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The Global Value Chain under Imperfect Capital Markets

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Abstract

This paper develops a model to study how suppliers' financial constraints interact with suppliers' position in a global value chain. I embed financial frictions into the property-rights model of the global value chain, as in Antràs and Chor (2013), to derive the optimal allocation of ownership rights along the global value chain. The model predicts that multinational firms are more likely to integrate downstream intermediate input suppliers in countries with weak financial institutions when the production process is sequential complements. Using U.S. intrafirm trade data for the years 2000–2010, together with a triple-interaction term between "downstreamness" of an industry, demand elasticity of an industry, and financial development of a country, I provide empirical evidence that supports the key prediction of the model.

Keywords: Global value chain; Imperfect capital markets.
JEL Code: D23, F12, F23, L23, O16

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1 Introduction

The production process has become closely intertwined across countries. Intermediate products cross borders several times on their way to becoming part of a final product. The phenomenon of this "global value chain" has been widely studied by researchers in the field of international trade. Starting with Dixit and Grossman (1982), several studies have investigated the economic impact of the global value chain on patterns of specialization or organizational form (Feenstra and Hanson, 1996; Grossman and Rossi-Hansberg, 2008; Costinot, Vogel and Wang, 2013; Antràs and Chor, 2013). However, little work has been done on how financial constraints affect patterns of specialization and organizational form along the global value chain.[1]

In this paper, I develop a model to study how financial constraints interact with suppliers' position in a global value chain. Specifically, I extend the property-rights model of the global value chain in Antràs and Chor (2013) to allow for financial frictions, as in Carluccio and Fally (2012). Expanding on the work of Antràs and Chor (2013), I further consider that financial markets are imperfect such that financial constraints may make it difficult for suppliers to contract with a final-good producer.

The core finding is that financial frictions affect the optimal organizational structure along the global value chain. Specifically, the impact of financial development on the pattern of ownership depends critically on whether the production stages are sequential complements or substitutes, as well as on the degree of downstreamness.[2] I derive analytical results on the optimal ownership structure along the value chain when financial constraints are severe (binding), which goes beyond the work of Antràs and Chor (2013).

When the production process is sequential complements, and financial constraints are not binding, the final-good producer finds it optimal to outsource all stages. Suppliers are more likely to invest in the outsourcing mode than in the

[1] Admittedly, there are a few notable theoretical models that introduce financial frictions into a model of trade with heterogeneous firms in the international trade literature (Manova, 2013; Feenstra, Li and Yu, 2014; Chaney, 2016). However, in this paper, I focus specifically on the interaction between credit constraints in the context of the global value chain, not international trade.

[2] Following Antràs and Chor (2013), suppliers' investments are sequential complements (resp. sequential substitutes) if higher investment levels by prior suppliers increase (resp. decrease) the value of the marginal product of a particular supplier's investment.

vertical integration mode because the supplier receives a more significant share of the ex-post joint surplus. On the other hand, in the vertical integration mode, because the final-good producer requires fewer upfront monetary transfers from the suppliers, the problem of financial constraints is alleviated. Facing this trade-off between underinvestment and financial constraints, it is always optimal for a final-good producer to use the outsourcing mode when suppliers' financial constraints are not binding and the production process is sequential complements.

However, if suppliers' financial constraints are binding, then the final-good producer vertically integrates suppliers for some stages. Vertical integration requires fewer upfront financial outlays by suppliers. Furthermore, I find that upfront outlays are higher for most downstream stages of the sequential complements process. Hence, liquidity constraints are more likely to be binding in downstream stages, and vertical integration arises from the most downstream stages when the production process is sequential complements.[3]

Finally, I find that a country's financial development will expand the range of stages that are outsourced, and that the effect of financial development is stronger in upstream stages, especially in the sequential complements case. This implies that multinationals are more likely to outsource upstream stages of production if the financial constraints are less binding.[4]

My findings have clear applications in the sourcing strategies of multinational firms. Suppose that the production process is sequential complements. Because multinationals require more upfront transfers by suppliers in downstream stages, downstream intermediate inputs are more likely to be sourced from financially developed countries. Vertical integration arises when the financial constraints problem is alleviated. Hence, multinationals are more likely to vertically integrate downstream intermediate suppliers in countries with weak financial development.

I test this model's key prediction by relating the share of U.S. intrafirm imports in total U.S. imports during the years 2000–2010 with a triple-interaction term between downstreamness of an industry, demand elasticity of an industry, and financial development of a country. I extend Antràs and Chor (2013)'s empirical frame-

[3]We also derive analytical results for a production process of sequential substitutes with binding financial constraints. The results are reversed: upfront transfers are higher for most upstream stages and vertical integration is more prevalent in upstream stages.

[4]Again, in the sequential substitutes case, the results are reversed. Multinationals are more likely to outsource stages that are closer to the downstream if the financial constraints are less binding.

work by incorporating the financial development of a country, which can affect multinationals' sourcing decisions along the value chain. The regression analysis confirms the relationship between the U.S. intrafirm import share and the triple-interaction term, while controlling for industry-year fixed effects and country-year fixed effects.

2 Literature Review

My model is closely related to multinational firms' sourcing strategy under credit constraints. Carluccio and Fally (2012) study the interaction between a supplier's credit constraints and contractual frictions in a vertical relationship. In their model, there are two tasks: basic tasks and complex tasks. Complex tasks are relationship-specific, and thus it is hard to sign a contract between a multinational firm and a supplier. The standard hold-up problem arises, and the multinational firm requires a higher compensating transfer fee from each supplier. Suppliers need more initial capital to perform complex tasks. Through this mechanism, Carluccio and Fally (2012) study the linkage between credit constraints and contractual frictions.

Basco (2013) studies a final-good producer's offshoring decision when the financial development of countries differs. A final-good producer in the North can source intermediate inputs from either Northern suppliers or Southern suppliers. They assume Northern suppliers require higher wages and that Northern countries have well-developed financial systems. Suppliers have to pay initial fixed costs, which can be financed by the final producer and by domestic banks. In the financially underdeveloped South, suppliers cannot rely on future profits to finance their tasks. Thus they need to receive transfers from a final-good producer. When that happens, the final producer raises its ex-post share to compensate for financing the supplier, which leads to a distortion of the contract. The final producer must confront this trade-off between cost efficiency and contractual friction.

Unlike these prior studies (Carluccio and Fally, 2012; Basco, 2013), I focus on how credit constraints affect firms' organizational choices along the global value chain. I investigate the differential impacts of credit constraints on the different stages of the production chains—i.e., upstream and downstream.

My model is, to some extent, related to the model of Acemoglu, Johnson and Mitton (2009) where they study an organizational form in the presence of contract enforcement problems and imperfect capital markets. Their main theoretical predictions are that vertical integration is more likely when credit market imperfections are limited, and that vertical integration is more likely when there are both more developed credit markets and more severe contract enforcement problems. Their main predictions are at odds with my model's key predictions because they predict that credit market imperfections make vertical integration less likely; my model argues that the opposite is the case. The key difference lies in the way the credit market imperfections are modeled. In their model, multinationals must raise enough finance to acquire intermediate input suppliers; in contrast, I model that financially constrained intermediate input suppliers will be unable to contract with a final-good producer.

My modeling framework builds on the property-rights model of the global value chain, as in Antràs and Chor (2013). They study how an organizational form is determined by the sequential production stages using the property-rights model of the firm. The hold-up problem arises as a result of an incomplete contract. They study how the incomplete contract affects along the global value chain and show that the optimal organizational mode depends crucially on two parameters: the degree of substitution between final goods and the degree of substitution between input stages. In this paper, I go beyond the work of Antràs and Chor (2013) by considering credit constraints along the global value chain. I show that credit constraints play a crucial role in shaping organizational forms and profit structure.

Another related study is by Kim and Shin (2012). They investigate the role of financial linkages between firms for sustaining production chains. As in my model, a sequence of stages is needed to produce a final product. Each stage takes one unit of time. When a firm has an option to choose between high effort and low effort, then the production chain may not be sustainable due to the hold-up problem. To solve the hold-up problem in the production chain, the authors develop the idea of payment delays between firms: between accounts receivable and accounts payable. Because firms are tightly linked with each other via trade credit, the production chain can be sustainable. However, firms that are credit constrained will not be able to participate in production chains. Moreover, if there are long delays in payments, upstream firms will need more working capital than downstream firms, and longer production chains will demand more working capital. I provide a different mechanism to explain that this is not necessarily the case. In my model, downstream stages require more initial liquidity when the production process is sequential complements.

Turning to empirical evidence, Antràs and Chor (2013) and Alfaro, Antràs, Chor and Conconi (2018) provide supporting evidence of the property-rights model of firm boundary choices along the global value chain using industry-level and firm-level data, respectively. They find that whether a firm integrates upstream or downstream suppliers depends crucially on the elasticity of demand for the final product. Del Prete and Rungi (2017) use a detailed firm-level dataset covering about 4,000 manufacturing parent companies and more than 90,000 affiliates in 150 countries and find supporting evidence for the property-rights model. Using city-level Chinese processing export data, Luck (2019) provides evidence that is consistent with the theoretical predictions of Antràs and Chor (2013). More broadly, our empirical analysis is related to previous work on the determinants of intrafirm trade (Corcos, Irac, Mion and Verdier, 2013; Defever and Toubal, 2013; Díez, 2014).

However, all the empirical analyses mentioned above are based on complete financial markets; my predictions have new components such that the determinants of organizational choices along the global value chain interact with financial constraints. Based on Antràs and Chor (2013)'s empirical framework, I incorporate a country's financial development into the regression equation; I find that multinationals are more likely to integrate downstream input suppliers in countries with weak financial institutions when the production process is sequential complements. In this regard, my analysis is most closely related to that of Manova and Yu (2016), who use matched customs and balance-sheet data from China to study how financial frictions affect firms' position in global supply chains. More recently, using a unique Italian firm-level dataset, Minetti, Murro, Rotondi and Zhu (2018) find that financially vulnerable firms are more likely to participate in supply chains to overcome liquidity shortages. I extend their studies by allowing for interacting effects between financial frictions, downstreamness, and sequential complements.

3 Model

3.1 Production

As in Antràs and Chor (2013), there is one final-good producer and a large number of suppliers. The production process requires a continuum of stages indexed by $j \in [0, 1]$, where a higher j denotes downstream stages and a lower j corresponds to upstream stages. In each stage, a supplier produces relationship-specific intermediate input that is requested by the final-good producer. The production function is as follows:

$$q = \left(\int_0^1 x(j)^\alpha I(j) dj \right)^{1/\alpha}$$

where $\alpha \in (0, 1)$ indicates the degree of substitution between stage inputs, $x(j)$ is the intermediate input that supplier j delivers to the final-good producer, and $I(j)$ denotes the indicator function such that it equals 1 if input j is produced after all inputs $j' < j$ have been produced and 0 otherwise. The production function can be expressed in the differential form:

$$q'(m) = \frac{1}{\alpha} x(m)^\alpha q(m)^{1-\alpha} I(m)$$

where $q(m) = \left(\int_0^m x(j)^\alpha I(j) dj \right)^{1/\alpha}$. The marginal increase in production is the Cobb-Douglas function of a stage-m supplier's input production and the production generated up to that stage.

There are a large number of profit-maximizing suppliers whose outside option is 0, and they can participate in input production. The marginal cost of investment is c for all stages $j \in [0, 1]$. One unit of investment generates one unit of stage-j compatible intermediate input. The input production is relationship-specific to the final-good producer, and hence the stage-j input is not applicable to other buyers. Therefore, an enforceable contract between suppliers and the final-good producer is impossible (Grossman and Hart, 1986).

3.2 Demand

Consumers have preferences with a constant elasticity of substitution across varieties:

$$U = \left(\int_{\omega \in \Omega} q(\omega)^{\rho} d\omega \right)^{1/\rho}$$

where Ω is the set of varieties and $\rho \in (0, 1)$ is the degree of substitution between varieties. Combining the production technology and the preference of consumers, the revenue of the final-good producer is represented as:

$$r = A^{1-\rho} \left(\int_0^1 x(j)^{\alpha} I(j) dj \right)^{\rho/\alpha}$$

where $A > 0$ is the industry-wide demand shifter.

3.3 Incomplete Contracts

The production of a relationship-specific intermediate input by suppliers generates a hold-up problem. If contracts were signed ex ante between two parties, suppliers have every incentive to produce incompatible inputs with lower costs. A court of law cannot verify the value of the inputs that suppliers produce. Thus payments to suppliers occur only after suppliers have produced the intermediate inputs and the final-good producer has investigated their quality. Because the intermediate input-m is only compatible with the final-good producer's output, the outside option for supplier-m is zero. Hence, the total surplus that needs to be divided between the supplier-m and the final-good producer is given by the incremental contribution to total revenue generated by supplier-m at that stage. To compute the incremental contribution by the supplier-m, $I(j) = 1$ for all $j < m$, and the value of final-good production secured up to that stage is given by:

$$r(m) = A^{1-\rho} \left(\int_0^m x(j)^{\alpha} dj \right)^{\rho/\alpha}.$$

Then, the additional contribution of stage-m supplier is given by:

$$r'(m) = \frac{\partial r(m)}{\partial m} = \frac{\rho}{\alpha} (A^{1-\rho})^{\alpha/\rho} r(m)^{(\rho-\alpha)/\rho} x(m)^{\alpha}. \tag{1}$$

In line with Grossman and Hart (1986), the organizational structure determines the share of quasi-rents that is distributed between the supplier and the final-good producer. For simplicity, the final-good producer will obtain $\beta_v r'(m)$ when the organizational structure is vertical integration and $\beta_o r'(m)$ when the organizational structure is outsourcing. We assume that $\beta_v > \beta_o$.

3.4 Financial Constraints

Following Carluccio and Fally (2012), we assume that financial markets are imperfect. Liquidity constraints may prevent suppliers from contracting with a final-good producer at the beginning of production, while final-good producers are assumed to be financially sound. To start operating, a supplier-m needs to cover initial costs $cx(m)$ and upfront financial transfers $T(m)$ that are requested by the final-good producer. Positive upfront transfer $T(m)$ refers to a licensing fee or royalty for participating in the production; negative transfer $T(m)$ refers to foreign direct investment (FDI) or co-financing. The supplier's initial liquidity is composed of two parts: initial cash holdings $W(m)$ and debt from local banks $L(m)$. The liquidity constraint is expressed as follows:

$$T(m) + cx(m) \leq W(m) + L(m).$$

The supplier can borrow $\kappa \in [0, 1]$ of its future revenue Y_s from local banks. The parameter κ indicates the country's level of financial development. Thus the debt L is limited as:

$$L(m) \leq \kappa Y_s.$$

3.5 Timeline

The timeline of a game between a final-good producer and a continuum of suppliers is given by:

1. A final-good producer posts contracts for each stage $m \in [0, 1]$to a continuum of suppliers specifying the amount of upfront transfer $T(m)$ and the organizational form $\beta(m)$: vertical integration or arm's length outsourcing. The upfront transfer may prevent some liquidity-constrained suppliers from entering the market.

2. Suppliers apply for each stage, and the final-good producer selects only one supplier for each stage. Selected suppliers pay the initial transfer $T(m)$ to the final-good producer.

3. Production takes place sequentially; each supplier receives the final good completed up to that stage $r(m)$.The supplier then decides how much to invest $x(m)$ under the constraint that its initial upfront transfer and investment cost cannot exceed its liquidity holdings.

4. The final-good producer and supplier-m bargain over the quasi-rent $r'(m)$, and the final-good producer pays the supplier. The supplier-m repays the local banks for any external debt it has incurred.

5. When the final stage of production is completed, the final-good producer sells the good in the market and receives total revenue $A^{1-\rho}q^{\rho}$.

4 Solution

4.1 The maximization problem of the final-good producer

The final-good producer's total profit equals its ex-post revenues plus transfers from suppliers. The final-good producer chooses organizational form $\beta(m) \in \{\beta_v, \beta_o\}$ and upfront transfer amount $T(m)$ for all stages $m \in [0,1]$ given three constraints: the participation constraint [PC], the financial constraint [FC], and the incentive compatibility constraint [IC].

$$
\begin{aligned}
\max_{\{\beta(m),T(m)\}_{m\in[0,1]}} \pi_F &= \int_0^1 \beta(m)r'(m)dm + \int_0^1 T(m)dm \\
\text{subject to} \quad T(m) &\leq (1-\beta(m))r'(m) - cx(m) \quad \forall m \quad [PC] \\
T(m) &\leq W(m) + \kappa[(1-\beta(m))r'(m)] - cx(m) \quad \forall m \quad [FC] \\
x(m) &= \arg\max_{x(m)} \{(1-\beta(m))r'(m) - cx(m)\} \quad \forall m \quad [IC]
\end{aligned}
$$

To solve for the subgame perfect equilibrium of the game described above, I use the "backward induction" method. First, I solve for the optimal investment level of a supplier-m, $x(m)$, given that the supplier takes the organizational form, $\beta(m)$, and the value of final-good production secured up to stage m, $r(m)$, as given. After I solve for the suppliers' optimal investment decisions, I plug the optimal investment level into either the participation constraint (when the financial constraint is not binding) or the financial constraint (when the financial constraint is binding) to derive the organizational forms and the upfront transfers.

4.2 Suppliers' optimal investments

Consider the problem of a stage-m supplier that is described by the incentive compatibility constraint. The supplier maximizes its ex-post revenues net of its costs given the final product up to that stage and the organizational form chosen by the final-good producer:

$$\begin{aligned}\max_{x(m)} \pi_S &= (1-\beta(m))r'(m) - cx(m) \\ &= (1-\beta(m))\frac{\rho}{\alpha}(A^{1-\rho})^{\alpha/\rho} r(m)^{(\rho-\alpha)/\rho} x(m)^{\alpha} - cx(m).\end{aligned}$$

The optimal investment for a stage-m supplier is given by:

$$x(m) = \left((1-\beta(m))\frac{\rho(A^{1-\rho})^{\alpha/\rho}}{c}\right)^{1/(1-\alpha)} r(m)^{(\rho-\alpha)/(\rho(1-\alpha))}. \tag{2}$$

The investment level for the stage-m supplier is increasing in demand A and the bargaining share for supplier $1-\beta(m)$. The investment level is higher in the outsourcing case β_o than in the vertical integration case β_v. Underinvestment is a bigger problem in vertical integration because the supplier receives a smaller share of ex-post quasi-rents. The investment decreases with marginal cost c. It increases with the value of final-good production secured up to that stage $r(m)$ in the sequential complements case $\rho > \alpha$; it decreases with the value of final-good production secured up to that stage $r(m)$ in the sequential substitutes case $\rho < \alpha$.[5]

Plugging the optimal investment for stage-m, $x(m)$, in equation (2) into equa-

[5]Following Antràs and Chor (2013), I refer the case $\rho > \alpha$ to sequential complements in the sense that higher investment levels by prior suppliers increase the marginal return of supplier-m's investment. In contrast, I denote the case $\rho < \alpha$ as sequential substitutes in the sense that higher investment levels by prior suppliers decrease the marginal return of supplier-m's investment.

tion (1) yields,

$$r'(m) = \frac{\rho}{\alpha}\left((1-\beta(m))\frac{\rho}{c}\right)^{\alpha/(1-\alpha)}(A^{1-\rho})^{\alpha/\rho(1-\alpha)}r(m)^{(\rho-\alpha)/(\rho(1-\alpha))}. \tag{3}$$

Solving the above differential equation with the initial condition $r(0) = 0$ yields,

$$\begin{aligned} r(m) = {} & A\left(\frac{1-\rho}{1-\alpha}\right)^{\rho(1-\alpha)/(\alpha(1-\rho))}\left(\frac{\rho}{c}\right)^{\rho/(1-\rho)} \\ & \times\left[\int_0^m (1-\beta(j))^{\alpha/(1-\alpha)}dj\right]^{\rho(1-\alpha)/(\alpha(1-\rho))}. \end{aligned} \tag{4}$$

Plugging this revenue function into equation (2) yields,

$$\begin{aligned} x(m) = {} & \left((1-\beta(m))\frac{\rho(A^{1-\rho})^{\alpha/\rho}}{c}\right)^{1/(1-\alpha)} \\ & \times\left[A\left(\frac{1-\rho}{1-\alpha}\right)^{\rho(1-\alpha)/(\alpha(1-\rho))}\left(\frac{\rho}{c}\right)^{\rho/(1-\rho)}\right]^{(\rho-\alpha)/(\rho(1-\alpha))} \\ & \times\left[\int_0^m (1-\beta(j))^{\alpha/(1-\alpha)}dj\right]^{(\rho-\alpha)/(\alpha(1-\rho))}. \end{aligned} \tag{5}$$

As can be seen from this expression, the investment level of the stage-m supplier depends on the previous organizational choices of the final-good producer. Given that the bargaining shares are constants along the global value chain $\beta(m) = \beta$, the investment level $x(m)$ is an increasing function of m in sequential complements $\rho > \alpha$; it is a decreasing function of m in sequential substitutes $\rho < \alpha$.[6]

4.3 Upfront transfers and optimal organizational structure

4.3.1 Financial constraint is not binding

Consider a case where all suppliers' initial liquidity holdings are sufficient to cover upfront transfers and costs. Then, the participation constraint determines the upfront transfer $T(m)$ from supplier-m to the final-good producer. Plugging the optimal investment level $x(m)$ in equation (2) into the participation constraint yields

[6] Differentiating the investment level $x(m)$ in equation (5) with respect to m yields the result.

the optimal upfront transfer $\overline{T}(m)$ as follows:

$$\overline{T}(m) = (1-\beta(m))^{1/(1-\alpha)} r(m)^{\rho-\alpha/\rho(1-\alpha)} \\ \times \rho^{1/(1-\alpha)} (A^{1-\rho})^{\alpha/\rho(1-\alpha)} (\frac{1}{c})^{\alpha/(1-\alpha)} (\frac{1-\alpha}{\alpha}). \tag{6}$$

Let $\overline{T}(m)_v$ be the optimal transfer under vertical integration and $\overline{T}(m)_o$ be the optimal transfer under outsourcing. Given the value of final good production up to stage m, the vertically integrated supplier pays less initial upfront transfer $\overline{T}(m)_v$ than the stand-alone supplier $\overline{T}(m)_o$.

Then, given the organizational form $\beta(m)$, how does the upfront transfer change with suppliers' position in the global value chain? Plugging the revenue function in equation (4) into the optimal upfront transfer equation (6) yields,

$$\overline{T}(m) = (1-\beta(m))^{1/(1-\alpha)} \rho^{1/(1-\alpha)} (A^{1-\rho})^{\alpha/\rho(1-\alpha)} (\frac{1}{c})^{\alpha/(1-\alpha)} (\frac{1-\alpha}{\alpha}) \\ \times \left[A \left(\frac{1-\rho}{1-\alpha} \right)^{\rho(1-\alpha)/(\alpha(1-\rho))} \left(\frac{\rho}{c} \right)^{\rho/(1-\rho)} \right]^{\rho-\alpha/\rho(1-\alpha)} \\ \times \left[\int_0^m (1-\beta(j))^{\alpha/(1-\alpha)} dj \right]^{\rho-\alpha/(\alpha(1-\rho))}. \tag{7}$$

Given the organizational form $\beta(m)$, the upfront transfer $\overline{T}(m)$ is an increasing function of m in the case of sequential complements; while it is a decreasing function of m in the case of sequential substitutes.[7] When the financial constraint is not binding, the final-good producer can extract all the quasi-rents. Thus the profit of the final-good producer is the joint surplus created along the global value chain. Plugging the participation constraint equation into the final-good producer's profit equation and using the equation $cx(m) = \alpha(1-\beta(m))r'(m)$ that is derived from the zero-profit condition for suppliers, I derive the following profit equation:

$$\overline{\pi}_F = \int_0^1 \beta(m) r'(m) dm + \int_0^1 \left[(1-\beta(m)) r'(m) - cx(m) \right] dm \\ = \int_0^1 \left[1 - \alpha(1-\beta(m)) \right] r'(m) dm \tag{8}$$

[7]Differentiating the upfront transfer $\overline{T}(m)$ in equation (7) with respect to m yields the result.

Substituting the expressions from equations (3) and (4) into the equation (8) yields,

$$\overline{\pi}_F = \Theta \int_0^1 \left[1-\alpha(1-\beta(m))\right](1-\beta(m))^{\alpha/(1-\alpha)} \times \left[\int_0^m (1-\beta(j))^{\alpha/(1-\alpha)}dj\right]^{(\rho-\alpha)/(\alpha(1-\rho))} dm$$

where $\Theta \equiv A\dfrac{\rho}{\alpha}\left(\dfrac{1-\rho}{1-\alpha}\right)^{(\rho-\alpha)/(\alpha(1-\rho))}\left(\dfrac{\rho}{c}\right)^{\rho/(1-\rho)}$ is a positive constant.

Let us solve the optimal organizational structure $\overline{\beta}(m)$. Defining

$$v(m) \equiv \int_0^m (1-\beta(j))^{\frac{\alpha}{1-\alpha}}dj,$$

we can write $\overline{\pi}_F$ as

$$\overline{\pi}_F(v) = \Theta \int_0^1 \left(1-\alpha v'(m)^{(1-\alpha)/\alpha}\right) v'(m)\left[v(m)\right]^{(\rho-\alpha)/(\alpha(1-\rho))} dm.$$

Finding maxima of functional $\overline{\pi}_F(v)$ is the calculus of variation problem, and I need to derive the Euler - Lagrange equation associated with choosing the real-valued function $v(m)$ that maximizes the functional $\overline{\pi}_F(v)$. Once we obtain $v(m)$, the optimal organizational structure $\overline{\beta}(m)$ can be derived using $\overline{\beta}(m) = 1 - v'(m)^{(1-\alpha)/\alpha}$.

Lemma 1 *When the financial constraint is not binding, the optimal organizational structure $\overline{\beta}(m)$ is given by:*

$$\overline{\beta}(m) = 1 - m^{(\alpha-\rho)/\alpha}.$$

Proof. See Appendix A.1. ■

Lemma 2 *Suppose that the financial constraint is not binding.*

(i) In the sequential complements case ($\rho > \alpha$), $\overline{\beta}(m)$ is increasing for all $m \in [0,1]$; and the final-good producer finds it optimal to choose outsourcing for all stages.

(ii) In the sequential substitutes case ($\rho < \alpha$), $\overline{\beta}(m)$ is decreasing for all $m \in [0,1]$; and there exists a unique $m^* \in (0,1)$ such that all stages $m \in [0,m^*]$ are vertically integrated and all stages $m \in [m^*,1]$ are outsourced.

Proof. See Appendix A.2. ■

In the sequential complements case, integrating early stages of production is especially costly because it reduces incentives to invest not only for suppliers in early stages and but also for suppliers in downstream stages where the incremental surpluses are particularly large. The final-good producer is more concerned with the investment inefficiency arising from vertical integration and less concerned with an incentive for rent extraction resulting from vertical integration for all stages of the production process.[8] Therefore the outsourcing mode is optimal for all stages.

However, in the sequential substitutes case, outsourcing early stages of production is particularly costly because high investments in early stages lead to reductions in investment in downstream stages. In this case, the final-good producer is more concerned with an incentive for rent extracting from the vertical integration and less concerned with the investment inefficiency arising from the vertical integration, especially for upstream stages. Therefore most upstream stages are vertically integrated and most downstream stages are outsourced.

4.3.2 Financial constraint is binding

Consider a case where the financial constraint is binding. In this case, the optimal transfer $T(m)$ does not satisfy the inequality in the financial constraint equation. This case occurs when the initial cash holding $W(m)$ is below a threshold in which the threshold cash holdings $\widetilde{W}(m)$ is given by:

$$\begin{aligned}\widetilde{W}(m) = (1-\beta(m))^{1/(1-\alpha)} r(m)^{\rho-\alpha/\rho(1-\alpha)} \\ \times \rho^{1/(1-\alpha)} (A^{1-\rho})^{\alpha/\rho(1-\alpha)} (\frac{1}{c})^{\alpha/(1-\alpha)} (\frac{1-\kappa}{\alpha}).\end{aligned} \tag{9}$$

[8] In a benchmark model without ex-ante transfers in Antràs and Chor (2013), both an outsourcing mode and an integration mode can co-exist along the production process in the sequential complements case. However, in the presence of the ex-ante transfer, only the outsourcing mode is optimal for all stages in the sequential complements case. See Antràs and Chor (2013) for more details.

Plugging the revenue function in equation (4) into the threshold equation (9) yields,

$$\begin{aligned}\widetilde{W}(m) &= (1-\beta(m))^{1/(1-\alpha)}\rho^{1/(1-\alpha)}(A^{1-\rho})^{\alpha/\rho(1-\alpha)}(\frac{1}{c})^{\alpha/(1-\alpha)}(\frac{1-\kappa}{\alpha}) \\ &\times \left[A\left(\frac{1-\rho}{1-\alpha}\right)^{\rho(1-\alpha)/(\alpha(1-\rho))}\left(\frac{\rho}{c}\right)^{\rho/(1-\rho)}\right]^{\rho-\alpha/\rho(1-\alpha)} \\ &\times \left[\int_0^m (1-\beta(j))^{\alpha/(1-\alpha)}dj\right]^{\rho-\alpha/(\alpha(1-\rho))}. \end{aligned} \tag{10}$$

Let $\widetilde{W}(m)_v$ be the threshold cash holdings under vertical integration and $\widetilde{W}(m)_o$ be the threshold cash holdings under outsourcing. Financial constraints are less likely to be binding for the vertically integrated supplier than for the stand-alone supplier $\widetilde{W}(m)_o > \widetilde{W}(m)_v$. The reason is that the final-good producer in the vertically integrated case can retain a greater share of quasi-rents and thus asks for fewer upfront transfers by suppliers.

Proposition 1 *Given the organizational form $\beta(m)$,*

(i) Financial development κ decreases the threshold cash holdings $\widetilde{W}(m)$;

(ii) In the sequential complements case ($\rho > \alpha$), the threshold cash holdings $\widetilde{W}(m)$ is an increasing function for $m \in [0,1]$; and the effect of financial development κ on the threshold cash holding $\widetilde{W}(m)$ is stronger especially in downstream stages;

(iii) In the sequential substitutes case ($\rho < \alpha$), the threshold cash holdings $\widetilde{W}(m)$ is a decreasing function for $m \in [0,1]$; and the effect of financial development κ on the threshold cash holding $\widetilde{W}(m)$ is stronger especially in upstream stages.

Proof. (i) Differentiating the threshold cash holdings $\widetilde{W}(m)$ in equation (10) with respect to κ yields the result, i.e., $\dfrac{\partial\widetilde{W}(m)}{\partial\kappa} < 0$.

(ii) If $\rho > \alpha$, then $\dfrac{\partial\widetilde{W}(m)}{\partial m} > 0$ and $\dfrac{\partial^2\widetilde{W}(m)}{\partial\kappa\partial m} < 0$.

(iii) If $\rho < \alpha$, then $\dfrac{\partial\widetilde{W}(m)}{\partial m} < 0$ and $\dfrac{\partial^2\widetilde{W}(m)}{\partial\kappa\partial m} > 0$. ■

It is worth noting that the possibility of financial constraints being binding increases in the downstream stages of the sequential complements case. Intuitively, when the production process is sequential complements, the additional contribution of the stage-m supplier, $r'(m)$, increases in m. Since ex-ante transfers allow the final-good producer to extract the joint surplus from its suppliers, the final-good producer requires more upfront transfers from more downstream suppliers, which implies that the downstream suppliers require more initial liquidity holdings.[9] Conversely, when the production process is sequential substitutes, the upstream suppliers require more initial liquidity holdings because the incremental surplus, $r'(m)$, is decreasing in m.

Financial development alleviates the liquidity constraints problem for all stages along the global value chain regardless of whether the production process is sequential complements or sequential substitutes. However, the benefits are biased toward downstream stages rather than upstream stages in the sequential complements case because downstream stages are more vulnerable to suppliers' financial constraints; the benefits are disproportionate for upstream stages in the sequential substitutes case because upstream stages are more vulnerable to suppliers' financial constraints.

Let us assume that all suppliers have the same initial cash holdings—i.e., $W(m) = W$ for all m. The final-good producer no longer extracts all the quasi-rents from the relationship when the financial constraints are binding; the profit for the final-good producer is represented as follows:

$$\begin{aligned}\widetilde{\pi}_F &= \int_0^1 \beta(m)r'(m)dm + \int_0^1 \{W + \kappa[(1-\beta(m))r'(m)]\}dm - \int_0^1 cx(m)dm \\ &= \int_0^1 \left[\beta(m) + (\kappa - \alpha)\left(1-\beta(m)\right)\right] r'(m)dm + W \end{aligned} \tag{11}$$

Substituting the expressions from equations (3) and (4) into the equation (11) yields,

$$\begin{aligned}\widetilde{\pi}_F = \Theta & \int_0^1 \left[\beta(m) + (\kappa-\alpha)\left(1-\beta(m)\right)\right]\left(1-\beta(m)\right)^{\alpha/(1-\alpha)} \\ & \times \left[\int_0^m \left(1-\beta(j)\right)^{\alpha/(1-\alpha)} dj\right]^{(\rho-\alpha)/(\alpha(1-\rho))} dm + W\end{aligned}$$

where $\Theta \equiv A\dfrac{\rho}{\alpha}\left(\dfrac{1-\rho}{1-\alpha}\right)^{(\rho-\alpha)/(\alpha(1-\rho))}\left(\dfrac{\rho}{c}\right)^{\rho/(1-\rho)}$ is a positive constant.

[9] This prediction is different from Kim and Shin (2012)'s result that upstream firms need more working capital than downstream firms, which stems from long delays in payments to upstream firms.

Proposition 2 *Suppose that the organizational form $\beta(m)$ is given and the financial constraints are binding for all stages. Then,*

(i) The final-good producer's profit increases with the level of financial development κ;

(ii) In the sequential complements case ($\rho > \alpha$), the effect of financial development κ on the final-good producer's profit $\widetilde{\pi}_F$ is stronger especially in downstream stages;

(iii) In the sequential substitutes case ($\rho < \alpha$), the effect of financial development κ on the final-good producer's profit $\widetilde{\pi}_F$ is stronger especially in upstream stages.

Proof. (i) Differentiating the profit of final-good producer $\widetilde{\pi}_F$ in equation (11) with respect to κ yields the result, i.e., $\dfrac{\partial \widetilde{\pi}_F}{\partial \kappa} > 0$.

(ii) If $\rho > \alpha$, then $\dfrac{\partial^2 \widetilde{\pi}_F}{\partial \kappa \partial m} > 0$.

(iii) If $\rho > \alpha$, then $\dfrac{\partial^2 \widetilde{\pi}_F}{\partial \kappa \partial m} < 0$. ■

A country's financial development affects the supplier's access to finance. The final-good producer can extract more upfront transfers from suppliers, mainly by financially binding those suppliers. Interestingly, the higher upfront transfers will bid up the profit for the final-good producer while decreasing the profit for suppliers. In the sequential complements case, the impacts of financial development are more substantial for the downstream stages because downstream stages are more likely to be financially binding; in contrast, in the sequential substitutes case, the impacts of financial development are more substantial for the upstream stages.

Next let us investigate organizational structure when financial constraints are binding for all stages. Defining

$$v(m) \equiv \int_0^m (1-\beta(j))^{\frac{\alpha}{1-\alpha}} dj,$$

we can write $\widetilde{\pi}_F$ as

$$\widetilde{\pi}_F = \Theta \int_0^1 \left(1 - (1-\kappa+\alpha) v'(m)^{(1-\alpha)/\alpha}\right) v'(m) \left[v(m)\right]^{(\rho-\alpha)/(\alpha(1-\rho))} dm + W.$$

Proposition 3 *When financial constraints are binding for all stages, the optimal organization structure $\widetilde{\beta}(m)$ is given by:*

$$\widetilde{\beta}(m) = 1 - \frac{\alpha}{1-\kappa+\alpha} m^{(\alpha-\rho)/\alpha}. \tag{12}$$

Proof. Let $\mathcal{L} \equiv \left(1-(1-\kappa+\alpha)(v')^{(1-\alpha)/\alpha}\right) v' v^{(\rho-\alpha)/(\alpha(1-\rho))}$.

$$\frac{\partial \mathcal{L}}{\partial v} = \frac{\rho-\alpha}{\alpha(1-\rho)} \left(1-(1-\kappa+\alpha)(v')^{(1-\alpha)/\alpha}\right) v' v^{(\rho-\alpha)/(\alpha(1-\rho))-1},$$
$$\frac{\partial \mathcal{L}}{\partial v'} = \left(1-\frac{1-\kappa+\alpha}{\alpha}(v')^{(1-\alpha)/\alpha}\right) v^{(\rho-\alpha)/(\alpha(1-\rho))}.$$

The Euler-Lagrange equation, then, is given by

$$v^{(\rho-\alpha)/(\alpha(1-\rho))}(v')^{(1-\alpha)/\alpha-1}\frac{1-\kappa+\alpha}{\alpha}\frac{1-\alpha}{\alpha}\left[v''+\frac{\rho-\alpha}{(1-\rho)}\frac{(v')^2}{v}\right]=0.$$

A strictly positive profit for the final-good producer is given by solving the following second-order differential equation.

$$v''+\frac{\rho-\alpha}{(1-\rho)}\frac{(v')^2}{v}=0.$$

Solving the second-order differential equation yields,

$$v(m) = \left(\frac{(1-\alpha)C_1}{1-\rho}(m-C_2)\right)^{(1-\rho)/(1-\alpha)},$$
$$v'(m) = C_1\left(\frac{(1-\alpha)C_1}{1-\rho}(m-C_2)\right)^{(\alpha-\rho)/(1-\alpha)}.$$

where C_1 is a positive constant and C_2 is a second constant of integration. The initial condition is given by $v(0)=0$ and the transversality condition is $v'(1)^{(1-\alpha)/\alpha} = \frac{\alpha}{1-\kappa+\alpha}$ at the right boundary of the unit interval. Note that the transversality condition is different from the case when the financial constraint is not binding. Using the two conditions, we can obtain $C_1 = \left[\frac{\alpha}{1-\kappa+\alpha}\right]^{\alpha/(1-\rho)}\left[\frac{1-\rho}{1-\alpha}\right]^{(\alpha-\rho)/(1-\rho)}$ and $C_2=0$. Plugging C_1 and C_2 into the $v'(m)$ equation, we obtain

$$v'(m) = \left[\frac{\alpha}{1-\kappa+\alpha}\right]^{\alpha/(1-\alpha)} m^{(\alpha-\rho)/(1-\alpha)}.$$

Therefore,

$$\widetilde{\beta}(m) = 1-v'(m)^{(1-\alpha)/\alpha} = 1-\frac{\alpha}{1-\kappa+\alpha}m^{(\alpha-\rho)/\alpha}.$$

■

Proposition 4 *Suppose that financial constraints are binding for all stages. Then,*

(i) In the sequential complements case ($\rho > \alpha$), $\widetilde{\beta}(m)$ is increasing for all $m \in [0,1]$ and there exists a unique $m^* \in (0,1]$ such that all stages $m \in [0, m^*)$ are outsourced and all stages $m \in [m^*, 1]$ are vertically integrated.

(ii) In the sequential substitutes case ($\rho < \alpha$), $\widetilde{\beta}(m)$ is decreasing for all $m \in [0,1]$ and there exists a unique $m^* \in (0,1]$ such that all stages $m \in [0, m^*)$ are integrated within firm boundaries and all stages $m \in [m^*, 1]$ are outsourced.

Proof. (i) If $\rho > \alpha$, then $\dfrac{\partial \widetilde{\beta}(m)}{\partial m} > 0$ for all $m \in [0,1]$. From the optimal organizational structure in equation (12), we obtain that $\lim_{m \to 0} \widetilde{\beta}(m) = -\infty$ and $\widetilde{\beta}(1) = 1 - \dfrac{\alpha}{1-\kappa+\alpha}$. Because the final-good producer would choose the minimum possible value of $\beta(m)$, the final-good producer finds it optimal to select outsourcing in the most upstream stage.

If $\beta_v > \beta_o > 1 - \dfrac{\alpha}{1-\kappa+\alpha}$, it is clear that $m^* = 1$ such that all stages will be outsourced. If $\beta_v < 1 - \dfrac{\alpha}{1-\kappa+\alpha}$, then $m^* \in (0,1)$ such that the most downstream stage will be vertically integrated and the most upstream stage will be outsourced. If $\beta_v > 1 - \dfrac{\alpha}{1-\kappa+\alpha} > \beta_o$, then there are two possible cases such that all stages are outsourced $m^* = 1$ or vertical integration and outsourcing coexist along the global value chain $m^* \in (0,1)$.

(ii) If $\rho < \alpha$, then $\dfrac{\partial \widetilde{\beta}(m)}{\partial m} < 0$ for all $m \in [0,1]$. From the optimal organizational structure in equation (12), we obtain that $\widetilde{\beta}(0) = 1$ and $\widetilde{\beta}(1) = 1 - \dfrac{\alpha}{1-\kappa+\alpha}$.

If $\beta_v < 1 - \dfrac{\alpha}{1-\kappa+\alpha}$, then $m^* = 1$ such that all stages will be vertically integrated. If $\beta_v > \beta_o > 1 - \dfrac{\alpha}{1-\kappa+\alpha}$, then vertical integration and outsourcing coexist along the global value chain, i.e., $m^* \in (0,1)$. If $\beta_v > 1 - \dfrac{\alpha}{1-\kappa+\alpha} > \beta_o$, then there are two possible cases such that all stages are vertically integrated $m^* = 1$ or vertical integration and outsourcing coexist along the global value chain $m^* \in (0,1)$. ■

In the absence of financial constraints, the final-good producer always prefers outsourcing to vertical integration for all stages in the sequential complements case, while vertical integration and outsourcing always coexist in the sequential substitution case. However, when the financial constraints are binding, these results no longer apply. The benefits of choosing outsourcing disappear when the financial constraints start to bind; financial constraints are less likely to bind under vertical integration.

When financial constraints are binding, it is possible that the final-good producer will select vertical integration for some stages because it alleviates the adverse effects on the financially constrained supplier. In vertical integration, the final-good producer requires fewer upfront transfers by suppliers than in the outsourcing mode. Even though outsourcing gives suppliers more incentives for investment, the final-good producer's higher bargaining share leads it to integrate suppliers vertically. Last, in the case of sequential complements, financial constraints affect most downstream stage suppliers. The final-good producer chooses vertical integration for most downstream stages. However, in the sequential substitutes case, financial constraints affect more upstream stage suppliers, so the final-good producer chooses vertical integration for upstream stages.

Proposition 5 *Suppose that financial constraints are binding for all stages and vertical integration and outsourcing coexist along the global value chain. Then,*

(i) An increase in financial development κ will expand the range of stages that are outsourced;

(ii) In the sequential complements case ($\rho > \alpha$), the effect of financial development κ on the organizational form $\widetilde{\beta}(m)$ is stronger, especially in upstream stages;

(iii) In the sequential substitutes case ($\rho < \alpha$), the effect of financial development κ on the organizational form $\widetilde{\beta}(m)$ is stronger, especially in downstream stages.

Proof. (i) Differentiating the optimal organizational structure in equation (12) with respect to κ yields the result, i.e., $\dfrac{\partial\widetilde{\beta}(m)}{\partial\kappa} < 0$.

(ii) If $\rho > \alpha$, then $\dfrac{\partial^2\widetilde{\beta}(m)}{\partial\kappa\partial m} > 0$.

(iii) If $\rho < \alpha$, then $\dfrac{\partial^2\widetilde{\beta}(m)}{\partial\kappa\partial m} < 0$. ■

Financial development mitigates the problem of financial constraints. Because vertical integration can alleviate the negative impacts of financial constraints on suppliers, the final-good producer can switch from vertical integration to outsourcing for some stages. As the effects of financial development on the organizational form are more significant in upstream stages in the sequential complements case, final-good producers are more likely to switch from vertical integration to outsourcing where stages are closer to upstream. Conversely, in the sequential substitutes case, final-good producers are more likely to switch from vertical integration to outsourcing where stages are closer to downstream.

5 Empirical Analysis

The model predicts that financial development will expand the range of stages that are outsourced (Proposition 5). When financial constraints on suppliers are not binding, a final-good producer will purchase all intermediate inputs in the sequential complements case (Lemma 2). When suppliers are financially constrained, the final-good producer will integrate stages that are closer to downstream (Proposition 4). Therefore, multinationals are more likely to integrate downstream intermediate input suppliers in countries with weak financial institutions when a production process is characterized by sequential complements.[10] To test this prediction, I specify the following regression equation using U.S. intrafirm imports:[11]

$$\begin{aligned} S_{ict} = \alpha &+ \beta_1 D_i \times SeqSub_i \times WeakFin_c \\ &+ \beta_2 D_i \times SeqCom_i \times WeakFin_c + \gamma_{it} + \delta_{ct} + \varepsilon_{ict} \end{aligned} \tag{13}$$

where i denotes an industry, c represents a country, and t is a year. S_{ict} is the U.S. intrafirm import share in industry i from country c in a given year t. D_i is a measure of downstreamness of an industry in production processes. Specifically, I use $DUse\_TUse$ and $DownMeasure$ to capture D_i.[12] Both measures are continuous variables which lie in the interval $[0, 1]$. $SeqSub_i$ (resp. $SeqCom_i$) is an indicator variable which equals 1 when the average demand elasticity faced by industries that purchase i as an input is below (resp. above) the cross-industry median value of this variable. $WeakFin_c$ is a measure of "financial under-development" which

[10]The prediction is reversed when a production process is characterized by sequential substitutes.

[11]The empirical specification is based on work by Antràs and Chor (2013) in which they tested a relation between the relative prevalence of vertical integration and an interaction term of the downstreamness and final-good demand elasticity. I extend their specification to allow for a triple-interaction term between downstreamness, final-good demand elasticity, and financial development of a country.

[12]$DUse\_TUse$ is defined as the ratio of aggregate direct use to aggregate total use of i as an input. $DownMeasure$ is a more complex measure that makes full use of the information on indirect input use further upstream, which can be represented as a function of the Leontief inverse matrix. See Antràs and Chor (2013) for more details.

is defined as the inverse of private credit as a share of GDP in country c. γ_{it} are industry-year fixed effects and δ_{ct} are country-year fixed effects.

The parameters of interest are β_1 and β_2. I expect that $\beta_1 < 0$ and $\beta_2 > 0$ in estimating equation (13). If U.S. intrafirm import shares are more likely to be imported from downstream industries and financially under-developed countries in the sequential substitutes case (resp. the sequential complements case), then the parameter will be negative (resp. positive) with statistical significance. Equation (13) is based upon equation (33) in Antràs and Chor (2013). I incorporate the measure of country-level "financial under-development" into their specification and interact it with the downstream measure and the demand elasticity of an industry (i.e. a triple-interaction term). In this regard, I use country-industry variation of a key independent variable; while their specification uses cross-industry variation. Hence, I can control for industry-year fixed effects along with country-year fixed effects in the main specification.

One may argue that it is arbitrary to use the cross-country median cutoff value for separating the sequential substitutes case from the sequential complements case. It is reasonable to expect that the positive effects of downstreamness combined with weak financial institution will be concentrated in the highest rages of the elasticity demand parameter. To investigate this effect, I further divide ranges of the elasticity demand parameter into quintiles and specify the following equation:

$$S_{ict} = \alpha + \sum_{q=1}^{5} \eta_q D_i \times Seq_i^q \times WeakFin_c + \gamma_{it} + \delta_{ct} + \varepsilon_{ict} \tag{14}$$

where Seq_i^q is an indicator variable which equals 1 when the average demand elasticity faced by industries that purchase i as an input falls within the q-th quintile.

5.1 Data

In order to test the model's key prediction, we need four variables: intrafirm import share, downstreamness, demand elasticity, and financial development. The first three variables are drawn from Antràs and Chor (2013) and the financial development variable is from Beck, Demirgüç-Kunt and Levine (2000).

The Antràs and Chor (2013) dataset covers the years 2000–2010 and the unit of observation is industry-country-year level. The dependent variable, the intrafirm import share, is calculated as the ratio of related trade to total trade at the industry- country-year cell.[13] I use two measures of downstreamness, $DUse\_TUse$ and $DownMeasure$, which are already defined.[14] Higher values of these measures indicate that most of the contribution of input i to production processes occurs in downstream stages. Demand elasticity is defined as the trade-weighted average elasticity of HS10 products using data on U.S. imports as weights at the industry level. U.S. import demand elasticities were originally estimated by Broda and Weinstein (2006) at the ten-digit HS product-level.[15]

The financial under-development variable is defined as the inverse of the amount of credit by banks and other financial intermediaries to the private sector as a share of GDP at the country level.[16] Although the size of the financial system is not a direct measure of a country's financial development, it provides a good proxy for the economy's financial soundness. In this analysis, a higher value of this measure indicates lower financial development. We use the year 2005 as the benchmark year.

Table 1: Descriptive Statistics

Variable	N	Mean	Median	SD	Level
Intrafirm Import Share	207,991	0.24	0.05	0.33	Industry-Country-Year
$DUse\_TUse$	253	0.61	0.65	0.23	Industry
$DownMeasure$	253	0.56	0.49	0.22	Industry
Demand Elasticity	253	10.22	7.70	11.12	Industry
$WeakFin$	181	0.05	0.03	0.06	Country

Table 1 provides descriptive statistics of the variables used in the regression analysis. The sample contains unbalanced panel data for 207,991 industry-country-year-level observations for 253 industries and 181 countries. The average intrafirm import share is 24 percent and the median is 5 percent, suggesting that the distribution of the variable is skewed to the right. The average value of $DUse\_TUse$

[13] Related trade is defined as trade between related parties. A related party is defined as a foreign counterpart in which the U.S. importer has at least a 6% equity interest.

[14] Antràs and Chor (2013) originally draw on the detailed Use Table by the BEA in the 2002 U.S. Input-Output Tables to construct this measure.

[15] See Antràs and Chor (2013) for more detailed explanations of each variable.

[16] The definition of financial development is the inverse of that of Manova (2013), which was originally obtained from Beck, Demirgüç-Kunt and Levine (2000).

is 0.61 with a standard deviation of 0.23; and the average value of $DownMeasure$ is 0.56 with a standard deviation of 0.22. The average value of demand elasticity is 10.22 with a standard deviation of 11.22. In the empirical specification, $SeqSub_i$ (resp. $SeqCom_i$) is an indicator variable that equals 1 if the value of industry i's demand elasticity measure is below (resp. above) the median value of 7.70.[17] The average value of financial under-development is 0.05 with a standard deviation of 0.06.

5.2 Results

In Table 2, I provide regression results for equations (13) and (14). In columns (1) and (2), I use $DUse\_TUse$ to capture D_i; while in columns (3) and (4), I use $DownMeasure$ to capture D_i. In columns (1) and (3), regression results of equation (13) are presented; while in columns (2) and (4), regression results of equation (14) are presented. The estimated β_2 and η_5 are positive and statistically significant, which support the model's key prediction: U.S. multinationals' intrafirm import shares are higher from downstream intermediate input suppliers in countries with weak financial institutions when the production process is the sequential complements case. The parameter β_1 shows no statistical significance. I expected the parameter to be negative with statistical significance. Turning our attention to the parameters η_1, η_2, η_3, and η_4, those estimates are all statistically insignificant, but the estimated values become larger in the higher ranges of the elasticity demand parameter, which are consistent with the model's ex-ante prediction.

Since the dependent variable, intrafirm import share, is bounded between 0 and 1, the OLS estimates may yield incorrect predictions. Following Papke and Wooldridge (1996), I repeat estimating equations (13) and (14) using a fractional probit regression method for robustness check. In Table 3, the parameters β_1 and η_1 are negative. Except the column (3), those parameters are all statistically significant, which supports my model's key prediction when the production process is

[17] It would be ideal to have a proxy variable for the degree of substitution between stage inputs, α, and compare that with the elasticity of substitution between varieties, ρ, to determine whether the production process is characterized by sequential complements or sequential substitutes. However, the degree of substitution between stage inputs, α, is not readily available in the literature. Therefore, I follow Antràs and Chor (2013) to define the sequential complements industry as the demand elasticity measure is above the cross-industry median value. In addition, I divide the ranges of the elasticity demand parameter into quintiles.

the sequential substitutes. In the sequential complements case, I found a positive with statistical significance case only for the parameter η_5 in column (4). However, as in the OLS case, the estimated values become larger in the higher ranges of the elasticity demand parameter, which still supports the key prediction of the model.

To sum up, although the empirical analysis does not give a clear cut support on the model's key prediction, the general patterns from the OLS regressions and the fractional probit regressions weakly confirm the key prediction of the model. First, the OLS method supports the key prediction in the sequential complements case. Second, the fractional probit regression method substantiates the sequential substitutes case. Lastly, in both cases, I found the increasing estimated values of β and η (i.e. estimated values are larger in the higher ranges of the elasticity demand parameter).

Table 2: Intrafirm Import and Financial Development, 2000–2010, OLS method

		Dependent Variable: Intrafirm Import Share			
		(1)	(2)	(3)	(4)
Downstreamness Measure:		$DUse\_TUse$		$DownMeasure$	
$D_i \times SeqSub_i \times WeakFin_c$,	β_1	0.057		-0.036	
		(0.127)		(0.115)	
$D_i \times SeqCom_i \times WeakFin_c$,	β_2	0.235*		0.317**	
		(0.142)		(0.153)	
$D_i \times Seq_i^1 \times WeakFin_c$	η_1		-0.077		-0.157
			(0.135)		(0.128)
$D_i \times Seq_i^2 \times WeakFin_c$	η_2		0.188		0.051
			(0.139)		(0.125)
$D_i \times Seq_i^3 \times WeakFin_c$	η_3		0.248		0.246
			(0.163)		(0.184)
$D_i \times Seq_i^4 \times WeakFin_c$	η_4		0.209		0.286
			(0.160)		(0.179)
$D_i \times Seq_i^5 \times WeakFin_c$	η_5		0.396**		0.439***
			(0.164)		(0.167)
Fixed Effects:					
Industry-Year		Yes	Yes	Yes	Yes
Country-Year		Yes	Yes	Yes	Yes
Observations		191,269	191,269	191,269	191,269
R-squared		0.241	0.241	0.241	0.241

Notes: The variable D_i is a continuous measure of downstreamness in industry i, which lie in the interval $[0, 1]$. $SeqSub_i$ (resp. $SeqCom_i$) is an indicator variable which equals 1 when the average demand elasticity faced by industries that purchase i as an input is below (resp. above) the cross-industry median value of this variable. Seq_i^q is an indicator variable which equals 1 when the average demand elasticity faced by industries that purchase i as an input falls within the q-th quintile. $WeakFin_c$ is a measure of "financial under-development" which is defined as the inverse of private credit as a share of GDP in country c. The mean value of dependent variable is 0.242. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Robustness Check: Intrafirm Import and Financial Development, 2000–2010, Fractional Probit Regression method

		Dependent Variable: Intrafirm Import Share			
		(1)	(2)	(3)	(4)
Downstreamness Measure:		$DUse\_TUse$		$DownMeasure$	
$D_i \times SeqSub_i \times WeakFin_c$,	β_1	-0.844*		-0.668	
		(0.468)		(0.445)	
$D_i \times SeqCom_i \times WeakFin_c$,	β_2	-0.076		0.731	
		(0.516)		(0.570)	
$D_i \times Seq_i^1 \times WeakFin_c$	η_1		-1.443***		-1.237**
			(0.527)		(0.526)
$D_i \times Seq_i^2 \times WeakFin_c$	η_2		-0.310		-0.253
			(0.518)		(0.487)
$D_i \times Seq_i^3 \times WeakFin_c$	η_3		-0.206		0.373
			(0.642)		(0.747)
$D_i \times Seq_i^4 \times WeakFin_c$	η_4		-0.252		0.540
			(0.602)		(0.674)
$D_i \times Seq_i^5 \times WeakFin_c$	η_5		0.529		1.176*
			(0.583)		(0.617)
Fixed Effects:					
Industry-Year		Yes	Yes	Yes	Yes
Country-Year		Yes	Yes	Yes	Yes
Observations		191,283	191,283	191,283	191,283

Notes: The variable D_i is a continuous measure of downstreamness in industry i, which lie in the interval $[0,1]$. $SeqSub_i$ (resp. $SeqCom_i$) is an indicator variable which equals 1 when the average demand elasticity faced by industries that purchase i as an input is below (resp. above) the cross-industry median value of this variable. Seq_i^q is an indicator variable which equals 1 when the average demand elasticity faced by industries that purchase i as an input falls within the q-th quintile. $WeakFin_c$ is a measure of "financial under-development" which is defined as the inverse of private credit as a share of GDP in country c. The mean value of dependent variable is 0.242. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

6 Conclusion

Building on the work of Antràs and Chor (2013), this study investigates how credit constraints can affect the property-rights model of the global value chain. I offer new predictions on multinational firms' sourcing decisions that depend on financial development, incomplete contracts, and different stages of production. When the average demand elasticity is high relative to input substitutability, multinationals are more likely to integrate downstream intermediate input suppliers in countries with weak financial institutions. In contrast, when the average demand elasticity is low relative to input substitutability, multinationals are more likely to integrate upstream intermediate input suppliers in countries with weak financial institutions. Using data on U.S. related-party trade shares, the model's key predictions are examined and validated.

This approach to incorporating credit constraints into the property-rights model of the global value chain could also be applied to other cases such as the presence of midstream parents. Del Prete and Rungi (2017) find that there are many cases of midstream parents—i.e., producers of intermediate inputs that can integrate either backward or forward along the chain. It would be interesting to study whether the results presented here also hold in the case of midstream parents. It would also be particularly interesting to use firm-level data to test my theoretical model's core predictions.

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Appendix

A Proofs

A.1 Proof of Lemma 1

Proof. Let $\mathcal{L} \equiv \left(1 - \alpha(v')^{(1-\alpha)/\alpha}\right) v' v^{(\rho-\alpha)/(\alpha(1-\rho))}$.

$$\frac{\partial \mathcal{L}}{\partial v} = \frac{\rho - \alpha}{\alpha(1-\rho)} \left(1 - \alpha(v')^{(1-\alpha)/\alpha}\right) v' v^{(\rho-\alpha)/(\alpha(1-\rho))-1},$$
$$\frac{\partial \mathcal{L}}{\partial v'} = \left(1 - (v')^{(1-\alpha)/\alpha}\right) v^{(\rho-\alpha)/(\alpha(1-\rho))}.$$

The Euler-Lagrange equation, then, is given by

$$\frac{\partial \mathcal{L}}{\partial v} - \frac{d}{dm}\frac{\partial \mathcal{L}}{\partial v'} = 0$$
$$\Longleftrightarrow v^{(\rho-\alpha)/(\alpha(1-\rho))}(v')^{(1-\alpha)/\alpha-1}\frac{1-\alpha}{\alpha}\left[v'' + \frac{\rho-\alpha}{(1-\rho)}\frac{(v')^2}{v}\right] = 0.$$

There are three types of solutions associated with the above equation, and we focus on the case which generates a strictly positive profit for the final-good producer:

$$v'' + \frac{\rho-\alpha}{(1-\rho)}\frac{(v')^2}{v} = 0.$$

Solving the second-order differential equation yields,

$$v(m) = \left(\frac{(1-\alpha)C_1}{1-\rho}(m - C_2)\right)^{(1-\rho)/(1-\alpha)},$$
$$v'(m) = C_1\left(\frac{(1-\alpha)C_1}{1-\rho}(m - C_2)\right)^{(\alpha-\rho)/(1-\alpha)}.$$

where C_1 is a positive constant and C_2 is a second constant of integration. The initial condition is given by $v(0) = 0$ and the transversality condition is $v'(1)^{(1-\alpha)/\alpha} = 1$ at the right boundary of the unit interval. Using the two conditions, we can obtain $C_1 = \left[\frac{1-\rho}{1-\alpha}\right]^{(\alpha-\rho)/(1-\rho)}$ and $C_2 = 0$. Plugging C_1 and C_2 into the $v'(m)$

equation, we obtain

$$v'(m) = m^{(\alpha-\rho)/(1-\alpha)}.$$

Therefore,

$$\overline{\beta}(m) = 1 - v'(m)^{(1-\alpha)/\alpha} = 1 - m^{(\alpha-\rho)/\alpha}.$$

■

A.2 Proof of Lemma 2

Proof. (i) If $\rho > \alpha$, then $\dfrac{\partial\overline{\beta}(m)}{\partial m} > 0$ for all $m \in [0,1]$; Because $\overline{\beta}(1) = 0$ and $\overline{\beta}(m)$ is an increasing function, it must be that $\overline{\beta}(m) \leq 0$ for all $m \in [0,1]$. The final-good producer would select the minimum possible value of $\overline{\beta}(m)$ for all stages. Because $\beta_v > \beta_o$, the outsourcing is optimal for all stages.

(ii) If $\rho < \alpha$, then $\dfrac{\partial\overline{\beta}(m)}{\partial m} < 0$ for all $m \in [0,1]$; Since $\overline{\beta}(0) = 1$ and $\overline{\beta}(1) = 0$, together with the optimal organizational form $\overline{\beta}(m)$ is a decreasing function of m, most upstream stages are always integrated while most downstream stages are always outsourced. ■