Intra-product Specialization, Technological Dependency and Organization Structure of Heterogeneous Firms

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Abstract. This document integrates GHM model and Nash-bargain game into dynamic game of north-south framework with heterogeneous firms, and uses backward deduction method to resolve the equilibrium organization structure of heterogeneous firms. This document argues that the degree of technological dependency of final-good producers on the intermediate suppliers is the key to the optimal organization structure of heterogeneous final-good produces. It concludes that when final-good producers in head-quarter intensive industry, get intermediate input from home country, and when final-good producers in component intensive industry get intermediate input from foreign the degree of technological dependency of final-good producer on intermediate supplier is very important for his organization structure.

Introduction

Since 1980s, international division of labor has developed from inter-industry to intra-industry and then intra-product. Vertical integration (Helpman, 1984; Helpman and Krugman, 1985) and horizontal integration (Markusen, 1984) is the earliest integration theories [1,2,3]. Then Markusen(2002) created a knowledge capital model incorporating both of them[4]. Motta and Norman(1996), Hanson, Mataloni and Slaughter(2001),Ekholm, Forslid and Markusen(2007) considered that two-countries model cannot explain the whole story of organization structure of firms specifically the export of foreign affiliate to the third country rather than home country and host country[5,6,7]. Ekholm, Forslid and Markusen(2007) created "export-platform" integration model explaining the foreign direct investment from home country to host country companied with the trade between host country and the third country. Yeaple(2003) quantized transportation cost, factor endowment and industry-specific factor intensity to analysis the complex strategies of heterogeneous[8].

At the end of 1990s, lots of empirical studies triggered the review on the assumption of homogeneous firms within industries. Clerides et al.(1996,1998) using clumbia data, Bernard and Jensen(1999,2009) , Helpman et al. (2004) and Yeaple(2012)using U.S. data, Bee-Yan et al. (2000) using Taiwan data and Baldwin and Gu (2003) using Canadian data found that only firms with large scale and high productivity exported in the so-called export industry[9,10,11]. Then Melitz(2003) constructed a Monopolistic competition model with heterogeneous firms which has been a footstone of studies on heterogeneous firms in an industry.[12] Antràs(2003) using U.S. panel data found that intrafirm imports in U.S., is significantly positive correlative with the capital intensity of the exporting industry and capital-labor ratio of the exporting country [13]. And it incorporated GHM with Krugman and Helpman (1985) and constructed a property right model to explain the phenomenon. It concluded that final-good producers in capital intensive sector preferred integration organization and obtained the intermediate input through intra-firm trade in capital abundant country. While final-good producers in labor intensive sector preferred outsourcing organization and obtained the intermediate inputs through arm's-length suppliers in labor abundant country. By extending Antràs (2003), Antràs and Helpman(2004) integrated Melitz(2003) with Helpman, Melitz and Yeaple(2003) into a theoretical framework Setup of model. It concluded that if the final goods are component intensive, the residual control rights of final-good producers are negative correlative

with their variable profit, and the variable profit is higher under outsourcing organization. If the final goods are head-quarter intensive, the residual control rights of final-good producers are positive correlative with their variable profit, and the variable profit is higher under integration organization.[14]

This document extends Antràs and Helpman(2004) by constructing an theoretical model and arguing that the degree of technological dependency of final-good producer on intermediate supplier also play an important role on the organization structure.

Setup

There are two countries: home (H) and foreign (F), sharing identical preference of representative consumers, which is given by a C.E.S. utility function

$$U = \sum_{j=1}^{J} \mu_j \log\left(\int_i y_{ij}^{\alpha} di\right)^{1/\alpha}, \text{ s.t. } \mu_j E_L = \sum_i p_{ij} y_{ij} \tag{1}$$

Where μ_j is the ratio of expenditure on final products in industry j to total income EL, L$\in${H,F}, and $\sum_j \mu_j = 1$. y_{ij} is final good in industry j. α ($0 < \alpha < 1$) represents elasticity of substitution between any two final varieties. Demand function of repensentive consumer is

$$y_{ij} = A_j p_{ij}^{-1/(1-\alpha)}, \text{ and } P_j = \int_i p_{ij}^{-\alpha/(1-\alpha)} \tag{2}$$

Where $A_j = \left(\mu_j E_L / P_j\right)$ is real total expendture in fianl goods of industry j in country L.

There are two kinds of producer, which are final-good producers Z_{ij} and intermediate input suppliers M_{ij}. Production function of final good is

$$y_{ij} = \theta_{ij}\left[\lambda_j h_{ij}^{\rho_i} + (1-\lambda_j) m_{ij}^{\rho_i}\right]^{1/\rho_i}, \text{ and } 0 < \lambda_j < 1, \rho_i < 1 \tag{3}$$

Where θ_{ij} is productivity of final-good producer Z_{ij}. h_{ij} and m_{ij} are intermediate inputs. h_{ij} is head-quarter intensive input and produced by Z_{ij} located in home country. m_{ij} is component intensive input and produced by M_{ij} located in either home country or foreign country. λ_j represents the intensity of head-quarter input in final-good product y_{ij}. ρ_{ij} represents the elasticity of substitution between h_{ij} and m_{ij}, and it represents the degree of technological dependency of Z_{ij} on M_{ij}. The larger ρ_{ij} is, the lower the degree of technological dependency of Z_{ij} on M_{ij}. And we assume that unit cost of production h_{ij} or m_{ij} is unit local labor hour. In home country wage is 1 and in foreign country wage is ω ($0 < \omega < 1$). Therefore we assume that foreign country has the unit cost advantage.

Since from now on we discuss a particular industry, we drop the index j from all the variables. Final-good producer Z_i can get m_i by two means which are integration (V) and outsourcing (O). Based on GHM model, under both organization, final-good producer needs to contract with intermedite supplier and suffers distortion of incomplete contrat, which measn they cannot sign ex-ante enforceable contracts specifying the price and quantity of m_i. Final-good producer and intermediate supplier bargains over the surplus from the relationship after m_i have been produced and delivered. The ex-post bargaining is as a Nash Bargaining game in which the final-good producer obtain a fraction β ($0 < \beta < 1$) of the ex-post gains from the relationship. Under integration organization, M_i is a division of Z_i and has no control rights over the m_i produced. If

negotiation fails, Z_i can fire M_i and seize the m_i.we assume that firing M_i results in a loss of $(1-\phi)y_i$, because Z_i cannot use the intermediate inputs effectively without cooperation of M_i. Under outsourcing organization, M_i is independent supplier, and a failure to reach an agreement on the distribution of the surplus leaves both parties with no income.

According to Nash bargain game, under integration organization, if they fail to agree on a contract, the outside option of M_i is zero. Z_i can get ϕy_i of final-goods, by firing M_i and his outside option is $\phi^{\alpha} R_i$,where $R_i = p_i y_i$ representing the total revenue. In equilibrium, the revenue Z_i can get is $\phi^{\alpha} R_i + \beta\left(1-\phi^{\alpha}\right)R_i = \beta^{V} R_i$ and the revenue M_i can get is $(1-\beta)\left(1-\phi^{\alpha}\right)R_i = \left(1-\beta^{V}\right)R_i$. Under outsourcing organization, M_i has the residual right of control over m_i. If they fail to agree on a contract, outside option of both Z_i and M_i are zero. In equilibrium, revenue of Z_i is $\beta R_i = \beta^{O} R_i$ and revenue of M_i is $(1-\beta)R_i = \left(1-\beta^{O}\right)R_i$ where $\beta^{V} > \beta^{O} = \beta$.

Upon paying the fixe cost of entry f_E, and knowing the productivity θ_i, Z_i decides whether to exit. If Z_i decides to stay and produce fina-good products, he has to bear an extra fixed cost of production $f_{Z_i}^{Lk}$, k∈{V,O}. The fixed cost of production for Intermediate supplier M_i is $f_{M_i}^{Lk}$. Under both integration and outsourcing organization, final-good producer Z_i has to contract with intermediate supplier M_i, while they cannot sign an ex-ante complete contract. After intermediate inputs m_i have been produced and delivered, they have deal with second negation. Because m_i is customized to $y_{i,j}$, in order to avoiding the hold-up problem, Z_i has offer M_i a transfer T_i^{Lk}, ex-ante.

First, by maximizing the profits of Z_i and M_i separately, we can get the output of h_i, m_i and y_i. Based on the expected profit, Z_i decides the organization structure while M_i decides whether to accept the transfer and produce m_i. Their expected profits are

$$\pi_{Z_i}^{Lk} = \beta^{k} A^{1-\alpha}\left(y_i^{Lk}\right)^{\alpha} - h_i^{k} - T^{Lk} - f_E - f_H^{Lk} \tag{4}$$

$$\pi_{M_i}^{Lk} = \left(1-\beta^{k}\right)A^{1-\alpha}\left(y_i^{Lk}\right)^{\alpha} - W^{L} m_i^{Lk} + T_i^{Lk} - f_M^{Lk} \tag{5}$$

And by maximizing their expected profit, we can get the output of h_i, m_i and y_i as follow

$$h_i^{Lk} = \left(\lambda\beta^{k}\right)^{\frac{1}{(1-\rho_i)}} A\theta_i^{\frac{\alpha}{(1-\alpha)}}\alpha^{\frac{1}{(1-\alpha)}}\left[\lambda^{\frac{1}{(1-\rho)}}\left(\beta^{k}\right)^{\frac{\rho_i}{(1-\rho_i)}} + (1-\lambda)^{\frac{1}{(1-\rho_i)}}\left(\frac{1-\beta^{k}}{W^{L}}\right)^{\frac{\rho_i}{1-\rho_i}}\right]^{\frac{\alpha-\rho_i}{\rho_i(1-\alpha)}} \tag{6}$$

$$m_i^{Lk} = \left[\frac{(1-\lambda)\left(1-\beta^{k}\right)}{W^{L}}\right]^{\frac{1}{(1-\rho_i)}} A\theta_i^{\frac{\alpha}{(1-\alpha)}}\alpha^{\frac{1}{(1-\alpha)}}\left[\lambda^{\frac{1}{(1-\rho_i)}}\left(\beta^{k}\right)^{\frac{\rho_i}{(1-\rho_i)}} + (1-\lambda)^{\frac{1}{(1-\rho_i)}}\left(\frac{1-\beta^{k}}{W^{L}}\right)^{\frac{\rho_i}{1-\rho_i}}\right]^{\frac{\alpha-\rho_i}{\rho_i(1-\alpha)}} \tag{7}$$

$$y_i^{Lk} = A\theta_i^{\frac{\alpha}{(1-\alpha)}}\alpha^{\frac{1}{(1-\alpha)}}\left[\lambda^{\frac{1}{(1-\rho_i)}}\left(\beta^{k}\right)^{\frac{\rho_i}{(1-\rho_i)}} + (1-\lambda)^{\frac{1}{(1-\rho_i)}}\left(\frac{1-\beta^{k}}{W^{L}}\right)^{\frac{\rho_i}{1-\rho_i}}\right]^{\frac{1-\rho_i}{\rho_i(1-\alpha)}} \tag{8}$$

Based on the free entry condition for M_i, we can get the transfer T_i^{Lk} as follow

$$T_i^{Lk} = -\left(1-\beta^k\right)A^{1-\alpha}\left(y_i^{Lk}\right)^{\alpha} + W^L m_i^{Lk} + f_M^{Lk} \tag{9}$$

To incorporate (6)-(9) into (4), we gan get the equilibrium profit of Z_i is

$$\pi_{Z_i}^{Lk} = A\alpha^{\frac{\alpha}{(1-\alpha)}}\Theta_i\left(\lambda^{\frac{1}{\rho_i}}\beta^k\right)^{\frac{\alpha}{(1-\alpha)}}\left(1+\Phi_i^{\mathrm{Lk}}\right)^{\frac{\alpha-\rho_i}{\rho_i(1-\alpha)}}\left[1-\alpha\beta^k+\Phi_i^{Lk}\left(1-\alpha+\alpha\beta^k\right)\right]-f^{LK}-f_E \tag{10}$$

Where $\Theta_i = \theta_i^{\frac{\alpha}{(1-\alpha)}}$, $\Phi_i^{Lk} = \left(\frac{1-\beta^k}{\beta^k W^L}\right)^{\rho_i/(1-\rho_i)}\left(\frac{1-\lambda}{\lambda}\right)^{1/(1-\rho_i)}$, $f^{Lk} = f_Z^{Lk} + f_M^{Lk}$.

Organization structure analysis

There are two kinds of organization structure, which are integration and outsourcing. To derivative the profit of Z_i with β^k, we have

$$\frac{\partial\pi_{Z_i}^{Lk}}{\partial\beta^k} = \mathrm{A}\alpha^{\frac{1}{1-\alpha}}\Theta_i\frac{(\beta^k\lambda^{\frac{1}{\rho_i}})^{\frac{\alpha}{1-\alpha}}}{\beta^k}(1+\Phi_i^{Lk})^{\frac{\alpha-\rho_i}{\rho_i(1-\alpha)}-1}\left[\frac{1-\beta}{1-\alpha}+\frac{1-2\beta}{(1-\rho_i)(1-\beta)}\Phi_i^{Lk}-\frac{\beta^2}{(1-\alpha)(1-\beta)}\Phi_i^{Lk2}\right] \tag{11}$$

Based on (11), we conclude that, the relationship between the profit of Z_i and the β^k depends on the expression in the square brackets, which is a quadratic function of Φ_i^{Lk} ($\Phi_i^{Lk} \geq 0$) and in (0, +∞) there is a unique solution $\Phi_0 = \frac{1}{2}\left(\frac{1}{\beta^k}\right)^2\left\{\frac{(1-2\beta^k)(1-\alpha)}{(1-\rho_i)}+\sqrt{\frac{(1-2\beta^k)^2(1-\alpha)^2}{(1-\rho_i)^2}+\left[2\beta^k\left(1-\beta^k\right)\right]^2}\right\}$. When $\Phi_i^{Lk} > \Phi_0$,we have $\left(\partial\pi_{Z_i}^{Lk}/\partial\beta^k\right) < 0$, which means profit of Z_i is larger under outsourcing organization. When $\Phi_i^{Lk} < \Phi_0$,we have $\left(\partial\pi_{Z_i}^{Lk}/\partial\beta^k\right) > 0$,which means profit of Z_i is larger under integration organization. Furthermore, the relationship between Φ_i^{Lk} and Φ_0 depends on the degree of technological dependency ρ_i, the intensity of head-quarter inputs λ and cost advantage in foreign country ω.

In head-quarter intensive industry, if Z_i gets m_i from M_i located in foreign country, the degree of technological dependency has no effect on his organization. Under integration organization he can gain higher profit comparing to outsourcing organization. If Z_i gets m_i from M_i located in home country, Z_i with higher degree of technological dependency on M_i will choose outsourcing organization and Z_i with lower degree of technological dependency on M_i will choose integration organization.

In component intensive industry, if Z_i gets m_i from M_i located in foreign country, Z_i with higher degree of technological dependency on M_i will choose integration organization and Z_i with lower degree of technological dependency on M_i will choose outsourcing organization. If Z_i gets m_i from M_i located in home country, the degree of technological dependency has no effect on his organization. Under outsourcing organization he can gain higher profit comparing to integration organization.

Summary

This document integrates GHM model and Nash-bargain game into dynamic game of north-south framework with heterogeneous firm, and uses backward deduction method to resolve the equilibrium organization structure of heterogeneous firms. This document argues that the degree of technological dependency of final-good producers on the intermediate suppliers is the key to the optimal organization structure of heterogeneous final-good produces. It concludes that when final-good producers in head-quarter intensive industry,get intermediate input from home country, and when final-good producers in component intensive industry get intermediate input from foreign the degree of technological dependency of final-good producer on intermediate supplier is very important for his organization structure.

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