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The Optimal Allocation of Ownership Right in Sequential Production Stage along the Global Value Chains

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Abstract: In this document, we have developed a model to analyze the optimal allocation of ownership right in sequential production stage along the global value chains. We have shown that, when the demand elasticity is low (high) relative to the degree of substitution among inputs in sequential production, and the bargaining weight of firm is low (high), integration (outsourcing) is the optimal organizational structure. And when both the demand elasticity is high (low) relative to the degree of substitution among inputs and the bargaining weight of firm is low(high), the firm will find it optimal to outsource(integrate) relatively upstream inputs, while to integrate(outsource) relatively the most downstream inputs.

Keywords: sequential production, optimal organization structure, upstreamness, global value chains

1. INTRODUCTION

Most production processes are sequential in nature. First raw materials are converted into basic inputs, which are next combined with other inputs to produce more complicated inputs, before themselves being assembled into final goods. The focus of this document is to analyze the optimal make-or buy decision of firms along the sequential production chain.

McLaren (2000) and Grossman and Helpman (2002) develop a simple model to analyze the make-or-buy decision of firms. In these documents, final goods firms find outsource more attractive in a thicker market in which there are more suppliers of intermediate goods. And similarly, suppliers of intermediate goods find it more attractive to operate in a thicker market in which there are more final goods firms [1, 2]. McLaren (2000) indicates that in autarky equilibrium, integration is only equilibrium structure in a small economy, and there is no room for outsource. While in a large economy integration and outsource can co-exist. Grossman and Helpman (2002) indicates that under outsourcing mode, specialized supplier can produce intermediate goods at lower cost but final good producer that outsourcing the intermediate goods has to face the costs of searching for a supplier that will deliver the agreed quality and quantity of intermediate goods. Searching cost is related to the probability of final good producer marching with a supplier successfully. And the probability is related to the thickness of the market. This means in a thicker (e.g. larger) market, the probability that a final good producer finds the qualified supplier is higher. Meanwhile in a thicker market, if the supplier fails to deliver, it is easier for the outsourcing firm to find an alternative solution. Therefore, outsourcing is more likely to succeed, in the larger industry and in the larger overall economy. Therefore firms in larger industries and in larger economies prefer outsourcing. Common drawback of their models is that both of them assume that matches between final goods firms and suppliers of intermediate goods are random.

Grossman and Helpman (2003, 2005) propose a model which assumes that relationship-specific investment of supplier is related to the technological proximity between the supplier of intermediate goods and the final goods firms. The thicker the market is, the higher the intensity of suppliers' dispersion and technological proximity is which reduces the risks of hold-up problem of suppliers. They highlight the complementarity between entry of the final goods firms and the entry of intermediate goods suppliers. Meantime, they extend the

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model into the north-south framework and conclude that as the expansion of south market, firms located in the North Country prefer outsource to the south country [3, 4].

Quality of the institutional framework is another important factor in determining whether to integrate or outsource. Because the contract between the final goods producer and the supplier of intermediate goods is incomplete, the higher the quality of the institutional framework is, the lower the risks of hold-up which suffered by supplier are. Nunn (2005) proposes a simple model in which the relative requirement of contract-dependent components varies across sectors. In his model, better contracting institutions reduce costs in sectors with a larger need for intermediate goods relatively more than in sectors with less need for intermediates goods[5]. Antràs and Helpman(2007) construct a model with heterogeneous firms, and show that better institutional framework for contracting in the south country increase the likelihood of outsourcing[6].

Empirical evidence also supports theoretical predictions above. Nunn(2007) using U.S. data shows that countries with higher quality of legal system specialize in industries that rely heavily on relationship-specific investment. Levchenko(2007) using US imports data for 1998, shows that the quality of institutional framework is the source of comparative advantage. In particular, countries with higher quality of institutions have a comparative advantage in goods with a complex production process. And he examines that the share of US imports in goods with complex production processes increase by 0.23 when the quality of institutions increases from bottom 15% to top75% [7].

Antràs(2003) using US imports data finds that capital intensive intermediate goods are imported through intra-firm trade, while labor intensive goods are imported through arm's-length trade. And the share of intra-firm imports is related to the ratio of capital to labor in US [8]. Antràs(2004) constructs a general equilibrium model and concludes that firms in capital intensive sector prefer vertical integration, while firms in labor intensive sectors prefer outsourcing[9]. Similarly, Nunn and Trefler(2008) finds that the intra-firm trade is higher in skill-intensive and capital-intensive sectors [10]. Antràs and Helpman(2004) proposes two new concepts of intensity of sector which are headquarter intensive sectors and component intensive sectors. In component intensive sectors, final goods producers should offer suppliers a higher incentive to constrain the under-investment of suppliers and reduce the distortion of incomplete contract; therefore outsourcing is a preferable form. In headquarter intensive sectors, final goods producers should have higher residual control rights and choose the vertical integration form. Antràs (2005) extends this model by incorporating theory product life cycle. He assumes that the intensity of component increase according to the maturity of product. And he concludes that as final goods are becoming mature, more and more firms prefer outsourcing [11].

Antràs and Helpman(2004) show how firms' decisions to integrate or outsource vary with the productivity of firms. In their model, the trade-off between vertical integration and outsourcing is driven by the trade-off between hold-up problem-related cost and the fixed costs of the particular type of organization. Specifically, because they assume that fixed costs of vertical integration are dominantly higher than fixed costs of outsourcing and that offshoring has higher fixed costs than inshoring, in headquarter intensive sector, vertical integration and outsourcing co-exist and in decreasing order of productivity, the most productive firms will choose international integration(FDI), firms with a medium-high level of productivity will international outsourcing, firms with medium-low level of productivity will choose domestic integration, the least productive firms will choose inshoring outsourcing.

Since 1990, fragmentation of production has been internationalizing and networking. Technological innovations in communication and transportation have lowered coordination cost and transportation cost, which has enabled an historic break-up of the production process by allowing firms to specialize in production of specific tasks or different production stages in disparate locations. GVCs offer countries opportunities to integrate into the world economy at lower cost and gain from it. As the international fragmentation of

production has become increasingly pronounced, the implications of such sequential production for the working of open-economy general equilibrium models have been widely explored in the international economics literature, such as Kremer(1993),Kohler(2004),and Costinot, Vogel and Wang(2011), Yi(2003), Harms, Lorz and Urban(2012), and Baldwin and Venables(2010).[12-17]

Upstreamness proposed by Antràs, P., Chor, D., Fally, T., and Hillbery, R.(2012), refers to the weighted distance of a stage of production from final-good production [18]. Fally(2012) and Antràs, Chor and Fally(2012) propose the measurement of upstreamness of a country or an industry in GVCs [19]. Fally(2012) defines upstreamness of industry i as $N_i = 1 + \sum_j \mu_{ij} N_j$,where μ_{ij} is the value of inputs from industry j used to produce one dollar of goods in industry i. Antràs et al.(2012) describes the upstreamness of industry i as $U_i = 1 \times \frac{F_i}{Y_i} + 2 \times \frac{\sum_{j=1}^{N} d_{ij} F_j}{Y_i} + 3 \times \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} d_{ik} d_{kj} F_j}{Y_i} + 4 \times \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{l=1}^{N} d_{il} d_{lk} d_{kj} F_j}{Y_i} + \ldots$, where d_{ij} is the dollar amount of industry i's output needed to produce one dollar worth of industry j's output. F_i is the sum value of output use as a final good. Y_i is the value of gross output of industry i. these two measures appear distinct, but they are in fact equivalent (Antràs et al., 2012). Based on the measure of upstreamness, Antràs and Chor(2013) develops a property-right model incorporating the analysis on organizational structure of firms into GVCs. Their model shows that the incentive to integrate suppliers varies systematically with the relative position in GVCs. Furthermore, they conclude that when the demand faced by the final goods producer is sufficiently elastic, there is an only one threshold production stages such that all stages prior to this stage are outsourced, while all stages after that are integrated. While when demand is inelastic, it is optimal for the firms located in relatively upstream stages to integrate, and for firms located in relative downstream stages to outsource [20].

In this document, we develop a model to analyze the optimal allocation of ownership right in sequential production stage along the global value chains. We analyze four cases, which are useful supplements to Antràs and Chor (2012).

2. BENCHMARK MODEL

There is one final good which is differentiated in the eyes of consumers and belongs to monopolistically competitive industry with heterogeneous firms, each producing a differentiated variety. Consumer preferences over the industry's varieties feature a constant elasticity of substitution (CES) so that the demand faced by the firm in question can be represented by

$$y = Ap^{-1/(1-\alpha)} \tag{1}$$

where $A > 0$ is real total expenditure of consumers on final varieties, and the firm takes as given. And $1/(1-\alpha)$, $\alpha \in (0,1)$ is the demand elasticity and is common for all firms in the final goods sector.

Obtaining the final goods require sequential production stages. These stages are indexed by $i \in [0, n]$, with a larger i corresponding to a stage closer to the finished good. Denoting $x(i)$ the value of the intermediate inputs that the supplier of stage i delivers to the firm, production function of final good is given by

$$y = \theta\left[\int_0^n x(i)^\rho di\right]^{1/\rho} \tag{2}$$

where θ is productivity of final-good producer. ρ is a parameter that captures the degree of substitutability among the stage inputs, and we define that $0 < \rho < 1$ which represents technological substitution

relationship among the stage inputs. We assume that for all i, $x(i)$ is customized to make it compatible with the needs of a firm who controls a final good. Combing demand function with production function, the revenue obtained by firm is given by

$$r = A^{1-\alpha}\theta^{\alpha}\left(\int_0^n x^{\rho}(i)di\right)^{\alpha/\rho} \tag{3}$$

We assume that each supplier undertake one stage of input production and a relationship-specific investment in order to produce a customized input. Firm should contract with the supplier. Following Grossman and Hart (1986), the terms of exchange between the firm and the supplier cannot be set in stone before the customized inputs are produced, the actual payment to a particular supplier is negotiated only after the input has been produced and delivered. The ex post bargaining is modeled as a Nash Bargaining game in which the firm obtains a share $\beta(\tau)$ of the incremental contribution that accrues to the firms in its bargaining with supplier τ, $\beta(\tau) \in (\beta_V, \beta_O)$. Following the property rights approach, we assume that ex post bargaining takes place both under outsourcing (O) and under integration (V), and $\beta_V > \beta_O$. Incompatible inputs can be produced by firm itself at a negligible cost, but they add no value to the final good. Based on (1) and (2), the accumulative revenue of intermediate input at stage τ is

$$r(\tau) = A^{1-\alpha}\theta^{\alpha}\left[\int_0^{\tau} x(i)^{\rho}di\right]^{\alpha/\rho} \tag{4}$$

So the incremental contribution to total revenue generated by the supplier at stage τ is

$$r'(\tau) = \frac{\partial r(\tau)}{\partial \tau} = \frac{\alpha}{\rho}\left(A^{1-\alpha}\theta^{\alpha}\right)^{\frac{\rho}{\alpha}} r(\tau)^{\frac{\alpha-\rho}{\alpha}} x(\tau)^{\rho} \tag{5}$$

The marginal revenue $r'(\tau)$ at stage τ depends on the total demand level A, demand elasticity parameter α, production substitutability among stages ρ, accumulative revenue $r(\tau)$ and the value of intermediate input at stage τ. Notice that in the ex post bargaining, the firm gets a share $\beta(\tau) \in (\beta_V, \beta_O)$ of $r'(\tau)$, while the supplier at stage τ gets $[1 - \beta(\tau)]$. The supplier at stage τ decide to produce $x(\tau)$ by maximizing his profit which is defined by

$$\pi_S(\tau) = (1 - \beta(\tau))\frac{\alpha}{\rho}\left(A^{1-\alpha}\theta^{\alpha}\right)^{\frac{\rho}{\alpha}} r(\tau)^{\frac{\alpha-\rho}{\alpha}} x(\tau)^{\rho} - cx(\tau) \tag{6}$$

Which delivers

$$x(\tau) = \left\{[1 - \beta(\tau)]\frac{\alpha\left(A^{1-\alpha}\theta^{\alpha}\right)^{\rho/\alpha}}{c}\right\}^{1/(1-\rho)} r(\tau)^{\frac{\alpha-\rho}{\alpha(1-\rho)}} \tag{7}$$

To plug ea. (7) into ea. (5) to obtain

$$r'(\tau) = \frac{\alpha}{\rho}(1-\beta(\tau))^{\frac{\rho}{1-\rho}}\left(\frac{A^{\frac{1-\alpha}{\alpha}}\alpha\theta}{c}\right)^{\frac{\rho}{1-\rho}} r(\tau)^{\frac{\alpha-\rho}{\alpha(1-\rho)}} \tag{8}$$

By solving this differential equation above, we have $r(\tau)$ and plug it into (7)

$$x(\tau) = A\left(\frac{1-\alpha}{1-\rho}\right)^{\frac{\alpha-\rho}{\rho(1-\alpha)}}\left(\frac{\alpha}{c}\right)^{1/1-\alpha}\theta^{\alpha/1-\alpha}\left[1-\beta(\tau)\right]^{1/1-\rho}\left[\int_0^\tau 1-\beta(i)^{\rho/1-\rho}di\right]^{(\alpha-\rho)/\rho(1-\alpha)} \tag{9}$$

According to (9), we can see that outsourcing increases $x(\tau)$, and the effect of accumulative outsourcing structure on $x(\tau)$ depends on relative relationship between α and ρ. If $\alpha > \rho$, the accumulative outsourcing structure increases $x(\tau)$, while if $\alpha < \rho$, the accumulative outsourcing structure depresses $x(\tau)$.

3. OPTIMAL ALLOCATION OF OWNERSHIP RIGHT

The firm will choose the optimal allocation of ownership right at each stage by maximize his profit. The firm's profit is given by

$$\pi_F = r - \int_0^n (1-\beta(i))r'(i)di \tag{10}$$

Plugging (3) and (5) into (10) to obtain

$$\pi_F = A\frac{\alpha}{\rho}\left(\frac{1-\alpha}{1-\rho}\right)^{(\alpha-\rho)/[\rho(1-\alpha)]}\left(\frac{\alpha\theta}{c}\right)^{\alpha/(1-\alpha)}\int_0^n \beta(i)\left[1-\beta(i)\right]^{\rho/(1-\rho)}\left[\int_0^i (1-\beta(j))^{\rho/(1-\rho)}dj\right]^{(\alpha-\rho)/\rho(1-\alpha)}di \tag{11}$$

The firm chooses the optimal $\beta(\tau)$, by maximizing π_F at stage τ. The partial derivative of π_F with respect to $\beta(\tau)$ can be expressed as

$$\frac{\partial\pi_F}{\partial\beta(\tau)} = \Omega\Theta(1-\beta(\tau))^{(2\rho-1)/(1-\rho)}(F(\tau)-G(\tau)) \tag{12}$$

where $\Omega = A\frac{\alpha}{\rho}\left(\frac{1-\alpha}{1-\rho}\right)^{\frac{\alpha-\rho}{\rho(1-\alpha)}}\left(\frac{\alpha}{c}\right)^{\frac{\alpha}{1-\alpha}}$, $\Theta = \theta^{\frac{\alpha}{1-\alpha}}$, $F(\tau) = \left(1-\frac{\beta(\tau)}{1-\rho}\right)\left[\int_0^\tau \left[1-\beta(k)\right]^{\rho/(1-\rho)}dk\right]^{\frac{\alpha-\rho}{\rho(1-\alpha)}}$,

and $G(\tau) = -\frac{\alpha-\rho}{(1-\rho)(1-\alpha)}\int_\tau^n \beta(j)(1-\beta(j))^{\frac{\rho}{1-\rho}}\left[\int_0^j (1-\beta(k))^{\rho/(1-\rho)}dj\right]^{\frac{\alpha-\rho}{\rho(1-\alpha)}-1}dj$.

Because $\Omega\Theta(1-\beta(\tau))^{(2\rho-1)/(1-\rho)} > 0$, whether the incentive for the firm to retain a larger surplus share increases or decreases along the value chain hinges on the relative sizes of the parameters $\beta(\tau)$, ρ and α.

Then we will discuss following four cases (the fifth case have been discussed in Antràs and Chor, 2012), see table 1.

3.1 PREVALENCE OF INTEGRATION

When $1-\rho > \beta_V$ and $\alpha \le \rho$, which means $\frac{\partial \pi_F}{\partial \beta(\tau)} > 0$, for stage τ, the larger $\beta(\tau)$ is, the greater π_F is(see case1 in table 1). Under this circumstance, integration is optimal organizational structure at stage τ. Intuitively, when α is small relative to ρ, outsourcing is particularly costly, because high investments reduce incentives to invest for downstream suppliers, while the firm captures a disproportionate amount of surplus by integrating. If the bargaining weight $\beta(\tau)$ was common for all stages along the value chain, the optimal structure along the whole value chain is integration.

Table 1. Four cases analysis

CASE	conditions	The optimal $\beta(\tau)$	The Optimal Allocation of Ownership Right
CASE 1	$\alpha < \rho$ and $\beta_V < 1-\rho$	π_F is increasing in $\beta(\tau)$	prevalence of integration
CASE 2	$\alpha > \rho$ and $\beta_0 > 1-\rho$	π_F is decreasing in $\beta(\tau)$	prevalence of outsourcing
CASE 3	$\alpha > \rho$ and $\beta_V < 1-\rho$	$\beta^*(\tau)$is increasing function of τ	$(0, \tilde{\tau})$outsourcing; $(\tilde{\tau}, n)$integration
CASE 4	$\alpha < \rho$ and $\beta_0 > 1-\rho$	$\beta^*(\tau)$is decreasing function of τ	$(0, \hat{\tau})$integration; $(\hat{\tau}, n)$outsourcing

3.2 PREVALENCE OF OUTSOURCING

When $1-\rho < \beta_0$ and $\alpha > \rho$, which means $\frac{\partial \pi_F}{\partial \beta(\tau)} < 0$, for stage τ, the smaller $\beta(\tau)$ is, the greater π_F is. Under this circumstance, outsourcing is optimal organizational structure at stage τ. Intuitively, when α is high relative to ρ, integration is particularly costly; because this reduces the incentive to invest of suppliers, although integration allows the firm to capture a disproportionate amount of surplus, the incremental surplus over which the firm and the supplier negotiate is particularly small. If the bargaining weight $\beta(\tau)$ was common for all stages along the value chain, the optimal structure along the whole value chain is outsourcing.

3.3 THE OPTIMAL SHARE OF THE INCREMENTAL PROFIT $\beta(\tau)$ IS INCREASING IN M

Setting $\frac{\partial \pi_F}{\partial \beta(\tau)} = 0$, for stage τ, there is the optimal division of surplus, which we denote by $\beta^*(\tau)$. Then we can have

$$\beta^*(\tau) = 1-\rho-\left[\frac{\alpha-\rho}{(1-\alpha)}\int_\tau^n \beta(j)(1-\beta(j))^{\frac{\rho}{1-\rho}}\left[\int_0^j (1-\beta(k))^{\rho/(1-\rho)}dj\right]^{\frac{\alpha-\rho}{\rho(1-\alpha)}-1}dj\right] \Big/ \left[\int_0^\tau [1-\beta(k)]^{\rho/(1-\rho)}dk\right]^{\frac{\alpha-\rho}{\rho(1-\alpha)}} \quad (13)$$

When $\alpha > \rho$, it is clear that the numerator in (13) is decreasing in τ, while the denominator is increasing in τ. Due to the negative sign in front of the ratio, $\beta^*(\tau)$ is increasing function of τ. That means the more close to the downstream stage; the optimal division of surplus to firm is greater (see Figure 1). Remember that $\beta_V > \beta_0$, if $\beta_V < 1 - \rho$, then there is a unique threshold $\tilde{\tau}$, all production stages prior to $\tilde{\tau}$ are outsourced; and all stages after $\tilde{\tau}$ are integrated. That means firm will find it optimal to outsource relatively upstream inputs, while to integrate relatively the most downstream inputs.

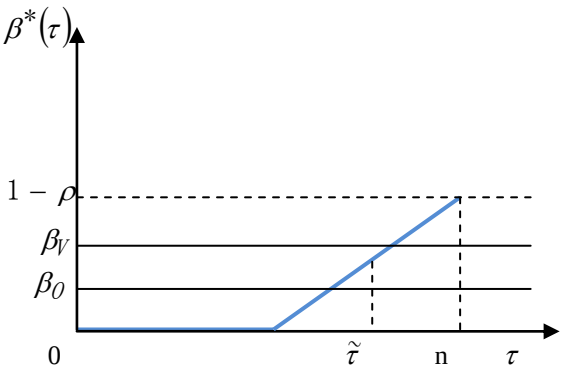

Figure 1

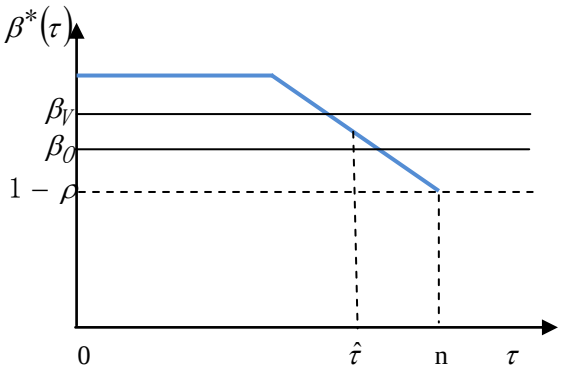

Figure 2

3.4 THE OPTIMAL SHARE OF THE INCREMENTAL PROFIT $\beta(\tau)$ IS DECREASING IN M

When $\alpha < \rho$, $\beta^*(\tau)$ is decreasing function of τ. That means the more close to the downstream stage; the optimal division of surplus to firm is smaller (see Figure 2). If $\beta_0 > 1 - \rho$, then there is a unique threshold $\hat{\tau}$, all production stages prior to $\hat{\tau}$ are integrated; and all stages after $\hat{\tau}$ are outsourced. That means firm will find it optimal to integrate relatively upstream inputs, while to outsource relatively the most downstream inputs.

4. CONCLUSIONS

In this document, we have developed a model to analyze the optimal allocation of ownership right in sequential production stage along the global value chains. We have shown that, for a particular stage, the firm's make-or-buy decision depends on the magnitude of the consumer demand elasticity α, the degree of substitution between inputs in sequential production ρ and the bargaining weight of firm(β_V and β_0). When the demand elasticity is low relative to the degree of substitution among inputs in sequential production, and the bargaining weight of firm is low, integration is the optimal organizational structure for whole value chains. When the demand elasticity is high relative to the degree of substitution among inputs in sequential production, and the bargaining weight of firm is high, outsourcing is the optimal organizational structure, for whole value chains. When the demand elasticity is high relative to the degree of substitution among inputs in sequential production, and the bargaining weight of firm is low, firm tend to outsource inputs at upstream stages, and to integrate inputs at downstream stages. When the demand elasticity is low relative to the degree of substitution among inputs in sequential production, and the bargaining weight of firm is high, firm tend to integrate inputs at

upstream stages, and to outsource inputs at downstream stages.

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