82,131</td>
<td>0.278</td>
<td>52,620</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.341)</td>
<td>(0.308)</td>
</tr>
<tr>
<td>SD (sales growth)</td>
<td>900</td>
<td>0.240</td>
<td>563</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.059)</td>
<td>(0.058)</td>
</tr>
<tr>
<td>SD (TFP shocks)</td>
<td>900</td>
<td>0.416</td>
<td>563</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.106)</td>
<td>(0.121)</td>
</tr>
<tr>
<td>Capital intensity, log</td>
<td>1,184</td>
<td>-2.009</td>
<td>762</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.608)</td>
<td>(0.838)</td>
</tr>
<tr>
<td>Skill intensity, log</td>
<td>1,180</td>
<td>-0.891</td>
<td>762</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.358)</td>
<td>(0.273)</td>
</tr>
<tr>
<td>Material intensity, log</td>
<td>1,184</td>
<td>1.034</td>
<td>762</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.545)</td>
<td>(0.675)</td>
</tr>
<tr>
<td>Share of value added</td>
<td>1,184</td>
<td>0.031</td>
<td>762</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.043)</td>
<td>(0.096)</td>
</tr>
<tr>
<td>External Financial Dependence</td>
<td>889</td>
<td>1.231</td>
<td>526</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100.741)</td>
<td>(42.428)</td>
</tr>
<tr>
<td>R &amp; D intensity</td>
<td>119</td>
<td>0.022</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.004)</td>
<td>(.013)</td>
</tr>
</tbody>
</table>

Notes: Standard deviations are in parentheses in mean columns. Standard errors from the two-group mean-comparison tests are in parentheses in the last column. ∆Mean is defined as ‘Mean(durable) - Mean(nondurable).’ Ext. Fin. Dep. denotes external financial dependence. *** denote significance at 1% level.
tries are importing from, only 5 countries have zero intrafirm import transactions. Table 2.3 compares the average industrial characteristics by durability.\footnote{Petroleum and coal products manufacturing (NAICS 324) is excluded in nondurable industries, but including them does not make any meaningful difference in the results of the mean-comparison analysis.} The share of intrafirm imports in durable industries is 7.8 percentage point higher on average, and the difference is statistically significant at 1 percent level. As Figure 2.2 shows, this pattern that durable industries have higher level of vertical integration is consistently found in all years of the sample. The two measures of demand uncertainty, which are the standard deviation of plant-level sales growths and TFP shocks by industry, have different signs in mean comparison. In durable industries, the standard deviation of sales growth is significantly higher than nondurable industries, but the standard deviation of TFP shocks is significantly lower than nondurable industries on average. This difference suggests that it is not clear if overall demand uncertainty is larger in durable industries.\footnote{In macroeconomics, it is well known fact that the consumption for durable goods is more volatile than nondurable goods. (See Baxter (1996), for example.) Higher volatility in consumption, however, does not directly indicate higher demand uncertainty of durable industries since the source of volatility can be from the supply side.}

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

\subsection*{2.3.4 Results}

I test our model following the specification in equation (2.22). First, I report the results when I do not consider the effect of durability on the relationship between demand uncertainty and the share of intrafirm imports. In column (1) in Table 2.4, I do not include

\begin{table}[ht]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Year} & \textbf{Share of Intrafirm Imports} & \textbf{Share of Value Added} \\
\hline
2010 & 0.10 & 0.20 \\
2011 & 0.11 & 0.21 \\
2012 & 0.12 & 0.22 \\
\hline
\end{tabular}
\caption{Average Industrial Characteristics by Durability}
\end{table}
### Table 2.4: Vertical integration and demand uncertainty - Baseline analyses

<table>
<thead>
<tr>
<th>Measure of Unc</th>
<th>Intrafirm Share (6-digit)</th>
<th>SD(sales growths)</th>
<th>SD(TFP shocks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Unc</td>
<td>0.397***</td>
<td>0.135</td>
<td>0.225***</td>
</tr>
<tr>
<td></td>
<td>(0.0980)</td>
<td>(0.123)</td>
<td>(0.0611)</td>
</tr>
<tr>
<td>(Unc)×(Dur)</td>
<td></td>
<td>0.235***</td>
<td>0.156***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0551)</td>
<td>(0.0270)</td>
</tr>
<tr>
<td>Capital Intensity</td>
<td>0.0109</td>
<td>0.0181</td>
<td>0.00814</td>
</tr>
<tr>
<td></td>
<td>(0.0121)</td>
<td>(0.0128)</td>
<td>(0.0115)</td>
</tr>
<tr>
<td>Skill Intensity</td>
<td>0.0226</td>
<td>0.0251</td>
<td>0.0154</td>
</tr>
<tr>
<td></td>
<td>(0.0201)</td>
<td>(0.0210)</td>
<td>(0.0203)</td>
</tr>
<tr>
<td>Material Intensity</td>
<td>-0.000558</td>
<td>0.00421</td>
<td>-0.0121</td>
</tr>
<tr>
<td></td>
<td>(0.0123)</td>
<td>(0.0122)</td>
<td>(0.0139)</td>
</tr>
<tr>
<td>Share of VA</td>
<td>0.109</td>
<td>0.121*</td>
<td>0.170**</td>
</tr>
<tr>
<td></td>
<td>(0.0768)</td>
<td>(0.0685)</td>
<td>(0.0860)</td>
</tr>
<tr>
<td>Ext. Fin. Dep.</td>
<td>-6.87e-05***</td>
<td>-6.08e-05***</td>
<td>-7.78e-05***</td>
</tr>
<tr>
<td></td>
<td>(1.83e-05)</td>
<td>(1.67e-05)</td>
<td>(2.05e-05)</td>
</tr>
<tr>
<td>(R &amp; D intensity)×(Rauch)</td>
<td>0.164</td>
<td>0.0844</td>
<td>0.150</td>
</tr>
<tr>
<td></td>
<td>(0.145)</td>
<td>(0.153)</td>
<td>(0.159)</td>
</tr>
<tr>
<td>Obs</td>
<td>21,962</td>
<td>21,962</td>
<td>21,962</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.192</td>
<td>0.194</td>
<td>0.193</td>
</tr>
</tbody>
</table>

Notes: Unc denotes demand uncertainty and Dur denotes durability. * denote significance at 10% level. ** denote significance at 5% level. *** denote significance at 1% level. Robust standard errors are clustered by industries and years. Country and year fixed effects are included.
the interaction term of demand uncertainty and durability. The coefficient of demand uncertainty, which is measured by the standard deviation of plant-level sales growth in each industry, is positive and significant. In column (2), I include the interaction term of demand uncertainty and durability, incorporating the difference-in-differences method in the analysis. The regression results show that the effect of demand uncertainty on the share of vertical integration is significantly different in durable and nondurable industries. According to $\beta_2$ in column (2), the effect of one standard deviation increase in demand uncertainty has 23.5 percentage point higher impact on the increase of the share of vertical integration in the durable industries than in the nondurable industries. The coefficient of uncertainty ($\beta_1$) is positive but insignificant. This suggests that, in nondurable industries, the effect of demand uncertainty has insignificant effect on the intrafirm imports share.

I have similar results in columns (3) and (4) when the measure of demand uncertainty is the standard deviation of plant-level TFP shocks in each industry. While the dispersion of sales growth across plants in an industry captures changes in demand, supply may also affect the sales growth. The dispersion of TFP shocks across plants in each industry is measured by the standard deviation of residuals of the autoregressive establishment-level TFP. Since the innovations to establishment level TFP contain demand shocks, I use this variable as an alternative of the dispersion of sales growth. Again, I draw the variable from Bloom et al. (2012) and it is built using the same data source as the sales growth variable, which is the Annual Survey of Manufacturing. The coefficients of uncertainty and the interaction of uncertainty and durability ($\beta_1, \beta_2$) are consistent with columns (1) and (2) with slightly smaller magnitude.

The control variables in the above regressions have mixed impacts on the share of vertical integration. The coefficients of capital intensity, skill intensity, and material intensity are insignificant in columns (1) through (4) in Table 2.4. The signs of the coefficients of capital and skill intensities are positive, which is consistent with the literature (Antràs, 2003; Nunn and Trefler, 2013). The coefficients of material intensity is mostly negative. The share of
value added of the industry in GDP, which measure the size of industries, are positive and mostly significant. The coefficients of external financial dependence are close to zero. Market differentiation is negatively correlated with vertical integration.

The results confirm the prediction of the model in the previous section that the higher demand uncertainty increases the choice of vertical integration in durable industries. Uncertainty in demand is a more relevant problem regarding the choice of sourcing options in durable industries since the production decision should be made earlier in durable industries than in nondurable industries. The positive relationship between demand uncertainty and vertical integration in durable industries suggests that the benefit of firm-level ability of management in an integrated institution under uncertainty outweighs the cost of initial investment required to build it. Also, the regression results show that the effect of uncertainty is weaker for nondurable industries, supporting the assumption that the relative management costs of vertically integrated firms is lower ($\lambda < 1$) in nondurable industries.

<table>
<thead>
<tr>
<th>Table 2.5: Vertical integration and demand uncertainty - Alternative measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
</tr>
<tr>
<td>Measure of Unc</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Unc</td>
</tr>
<tr>
<td>(Unc)×(Dur)</td>
</tr>
<tr>
<td>Obs</td>
</tr>
<tr>
<td>R-squared</td>
</tr>
</tbody>
</table>

Notes: * denote significance at 10% level. ** denote significance at 5% level. *** denote significance at 1% level. Robust standard errors are clustered by industries and years. In columns (1) and (2), country and year fixed effects are included in the regressions. In columns (3) and (4), only year fixed effects are included since ‘Vertical Relatedness’ does not have country dimension. All control variables in the baseline analysis are included.
Table 2.6: Vertical integration and demand uncertainty - Poisson distribution

<table>
<thead>
<tr>
<th>Measure of Unc</th>
<th>Intrafirm Share (6-digit)</th>
<th>Intrafirm Share (4-digit)</th>
<th>VI index (6-digit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD(sales)</td>
<td>SD(TFP)</td>
<td>Volatility</td>
</tr>
<tr>
<td>Unc</td>
<td>0.383</td>
<td>0.275</td>
<td>-8.126</td>
</tr>
<tr>
<td></td>
<td>(0.449)</td>
<td>(0.222)</td>
<td>(7.517)</td>
</tr>
<tr>
<td>(Unc) × (Dur)</td>
<td>0.864***</td>
<td>0.566***</td>
<td>11.98*</td>
</tr>
<tr>
<td></td>
<td>(0.210)</td>
<td>(0.0999)</td>
<td>(6.828)</td>
</tr>
</tbody>
</table>

Year FE: Yes, Yes, Yes, Yes, Yes
Country FE: Yes, Yes, Yes, -, -

Log pseudolikelihood: -12258.672, -12255.198, -8590.5806, -152.72681, -152.73101
Observations: 21,962, 21,962, 16,617, 285, 285

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

2.4 Extensions and robustness analysis

I present the regression results with another measure of demand uncertainty in Table 2.5, which is the industrial volatility. I use this variable as an alternative measure since the fluctuations of industry productions can partly capture the demand uncertainty. Following Bergin et al. (2009), I use the monthly production worker employment data from Current Employment Survey (CES) in the Bureau of Labor Statistics from 2002 to 2009. Since the CES industry identifier is unique and often combines several 5- or 6-digit NAICS industries, I match the industry classification of CES with 4-digit NAICS. I seasonally adjust, log, and HP-filter the data. Then I take the standard deviation of the data by 2 years, which means one period’s volatility is based on the standard deviation of 24 observations.

The coefficient estimates with this alternative variable of demand uncertainty is in column (1) and (2) in Table 2.5. Column (1) does not include the interaction term of uncertainty and durability, and the results are similar to the baseline analyses, where the coefficient of
uncertainty is positive and significant. Interestingly, the coefficient of uncertainty in column (2), where the interaction term is included, is negative. This result suggests that, in nondurable industries, outsourcing is prevalent as volatility increases. However, the coefficient is not significant. The coefficient of the interaction term ($\beta_2$) is positive and significant, which is consistent with the baseline analyses. Therefore, the results in both Table 2.4 and Table 2.5 show that demand uncertainty is significantly and positively related with higher intrafirm share of the durable industries, but not significantly affect intrafirm share of the nondurable industries.

I also use an alternative measure of vertical integration that calculates the probability that firms in an industry have vertically integrated operations as in Fan and Lang (2000) and Acemoglu et al. (2009). This variable shows how much dollar value of inputs the firm can procure from the firm’s own operations to produce one dollar’s worth of an output. Thus, this variable is an approximation of vertical integration based on input-output table and the information of the industries at which firms operate. To compute this measure, I first use the benchmark input-output table in 2002 from the U.S. Bureau of Economic Analysis (BEA). The input-output requirement table reports the dollar value of each input industry $i$ to produce one dollar’s worth of the output industry $j$, $IO_{ij}$, for all 435 industries in the U.S. The industry classification in the input-output table (IO code) is based on 2002 NAICS but aggregated at various digit-levels. For example, transportation and warehouse industries are matched with 3-digit NAICS code while many manufacturing industries are matched with 5- or 6-digit NAICS code. Using the concordance table from BEA,\(^{20}\) I match the NAICS code with the IO code. I drop government and special industries since they are not included in NAICS. I also exclude wholesale and retail trade following Fan and Lang (2000) and construction since they are defined only in 2-digit NAICS code. Then I combine this information with Compustat’s segment data that reports the multiple industries in which each U.S. public firm is operating. The vertical integration index for firm $f$ primarily

operating in industry $i$ in year $t$ is defined as

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

(2.23)

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

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

(2.24)

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

The regression results with the VI index as a measure of vertical integration are in columns (3) and (4) in Table 2.5. The demand uncertainty variable is the standard deviation of sales in column (3) and of TFP in column (4). Since the number of observations in these two analyses is smaller, I use 1-year period values instead of 2-year average values. The signs of coefficients $\beta_1$ and $\beta_2$ are consistent with the baseline analyses, but they are not as significant. Thus, the relationship of demand uncertainty and vertical integration is not clear when the VI index is used as a measure of vertical integration. However, poisson regressions below give significant results.

Table 2.6 reports the estimation results with poisson regression. I use this method as a robustness check because the dependent variable is a share ranging from 0 to 1. The dependent variable is intrafirm imports share in columns (1) to (3), and the VI index in columns (4) and (5). The results are mostly similar to the baseline analyses, but $\beta_2$’s are significant even when the VI index is used as the dependent variable.
2.5 Conclusion

This paper investigates the demand uncertainty as a determinant of the boundaries of firms. Based on the simplified model of Grossman and Helpman (2002), I show the positive relationship between vertical integration and demand uncertainty in durable industries and insignificant relationship in nondurable industries. The importance of adaptability of internal structures (integration) outweighs the flexibility of market transactions (outsourcing) when demand uncertainty affects production decisions more. This prediction is tested using the US intrafirm trade in manufacturing industries. Future work includes extending the model into dynamic framework to treat the durability of industries and the time gap between production decisions and sales more extensively.
Chapter 3

The Great Trade Collapse and Intrafirm Trade

3.1 Introduction

The unprecedented drop in international trade during the recent 2008-2009 Great Recession, or the Great Trade Collapse (GTC), stimulated substantial amount of research regarding causes and consequences.\textsuperscript{1} Studies now generally agree that the main cause of the GTC is a large decrease in demand, which spread from the US to the world through the global value chain.\textsuperscript{2} The importance of the global value chain is reflected in the facts that intermediate goods trade constitutes the majority of trade (roughly half of total trade for the US) and that intermediate goods trade dropped more than final goods trade. Interestingly, within the intermediate goods sector, intrafirm trade adapted to the changes in the level of demand more swiftly than arm’s length trade, resulting in a faster drop and recovery (Altomonte et al., 2012; Carballo, 2014). Furthermore, intrafirm transactions have shown more resilience (i.e., lower drop in trade) to the adverse aggregate shock (Bernard et al.,

\textsuperscript{1}See Bems et al. (2010), Levchenko et al. (2010), or Baldwin (2009), for example.

\textsuperscript{2}Eaton et al. (2011) argues that the drop in aggregate demand explains 80 percent of the collapse in trade. Gopinath et al. (2012) show that prices stayed largely stable during the GTC, expressing concerns about putting emphasis on the cost side of the recession. Bussière et al. (2013) claim that trade fell more than GDP during the GTC since a large part of import is procyclical. Another strand of research points out trade finance as a minor but important source of the collapse in trade as in Amiti and Weinstein (2011) and Chor and Manova (2012).
2009; Lanz and Miroudot, 2011). This paper aims to offer a macroeconomic framework with microfoundations to explain the heterogenous responses of intrafirm and arm’s length trade during and after the Great Trade Collapse.

I propose that organizational differences regarding inventory managements as a cause of the heterogenous responses of intrafirm and arm’s length trade. When firms source intermediate goods through the global value chains, they generally choose between two organizational options: outsourcing (buying from independent firms) or vertical integration (supplying from own affiliates). The two sourcing options have the following trade-offs with regard to aggregate shocks: outsourcing firms can exit the market more easily since their initial investment is smaller. Vertically integrated firms have better ability to manage their inventory and production to adapt to the lower demand in the market. Therefore, the resilience of the intrafirm trade may result from their more effective inventory management.

This investigation about whether the effective inventory management of multinational organizations explains resilient intrafirm trade during the recession is motivated by the following findings. First, inventory is an important mechanism behind the GTC: Alessandria et al. (2011) and Altomonte et al. (2012) explain that, during the recent recession, demand dropped and unsold goods increased inventories. Consequently, firms dropped placing new orders and this resulted in the collapse in trade. If, however, a firm is able to manage inventory more effectively, then the buffer inventory, which the firm keeps to avoid stockout, level would be lower. This, in turn, implies that the drop in orders and international trade would be lower. Second, transaction cost economics claims that integrated organizations offer better (inventory) management systems. In fact, Keane and Feinberg (2007) report that

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3There is a large literature on the determinants of the choice of multinational firms between these options, such as headquarter intensity and the importance of the intangible knowledge (Markusen, 1995; Markusen and Maskus, 2001; Antrás, 2003; Antrás, 2005; Corcos et al., 2013). This paper keeps the choice exogenous so as to focus on the responses of the two sourcing options to aggregate economic shocks.

4Consistent with this argument, Carballo (2014) shows that the role of the extensive margin is larger for arm’s length trade than intrafirm trade; the real option literature (Bloom et al. (2007), for example) deals with the issue of initial investment extensively. Both Coughlin (2014) and Novy and Taylor (2014) show that, in the US, the trade collapse in 2008-09 was largely in the intensive margin, which means that existing exporting firms largely stayed in the market but reduced the quantity of exports.
US multinational firms vastly improved their inventory control systems during the 1980s thanks to the introduction of the just-in-time (JIT) production system. One may argue that outsourcing firms may have benefited from adopting JIT as well. However, JIT requires close links between upstream and downstream firms through, for example, minority equity holdings, relationship specific assets, and shared employees (see Feinberg and Keane, 2007). Thus, I argue that intrafirm trade was more resilient to the recent recession because of the more effective inventory management of integrated firms.

In the next section, I first document the heterogenous responses of intrafirm and arm’s length trade during the recent recession. Since the statistics regarding detailed intrafirm and arm’s length trade are rare, I draw the statistics on the heterogenous responses of trade from various studies that use detailed data. According to BEA data, intrafirm and arm’s length exports fell by 5.32 and 22.10 percent in the US during GTC. Also, intrafirm trade recovered faster to the pre-crisis level compared to arm’s length trade in both US and French firm level data. Such faster recovery is mostly found in intermediate goods sector. Second, I report some facts on the intrafirm trade and inventory controls. Even at an aggregate level, the inventory-to-sales (I/S) ratio and intrafirm trade have a negative relationship: the correlation is \(-0.3695\) and \(-0.0572\) in intrafirm exports and imports, respectively. While the overall correlation between intrafirm imports and the I/S ratio is small, intrafirm imports from less developed countries, such as BRIC countries (-0.2701) and China (-0.18) are higher. Also, I use US monthly merchandise imports data by port of entry and origin country with related party trade data to compare the frequency of shipments of intrafirm and arm’s length imports. In some selected cases that meet the conditions for fair comparison, shipments of intrafirm trade is roughly 2 to 4 times more frequent than arm’s length trade, which implies that the friction of placing orders is lower. The statistics presented in this section may not represent the complete picture, but still suggest that integrated firms manage inventory more

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5It requires not only the transaction records but also the ownership information of the parties of transactions with monthly or at least quarterly reports. While the US related party transaction database categorizes all trade transactions into related and non-related party trade, the frequency of the data is yearly and it doesn’t give much dynamics of the trade during the recent recession.
effectively.

In section 3.3, I develop a general equilibrium model of trade with \((S, s)\) inventory controls based on Alessandria et al. (2010a). Home and Foreign firms specialize in final and intermediate goods production, respectively. Final good producers at Home are either vertically integrated with intermediate good producers in the foreign country or outsourcing to the foreign firms. Both integrated and outsourcing final good producers keep inventory and place orders of intermediate goods occasionally, since there are frictions regarding placing orders. Specifically, there are fixed costs for ordering and the arrival of orders are often delayed. I assume that vertically integrated firms have reduced lead time, the time between ordering and receiving the order, by paying a higher cost.\(^6\) The fixed cost of ordering for integrated firms is assumed to be higher than it is for outsourcing firms.\(^7\) Also, the marginal cost of production of the intermediate goods is higher for integrated firms than it is for outsourcing firms in the model to reflect the managerial and bureaucracy costs of larger organizations as in Grossman and Helpman (2002).

In section 3.4, I calibrate the model and show that integrated firms have a lower threshold of inventory that triggers new orders than the threshold for outsourcing firms. The difference of the order threshold between integrated and outsourcing firms rises with the idiosyncratic demand shock each firm faces. Lower thresholds imply a greater ability to avoid stock out with lower stock holding, and this is primarily due to the shorter lead time for integrated firms. Also integrated firms’ prices are more stable than outsourcing firms’ prices even when the stock level is very low.

When an aggregate demand shock is introduced to the model to replicate the recent recession, in section 3.5, the model is able to account for the resilience of intrafirm trade relative to arm’s length trade, as well as the large drop in total trade. Total imports drop by 27.2 percent in response to a 7 percent drop in demand, which accounts for the large

\(^6\)Ben-Daya and Raouf (1994) note that lead time can be reduced at an added cost in many practical cases.

\(^7\)It is possible that intrafirm shipments are more frequent while their fixed costs of ordering is higher if the cost of keeping inventory is expensive.
drop in trade of GTC than GDP. Arm’s length imports and intrafirm imports collapse by 30.8 and 18.7 percent of the steady state, respectively. Therefore, the effective management of inventory can explain the resilience of intrafirm trade. The recovery of intrafirm trade, however, is slower than arm’s length trade right after the drop. It takes 4 quarters for the two types of trade to converge in terms of the speed of recovery. While the effectiveness of inventory management explains the resilience of intrafirm trade, the speed of recovery might need another explanations such as adjustment in internal pricing or reallocation of global production as discussed in Bernard et al. (2009).

This work contributes to the literature as follows. First, it reveals an important and specific mechanism behind the heterogenous responses of intrafirm and arm’s length trade to the Great Recession. Several studies have suspected that different inventory management causes such heterogeneity, but this paper specifies in a theoretical model the inventory management ability as the mechanism behind the heterogeneity. This work is complementary to Carballo (2014), who explains the heterogenous responses of intrafirm and arm’s length trade using entry and exit decisions of outsourcing and vertically integrated firms. Second, this paper provides some evidence regarding the different inventory management depending on types of firms. While inventory management is one of important reasons for the integration of manufacturers and distributors (Williamson, 1985, p.114), evidence of the superior inventory management of integrated firms is rare. In this paper, examples regarding the lower inventory-to-sales ratio and more frequent placement of international orders of integrated firms is given.

3.2 Facts

In this section, I first review empirical facts from the literature regarding the heterogenous responses of intrafirm and arm’s length trade to the recessions. Then, I describe how the inventory management practices differ in outsourcing and vertically integrated.
3.2.1 Intrafirm trade: resilience to and swift recovery after recessions

Several studies in the recent trade literature find that intrafirm trade is more resilient to recession than arm’s length trade. Bernard et al. (2009) find evidence using the Asian financial crisis of 1997. They use the US Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which links the US firms to each trade transactions, to report that overall US exports to Asian countries in crisis declined 19 percent between 1996 and 1998. Intrafirm exports declined by only 4 percent, while arm’s length exports declined by 26 percent.\(^8\) Carballo (2014) uses the same database to examine the heterogenous responses to the Great Recession in 2008-09. The results are similar to Bernard et al. (2009): while intrafirm exports fell 17 percent, arm’s length exports fell 19 percent. Even though the difference between the two types of exports looks smaller than in the Asian crisis case, Lanz and Miroudot (2011) suggests that the resilience of the intrafirm trade is stronger within the global value chains. They find that, within the same level of downward linkages, one percentage point higher share of intrafirm trade of a product is associated with 12 percent lower drop in imports.

Table 3.1 lists changes in US intrafirm and arm’s length imports after GTC by 3-digit NAICS industry. The data used is the related party trade from US Census. Panel A lists manufacturing industries that mainly produce intermediate goods and panel B lists other manufacturing industries. The classification follows the Main Industrial Grouping from Eurostat.\(^9\) Among intermediate goods industries in panel A, the collapse in intrafirm trade is generally smaller than the collapse in arm’s length trade. Among non-intermediate goods industries in panel B, however, the change in intrafirm trade is always larger than the change in arm’s length trade. Even though the grouping of intermediate goods is broad in this table,

\(^8\)Conversely, imports from Asia increased 19 percent, where arm’s length and intrafirm imports went up by 11 and 28 percent, respectively. Again, intrafirm imports went up more than two times compared to arm’s length imports. Bernard et al. (2009) define the crisis countries in Asia as Indonesia, Korea, Malaysia, the Phillippines, and Thailand.

\(^9\)The correspondence table between NACE (rev.2) and NAICS 2007 was used to construct the table.
it still reveals the resilience of intrafirm trade in the global value chains.

Table 3.1: Intrafirm and arm’s length trade during the Great Trade Collapse

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Industry Description</th>
<th>US Imports in 2009</th>
<th>Change in 2009 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Value I (%) A (%)</td>
<td>ΔValue ΔI ΔA</td>
</tr>
<tr>
<td>311</td>
<td>Food and Kindred Products</td>
<td>36,144 32.8 67.2</td>
<td>-9.6 -5.8 -11.3</td>
</tr>
<tr>
<td>313</td>
<td>Textiles and Fabrics</td>
<td>5,287 22.2 77.8</td>
<td>-23.9 -21.1 -24.6</td>
</tr>
<tr>
<td>314</td>
<td>Textile Mill Products</td>
<td>13,229 13.2 86.8</td>
<td>-11.7 -17.9 -10.7</td>
</tr>
<tr>
<td>321</td>
<td>Wood Products</td>
<td>9,750 23.4 76.6</td>
<td>-31.1 -28.0 -31.9</td>
</tr>
<tr>
<td>322</td>
<td>Paper</td>
<td>18,496 36.0 64.0</td>
<td>-23.0 -28.2 -19.7</td>
</tr>
<tr>
<td>324</td>
<td>Petroleum and Coal Products</td>
<td>75,216 54.0 46.0</td>
<td>-42.5 -45.2 -38.9</td>
</tr>
<tr>
<td>325</td>
<td>Chemicals</td>
<td>162,208 72.8 27.1</td>
<td>-17.3 -13.8 -25.4</td>
</tr>
<tr>
<td>326</td>
<td>Plastics and Rubber Products</td>
<td>27,757 41.3 58.7</td>
<td>-15.9 -16.8 -15.3</td>
</tr>
<tr>
<td>327</td>
<td>Nonmetallic Mineral Products</td>
<td>13,081 28.6 71.4</td>
<td>-27.6 -24.5 -28.8</td>
</tr>
<tr>
<td>331</td>
<td>Primary Metal</td>
<td>55,354 34.4 65.6</td>
<td>-44.3 -46.0 -43.4</td>
</tr>
<tr>
<td>332</td>
<td>Fabricated Metal Products</td>
<td>39,799 33.8 66.2</td>
<td>-23.3 -25.0 -22.5</td>
</tr>
<tr>
<td>334</td>
<td>Computer and Electronic products</td>
<td>265,629 61.6 38.4</td>
<td>-11.6 -10.2 -13.7</td>
</tr>
<tr>
<td>335</td>
<td>Electrical Equipment and Components</td>
<td>55,558 49.1 50.9</td>
<td>-18.0 -15.4 -20.3</td>
</tr>
<tr>
<td>339</td>
<td>Miscellaneous Manufacturing</td>
<td>82,479 40.1 59.9</td>
<td>-15.9 -5.4 -21.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Industry Description</th>
<th>US Imports in 2009</th>
<th>Change in 2009 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Value I (%) A (%)</td>
<td>ΔValue ΔI ΔA</td>
</tr>
<tr>
<td>312</td>
<td>Beverages and Tobacco Products</td>
<td>14,455 27.0 72.5</td>
<td>-8.9 -13.0 -7.4</td>
</tr>
<tr>
<td>315</td>
<td>Apparel and Accessories</td>
<td>66,821 12.6 87.4</td>
<td>-12.3 -12.8 -12.2</td>
</tr>
<tr>
<td>316</td>
<td>Leather and Allied Products</td>
<td>25,547 8.9 91.1</td>
<td>-13.3 -17.8 -12.9</td>
</tr>
<tr>
<td>323</td>
<td>Printed Matter and Related Products</td>
<td>4,901 18.6 81.4</td>
<td>-20.8 -26.3 -19.4</td>
</tr>
<tr>
<td>333</td>
<td>Machinery, Except Electrical</td>
<td>86,893 48.6 51.4</td>
<td>-29.7 -32.1 -27.3</td>
</tr>
<tr>
<td>336</td>
<td>Transportation Equipment</td>
<td>179,732 73.9 26.1</td>
<td>-29.3 -30.1 -27.0</td>
</tr>
<tr>
<td>337</td>
<td>Furniture and Fixtures</td>
<td>21,569 15.1 84.9</td>
<td>-18.1 -27.4 -16.1</td>
</tr>
</tbody>
</table>

Notes: Classification of intermediate and non-intermediate goods follow Main Industrial Grouping (MIG) and correspondence table between NACE (rev.2) and NAICS 2007 from Eurostat. The values of US imports are in millions of US dollars. ‘I’ denotes intrafirm trade and ‘A’ denotes arm’s length trade. The related trade data is from the US Census.

Another feature of intrafirm imports regarding the responses to recessions is faster recovery to the before-crisis level. Using French transacion-level data, Altomonte et al. (2012) find different dynamics for intrafirm and arm’s length trade during and after the recent recession of 2008-09. They observe French monthly exports and imports from January 2007 to
Figure 3.1: Organizational modes and trade collapse in 2007-2009

A. Exports and imports of intermediate goods

B. Exports and Imports of capital goods

C. Exports and imports of consumption goods

D. Total exports and imports

Source: Altomonte et al. (2012). Notes: Monthly growth rates are illustrated on the year-on-year basis
December 2009, which covers the total period of the trade collapse and recovery.\textsuperscript{10} They find that intrafirm imports and exports of intermediate goods declined and then recovered faster than arm’s length trade. Figure 3.1 reports monthly growth rates of intrafirm and arm’s length trade during and after the GTC for three end-user categories, which are consumption goods, capital goods, and intermediate goods. In panel A (intermediate goods) and panel D (total trade), trade of vertically integrated firms collapses faster at the beginning of the crisis and rebounds faster during the recovery periods. This heterogenous dynamics between intrafirm and arm’s length trade is not observed in panel B (capital goods) and panel C (consumption goods). Thus, the faster adaptation of total trade to the aggregate demand is mostly driven by intermediate goods, which account for about 58 percent of both total import and export in France. Carballo (2014) also reports that, in the US, the number of varieties of goods traded for intrafirm trade recovered faster after GTC in 2008-09. At the end of 2009, the number of varieties in intrafirm trade reached its pre-crisis level in 2008, but arm’s length trade was 5.07 percent lower than its peak.

### 3.2.2 Inventory management of integrated firms

Table 3.2: Correlation of intrafirm trade share and inventory-to-sales ratio

<table>
<thead>
<tr>
<th>Trading partner countries</th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>All countries</td>
<td>-0.3695</td>
<td>-0.0572</td>
</tr>
<tr>
<td>NAFTA</td>
<td>-0.0617</td>
<td>-0.0481</td>
</tr>
<tr>
<td>EU</td>
<td>-0.3197</td>
<td>0.0531</td>
</tr>
<tr>
<td>EE5</td>
<td>-0.3209</td>
<td>-0.2701</td>
</tr>
<tr>
<td>BRIC</td>
<td>-0.2915</td>
<td>-0.2618</td>
</tr>
<tr>
<td>CHINA</td>
<td>-0.2142</td>
<td>-0.18</td>
</tr>
<tr>
<td>OECD</td>
<td>-0.2926</td>
<td>-0.0999</td>
</tr>
</tbody>
</table>

Notes: EE5 countries are Indonesia, South Africa, Brazil, China and India

The explanatory hypothesis of Altomonte et al. (2012) with regard to the swift recovery

\textsuperscript{10}The source of their dataset is the following: monthly data for exports and imports of French customs, Orbis by Bureau Van Dijk for annual balance sheet data, and the Ownership Database by Bureau Van Dijk for data on intra-group linkages.
Table 3.3: Shipment frequency of motor vehicle parts in intrafirm and arm’s length imports

<table>
<thead>
<tr>
<th>Description</th>
<th>Motor vehicle brakes</th>
<th>Motor vehicle bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS 870830</td>
<td>870710, 870790</td>
<td></td>
</tr>
<tr>
<td>NAICS 336340</td>
<td>336211</td>
<td></td>
</tr>
<tr>
<td>Years 2007-2010</td>
<td>2005-2006</td>
<td></td>
</tr>
<tr>
<td>Origin country</td>
<td>Egypt Malaysia</td>
<td></td>
</tr>
<tr>
<td>Intrafirm Imports Share</td>
<td>0.99 0.00</td>
<td></td>
</tr>
<tr>
<td>Total value of imports</td>
<td>6,970,556 3,949,126</td>
<td></td>
</tr>
<tr>
<td>Frequency of shipments</td>
<td>268 80</td>
<td></td>
</tr>
<tr>
<td>Ratio of frequencies</td>
<td>1.90* 4.22*</td>
<td></td>
</tr>
</tbody>
</table>

*: The weighted average of the two values (by the volume of imports) is 2.91

of intrafirm trade is “better handling of inventories thanks to the ability to react faster and optimize management of stocks within the boundaries of the group (p.20).” Other studies cited above also attribute the resilience and swift recovery to the superior inventory management of integrated firms. Thus, I document some evidence concerning the type of firms (integrated and outsourcing) and inventory management. While many studies agree that vertically integrated firms offer better inventory management than outsourcing firms, specific evidence is rare. With available data, I ask the following questions regarding inventory management. First, I ask whether integrated firms keep their inventory level lower than outsourcing firms, which implies better technology of inventory management when other things are equal. To answer this question I first exploit inventory-to-sales(I/S) ratio data from the BEA for the 2002 to 2013 period. This data is available in NAICS 3-digit manufacturing industries only. As in Table 3.2, the correlation of I/S ratios and the intrafirm trade share is overall negative, but the correlation is stronger for exports than imports: the correlation with the intrafirm export share is −0.3695 and with the intrafirm import share is −0.0572. The I/S ratio is more negatively related with the intrafirm imports share in BRIC and EE5 (Indonesia, South Africa, Brazil, China and India) countries.

The second question is about the inventory management. I ask whether vertically integrated firms place orders more frequently. The intuition is as follows: better inventory
management may be characterized by lower I/S ratio, which allows firms to pay lower inventory carrying costs but still avoid stockout. Lower I/S ratio in turn may imply fewer delays in receiving orders, and more frequent placements of orders.

I draw evidence from a combination of the following data. First, I use the US monthly merchandise trade data, which provide information on monthly import transactions to the US with origin country, port of entry and value of imports at up to HS 10-digit level.\textsuperscript{11} This data let me count the number of shipments from each foreign country to each port of entry at each month from 2002 forward. To distinguish whether each transaction is intrafirm or outsourcing, I also use the related party trade data from the US census bureau. This data, however, is at most at the NAICS 6-digit level and many disaggregated industries have a mix of intrafirm and arm’s length transactions. So I choose a sample to examine with the following criteria: 1) The industry/goods description in HS6 and NAICS6 classifications should be well matched. 2) In the related trade data, the year-industry-country (-of-origin) cells should be either all arm’s length or all intrafirm imports transactions in consecutive years.

As in Table 3.3, I find that the frequency of shipments for intrafirm imports is two to four times more frequent than the frequency for arm’s length imports. The first industry that meets the criteria above is “Motor vehicle brake systems” in NAICS (336340) and “Brakes and servo-brakes; Parts thereof (for motor vehicles)” in HS (870830). In this industry, I compare the frequency of shipments from Egypt and Malaysia. During 2007-2010, 99.3% of motor vehicle brakes imports from Egypt was intrafirm (100% during 2008-2009), and 100% from Malaysia was arm’s length. The frequency of shipments from Egypt to various ports of US was 268, but from Malaysia was only 80. Considering that the total value of shipments from Egypt was 1.77 times larger than Malaysia, the shipments from Egypt was 1.90 times more frequent than Malaysia. The second industry is “Motor vehicle bodies” in NAICS (336211) and “Bodies for specific motor vehicles” in HS (870710, 870790). During

\textsuperscript{11}There are some missing data points, however.
2005 to 2006, 100% of motor vehicle bodies imports from Poland was intrafirm and 100% from Turkey was arm’s length. The frequency of shipments from Poland to the US was 11 and from Turkey was 9. But, the value of shipments from Turkey was 3.46 times larger than Poland. Taking this into account, I conclude that the shipments from Poland was 4.22 times more frequent than Turkey. The average of the two weighted by the volume of import is 2.91. Thus, in the two examples, vertically integrated firms place orders about 3 times more frequently than outsourcing firms. This implies that integrated firms are able to adjust inventories more flexibly. While this value does not represent the whole sample, the number is consistent with the predictions of transaction cost economics.

### 3.3 Model

Based on Alessandria et al. (2010a) and Grossman and Helpman (2002), I develop an environment where vertically integrated and outsourcing firms exhibit different abilities of inventory management. There are two asymmetric countries in this economy: Foreign produces intermediated goods, and Home imports the intermediate goods to produce final goods. Monopolistically competitive home firms source inputs either from their affiliates or from independent suppliers. Because of the frictions of importing from the foreign country, home firms store inventory. Since integrated firms have better ability to manage the inventory, they have lower inventory-to-sales ratio than outsourcing firms. On the other hand, independent firms have cost advantages when placing orders. This environment captures the different response of intrafirm and arm’s length trade in time of economic downturns.

#### 3.3.1 Consumers

At Home, utility comes from consumption of a composite of heterogenous goods \( C_{1t} \), a homogenous good \( C_{2t} \), and leisure \( 1 - L_t \), where \( L_t \) is the supply of labor at time \( t \). The lifetime expected utility of a representative consumer, \( U \), is as following:
\[
U = E_0 \sum_{t=0}^{\infty} \beta^t u[C_{1t}, C_{2t}, L_t],
\]

(3.1)

where \( u = \mu \log C_{1t} + (1 - \mu) \log C_{2t} - L_t \) and \( C_{1t} = \left[ \int_0^N \exp(\theta(i, t)^\frac{1}{\varepsilon}) y(i, t)^\frac{\varepsilon+1}{\varepsilon} di \right]^\frac{\varepsilon}{\varepsilon+1} \). The parameter \( \varepsilon \) measures the elasticity of substitution among varieties in sector 1, and \( y(i, t) \) is the demand of variety \( i \) at time \( t \). \( N \) is the number of varieties produced in the heterogeneous goods sector. The weight of each variety \( \theta(i, t) \) in the composite \( C_{1t} \) is subject to idiosyncratic shocks: this easily generates the heterogeneity among the final good producers.

A representative consumer in Foreign has identical preferences with Home consumers, but with foreign consumption \( C_{1t}^* = \left[ \int_0^{N^*} \exp(\theta(i, t)^\frac{1}{\varepsilon}) y^*(i, t)^\frac{\varepsilon+1}{\varepsilon} di \right]^\frac{\varepsilon}{\varepsilon+1} \) and \( C_{2t}^* \), and foreign labor supply \( L_t^* \). The idiosyncratic demand shocks at Home and Foreign are identical. (Asterisks notate the variables of the foreign country throughout this paper.)

A representative consumer at Home has endowment \( x \) times the price of the homogenous goods, and earns wage \( W_t \) by providing labor \( L_t \). The budget constraint of a representative consumer at Home is therefore:

\[
\int_0^N p(i, t) y(i, t) di + p_2 C_{2t} \leq E_t = W_t L_t + p_2 x,
\]

(3.2)

where \( p(i, t) \) is the price of a final heterogenous good \( i \);\(^{12} \) \( p_2 \) is the price of the homogenous good, which is normalized to 1. \( E_t \) is the total expenditure of the representative consumer. The budget constraint of the Foreign representative consumer is:

\[
\int_0^N p(i, t) y^*(i, t) di + p_2 C_{2t}^* \leq E_t^* = W_t^* L_t^* + p_2 x^*.
\]

(3.3)

The representative Home consumer’s problem is solved in two steps taking the prices and wages as given. First, the consumer chooses how much to purchase of each variety \( i \) at time

---

\(^{12}\)In the production section, I notate prices of the final goods using an additional subscript, \( p_f(i, t) \) where \( f \in \{v, o\} \), to specify the sourcing option (vertical integration (\( v \)) or outsourcing (\( o \))) of firm \( i \). Thus, \( p(i, t) \) is either \( p_v(i, t) \) or \( p_o(i, t) \), depending on the sourcing option of firm \( i \).
in sector 1 by minimizing expenditures. This yields the following demand function:

\[ y(i, t) = \exp(\theta(i, t)) \left[ \frac{p(i, t)}{P_{1t}} \right]^{1-\varepsilon} C_{1t}, \]  

(3.4)

where \( P_{1t} \equiv \left[ \int_0^N \exp(\theta(i, t))p(i, t)^{1-\varepsilon}di \right]^{1/\varepsilon} \) is the aggregate price index for the heterogenous sector. The second step is to maximize the lifetime utility in (3.1) subject to the budget constraint in (3.2). This yields the consumer’s demand for the homogenous good

\[ C_{2t} = (1 - \mu)E_t \]  

(3.5)

and equilibrium wage

\[ W_t = p_2C_{2t} \frac{1}{1 - \mu}. \]  

(3.6)

Foreign consumers solve similar problems. The homogenous goods sector clears every period: the world consumption of homogenous goods is equal to the world endowment.

\[ C_{2t} + C^*_2 = x + x^* = X^w \]  

(3.7)

### 3.3.2 Producers

In the heterogenous sector, Home produces final goods and Foreign produces intermediate goods that are necessary for the production of final goods. I assume that final goods require skilled-labor and intermediate goods require unskilled-labor. Furthermore, Home is abundant in skilled-labor and Foreign is abundant in unskilled-labor. Due to the comparative advantage of each country, Home specializes in producing final goods and Foreign specializes in producing intermediate goods. At Home, all final good producers source their intermediate goods from Foreign suppliers. A group of firms outsource their intermediate goods, and the rest of the firms have vertically integrated suppliers at Foreign.

Each Home firm is matched with a same type of Foreign firm in one-to-one fashion. All
Foreign firms in the heterogenous sector produce intermediate goods and export to Home. The division of firm types (outsourcing and vertical integration) is identical in each country and is determined exogenously for simplicity. The import transactions between integrated firms yield intrafirm trade, and the transaction between outsourcing firms yield arm’s length trade.

In Foreign, using labor, perfectly competitive firms produce intermediate goods. An outsourced producer requires one unit of labor to produce one unit of intermediate, whereas a vertically integrated producer requires $\lambda > 1$ unit of labor to produce one unit of intermediate. This assumption is based on the transaction cost economics, which suggests that integrated firms have higher bureaucracy and management costs. Higher costs of production, however, also imply that the integrated firms have better management skills and internal communication systems. The technology of vertically integrated firms is $qm_v(i, t) = \frac{l_v(i, t)}{\lambda}$, and of outsourced firms is $qm_o(i, t) = l_o(i, t); qm_f(i, t)$ is the quantity produced of intermediate goods by the Foreign affiliate of Home firm $i$, and $l_f(i, t)$ is labor hired. The subscript $f \in \{v, o\}$ indexes whether the firm type is vertically integrated supplier $v$, or independent supplier $o$. The price of the intermediate goods is $\omega_{ft}$. All intermediate good suppliers pay the competitive wage $W^*_t$. Both types of suppliers choose the amount of labor to hire to maximize profits given the price of the intermediate good and wage in the market. The resulting prices of intermediate goods for integrated and outsourcing firms are $\omega_{vt} = \lambda W^*_t$ and $\omega_{ot} = W^*_t$, respectively.

Each final good producer at Home produces a variety $i$ and has the ability to transform the imported intermediate goods into final goods. The amount of final good production is, therefore, equal to the amount of intermediate goods. Once entering the final goods market, an outsourcing final good producer is matched with a Foreign intermediate good supplier at no costs. When a final good producer places an order to its matched supplier, the supplier produces the intermediate goods. After the production of the intermediate goods, the two

\[13\text{See Grossman and Helpman (2002), for example.}\]
parties bargain over the expected profit. Then the supplier ships the intermediate goods and
the downstream party at Home produces the final goods and sells them. Vertically integrated
final good producers enter the market with already matched Foreign affiliate. They directly
determine the amount to produce and place orders to their foreign affiliate. The unit wage
for home workers is \( W_t \).

I assume that both independent and integrated firms keep inventories, \( s_f(i,t) \). The
inventories depreciate at the rate of \( \delta \) at both types of firms. There exist some frictions
when it comes to placing new orders. First, final good producers can place only nonnegative
orders, \( z_f(i,t) \geq 0 \). Second, each order requires fixed units of Home labor, \( \phi_f \), where
\( f \in \{v,o\} \) and \( \phi_v > \phi_o \). Third, only a certain proportion of an order, \( \xi_f \in [0,1] \) where
\( \xi_v > \xi_o \), at date \( t \) arrives immediately, and the remaining order arrive at date \( t+1 \). I assume
that more orders arrive on time in vertical integration. The second and third frictions imply
that integrated firms offer better inventory management (less delay in orders) by paying
a higher cost (higher fixed costs of orders). Since more orders arrive on time, integrated
firms can make more sales and keep less inventory-to-sales ratio than outsourcing firms.
As in Feinberg and Keane (2006), the ability to keep the I/S ratio lower reflects superior
management skills. Lastly, final good producers can only sell goods in hand. Thus, the
following inequality between sales \( q_f(i,t) \), and inventories \( s_f(i,t) \) holds:

\[
q_f(i,t) \leq s_f(i,t) + \xi_f z_f(i,t).
\]  
(3.8)

The two types of firms end up solving similar maximization problems: regardless of the
bargaining weight, a downstream firm takes all the profits of the matched upstream firm
using a lump sum transfer. The main difference between the problems of independent firms
and integrated firms are the proportion of delay, price of the intermediate good, and the costs
of placing orders. Both types of Home firms \( (f \in \{v,o\}) \), taking wages in both countries
and the world demand for heterogenous goods as given, solve the following maximization
The problem:

\[ \max_{\{z_f(i,t), pf(i,t)\}} \sum_{t=0}^{\infty} [p_f(i,t)q_f(i,t) - \omega_f z_f(i,t) - W_f \phi_f \times 1_{z_f(i,t) > 0}] \]

subject to

\[ q_f(i,t) = \min \left[ e^{\theta(i,t)} \left( \frac{p_f(i,t)}{P_{1t}} \right)^{-\varepsilon} (C_{1t} + C^*_1), s_f(i,t) + \xi_f z_f(i,t) \right] \]

\[ s_f(i,t + 1) = (1 - \delta) (s_f(i,t) - q_f(i,t) + z_f(i,t)) \]

\[ z_f(i,t) \geq 0. \]

(3.9)

The first constraint in equation (3.9) shows that the sales of a firm \( i \) is the minimum of the world demand of \( i \) and its current stock. This problem can be solved recursively. I define \( V^a(s) \) as a firm’s value of adjusting its stock of inventories by placing an order and \( V^n(s) \) as the value of inaction. Then the value of the firm is: \( V(s) = \max [V^a(s), V^n(s)] \). The following describes the recursive problem of Home firms:

\[ V^a(s) = \max_{\{pf, zf>0}\}} q_f(s)pf - \omega_f^*zf - W_f\phi_f + \beta V(s') \]

\[ V^n(s) = \max_{\{pf}\}} q_f(s)pf + \beta V(s') \]

where

\[ q_f = \min \left[ e^{\theta} \left( \frac{p}{P_1} \right)^{-\varepsilon} (C_1 + C^*_1), s_f + \xi_f z_f \right] \]

\[ s'_f = (1 - \delta) (s_f - q_f + z_f) \]

\[ z_f \geq 0. \]

(3.10)

3.3.3 Equilibrium

At the equilibrium, the Home representative consumer’s choice of the consumptions of heterogenous, and homogenous, and labor supply, \( \{y(i,t), C_2, L_t\}_{i=1}^{\infty} \), solves the utility maximization problem. The Foreign representative consumer’s choice does likewise. The home producers’ choice of prices and orders, \( \{p_f(i,t), z_f(i,t) \}_{f=v,o}^{N, \infty}_{i=1, t=1} \), solves their profit maximization problem.
All goods market clear at the equilibrium. First, the intermediate goods markets clear: the production and orders of intermediate goods are equal for all firms that sell to Home and Foreign consumers.

\[
\int_0^n qm_v(i,t)di + \int_n^N qm_o(i,t)di = \int_0^n z_v(i,t)di + \int_n^N z_o(i,t)di \quad (3.11)
\]

Second, final goods markets clear: final goods not sold at the same period are kept as stock. The end-of-period stock of inventories of a final good producer \(i\) with sourcing option \(f\) serving the consumers in country \(c\) is:

\[
s_f(i,t + 1) = (1 - \delta)(s_f(i,t) - q_f(i,t) + z_f(i,t)). \quad (3.12)
\]

Also, labor market at Home and Foreign clear. Home labor is required every time a final good producer places an order as in equation (3.9). Foreign labor is demanded for the production of the intermediate goods. Thus, Home and Foreign labor demand are as below.

\[
L^D_t = \phi^n \int_0^n 1_{z_v(i,t) > 0}di + \phi^o \int_n^N 1_{z_o(i,t) > 0}di \quad (3.13)
\]

\[
L^D^*_t = \lambda \int_0^n qm_v(i,t)di + \int_n^N qm_o(i,t)di \quad (3.14)
\]

Finally, trade balances each period. Total imports and exports at the heterogeneous goods sector at Home at each period are as following:

\[
IM_t = \int_0^n \omega_{vt} z_v(i,t)di + \int_n^N \omega_{ot} z_o(i,t)di
\]

\[
EX_t = P_1 t C^*_it.
\]

Home exports at sector 1 at each time period are equivalent of the sales of all Home final good producers to Foreign customers. The trade in homogenous goods sector balances the
3.4 Parameterization and policy rules

3.4.1 Parameterization

I begin by reporting preference parameters. The discounting factor is set to $\beta = 0.96^{1/4}$ to reflect a US real interest rate of around 4 percent and that a time period of a quarter. The expenditure on the heterogeneous sector is set to $\mu = 0.25$ to match the average imports of Home to be 25 percent of GDP.\(^{14}\)

I set the depreciation rate of inventory to $\delta = 0.078$. Alessandria et al. (2010b) claim that annual non interest inventory carrying costs, which include taxes, warehousing, physical handling, obsolescence, pilfering, insurance, and clerical controls, range from 19 to 43 percent of a firm’s inventories in the US. It implies that the quarterly costs range from 4.75 to 10.75 percent. The value $\delta = 0.078$ is in the mid-range of the values.

The elasticity of substitution between varieties of domestic final goods is set to $\varepsilon = 5.17$, which is the median elasticity of substitution of all industries calibrated by Imbs and Méjean (2014). This value yields a 24 percent markup for firms in the model. The standard deviation of the idiosyncratic demand shock is set to $\sigma = 0.80$. The relative intermediate goods price of vertical integration and outsourcing ($\omega_{vt}/\omega_{to}$) is set $\lambda = 1.24$ so that one third of the total imports is intrafirm given other parameter values. (Antràs, 2003; Lanz and Miroudot, 2011).

The proportion of orders receiving on time $\xi_f$ is chosen to reflect the fact that vertically integrated firms manage inventory more efficiently than outsourcing firms. Specifically, integrated firms 1) experience fewer delays in receiving orders, 2) place orders more often, and 3) have lower inventory to sales ratio than outsourcing firms. As argued in the previous

\(^{14}\)The average imports share of GDP in the US from 2004 to 2013 is 15.9 percent. This figure, however, is lower than the average of other OECD countries. So I target 25 percent, which is the average imports share of GDP of Canada, Japan, US, and Euro area countries from 2004 to 2009. The source of the OECD data is OECD Library (http://dx.doi.org/10.1787/888932534976).
section, integrated firms place order 2.5 time more frequently than outsourcing firms. I set \( \xi_o = 0 \) to assume that orders of outsourcing firms is always delayed by one period or three months. For vertically integrated firms, I set \( \xi_v = 0.58 \): the orders of integrated firms arrive in around five weeks on average. I set integrated firms’ fixed costs of ordering 10 percent higher than outsourcing (\( \phi_v > \phi_o \)) to reflect that integrated firms pay more costs for faster shipments.

### 3.4.2 Policy rules

Figure 3.2: Inventory threshold of placing new orders by demand

I present the optimal choice of orders and prices of the final good producers at Home. I choose the same level of idiosyncratic demand for both integrated and outsourcing firms and compare the optimal policy rules regarding orders and prices for each level of inventory relative to the average sales of the economy. Also, I assume that there is no aggregate demand
Figure 3.3: Policy rules
shock. The threshold of inventory at which a firm starts to place orders varies depending on the idiosyncratic demand level as Figure 3.2 shows. The overall pattern of the policy rules, however, carries over regardless of the demand level.

The top panel of Figure 3.3 shows the order policy rules. More about (S,s) models. Both types of firms place orders only when the inventory level goes below the threshold. Due to the frictions in placing orders, firms place orders infrequently, only when the inventory falls below the order threshold(s). The level of order threshold depends on the type of firms and the idiosyncratic demand realized for each firm. As expected, vertically integrated firms have lower threshold, which means they are able to keep a lower stock level than outsourcing firms since, on average, 40 percent of their orders arrive on time. The orders of outsourcing firms arrive with a period, and the outsourcing firms need to keep higher stocks. Also, the quantity of each order that firms place depends on the type of firms. Outsourcing firms always order the same quantity regardless of the stock level as long as they are below the order threshold. This is due to the delay in arrival of the orders. Vertically integrated firms, however, place lower quantity orders as the inventory goes up since some of their orders arrive on time. The unit of order in the vertical axis is percentage of total sales of each firm type. When the idiosyncratic demand shock is 1 \((\exp(0))\), i.e. the idiosyncratic shock is at the average, an outsourcing firm places 15 percent of its total sales when the stock is short, and a vertically integrated firm starts with placing 10 percent of its total sales.

The second panel of Figure 3.3 displays the optimal prices as functions of stock relative to the mean sales of the economy. Prices for both firm types are negatively related with stock: as stock levels go down, prices go up. In the region where the stock level is very low, both types of firms increase their prices, but the outsourcing firms’ prices soar more than the integrated firms’ prices. This is due to the fact that even if outsourcing firms place new orders when stocks are near zero, it takes one period to receive them. The stock level moves slowly and this may raise their prices. On the other hand, prices of vertically integrated firms do not go up much when they are out of stock, since their order arrives relatively sooner.
than outsourcing firms. In a monopolistically competitive environment, soaring prices is less profitable to the firms. This result is consistent with the previous chapter, where I show that vertical integration is more profitable under demand uncertainty in durable industries. Considering the fact that roughly 70 percent of total trade is for durable goods (Engel and Wang, 2011), the results in this chapter and the previous chapter are complementary.

3.5 Experiments

Based on the model and the optimal policy rules, I perform a number of experiments that allow for aggregate demand shocks. Importantly, I examine whether the model yields heterogenous responses for intrafirm and arm’s length imports. The two types of imports are assumed different in the model in terms of the timing (delay) of receiving the orders ($\alpha_o > \alpha_v$), marginal costs of production ($\lambda > 1$), and fixed costs of placing orders ($\phi_v > \phi_o$). I evaluate the roles of these assumptions.

To consider a shock similar to the recent recession in 2008-09, I specify the shock as a drop and recovery of the demand for the heterogenous sector: I assume that the expenditure on sector 1, $\mu$, experiences AR (1) shock as follows:

$$\mu_{t+1} = (1 - \rho)\mu_0 + \rho \mu_t + \epsilon_{t+1},$$

where $\rho = 0.75$ and the steady state is $\mu_0 = 0.25$. We assume a negative 7 percent temporary shock: thus, the disturbance $\epsilon_{t+1}$ is $\epsilon_1 = -0.07 \times \mu_0$ when $t = 0$ and zero otherwise.

The responses are displayed in Figure 3.4. First, I check whether the responses of arm’s length and intrafirm imports are heterogenous in terms of resilience and speed of recovery. Figure 3.4 indicates that the drop in arm’s length imports is more severe than intrafirm imports. Initially, total imports fall by 27.2 percent, among which the decrease in arm’s length imports is 30.8 percent and the decrease in intrafirm imports is 18.7 percent. Overall, the drop in intrafirm imports is only 60.7 percent of the drop in arm’s length imports. This
Figure 3.4: Impulse responses of intrafirm and arm’s length trade
result is consistent with the data presented in Bernard et al. (2009), Lanz and Miroudot (2011), and Carballo (2014). Thus, the superior inventory management practices of integrated firms (with higher marginal and fixed costs) is an important mechanism that let intrafirm transactions more resilient than outsourcing firms under uncertainty.

Figure 3.5: Speed of recovery of intrafirm and arm’s length trade

Second, the speed of recovery is generally faster in arm’s length trade initially. Figure 3.5 plots the quarterly growth rates of intrafirm and arm’s length imports from the second quarter, when the economy starts to recover from the shock. The arm’s length imports recover in faster rate of growth in the first 4 periods. The speed of the two types of imports converge at the 6th quarter and then there are small ups and downs in the gap between the two until they reach zero around period 17. The model predicts that the speed of recovery is faster in arm’s length trade, and it is different from the facts in section 3.2. One
explanation is that, unlike the data, the model assumes that the collapse of the international trade occurs at one period. In French data, from Figure 3.1, show that intrafirm imports took 3 months to reach the trough and it took another 6 months to eventually start to recover. A shock specified closer to the real shock that the world economy experienced may reflect the faster speed of recovery of intrafirm trade than arm’s length trade. Another explanation is that the reason behind the faster recovery of intrafirm trade is unrelated to inventory management. As Bernard et al. (2009) submits, integrated ‘multinational firms may have reallocated global production or adjusted internal pricing in response to the crisis (p.491).’ Since the model assumes that the marginal cost of production, which is equal to the price of intermediate goods, is fixed, it does not consider internal pricing of integrated firms.

3.6 Conclusion

I study whether better inventory management skills of integrated multinational firms can account for the heterogeneous responses of intrafirm and arm’s length trade during the Great Trade Collapse. The ability to keep stock holdings low, place orders more often, and receive deliveries faster lets integrated firms be more flexible. The two country dynamic stochastic general equilibrium model with $(S, s)$ inventory policies in this paper assumes the heterogeneity of integrated and outsourcing firms regarding the inventory management. The trade-offs for the superior inventory system is higher costs of placing orders and production. Experiments show that the intrafirm imports drops 18.7 percent while arm’s length imports drop 30.8 percent. The model mimics the resilience of intrafirm trade of the real world. The model, however, does not explain the swift recovery of intrafirm trade after the recent recession. The faster recovery of the intrafirm trade to the pre-crisis level may need to be explained with different mechanism, which I leave for future research. Another possible future research topic is to find more concrete evidence regarding the different inventory management practice.
Bibliography


Appendix for chapter 1: Proofs

Derivation of differential equations for evolution of trust.
Evolution of trust using Bayesian equation can be reduced as following:

\[ x_{t+dt} = \frac{x_t(1 - m_t dt - r_t dt)}{x_t(1 - m_t dt - r_t dt) + (1 - x_t)(1 - m_t dt - \bar{r} dt)} \]

With \( dt \) being infinitesimally small, we obtain the first-order approximation:

\[ x_{t+dt} = x_t \left[ 1 - r_t dt + x_t r_t dt + (1 - x_t)\bar{r} dt \right] \]

And thus, after defining \( \Delta r_t = \bar{r} - r_t \):

\[ \dot{x}(t) = \frac{dx(t)}{dt} = x_t(1 - x_t)\Delta r_t \]

When written in terms of \( \theta_t \), we obtain:

\[ \dot{\theta}(t) = \frac{d\theta(t)}{dt} = \frac{\dot{x}_t}{(1 - x_t)^2} = \frac{x_t}{1 - x_t} \Delta r_t = \theta_t \Delta r_t. \]

Good agent’s value function when bonus and the effort of the good agent is fixed.
Subtracting \( V_G \) from the value function for good agent:

\[ 0 = [b(\theta) - g(r)]dt - \mu dt V_G(\theta) + \theta \Delta r \frac{\partial V_G}{\partial \theta} dt \]

\[ \mu V_G(\theta) - \theta \Delta r \frac{\partial V_G}{\partial \theta} = b(\theta) - g(r) \]

Alternatively (maybe not needed), this can be re-expressed as:

\[ \iff \theta \frac{\partial V_G}{\partial \theta} - \frac{\mu}{\Delta r} V_G(\theta) = - \frac{b(\theta) - g(r)}{\Delta r} \]

\[ \iff \theta^{-\beta + 1} \frac{\partial V_G}{\partial \theta} - (\beta - 1) \theta^{-\beta} V_G(\theta) = - \theta^{-\beta} \left[ \frac{b(\theta) - g(r)}{\Delta r} \right] \]

\[ \iff \frac{\partial}{\partial \theta} \left\{ \theta^{-\beta + 1} V_G(\theta) \right\} = - \theta^{-\beta} \left[ \frac{b(\theta) - g(r)}{\Delta r} \right] \]

with \( \beta = \frac{m + \bar{r}}{\Delta r} \).
When \( b(\theta) = b, r \) and \( \Delta r \) are constant on \([\theta, +\infty]\), we get a simple expression for \( V_G(\theta) \):

\[
V_G(\theta) = \frac{b - g(r)}{\mu}
\]

**Bad Agent’s value function when bonus and the effort of the good agent is fixed.**

\[
V_B(\theta) = [b(\theta) + \tau]dt + (1 - \bar{\mu}dt)V_B(\theta + \theta \Delta dt)
\]

\[
\Leftrightarrow 0 = [b(\theta) + \tau]dt - \bar{\mu}dt V_B(\theta) + \theta \Delta \frac{\partial V_B}{\partial \theta} dt
\]

\[
\Leftrightarrow \bar{\mu}V_B(\theta) - \theta \Delta r \frac{\partial V_B}{\partial \theta} = b(\theta) + \tau
\]

\[
\Leftrightarrow \theta \frac{\partial V_B}{\partial \theta} - \frac{\bar{\mu}}{\Delta r} V_B(\theta) = -\frac{b(\theta) + \tau}{\Delta r}
\]

\[
\Leftrightarrow \theta^{-\beta} \frac{\partial V_B}{\partial \theta} - \beta \theta^{-\beta-1} V_B(\theta) = -\theta^{-\beta-1} \left[ \frac{b(\theta) + \tau}{\Delta r} \right]
\]

When \( b(\theta) = b \) and \( \Delta r \) are constant, we get a simple expression for \( V_B(\theta) \):

\[
V_B(\theta) = \frac{b + \tau}{\bar{\mu}}
\]

**Principal’s value function when bonus and the effort of the good agent is fixed.**

Since the value function for principal is given by

\[
V_p(\theta) = [R - b(\theta)]dt + (1 - \bar{\mu}(\theta)dt)V_P(\theta + \theta \Delta r dt),
\]

with \( \bar{\mu}(\theta) \equiv \frac{\bar{\mu}}{\theta + 1} + \frac{\mu_1 \theta}{\theta + 1} \) is the expected rate of failure, value for principal satisfies:

\[
\frac{\partial}{\partial \theta} \{\theta^{-\beta}(\theta + 1)V_P(\theta)\} = -\theta^{-\beta-1}(\theta + 1) \left[ \frac{R - b(\theta)}{\Delta r} \right]
\]

where \( \beta \) is defined by \( \beta = \frac{\bar{r} + m}{\Delta r} \) and is supposed to be locally constant.

The principal’s value function is successively equivalent to:

\[
\Leftrightarrow 0 = [R - b(\theta)]dt - \bar{\mu}(\theta)V_P(\theta)dt + \theta \Delta r \frac{\partial V_P}{\partial \theta} dt
\]

\[
\Leftrightarrow 0 = [R - b(\theta)] - \bar{\mu}(\theta)V_P(\theta) + \theta \Delta r \frac{\partial V_P}{\partial \theta}
\]

\[
\Leftrightarrow \theta \frac{\partial V_P}{\partial \theta} - \frac{\bar{\mu}(\theta)}{\Delta r} V_P(\theta) = -\frac{R - b(\theta)}{\Delta r}
\]
With $\tilde{\mu}(\theta) = \bar{\mu} - \frac{\theta}{1+\theta}\Delta r$, we get:

\[
\Leftrightarrow \theta \frac{\partial V_P}{\partial \theta} + \frac{\theta}{1+\theta} V_P(\theta) - \frac{\bar{r}}{\Delta} V_P(\theta) = -\frac{R - b(\theta)}{\Delta} \\
\Leftrightarrow (1 + \theta)\theta \frac{\partial V_P}{\partial \theta} + \theta V_P(\theta) - (1 + \theta)\frac{\bar{r}}{\Delta} V_P(\theta) = -(\theta + 1)\left(\frac{R - b(\theta)}{\Delta} \right)
\]

Denoting $\beta = \frac{\bar{r} + m}{\Delta r} > 1$, we get:

\[
\Leftrightarrow (1 + \theta)\theta \frac{\partial V_P}{\partial \theta} + \theta V_P(\theta) - \beta(1 + \theta)V_P(\theta) = -(\theta + 1)\frac{R - b(\theta)}{\Delta r} \\
\Leftrightarrow \frac{\partial}{\partial \theta} ((1 + \theta)\theta^{-\beta}V_P(\theta)) = -(\theta + 1)\theta^{-\beta-1}\frac{R - b(\theta)}{\Delta r}
\]

When $b(\theta) = b$ and $\Delta r$ are constant, we can integrate and this gives:

\[
V_P(\theta) = (R - b)\left[\frac{\theta}{1 + \theta \mu} + \frac{1}{1 + \theta \bar{\mu}}\right] \\
\Leftrightarrow V_P(x) = (R - b)\left[\frac{x}{\mu} + \frac{1 - x}{\bar{\mu}}\right]
\]

Detailed calculations for the conditions of optimal ownership structure with rigid ownership.

The results are obtained by comparing the value of the relationship for the principal before initial investments are made. Under outsourcing, this gives:

\[
V_P(\theta_0) = \left(\frac{R - c}{\mu_o} - F\right)\left(\frac{\theta_0}{1 + \theta_0}\right) + \left(\frac{R - c}{\bar{\mu}_o} - \frac{\mu_o}{\bar{\mu}_o}\frac{F}{r}\right)\left(\frac{1}{1 + \theta_0}\right)
\]

and under integration this gives:

\[
V_P(\theta_0) - F = \left(\frac{R - c}{\mu_I}\right)\left(\frac{\theta_0}{1 + \theta_0}\right) + \left(\frac{R - c}{\bar{\mu}_I}\right)\left(\frac{1}{1 + \theta_0}\right) - F
\]

When the first expression is larger than the second expression then outsourcing is preferred, otherwise integration is preferred.

The difference between the first and second expressions are:

\[
\left(\frac{\theta_0}{1 + \theta_0}\right) (R - c) \left(\frac{1}{\mu_o} - \frac{1}{\mu_I} - \frac{F}{R - c}\right) + \left(\frac{1}{1 + \theta_0}\right) (R - c) \left(\frac{1}{\mu_o} - \frac{1}{\bar{\mu}_o} - \frac{F}{\bar{\mu}_o} \frac{F}{R - c}\right) + F
\]
Taking out the fixed cost, this gives:

\[
\begin{align*}
&= \left( \frac{\theta_0}{1 + \theta_0} \right) (R - c) \left( \frac{1}{\mu_o - 1} \right) + \left( \frac{1}{1 + \theta_0} \right) (R - c) \left( \frac{1}{\mu_o - 1} \right) + \left( \frac{1}{1 + \theta_0} \right) \left( \frac{1}{\mu_o} \right) F \\
&= \left( \frac{\theta_0}{1 + \theta_0} \right) (R - c) \left( \frac{1}{\mu_o - 1} \right) + \left( \frac{1}{1 + \theta_0} \right) (R - c) \left( \frac{1}{\mu_o - 1} \right) + \left( \frac{1}{1 + \theta_0} \right) \left( \frac{\Delta r_L}{\mu_o} \right) F \\
&= \left( \frac{\theta_0}{1 + \theta_0} \right) (R - c) \left[ \frac{1}{\mu_o - 1} \right] + \left( \frac{1}{1 + \theta_0} \right) (R - c) \left[ \frac{1}{\mu_o - 1} + \frac{\Delta r_L}{\mu_o} \frac{F}{R - c} \right]
\end{align*}
\]

If both terms in brackets are positive, then outsourcing is better whatever \( \theta_0 \). If both terms in brackets are negative, then integration is better whatever \( \theta_0 \). Interesting things happen when one of the terms in bracket is positive while the other is negative, i.e. when the ratio of these two terms (equal to \( \Theta \)) is negative. Note that \( \bar{\mu}_o - \mu_o = \Delta r_L \) and \( \mu_o = r_L + m_H \) and \( \bar{\mu}_o = r + m_H \) and \( \Delta r_L = r - r_L \).

**proposition 1.**

(1) Suppose that the switch of ownership occurs at the trust level \( \theta^*_I > 0 \).

For \( \theta > \theta^*_I \), we have:

\[
V_P(\theta) = \left( \frac{R - c}{\mu_I} \right) \left( \frac{\theta}{1 + \theta} \right) + \left( \frac{R - c}{\bar{\mu}_I} \right) \left( \frac{1}{1 + \theta} \right)
\]

At \( \theta = \theta^*_I \), the Agent sells the asset to the Principal. This is accompanied by a transfer \( F \) from the Principal to the agent. The value for the good agent after the transfer is zero, and \( F \) below the transfer.

For trust \( \theta \) below \( \theta^*_I \), we have:

\[
\begin{align*}
\frac{\partial}{\partial \theta} \left\{ \theta^{-\beta_o}(\theta + 1)V_P(\theta) \right\} &= -\theta^{-\beta_o-1}(\theta + 1) \left[ \frac{R - c - \mu_o F}{\Delta r_L} \right]
\end{align*}
\]

where \( \beta_o \) is defined by \( \beta_o = \frac{\bar{r} + m_H}{\Delta r_L} = \frac{\bar{\mu}_o}{\Delta r_L} \).

After integrating between \( \theta_0 \) and \( \theta^*_I \), we obtain:

\[
\begin{align*}
\theta_0^{-\beta_o}(\theta_0 + 1)V_P(\theta_0) &= \left( \theta^*_I \right)^{-\beta_o}(\theta^*_I + 1) \left[ \left( \frac{R - c}{\mu_I} \right) \left( \frac{\theta^*_I}{1 + \theta^*_I} \right) + \left( \frac{R - c}{\bar{\mu}_I} \right) \left( \frac{1}{1 + \theta^*_I} \right) - F \right] \\
&\quad + \left( \frac{R - c}{\mu_o} - F \right) \left( \theta^*_I - \beta_o - (\theta^*_I)^{1-\beta_o} \right) + \left( \frac{R - c}{\bar{\mu}_o} - \frac{\mu_o F}{\bar{\mu}_o} \right) \left( \beta_o - (\theta^*_I)^{-\beta_o} \right) \\
&= \left( \frac{R - c}{\mu_I} - \frac{R - c}{\mu_o} \right) (\theta^*_I)^{1-\beta_o} - \left( \frac{R - c}{\bar{\mu}_I} - \frac{R - c}{\bar{\mu}_o} - \frac{\Delta r_L}{\bar{\mu}_o} F \right) (\theta^*_I)^{-\beta_o} \\
&\quad + \left( \frac{R - c}{\mu_I} - F \right) \theta_0^{1-\beta_o} + \left( \frac{R - c}{\bar{\mu}_o} - \frac{\mu_o F}{\bar{\mu}_o} \right) \theta_0^{-\beta_o}
\end{align*}
\]
What is the optimal $\theta^*_I$? Since the principal would like to maximize $V_P(\theta_0)$, he will choose $\theta^*_I$ to maximize the expression above, which is equivalent to maximizing this term (the only part that depends on $\theta^*_I$):

$$
\left( \frac{R - c}{\mu_I} - \frac{R - c}{\mu_o} \right) (\theta^*_I)^{1-\beta_o} - \left( \frac{R - c}{\mu_I} - \frac{R - c}{\mu_o} - \frac{\Delta r_L F}{\mu_o} \right) (\theta^*_I)^{-\beta_o}
$$

The above expression attains a maximum for a particular switching trust threshold $\theta^*_I$:

$$
\theta^*_I = \frac{\mu_o}{\mu_o} \Theta > 0
$$

Note that big theta is equal to the ratio of the terms in parentheses in the expression to maximize, and the ratio of $\mu$’s is equal to $\frac{\beta}{\beta - 1}$.

This is the optimal level of trust to switch from outsourcing to integration.

(2) Suppose that the switch of ownership occurs at the trust level $\theta^*_o > 0$.

For $\theta > \theta^*_o$, we have:

$$
V_P(\theta) = \left( \frac{R - c}{\mu_I} - F \right) \left( \frac{\theta}{1 + \theta} \right) + \left( \frac{R - c}{\mu_o} - \frac{\mu_o F}{\mu_o} \right) \left( \frac{1}{1 + \theta} \right)
$$

At $\theta = \theta^*_o$, the Agent buys the asset from the Principal. This is accompanied by a transfer $F$ from the Agent to the Principal. The value for the good agent before the transfer is zero, and $F$ after the transfer.

For trust $\theta$ below $\theta^*_o$, we have:

$$
\frac{\partial}{\partial \theta} \left\{ \theta^{-\beta_I} (\theta + 1)V_P(\theta) \right\} = -\theta^{-\beta_I - 1}(\theta + 1) \left[ \frac{R - c}{\Delta r_H} \right]
$$

where $\beta_I$ is defined by $\beta_I = \frac{\bar{r} + m_L}{\Delta r_H} = \frac{\bar{\mu}_I}{\Delta r_H}$.

After integrating between $\theta_0$ and $\theta^*_o$, we obtain:

$$
\theta^*_o^{-\beta_I} (\theta_0 + 1)V_P(\theta_0) = (\theta^*_o)^{-\beta_I} (\theta^*_o + 1) \left[ \left( \frac{R - c}{\mu_o} \right) \left( \frac{\theta^*_o}{1 + \theta^*_o} \right) + \left( \frac{R - c}{\mu_o} + \frac{\Delta r_L F}{\mu_o} \right) \left( \frac{1}{1 + \theta^*_o} \right) \right]
$$

$$
+ \left( \frac{R - c}{\mu_I} \right) \left( \theta^*_o^{1-\beta_I} - (\theta^*_o)^{1-\beta_I} \right) + \left( \frac{R - c}{\mu_I} \right) \left( \theta^*_o^{-\beta_I} - (\theta^*_o)^{-\beta_I} \right)
$$

$$
= \left( \frac{R - c}{\mu_o} - \frac{R - c}{\mu_I} \right) (\theta^*_o)^{1-\beta_I} - \left( \frac{\Delta r_L F}{\mu_o} - \frac{R - c}{\mu_I} + \frac{R - c}{\mu_o} \right) (\theta^*_o)^{-\beta_I}
$$

$$
+ \left( \frac{R - c}{\mu_I} \right)^{1-\beta_I} + \left( \frac{R - c}{\mu_I} \right) \theta^*_o^{-\beta_I}
$$

What is the optimal $\theta^*_o$? Since the principal would like to maximize $V_P(\theta_0)$, he will
choose $\theta^*_o$ to maximize the expression above, which is equivalent to maximizing this term (the only part that depends on $\theta^*_o$):

$$\left(\frac{R - c}{\mu_o} - \frac{R - c}{\mu_I}\right) (\theta^*_o)^{1-\beta_I} - \left(\frac{\Delta r L F - R - c}{\bar{\mu}_o} + \frac{R - c}{\bar{\mu}_o}\right) (\theta^*_o)^{-\beta_I}$$

The above expression attains a maximum for a unique switching trust threshold:

$$\theta^*_o = \frac{\bar{\mu}_I}{\mu_I} \Theta > 0$$

This is the optimal level of trust to switch from integration to outsourcing.

Appendix for chapter 1: List of Countries by OECD membership in 2011

- OECD member countries
  - Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Mexico, New Zealand, Netherlands, Norway, Poland, Portugal, Slovak, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, and United Kingdom

- OECD Non-member Countries
  - Afghanistan, Albania, Algeria, Angola, Argentina, The Bahamas, Bahrain, Bangladesh, Bahrain, Barbados, Belize, Benin, Bermuda, Brunei, Burkina, Faso, Burundi, Cambodia, Cameroon, Cayman Islands, Chad, China, Colombia, Comoros, Congo, Cuba, Cyprus, Djibouti, Ecuador, Egypt, Equador, Guinea, Ethiopia, Falkland Islands, Fiji, Gabon, The Gambia, Ghana, Gibraltar, The Gambia, Ghana, Gibraltar, Greenland, Guatemala, Guinea, Guyana, Haiti, Hong Kong, Honduras, Hungary, India, Indonesia, Iran, Iraq, Israel, Jamaica, Jordan, Kenya, Kiribati, Kuwait, Laos, Lebanon, Libya, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritius, Mauritania, Morocco, Mozambique, Nepal, Mozambique, Nepal, Nicaragua, Niger, Nigeria, North Korea, Oman, Pakistan, Panama, Paraguay, Peru, The Philippines, Qatar, Reunion, Romania, Russia, Rwanda, Saudi Arabia, Saint Helena, Salvador, Senegal, Seychel, Sri Lanka, Sudan, Surinam, Syria, Taiwan, Thailand, Tanzania, Togo, Trinidad and Tobago, Tunisia, Turks and Caicos, Islands, Uganda Urugua, Venezuela, Vietnam, Zambia, and Zimbabwe