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Multiplant Strategy under core-periphery structure

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March 2012

Abstract

A typical implicit assumption on monopolistic competition models for trade and economic geography is that firms can produce and sell only at one place. This paper allows endogenous determination of the number of plants in a new economic geography model and examines the stable outcomes of organization choice between single-plant and multi-plant in two regions. We explicitly consider the firms' trade-off between larger economies of scale under single plant configuration and the saving in interregional transport costs under multi-plant configuration. We show that organization change arises under decreasing transportation costs and observe several organization configurations under a generalized cost function.

Keywords: Multi-plant firms, Transaction costs, New economic geography
JEL classification: D21, F12, L23, R12,

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1 Introduction

As is confirmed by many studies, economic activities are unevenly distributed among countries and regions.[1] Krugman (1991) and Fujita, Krugman and Venables (1999) established a systematic framework to analyze endogenous agglomeration of workers and firms using a combination of increasing returns and transportation costs, called the New Economic Geography (henceforth, NEG). While there are a number of model variants proposed, it is a typical assumption that each firm consists of a single plant. But in reality, when transportation costs are very high, it would be rational to establish another plant in a distant market (Brainard (1997)). Firms face proximity-concentration trade-off in serving for distant markets, i.e., depending on the degree of transportation costs including communication costs (c.f. trade costs), firms may want to build a new plant there, or export from the existing plant in their home market. While proximity to market enables firms to earn larger profit by reducing trade costs, firms can exploit scale economies by concentrating their production at one place. Thus, for a firm, the number of places for production must also be a choice variable as important as their location.

Several factors can cause decrease in transportation costs such as advancement in transport technology (airplanes, ships, trucks, rails, roads, etc.) and information technology (telegraphs, telephones, facsimiles, Internet, communication satellites, etc.), a tariff reduction and harmonization of documentation for custom by trade agreements, etc. A wider acceptance of English as business language in the market could also be included in communication costs reduction. Mutual understandings among different cultures may decrease management costs among workers and managers. Such decrease in broadly defined transportation costs affect the organization of firms internationally and domestically.

In fact, there is a substantial presence of multiplant (unit) firms in reality among countries and regions. From the international point of view, Tomiura (2007) shows that, in Japanese manufacturing, the share of multiplant firms as FDI is 31.8% in multinational firms which engage in multinational activities such as exporting, foreign outsourcing, foreign affiliates, etc.[2] From the regional point of view, the share of multi establishment varies across regions and among industries: agriculture (28.3%), manufacturing (36.3%), and retailing (60.2%).[3] The share of multi-establishment firms is

[1]See, e.g., Combes and Overman (2004) for the case of EU, and Fujita, Mori, Henderson and Kanemoto (2004) for the case of Japan.

[2]Note that the share of multinational firms accounts for 9.4% in total of 118,300 samples in 1998.

[3]The data source is from "Establishment and enterprise census of Japan" in 2006 which covers all

lower in Agriculture, Fisheries, and Forestry. On the other hand, manufacturing is relatively higher and service sectors are much higher. In other words, primary products have relatively smaller supply chain and services have larger supply networks. Since most of services needs face to face communication with customers, it is difficult to ship the services to the other regions. In both of international and regional aspects, multiplant (unit) firms are not negligible organization type.

The aim of this paper is to propose a simple modification to NEG models, which allows firms to endogenize both the number and location of their plants in a two-region economy. It is shown that the option to be multiplant changes the location equilibria which have been obtained in the previous studies assuming single-plant firms: since the firms can change the number of plants beside the location of each plant. In particular, the organization change of a firm is not necessarily associated with population migration across regions. The conditions for equilibria and their stability under different plant organization of firms are fully analyzed, whose results are consistent with the above international and regional facts.

There are some early attempts of modeling the spatial organization of multiplant firms. In the context of international trade, multiplant strategy is called horizontal foreign direct investment (FDI). Markusen (1984) is the first to explain horizontal FDI in trade, while Ota and Fujita (1993) was first to solve location problem of multiplant (-unit) firms in the continuous urban space. In monopolistic competition framework, multiplant firms have first been introduced by Markusen and Venables (1998) in trade, although their results heavily rely on numerical examples. Toulemonde (2008) also consider multiplant firms in Footloose Capital model and analyze monotonic organization change from multi-plant case to single-plant case under decreasing transportation costs. Yeaple (2003) considers the optimal organization of multinationals in three country model across all possible configurations. However stability analysis is still left aside. Ekholm and Forslid (2001) is the closest in spirit to the present paper as they introduced multiplant firms in the NEG framework. However, due to their model specification, formal results obtained are rather limited. Recent works by Fujita and Thisse (2006) and Fujita and Gokan (2005) consider multiplant firms in the NEG framework. Their analysis focus on headquarter and plant location under Marshallian externalities among headquarters. However, since Brainard (1993), Brainard (1997), Markusen and Venables (1998) and others, none of them analyzes non-monotonic organization changes. Building on Forslid and Ottaviano (2003) with simple modification and gen-

the firms in Japan except foreign affiliates. The definition of "multiplant (multi-unit) firm", here, is that an establishment which is not independent and is either main or branch establishment.

eralization in cost function, we show how proximity-concentration tradeoff appears in NEG framework and non-monotonic organization changes. This non-monotonic organization changes with decreasing transportation costs would offer better understandings of multinational firms. Against the theoretical prediction in the literature, the common wisdom would insist that concentration of production comes after exporting. A firm starts domestic supply, subsequently engages in exporting, then establish foreign affiliates and later concentrate its production in the most cost-efficient location. However, to my best knowledge, all of the previous theoretical studies including models with heterogeneous firms propose the scenario that reduction in transportation costs always encourage multi-plant firms to become a single-plant exporters to exploit scale economies. Our generalized model explains the above non-linear organizational change in terms of effects on fixed costs of multinationals from transportation (trade) costs including the need for adjustment for local markets and language barriers be the determinant for organization as well as those on variable costs.

The rest of this paper is organized as follows; in section 2, a two-region single-plant model is presented as a benchmark. In section 3, multiplant case is allowed, and is compared with the previous results. First, given a gradual decrease in transportation costs, the comparison shows monotonic organization change from multiplant to single plant. In the second step, we extend and generalize our model in order to show more realistic non-monotonic organization changes. Possible caveats and future extensions are discussed in the final section.

2 Location choice without organization choice

The economy is composed of symmetric two regions *1* and *2*. There are two production factors: H units of skilled workers and L units of unskilled workers. While unskilled workers are equally distributed between regions and are immobile, skilled workers can freely mobile between the two regions.

2.1 Consumers

We assume that preference is identical across all workers and is expressed by

$$U = \frac{A^{1-\mu} Q^{\mu}}{\mu^{\mu} (1-\mu)^{1-\mu}}, \tag{1}$$

where A stands for the consumption of agricultural good, $q(i)$ is the consumption of manufactured good variety $i \in [0,\ N]$ and Q is an index of manufactured good consumption $Q = \left[\int_0^N q(i)^{\frac{\sigma-1}{\sigma}} d_i\right]^{\frac{\sigma}{\sigma-1}}$. N indicates the size of differentiated varieties of manufactured goods and $\sigma > 1$ is the elasticity of substitution between any pair of varieties. The expenditure share of manufactured goods is μ and that of agricultural good is $1-\mu$. We posit p^A and $p(i)$ as the price of agricultural good and the delivered price of a differentiated manufactured good i. Interregional trade of manufactured goods incurs "iceberg" transportation costs and selling one unit in the other region requires $\tau \geq 1$ units to be shipped. Transportation costs can be alternatively interpreted as trade costs. For later reference, we posit $\phi = \tau^{1-\sigma} \in [0,1]$ as alternative measure of transportation costs. We may call ϕ as trade freeness. When transportation costs are high (low), ϕ takes the value close to zero (one). Then increasing ϕ expresses the decreasing transportation costs and no transportation costs can be expressed by $\phi = 1$. If the price index of manufactured goods is expressed by $P = \left[\int_0^N p(i)^{1-\sigma} d_i\right]^{\frac{1}{1-\sigma}}$, then we obtain the demand function for a differentiated manufactured good and the indirect utility function as,

$$q(i) = \mu \left(\frac{P}{p(i)}\right)^{\sigma} \frac{Y}{P}, \tag{2}$$

$$v = \left(p^A\right)^{-(1-\mu)} P^{-\mu} w, \text{ for unskilled worker,} \tag{3}$$

$$V = \left(p^A\right)^{-(1-\mu)} P^{-\mu} W, \text{ for skilled worker.} \tag{4}$$

Wages for skilled and unskilled worker are expressed by W and w, respectively. We set λ_r as the share of firms in region r, where $\sum_r^2 \lambda_r = 1$. Subscript indicates the location, $r \in [1,2]$. Then we may write regional total income as

$$Y_r = \frac{L}{2} w_r + W_r H \lambda_r. \tag{5}$$

While the distribution of skilled workers is endogenous, for the simplicity of analysis, we set the distribution of unskilled workers to be uniform across the two regions, and normalize the population size as, $L = H = 1$.

2.2 Agriculture

Agricultural sector produces a homogeneous good under perfect competition and constant returns to scale using unskilled labour input only. This good is traded costlessly. Thus we take agricultural good as numéraire and normalize the wage of one unit of unskilled workers to be one across regions, $p_A = w_r = w_s = 1$.

2.3 Single-plant firm

In manufacturing sector, we assume that firms are imperfectly competitive *à la Dixit-Stiglitz* and produce differentiated goods. Production of a differentiated good incurs one unit of skilled workers as fixed costs and one unit of unskilled workers as marginal labour requirement. When a single-plant firm locates in region r, it faces the demand from the same region, $\left(\frac{P_r}{p_r(i)}\right)^{\sigma}\frac{\mu Y_r}{P_r}$, and the demand from the other region to export, $\left(\frac{P_s}{p_{rs}(i)}\right)^{\sigma}\frac{\mu Y_s}{P_s} = \left(\frac{P_s}{p_r(i)}\right)^{\sigma}\frac{\mu Y_s}{P_s}\phi$, where the delivered price of product from region r to s is expressed as a $p_{rr}(i) = p_r(i)$ and $p_{rs}(i) = p_r(i)\,\tau$. Then the total demand for a differentiated good can be written as,

$$q_r(i) = \left(\frac{P_r}{p_r(i)}\right)^{\sigma}\frac{\mu Y_r}{P_r} + \left(\frac{P_s}{p_r(i)}\right)^{\sigma}\frac{\mu Y_s}{P_s}\phi. \tag{6}$$

When single-plant firms export their products to the other region where they do not locate, they incur transportation costs. The price indices in this case can be written as

$$P_r^{1-\sigma} = \sum_{r=1,2}\int_0^{n_r} p(i)^{1-\sigma}\,d_i, \tag{7}$$

where n_r is the number of firms in region r. As is mentioned in the introduction, all imperfectly competitive firms are assumed to be exporters with single-plant, when the number of plants is not a choice variable of a firm. We assume the total mass of firms as $N = H = 1$, as long as all firms are single-plant. Moreover, marginal input is assumed to be one unit of unskilled workers. The profit function of a differentiated good firm with single-plant in one region r can be written as

$$\pi_r^S(i) = (p_r(i) - w_r)\,q_r(i) - W_r^S(i)\,. \tag{8}$$

The single-plant firm producing variety i chooses its mill price to maximize profit $\pi_r(i)$. The price resulting from the profit maximization is a markup over marginal costs as,

$$p_r(i) = \frac{\sigma}{\sigma-1}. \tag{9}$$

Substituting equilibrium price (9) into (7), we obtain

$$P_r^{1-\sigma} = \left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma} \Delta_r,$$

where $\triangle_r \equiv [\lambda_r + \lambda_s \phi]$, which expresses the distribution of firms with respect to region r. Using the optimal prices both in profit function and in price index, we could obtain the equilibrium profits as,

$$\pi_r^S(i) = \frac{\mu}{\sigma N}\left[\frac{Y_r}{\Delta_r} + \frac{Y_s}{\Delta_s}\phi\right] - W_r^S(i), \tag{10}$$

Imposing the free-entry condition on this monopolistically competitive sector with the equation in (10) and substituting the total mass of firms, we could find skilled workers' reward of an exporting firm in region r with a single-plant as,

$$W_r^S(i) = \frac{\mu}{\sigma}\left[\frac{Y_r}{\Delta_r} + \frac{Y_s}{\Delta_s}\phi\right]. \tag{11}$$

Using (5) and (11), we could perform the analysis on location equilibria with single-plant monopolistically competitive firms. Location equilibrium is derived from the comparison of real wage of skilled workers which can be written as,

$$\frac{\varpi_r^S}{\varpi_s^S} = \frac{W_r^S}{W_s^S}\left(\frac{\triangle_r}{\triangle_s}\right)^{\frac{\mu}{\sigma-1}}. \tag{12}$$

A stable location equilibria is associated with either a symmetric distribution of skilled workers between the two regions or the full agglomeration in one region of the two regions. The latter case is called the core-periphery structure, where $\lambda_1 = 1$, $\lambda_2 = 0$. Since all firms are located in one region, this region is called *core* and the other *periphery.* The critical values for trade freeness at which a symmetric equilibrium becomes stable to unstable under decreasing transportation costs, $\frac{d}{d\lambda_r}\left(\varpi_s^S/\varpi_r^S\right)\Big|_{\lambda_r=\frac{1}{2}} < 0$, is called the *symmetry break point* and given by

$$\phi_{sym} = \frac{\left(1 - \frac{\mu}{\sigma}\right)\left(1 - \frac{\mu}{\sigma} - \frac{1}{\sigma}\right)}{\left(1 + \frac{\mu}{\sigma}\right)\left(1 + \frac{\mu}{\sigma} - \frac{1}{\sigma}\right)}. \tag{13}$$

When the second term of numerator is negative, it means symmetric distribution never be equilibrium. We may call the condition where core-periphery structure is always dominant as black-hole condition and show $\sigma - \mu < 1$. Note that higher μ indicates larger expenditure on differentiated goods and smaller σ indicates a greater love for variety (hence, larger demand externalities) and more differentiation among the goods. When expenditure share and the love for variety of differentiated goods are larger (larger $\frac{\mu}{\sigma}$), firms and skilled workers have stronger incentives to agglomerate, both of symmetry break point and sustain point are to be lower. Thus we may call $\frac{\mu}{\sigma}$ as a *composite of agglomeration forces*, which appears throughout this paper. Holding the no-black-hole condition, $\sigma - \mu > 1$, the effect of composite of agglomeration forces is always negative and it means that when agglomeration forces are stronger, the less stable symmetric equilibrium is.

On the other location equilibrium, core-periphery structure, where all skilled workers stay in region r, is locally stable if $\left(\varpi_s^S/\varpi_r^S\right)\big|_{\lambda_r=1} < 1$. As transportation costs increase, core-periphery structure become unstable, $\left(\varpi_s^S/\varpi_r^S\right)\big|_{\lambda_r=1} > 1$. We define *sustain point* as the critical values for trade freeness at which the core-periphery equilibrium becomes unstable under increasing transportation costs, $\left(\varpi_s^S/\varpi_r^S\right)\big|_{\lambda_r=1} = 1$ and express sustain point by ϕ_{sus}. Then we could obtain the sustain point in the following implicit form:

$$1 + \frac{\mu}{\sigma}{\phi_{sus}}^2 + {\phi_{sus}}^2 - \frac{\mu}{\sigma} - 2{\phi_{sus}}^{1-\frac{\mu}{\sigma-1}} = 0. \tag{14}$$

Differentiating equation (14), we have $\frac{d}{d\mu}S(\phi) = -\frac{1}{\sigma}\left(1-\phi^2\right) + \frac{2\phi^{1-\frac{\mu}{\sigma-1}}}{\sigma-1}\ln\phi < 0$ and $\frac{d}{d\sigma}S(\phi) = \frac{\mu}{\sigma^2}\left(1-\phi^2\right) - 2\phi^{1-\frac{\mu}{\sigma-1}}\frac{\mu}{(\sigma-1)^2}\ln\phi > 0$.With these results, the effect comes from the composite of expenditure share and elasticity of substitution, $\frac{\mu}{\sigma}$, is clearly negative on the critical value for sustain point. It means that core-periphery structure is more sustainable when agglomeration forces are strong. The composite acts as agglomeration forces.

3 Location and organization choice

In this section, we study the location and organization choice of firms. We only modify the assumption on the number of plants. Introduction of multiplant firms means an additional choice for skilled workers. The share of skilled workers in multiplant firms and that of single-plant firms in region r $(=1,2)$ are denoted by, m_r and $(1-m_r)$, respectively. Nominal rewards to skilled workers in multiplant firms are assumed to be the same across regions. Following these specifications, we rewrite regional income in (5) as

$$Y_r = \frac{L}{2} + \left((1-m_r)\,W_r^S + m_r\,(1+\alpha)\,W^M\right)N\lambda_r. \tag{15}$$

Contrary to single-plant firms, multiplant firms can serve both regions without incurring transportation costs. While for single-plant firms they incur one unit of skilled workers as is assumed in the previous section, for multiplant firms they incur additional fixed requirements of skilled workers. This additional fixed costs to maintain an additional plant is expressed by α, which capture communication costs between plants and management costs for additional managers and engineers.

3.1 Multiplant producer

Multiplant firms are also assumed to be monopolistically competitive firms *à la Dixit-Stiglitz* and produce a differentiated good. The only modification from the single-plant exporter is that establishment of multiplant incurs additional fixed cost, $\alpha > 0$. This fixed costs, α, include the costs for maintaining a subsidiary in the other region and the duplicate overhead production costs.[4] For simplicity, we assume that all of the skilled workers in a given multiplant firm reside in one of the two regions (but not both).[5]

For the production, multiplant firms employ unskilled workers in both regions as variable input. Contrast to the cost function of single-plant firms, since multiplant firms locate in each region, the shipment of products by multiplant firms doesn't incur transportation costs, $\phi_{rr} = 1$ for $(r = 1, 2)$. Thus the trade-off between single- and multi-plant configuration is that between transportation costs (proximity) and the scale economies in single-plant (concentration). Taking each regional demand as given in (2), multiplant firms maximize their profit. Then the output and the profit function of a multiplant firm can be written as

$$
\begin{aligned}
q_{rr}^{M}(i) &= \left(\frac{P_r}{p_r(i)}\right)^{\sigma}\frac{\mu Y_r}{P_r}, &(16)\\
q_{r}^{M}(i) &= q_{rr}^{M}(i) + q_{ss}^{M}(i), &(17)\\
\pi^{M}(i) &= (p_r(i) - w_r)\,q_{rr}^{M}(i) - (p_s(i) - w_s)\,q_{ss}^{M}(i) - (1+\alpha)\,W^{M}(i), &(18)
\end{aligned}
$$

where superscript M indicates multiplant firms and W^M is a skilled workers' reward in multiplant firms. Since there is no location choice for multiplant firms, their profit

[4]Fujita and Gokan (2005) assume that the fixed cost of a multi-plant firm is larger than that for a single plant firm. Toulemonde (2008) lists several factors affect the fixed costs of a multinational.

[5]Since skilled workers obtain the same nominal wage under mulitplant firms, they reside in the region with the smaller cost of living, i.e., the smaller price index for differentiated goods. The possible symmetric distribution of skilled workers may occur only when everything is symmetric and can be a knife-edge case.

function and their wage for skilled worker do not include region specific subscript.[6] A multiplant firm producing variety i sets region-specific mill price to maximize profit $\pi^M(i)$ under discriminatory pricing. The optimal price is given by a markup over marginal costs as

$$p_r(i) = \frac{\sigma}{\sigma - 1}, \quad r = 1, 2. \tag{19}$$

Substituting the optimal prices into price index, instead of (7), we obtain the price index of the varieties sold in region r as

$$\begin{aligned} P_r^{1-\sigma} &= \sum_{o=M,S} \sum_{r=1,2} \int_0^{n_r^o} p(i)^{1-\sigma} d_i \\ &= N \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} [\lambda_r (1 - m_r) + \lambda_s (1 - m_s) \phi + (\lambda_r m_r + \lambda_s m_s)] \qquad (20) \\ &= N \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} \triangle_r \qquad (21) \end{aligned}$$

where n_r^o is the number of firms in region r whose organization type is o, $o =$ *multiplant (M)* and *single-plant (S)*. We put $\triangle_r$ as the bracketed term in price indices, (20), of region r. We explicitly express the shares of different organization types across regions by the distribution of skilled workers' residence and the share of each organization type in each region. In the bracketed term of (20), the first, second and third terms represent the share of goods supplied from region r, from region s and by multiplant firms, respectively. Then the equilibrium profits can be obtained as follows

$$\pi^M(i) = \frac{\mu}{\sigma N} \left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s} \right] - (1 + \alpha) W^M(i). \tag{22}$$

The wage of skilled workers are obtained from the zero profit condition, (22). Single-plant firms' offer to skilled workers are obtained from the same procedure as in (10) except that the price index is different. The free-entry condition should hold for any organization. Hence the condition becomes

$$\max \left\{ \pi_r^S(i), \pi_s^S(i), \pi^M(i) \right\} = 0. \tag{23}$$

Then, we obtain the skilled workers' reward for single-plant firm i and multiplant firm

[6]Note that the regional subscript for multi-plant firms are dropped since the symmetric technology implies the profit of the multi-plant firms as the same, $\pi_r^M(i) = \pi_s^M(i)$. There could be only the difference at the real wage for skilled workers.

j in region r as,

$$W_r^S(i) = \frac{\mu}{\sigma}\left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s}\phi\right], \tag{24}$$

$$W^M(j) = \frac{\mu}{\sigma(1+\alpha)N}\left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s}\right]. \tag{25}$$

Note that $1/\sigma$ in (24) and (25) reflects the share of skilled worker's reward in profit. Under the same organization, assuming the symmetry of firms in monopolistically competitive sector, without loss of generality, we drop the individual index of i and j.[7] Using five equations, (15), (24) and (25) , W_A^S, W_B^S, W_r^M, Y_A, and Y_B can be derived explicitly (See Appendix II). Then we obtain the relative real wages across regions and organizational patterns as follows:

$$\frac{\varpi_r^S}{\varpi_r^M} = \frac{W_r^S}{W^M},\ \frac{\varpi_r^S}{\varpi_s^M} = \frac{W_r^S}{W^M}\left(\frac{\triangle_r}{\triangle_s}\right)^{\frac{\mu}{\sigma-1}},\ \frac{\varpi_s^S}{\varpi_r^S} = \frac{W_s^S}{W_r^S}\left(\frac{\triangle_s}{\triangle_r}\right)^{\frac{\mu}{\sigma-1}}, \tag{26}$$

$$\frac{W_r^S}{W^M} = \frac{\phi\triangle_r + \triangle_s + \frac{\mu}{\sigma}(\lambda_r m_r + \phi\lambda_s m_s)(1-\phi) - \frac{\mu}{\sigma}\lambda_s(1-\phi)(1+\phi)}{\triangle_r + \triangle_s - \frac{\mu}{\sigma}\lambda_r(1-m_r)(1-\phi) - \frac{\mu}{\sigma}\lambda_s(1-m_s)(1-\phi)}\Gamma, \tag{27}$$

$$\frac{W_s^S}{W_r^S} = \frac{\triangle_r + \phi\triangle_s + \frac{\mu}{\sigma}(1-\phi)(\phi\lambda_r m_r + \lambda_s m_s - \lambda_r(1+\phi))}{\phi\triangle_r + \triangle_s + \frac{\mu}{\sigma}(1-\phi)(\lambda_r m_r + \phi\lambda_s m_s - \lambda_s(1+\phi))}, \tag{28}$$

where $\Gamma \equiv 1+\alpha$. In a region, both types of organization can exist only when $\varpi_r^M = \varpi_r^S\ \left(= W_r^S = W_r^M\right)$ holds. Since the price indices are identical in the same region, comparison of real wages in the same region is boiled down into that of nominal wages. On the other hand, when all firms are either single-plant or multiplant in a region, equilibrium wage condition is $W_r^S > W^M$, or $W^M > W_r^S$, respectively.

3.2 Location equilibrium

Unlike the standard NEG models, there are two choices for firms to be considered; location and organization. The timing of the decisions follows in the two steps. First, given the location of skilled workers, firms choose its location. Second,for the given location, organization is determined. Using (26) to (28), the indirect utility differentials on locations or organizations are defined. Since we have three variables which determine

[7] In each case, the labour market clearing condition of skilled workers implies the total mass of firms as $N = 1$ for the case of single-plant firms and $N = 1/(1+\alpha)$ for the case of multi-plant firms. Note that, obviously, the number of firms under all-multi-plant-firms case is smaller than that under all-single-plant-firms case. On the other hand, when both types co-exist, the total mass of firms is given by $N = \frac{1}{\lambda_1(1-m_1)+\lambda_2(1-m_2)+(1+\alpha)(\lambda_1 m_1+\lambda_2 m_2)}$.

the equilibrium, λ,[8] m_r, and m_s, this system of equations is highly complicated.

If the offered wage of a firm is less than the others', the firm cannot enter or remain the market because of the lack of fixed requirement. Organization of firms is determined according to profit maximization. Clearly, when the operational profit (and hence the bid wage for skilled workers) is larger for a given organization, this organization is adopted. Otherwise, both organizations coexist, $\varpi_r^S = \varpi_r^M$. An organization equilibrium is stable if, for any marginal deviation from the equilibrium, the ordering of real wages under different organization choices is unchanged. An organization and location equilibrium is defined by a set of payoffs $\left\{\varpi_r^S(i), \varpi_s^S(i), \varpi_r^M(i), \varpi_s^M(i)\right\}$ and outcomes of organization type in terms of the share of multiplant firms in core-region, m_r and m_s.

Due to the complexity of equilibrium, we focus on core-periphery structure and the organization equilibrium. Similarly to the previous section, the sustainability condition of core-periphery structure is expressed as $\left(\varpi_s^S/\varpi_r^S\right)\big|_{\lambda_r=1} < 1$. The critical value as *sustain point* changes from the one in (14) to the one as,

$$\begin{aligned}
&\left.\frac{\varpi_s^S}{\varpi_r^S}\right|_{\lambda_r=1} - 1 \equiv \Theta\left(m_r, \phi_{sus}^M\right) \\
&= \left(\phi_{sus}^M\left(1-\phi_{sus}^M\right)\left(1+\tfrac{\mu}{\sigma}\right)m_r + \left(1+\left(\phi_{sus}^M\right)^2 - \tfrac{\mu}{\sigma}\left(1-\phi_{sus}^M\right)\left(1+\phi_{sus}^M\right)\right)\right) \\
&\qquad - \left(m_r\left(1-\phi_{sus}^M\right)+\phi_{sus}^M\right)^{-\frac{\mu}{\sigma-1}}\left(\left(1-\phi_{sus}^M\right)\left(1+\tfrac{\mu}{\sigma}\right)m_r + 2\phi_{sus}^M\right) = 0.
\end{aligned} \tag{29}$$

As long as transportation costs, ϕ, holds the range of $\Theta(m_r, \phi) < 0$, the core-periphery structure is sustainable. Note that this expression doesn't contain the term of cost differential between single and multi plant firms but contain the share of multi-plant only. This is because above equation is location choice of single-plant firms not organization choice between single and multi plant firms, whose determination is shown in the next section. When there is no multi-plant firms, $m_r = 0$, the expression in (29) is boiled down into (14). Detailed derivation is in Appendix III. In order to examine the effect of multi-plant, we obtain the difference and its derivative of (29), compare the sustain point under all-single plant, ϕ_{sus}^S, and under multi-plant, ϕ_{sus}^M. Then we have $\phi_{sus}^M < \phi_{sus}^S$ for $\forall m_r \in (0,1]$. Summarizing the above results, we have the following proposition.

Proposition 1 *Presence of multiplant firms unambiguously decrease the sustain point.*

As is stated in Proposition 1, the presence of multiplant firms makes the core-

[8] Note that we put $\lambda \equiv \lambda_r$ since $\lambda_r + \lambda_s = 1$ in two region model.

periphery structure more sustainable. For a given $\phi < \phi^S_{sus}$, the share of multiplant firms which satisfies (29) can be interpreted as the minimum share of multiplant firms which insures core-periphery structure, which is analyzed in the next section. From these conditions, we understand that the possible unstability of core-periphery structure may arise only if $\phi < \phi^S_{sus}$ and if m_r is smaller than the minimum value, which appears in footnote 10.

3.3 Organization equilibrium

We consider core-periphery structures of regions where skilled mobile workers stay in one region and number the core region as *1* and periphery as *2*. In order to clarify the possible organization changes, we identify critical values for three organization cases; all-firms-multiplant, mixed, and all-firms-single-plant. Using (26) and (27), and evaluating each equations for the two extreme case that all firms are the same organization type, then we obtain the following critical values respectively;

$$\begin{aligned} \left.\frac{W_1^S}{W^M}\right|_{m_1=1} &= \frac{(1+\alpha)}{2}\left(1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)\right) \lesseqgtr 1 \\ &\Leftrightarrow \phi \gtreqless \phi^M = \frac{\left(1-\frac{\mu}{\sigma}\right)-\alpha\left(1+\frac{\mu}{\sigma}\right)}{(1+\alpha)\left(1-\frac{\mu}{\sigma}\right)}, \qquad (30) \\ \left.\frac{W_1^S}{W^M}\right|_{m_1=0} &= \frac{2(1+\alpha)\phi}{\left(1-\frac{\mu}{\sigma}\right)+\left(1+\frac{\mu}{\sigma}\right)\phi} \lesseqgtr 1 \\ &\Leftrightarrow \phi \lesseqgtr \phi^S = \frac{1-\frac{\mu}{\sigma}}{1-\frac{\mu}{\sigma}+2\alpha}. \qquad (31) \end{aligned}$$

We define ϕ^M as the critical value for trade freeness below which all the firms are multiplant and ϕ^S as the one above which all firms are single-plant. For a given additional fixed costs, ϕ^M and ϕ^S determine the boundaries that all firms are the same organization or not. The solid lines depict ϕ^M and the dashed lines depict ϕ^S, respectively. The possible organization configuration is described in Figure 1.[9]

From (30) and (31), we could observe there are two forces at work. One is the mag-

[9]The parameters to be specified follows the average of the estimation results in Table 4 by Hanson (2005) as $\sigma = 2.11$, and $\mu = 0.71$. Under these specifications, we have the break point in (13) and sustain point (14) as 0.109 and 0.047. The sustain point, ϕ^S_{sus},is indicated by dotted line.

In order to insure the existence of sustain point, we check the stability of core-periphery structure by utilizing (29). Avoiding black-hole condition, $1 > \frac{\mu}{\sigma-1}$, core-periphery structure may be unstable when transportation costs are very high. As is stated in Proposition 1, some presence of multiplant firms makes core-periphery structure more stable. In other words, some portion of multiplant firms are needed to be stable core-periphery structure. We can check this condition by substituting $\phi = 0$ into $\Theta(m_r, \phi)$ and solving for m_r. Then we have the minimum share of multiplant firms which insures

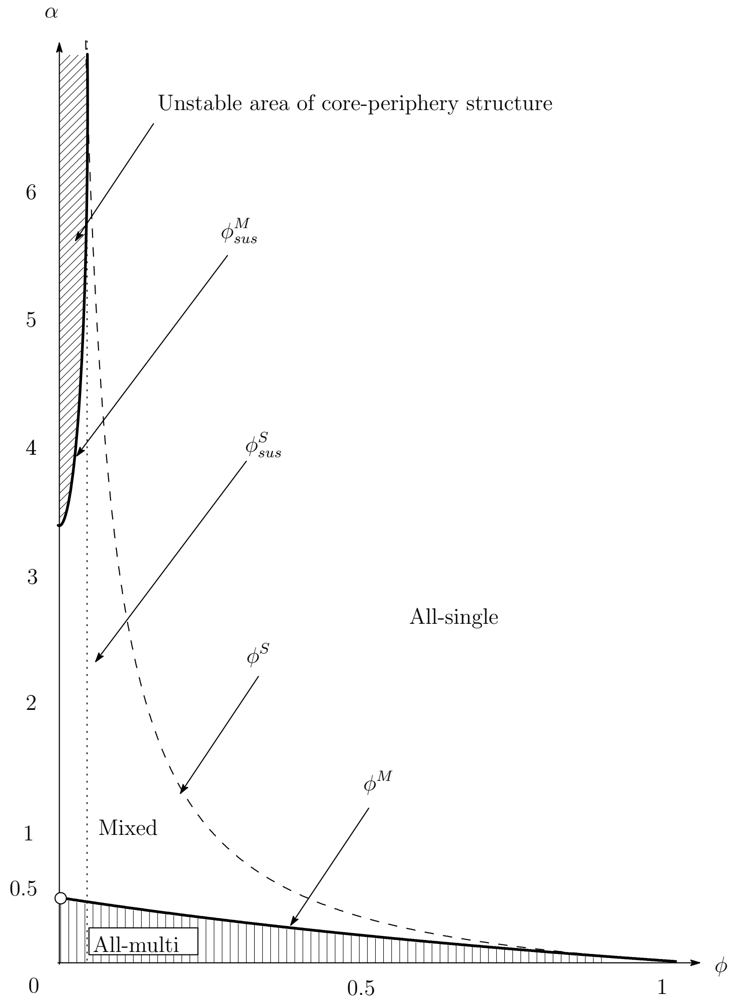

Figure 1: Organization configration

nitude of additional fixed costs, α, and the other is the agglomeration force, $\frac{\mu}{\sigma}$, which also appears in symmetry break point in (13) and expresses the market size in terms

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core-periphery structure as,

$$m_r = \left(\frac{1-\frac{\mu}{\sigma}}{1+\frac{\mu}{\sigma}}\right)^{\frac{1}{1-\frac{\mu}{\sigma-1}}}.$$

When the share of multiplant is smaller than the minimum value, core-periphery structure is unstable at $\phi = 0$. For a given $\phi < \phi^S_{sus}$, the munimum value can be obtained numerically and be characterized by m_r which satisfies $\Theta(m_r, \phi) = 0$. As is obtained in Appendix IV, the share of multiplant firms is a decreasing function of transportation costs and additional fixed costs. Thus the unstable area of core-periphery structure should be bounded by ϕ^S_{sus}, ϕ^M_{sus} and vertical axis, which is shown in Figure 1. ϕ^M_{sus} is indicated by solid line. Note when $1 < \frac{\mu}{\sigma-1}$, m_r exceeds its permissible range. This is the case of black-hole condition where core-periphery structure is always stable. The minimum share of multiplant which insures core-periphery structure is 14.3% when $\alpha = 3.466$ at $\phi = 0$. As the comparative statics of m_1 is shown in appendix, higher additional costs and transportation costs decrease the share of multiplants. Thus as transportation costs decreases, the minimum share of multiplant at a given transportation costs is smaller than the one at $\phi = 0$. In this sence, the one obtained above can be called *the maximum of minimum share of multiplant firms.*

of expenditure share and the degree of differentiation among products. The two forces clearly show the proximity-concentration trade off. While when trade freeness is low, multiplant is adopted to be close to the markets, when trade freeness is high, concentration of plants as single-plant firm is adopted. However, when the additional fixed costs is so high, only some firms can adopt multiplant. From (30), if cost differential between single-plant and multiplant is large, $\alpha > \left(1-\frac{\mu}{\sigma}\right)/\left(1+\frac{\mu}{\sigma}\right)$, then ϕ^M always takes negative values and all-firms-multiplant case never happens.

As the additional fixed costs becomes smaller, the ranges that all firms are multiplant expands. For $\phi < \phi^M$, all firms are multiplant and for $\phi^S < \phi$, all firms choose to locate in core-region and be single-plant. Thus when firms face decreasing transportation costs, the organization configuration goes through mixed case to all-single case. Decreasing transportation costs makes the the magnitude of agglomeration force larger and induce the share of multiplant firms smaller. For the range of $\phi^M < \phi < \phi^S$, since some firms are single-plant, this is the mixed configuration of organizations.[10] Thus we could find that *there are always incentives for some firms to be multiplant.* When transportation costs are high, firms have incentives to be multiplant. Above discussions could be summarized by the following proposition. Moreover, since ϕ^M_{sus} and ϕ^S_{sus} is continuous at $m_r = 0$, the intersection of ϕ^S_{sus} and ϕ^S coincides the one with ϕ^M_{sus}.

Proposition 2 *For a given additional fixed costs,* $\alpha \in (0,1]$, *firms choose their organization as,*

i) if $0 < \phi < \phi^M$, *all firms are multiplant,*

ii) if $\phi^M < \phi < \phi^S$, *multiplant and single-plant firms are mixed,*

iii) if $\phi^S < \phi < 1$, *all firms are single-plant.*

See the proof in Appendix IV. Conducting comparative statics, we have $\frac{d}{d\alpha}\phi^M = -\frac{2}{(1+\alpha)^2\left(1-\frac{\mu}{\sigma}\right)} < 0$, $\frac{d}{d\alpha}\phi^S = -\frac{2\left(1-\frac{\mu}{\sigma}\right)}{\left(1-\frac{\mu}{\sigma}+2\alpha\right)^2} < 0$. Increase in the additional fixed costs induce both critical values smaller and makes the ranges for all-firms-multiplant shrinks. If cost structure of multiplant and single-plant is such that $\alpha \leq 0$, then multiplant organization is always dominant. Note when $\alpha = 0$, we have $\phi^M = \phi^S = 1$ but the possibility of single-plant is measure zero at $\phi = 1$. Moreover, we have $\frac{d}{d\frac{\mu}{\sigma}}\phi^M = -\frac{2\alpha}{(1+\alpha)\left(1-\frac{\mu}{\sigma}\right)^2} < 0$, $\frac{d}{d\frac{\mu}{\sigma}}\phi^S = -\frac{2\alpha}{\left(1-\frac{\mu}{\sigma}+2\alpha\right)^2} < 0$. When the products are more differentiated and their expenditure share is larger, the ranges for all-firms-multiplant shrinks, as well. These results are consistent with the prediction of the facts mentioned in the

[10]There is always one critical value of ϕ^S and it exhibits inverse proportion which doesn't cross alpha-axis. So there are always the ranges for the coexistence of single-plant exporter and multiplant. The uniquness of the solution is shown in Appendix IV.

introduction that secondary and tertiary sector, which produce more differentiated products than agriculture have larger share of mulit-establishment.

It should be mentioned on organization equilibrium under unstable area of core-periphery structure. The conditions of unstable core-periphery structure is that transportation costs are higher than sustain point and that share of multiplant is smaller than its minimum value. The former is the necessary condition and implies $\omega_2^S > \omega_1^S$. The latter implies that the organization configuration is mixed, $W_1^M = W_1^S$. Additionally, since periphery region needs to import all the manufactured goods produced by single plant firms, its price index is higher, $P_2 > P_1$. Thus we have $\frac{\omega_2^M}{\omega_1^M} = \frac{P_1 W^M}{P_2 W^M} = \frac{P_1}{P_2} < 1$. From these conditions, when core-periphery structure is unstable, we have

$$\omega_2^S > \omega_1^S = W_1^S = W_1^M = \omega_1^M > \omega_2^M. \tag{32}$$

4 Generalization

Before dealing with generalization, let us summarize our main results. When we consider organization choice in a two-region model, as is shown in the previous section, we could find three organization configurations under core-periphery structure; all-multiplant , mixed, and all-single-plant. From the critical values of organization configuration in (30) and (31), the proximity-concentration tradeoff is observed and always exists.

It would give us sufficient discussions to examine more on the specification of the additional fixed costs for multiplant firms. Until previous sections, we assumed constant fixed costs on both types of organization. However, it might be reasonable to think the fact that high transportation costs could be applied not only for goods transportation but also for establishment of secondary plants, transfer of managers, and supplemental communication across borders. Due to cultural and language differences, managers may confront communication difficulties with local unskilled workers and unexpected extra works for the resolutions. Tastes difference in each market needs further investment in research and development activities in which skilled workers engage. Such additional fixed costs can be captured as a function of broadly defined transportation costs which include communication costs as well. In order to capture these aspects, differently from the constant additional fixed costs case, (18), we simply reformulate the fixed cost to have another plant to be $\alpha\phi^{-b}$ so that the profit of a multiplant firm can be rewritten as,

$$\pi^M(i) = (p_r(i) - w_r)\, q_{rr}^M(i) - (p_s(i) - w_s)\, q_{ss}^M(i) - \left(1 + \alpha\phi^{-b}\right) W^M(i), \tag{33}$$

For a better notation, we define the difference in fixed costs as $\Gamma \equiv \left(1 + \alpha\phi^{-b}\right)$. The demand functions are unchanged as in the last section, (16) and (17). Then the profit maximization yields the same price as in (19). Substituting this optimal price into profit function and price index, normalization of labour wage in competitive sector as one, $w_r = w_s = 1$, the equilibrium profits under a given distribution of firms can be obtained as follows,

$$\pi^M(i) = \frac{\mu}{\sigma N}\left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s}\right] - \Gamma W^M(i), \tag{34}$$

where $\triangle_r$ and $\triangle_s$ expresses the brackets of price indices in region r and s, $P_r = \triangle_r^{\frac{1}{1-\sigma}}$, which is the same as the last section[11]. Applying the zero profit condition on this profit function, we obtain the wage of skilled workers as follows,

$$W^M(j) = \frac{\mu}{\sigma\Gamma N}\left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s}\right]. \tag{35}$$

Moreover, regional income is expressed not as in (15) but as

$$Y_r = \frac{L}{2} + \left((1 - m_r) W_r^S + m_r \Gamma W^M\right) N\lambda_r.$$

Again, skilled workers seek for the firm which offers highest rewards. Since the reformulation in the additional fixed costs, Γ, doesn't affect neither the system of equations listed in $(A1)$ nor the solutions in $(A2)$, we could fully utilize the previous results in Appendix V[12] and we obtain the nominal wage differential as

$$\left.\frac{W_1^S}{W^M}\right|_{m_1=1} = \frac{\Gamma}{2}\left(1 + \frac{\mu}{\sigma} + \left(1 - \frac{\mu}{\sigma}\right)\phi\right) = 1 \tag{36}$$

$$\left.\frac{W_1^S}{W^M}\right|_{m_1=0} = \frac{2\Gamma\phi}{\left(1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi\right)} = 1 \tag{37}$$

[11]Note that the size of firms changes as $N = \frac{1}{\lambda_1(1-m_1)+\lambda_2(1-m_2)+\Gamma(\lambda_1 m_1+\lambda_2 m_2)}$ when both types co-exisit, $N = \frac{1}{\Gamma(\lambda_1 m_1+\lambda_2 m_2)}$ when all-multiplant firms case.

[12]As is shown in appendix, the systems of equations in Sections 3 and 4 are identical except the specification in the cost differential, Γ. Thus when we could obtain the result by using (27). Note that $\Gamma \in [0,1]$, since $\Gamma > 0$ and $\Gamma - 1 = -\alpha\phi^{-b}/(1 + \alpha\phi^{-b}) < 0$.

Substituting $\Gamma \equiv \left(1+\alpha\phi^{-b}\right)$, critical values of ϕ consistent with $W_1^S = W^M$ for (36) and (37) are obtained in the following implicit form;

$$\begin{aligned} \frac{\left(\phi^M\right)^b \left(1-\phi^M\right)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi^M\left(1-\frac{\mu}{\sigma}\right)} &= \alpha, & (38) \\ \frac{1}{2}\left(\phi^S\right)^{b-1}\left(1-\phi^S\right)\left(1-\frac{\mu}{\sigma}\right) &= \alpha, & (39) \end{aligned}$$

respectively. To illustrate the result, Figure 2 depicts the case of $b = 1$, $\Gamma \equiv 1 + \alpha\phi^{-1}$ where additional fixed costs is a function of trade costs. From this figure, when additional fixed costs is relatively low with decreasing trade costs, we could observe non-linear configuration of organizations, which starts from mixed case and moves to all-multiplant, all-multiplant to mixed and mixed to all-single. The condition for this organization configuration is $\alpha < \phi(1-\phi)\left(1-\frac{\mu}{\sigma}\right) / \left(1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)\right)$, which is the case of $b = 1$ of (38). Then we have two critical values of ϕ^M and between the two critical values, there is organization configuration that *all firms are multiplant*. On the other hand, when additional fixed costs is relatively high, organization changes from mixed into all-single, monotonically. Note on the stable range of core-periphery structure, as is in the previous section, the intersection of ϕ^S_{sus} and ϕ^S coincides the one with ϕ^M_{sus}. For further discussion, in Figure 3 we show the critical values of ϕ under different values of b. The effect of transportation costs on additional fixed costs of multiplant may be more than proportional. Such cases are described in this figure. When the parameter of additional fixed costs, α, is large, the organization configuration that all firms are single plant is dominant and no possible organization change. When it is smaller, we could confirm that possible organization configuration of three types (all-multi, mixed, and all-single). The unstable area of core-periphery structure is omitted in Figure 3 for clarity but the property is the same as previous ones. When transportation costs are very high, firms cannot establish multiplant due to high additional fixed costs so they export. With decreasing transportation costs, firms don't export but establish multiplant. With further decrease in transportation costs, the economies of scale in single-plant become sufficient and afford transportation costs so that firms choose to concentrate their production into single location. The results fully describe the proximity-concentration tradeoff of reality. In certain ranges of α, we could confirm that organization change occurs as single-plant to multiplant and multiplant to single-plant. The possible organization configurations are from all-single to mixed, mixed to all-multi, and vice versa. If $\alpha \le \phi^b \frac{(1-\phi)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)}$ holds, there is at least one critical value of

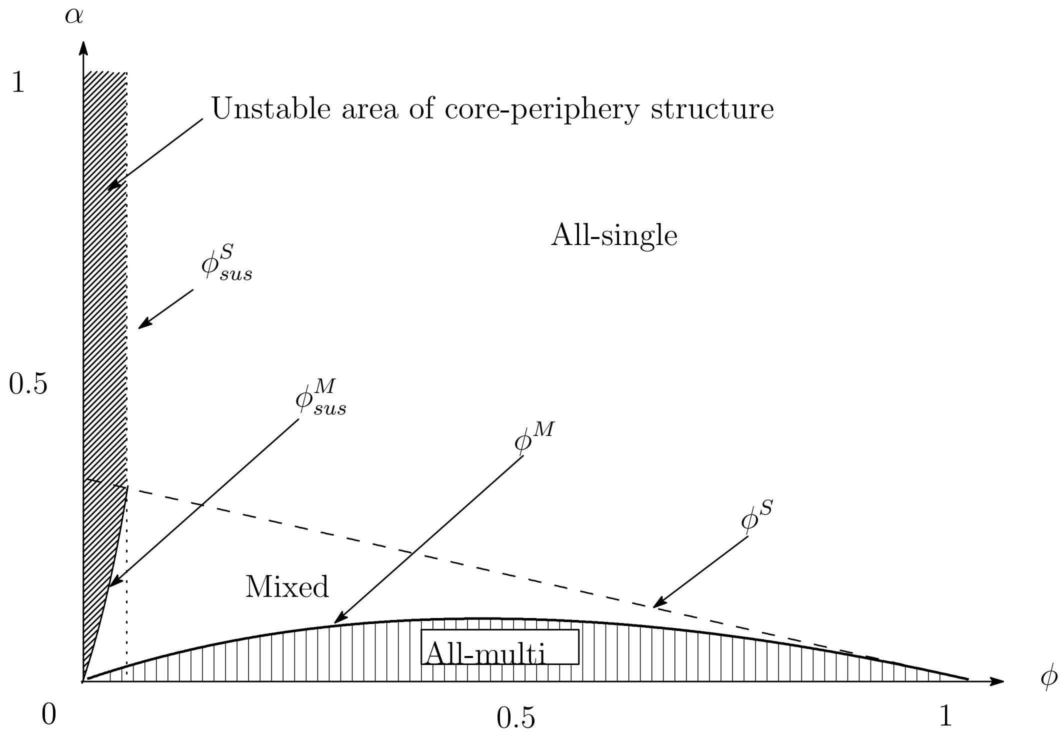

Figure 2: Organization configration when $b = 1$

ϕ^M and three organization configurations. If $\alpha \leq \frac{1}{2}\phi^{b-1}(1-\phi)\left(1-\frac{\mu}{\sigma}\right)$ holds, there is at least one critical value of ϕ^S and at least two organization configurations. Note that when $\phi^b \frac{(1-\phi)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)} < \alpha \leq \frac{1}{2}\phi^{b-1}(1-\phi)\left(1-\frac{\mu}{\sigma}\right)$ hold, we have mixed case guaranteed by $\omega_1^S = \omega_1^M$ and the share of multiplant firms can be written as $m_1 = \frac{2\Gamma\phi - \phi\left(1+\frac{\mu}{\sigma}\right) - \left(1-\frac{\mu}{\sigma}\right)}{(1-\phi)(1-\Gamma)\left(1+\frac{\mu}{\sigma}\right)}$. For detailed derivation, see Appendix V. Summarizing the above discussions leads the following proposition.

Proposition 3 *Suppose that the additional fixed costs for multiplant is a function of transportation costs,* $\left(1+\alpha\phi^{-b}\right)$.

i) if $\alpha \leq \phi^b \frac{(1-\phi)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)}$ *holds, all-multiplant organization is dominant.*

ii) if $\phi^b \frac{(1-\phi)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)} < \alpha \leq \frac{1}{2}\phi^{b-1}(1-\phi)\left(1-\frac{\mu}{\sigma}\right)$ *holds, organization is mixed between single-plant and multiplant.*

iii) if $\alpha > \frac{1}{2}\phi^{b-1}(1-\phi)\left(1-\frac{\mu}{\sigma}\right)$ *holds, single-plant organization is dominant.*

Compared to the results in the previous section, we find the possible organization changes from single-plant into multiplant and multiplant to single plant. If the cost differential between the two organizations is small enough, the range of multiplant firms is larger. On the other hand, when the cost differential is larger, single-plant

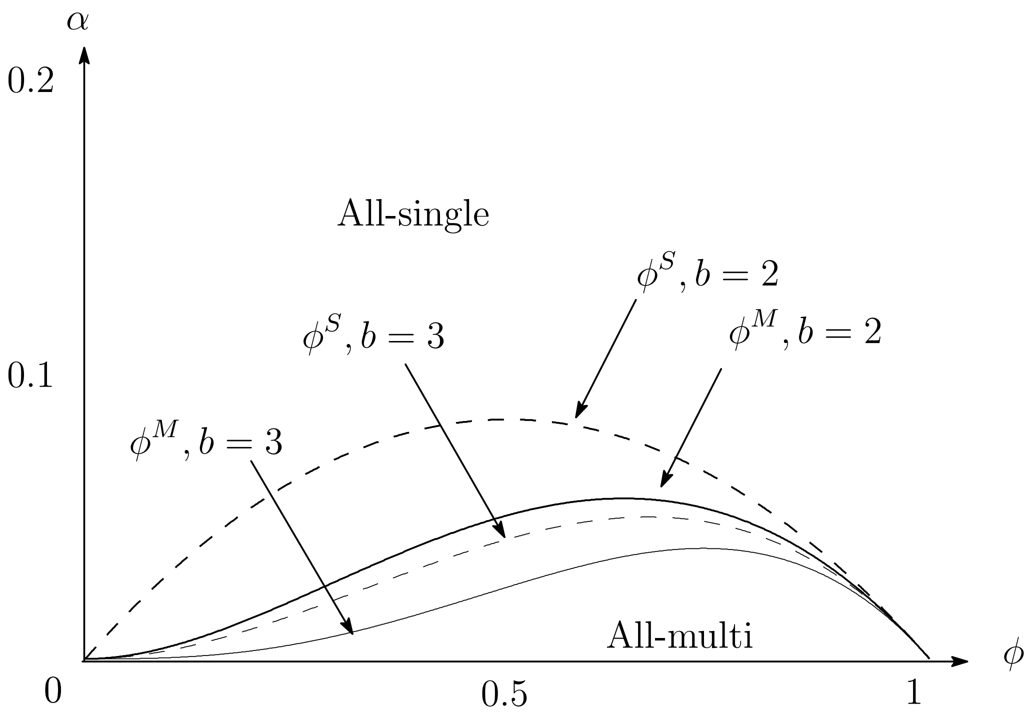

Figure 3: Organization configrations for several cases

is organizationally dominant. In the other words, for smaller additional fixed costs, α, more likely firms become multiplant. Differently from the previous studies in the literature, from the generalized analysis, we observe non-monotonic organization change as single-plant to multiplant and from multiplant to single-plant. In the other words, when $\alpha \leq \phi^b \frac{(1-\phi)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)}$ holds, there are three organizations, all-single, mixed and all-multiplant. When $\phi^b \frac{(1-\phi)\left(1-\frac{\mu}{\sigma}\right)}{1+\frac{\mu}{\sigma}+\phi\left(1-\frac{\mu}{\sigma}\right)} < \alpha \leq \frac{1}{2}\phi^{b-1}(1-\phi)\left(1-\frac{\mu}{\sigma}\right)$ holds, there are mixed organization and single-plant. Otherwise, there are always all-single plant organization.

5 Conclusion

The globalization and the development of transportation and information technologies can be characterized by lower transportation costs of factors. At the same time, it is not negligible that there is a certain presence of multiplant firms in international and regional economies. In order to focus on the behavior and organization of multiplant, we explicitly relax the implicit and typical assumption on the solitariness of firms' organization in monopolistic competition. In particular, we focus on the case which starts from the core-periphery structure; all skilled workers locates in one region.

Firstly, we show that the decrease in transportation costs induce firms concentrate their production from multiplant into a single-plant in all cases. As Ekholm and Forslid (2001) pointed out, "the fact that trade costs and the degree of multiplant economies of scale may change simultaneously has important implications". We show that the combination of transportation costs and the cost differential between the two organization crucially affects the organization change. This is consistent with the simulation results in Markusen and Venables (1998). In the next step, we specify the additional fixed costs to be multiplant as a function of transportation costs. Then we could observe the organization change not only from multiplant into single-plant but also single-plant to multiplant. Intuitively, most of the histories of multiplant (multinational) firms would be such that firstly a firm was established in a region, served the region domestically, gradually started exporting from there, subsequently established secondary plants in the other regions, and later concentrated some of the plants into a few. Our generalized results that firms change their organization non-monotonically could explain this intuitive history of multiplant (multinational) firms. In our model, the regions are symmetric except mobile skilled workers. Introduction of asymmetric wage could capture the other motivations which is not examined in this paper, c.f. cheaper-wage-seeking vertical FDI. In empirical analysis following Brainard (1997), it sometimes occurs that the coefficients of tariff and transportation costs are insignificant or wrong sign. These may capture the nonlinear effects of broadly defined trade costs on fixed requirements as shown in the previous section.

From our analysis, some analytical results are emphasized. Firstly, the difference in fixed costs between single-exporter and multiplant firm influences on the stability of core-periphery structure. When it is easier to become multiplant, lower additional establishment costs, then core-periphery structure is more sustainable than the case without multiplant firms. When establishment costs becomes lower, more firms choose multiplant. Secondly, under core-periphery structure, we show that there is a range of transportation costs where there is mixed organization and that the cost differential between two organization and agglomeration forces exhibit the proximity-concentration trade off. Thirdly, nonlinear effect of transportation costs on fixed costs could show non-monotonic organization change. Through our analysis, we could confirm that transaction costs unambiguously affects not only the location choice of firms but also affects their organization choice.

More detailed analysis would show some more interesting possibilities. There would be other formulation on the differences of transaction costs in different organization. In particular, in our model, the role of establishment costs needs managers or skilled workers. They are assumed to consume in the region of their residency, or say the place of headquarter. However, in the process of establishment of multiplant, many managers are sent to the region and sometimes they spend more than ten years. It might be one way to change the assumption on the location of consumption. Hence, it would be interesting to relax single-location assumption for skilled workers in multiplant firms. Such extensions is left for the future work.

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Appendix I

Using four equations, $(5),(11)$,and the corresponding equations for the other region, we obtain W_1^S, W_2^S, Y_1, Y_2 explicitly.

$$\left.\begin{array}{c} W_1^S = \frac{\mu}{\sigma}\left[\frac{Y_1}{\triangle_1} + \frac{Y_2}{\triangle_2}\phi\right], \\ W_2^S = \frac{\mu}{\sigma}\left[\frac{Y_1}{\triangle_1}\phi + \frac{Y_2}{\triangle_2}\right], \\ Y_1 = \frac{1}{2} + \lambda W_1^S, \\ Y_2 = \frac{1}{2} + (1-\lambda) W_2^S, \end{array}\right\}$$

where $\Delta_1 = [\lambda + (1-\lambda)\phi]$, $\Delta_2 = [\lambda\phi + (1-\lambda)]$. Note that since $H = L = 1$ and $N = 1$. This yields a unique solution as,

$$\left.\begin{array}{c} Y_1 = \frac{\triangle_1\left(\triangle_2 - \frac{\mu}{\sigma}((1-\lambda)-\lambda\phi)\right)}{2\Phi_S}, \\ Y_2 = \frac{\triangle_2\left(\triangle_1 - \frac{\mu}{\sigma}(\lambda+(1-\lambda)\phi)\right)}{2\Phi_S}, \\ W_1^S = \frac{\mu}{\sigma}\frac{\phi\triangle_1+\triangle_2-\frac{\mu}{\sigma}(1-\phi)(1+\phi)(1-\lambda)}{2\Phi_S}, \\ W_2^S = \frac{\mu}{\sigma}\frac{\triangle_1+\phi\triangle_2-\frac{\mu}{\sigma}\lambda(1-\phi)(1+\phi)}{2\Phi_S}, \end{array}\right\}$$

where $\Phi_S = \triangle_1\triangle_2 - \frac{\mu}{\sigma}(1-\lambda)\triangle_1 - \frac{\mu}{\sigma}\lambda\triangle_2 + \left(\frac{\mu}{\sigma}\right)^2 \lambda(1-\phi)(1+\phi)(1-\lambda)$.

Appendix II

We set the share of single-plant firms and that of multiplant firms as $(1-m_r)$ and m_r, $r = 1, 2$ and put $\Gamma \equiv (1+\alpha)$. Note that, for simpler notation, we set the share of firms in each region as λ_r, where $\sum_r^2 \lambda_r = 1$.

$$\left.\begin{array}{c} W_r^S = \frac{\mu}{\sigma N}\left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s}\phi\right], \\ W^M = \frac{\mu}{\sigma\Gamma N}\left[\frac{Y_r}{\triangle_r} + \frac{Y_s}{\triangle_s}\right], \\ Y_r = \frac{L}{2} + \lambda_r(1-m_r) W_r^S + \lambda_r m_r \Gamma W^M, \end{array}\right\} \tag{A1}$$

where $\triangle_r = \lambda_r(1-m_r) + \lambda_s(1-m_s)\phi + (\lambda_r m_r + \lambda_s m_s)$. Since there are five unknown variables with five equations, we obtain a unique solution. Wages for each firms are as follows

$$\left.\begin{array}{c} W_1^S = \frac{\frac{\mu}{\sigma}\left(\phi\triangle_1+\triangle_2+\frac{\mu}{\sigma}(1-\phi)(\lambda_1 m_1+\phi\lambda_2 m_2-\lambda_2(1+\phi))\right)}{2N\Phi_M} \\ W_2^S = \frac{\frac{\mu}{\sigma}\left(\triangle_1+\phi\triangle_2+\frac{\mu}{\sigma}(1-\phi)(\phi\lambda_1 m_1+\lambda_2 m_2-\lambda_1(1+\phi))\right)}{2N\Phi_M} \\ W^M = \frac{\frac{\mu}{\sigma}\left(\triangle_1+\triangle_2-\frac{\mu}{\sigma}(1-\phi)(\lambda_1(1-m_1)+\lambda_2(1-m_2))\right)}{2\Gamma N\Phi_M} \end{array}\right\} \tag{A2}$$

where $\Phi_M = \triangle_1\triangle_2 - \frac{\mu}{\sigma}\lambda_1\triangle_2 - \frac{\mu}{\sigma}\lambda_2\triangle_1 + \left(\frac{\mu}{\sigma}\right)^2\lambda_1\lambda_2(1-\phi)(\phi(1-m_2)(1-m_1)+1-m_1m_2)$. As is expected, when all firms are single plant, $m_1 = m_2 = 0$, this denominator is identical to the one in the previous section, Φ_S, and wage equations as well.

Appendix III

Since sustain points are not obtained analytically, we define them implicitly. In order to examine the effect from the existence of multi-plant firms to location equilibrium under core-periphery structure, we compare the sustain point under all-single plant, ϕ^S_{sus}, and under multi-plant, ϕ^M_{sus}. Precisely, we obtain the derivative of implicit function of sustain point, $\Theta(m_r, \phi)$, and show $\frac{d}{dm_r}\Theta(m_r,\phi)\Big|_{m_r=0} < 0$ at $\phi = \phi^S_{sus}$.

Proof. Using the equations $(A2)$ listed in Appendix II, we have the sustainability condition, $\left(\varpi^S_s/\varpi^S_r\right)\big|_{\lambda_r=1} < 1$, and the sustain point as

$$(m_r(1-\phi)+\phi)^{\frac{\mu}{\sigma-1}}\frac{\phi(1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_r+\left(1+\phi^2-\frac{\mu}{\sigma}(1-\phi)(1+\phi)\right)}{(1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_r+2\phi} = 1.$$

Rearranging this equation, we could implicitly define the sustain point, ϕ^M_{sus}, transportation costs, which satisfy the following equality and guarantee the core-periphery structure, as

$$\Theta(m_r,\phi) \equiv \left(\phi(1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_r + \left(1+\phi^2-\frac{\mu}{\sigma}(1-\phi)(1+\phi)\right)\right) - (m_r(1-\phi)+\phi)^{-\frac{\mu}{\sigma-1}}\left((1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_r+2\phi\right) = 0.$$

Note that $\Theta(0,0) = 1-\frac{\mu}{\sigma}$, $\Theta(0,1) = 0, \Theta(1,0) = -2\frac{\mu}{\sigma}$, and $\Theta(1,1) = 0$. The sustain point for all-single plant in (14), ϕ^S_{sus}, is obtained by specifying $m_r = 0$ as, $\Theta(0,\phi) \equiv \left(\phi^2 - \frac{\mu}{\sigma}(1-\phi)(1+\phi)+1\right) - 2\phi^{1-\frac{\mu}{\sigma-1}} = 0$.

$$\frac{d}{dm_r}\Theta(m_r,\phi) = -(1-\phi)\left(\frac{(1-\phi)\left(1+\frac{\mu}{\sigma}\right)\left(1-\frac{\mu}{\sigma-1}\right)m_r+\phi\left(1-\frac{\mu(\sigma+1)}{\sigma(\sigma-1)}\right)}{(m_r+(1-m_r)\phi)^{1+\frac{\mu}{\sigma-1}}} - \phi\left(1+\frac{\mu}{\sigma}\right)\right),$$

$$\frac{d}{dm_r}\Theta(m_r,0) = -m_r^{1-\frac{\mu}{\sigma-1}}\left(1-\frac{\mu}{\sigma-1}\right)\left(1+\frac{\mu}{\sigma}\right) < 0,$$

$$\frac{d}{dm_r}\Theta(m_r,1) = 0,$$

$$\frac{d}{dm_r}\Theta(0,\phi) = -(1-\phi)\left(\phi^{-\frac{\mu}{\sigma-1}}\left(1-\frac{\mu(\sigma+1)}{\sigma(\sigma-1)}\right) - \phi\left(1+\frac{\mu}{\sigma}\right)\right),$$

$$\frac{d}{dm_r}\Theta(1,\phi) = (1-\phi)\left(\phi\left(1-\frac{\mu(\sigma+1)}{\sigma(\sigma-1)}\right) + (1-\phi)\left(1+\frac{\mu}{\sigma}\right)\left(1-\frac{\mu}{\sigma-1}\right) - \phi\left(1+\frac{\mu}{\sigma}\right)\right).$$

The plot of this difference and its derivative are shown in Figure 4.[13] In the figure, thin line indicates $\Theta(0,\phi)$, the dotted line $\Theta(m_r,\phi)$, and dashed line $\frac{d}{dm_r}\Theta(m_r,\phi)$. As is repeated, the value where $\Theta(0,\phi) = 0$ indicates ϕ^S_{sus}.

When ϕ^S_{sus}, which satisfies $\Theta(0,\phi) = 0$, is smaller than $\frac{d}{dm_r}\Theta(m_r,\phi) = 0$, then we have $\frac{d}{dm_r}\Theta(m_r,\phi)\Big|_{m_r=0} < 0$ at $\phi = \phi^S_{sus}$ and $\phi^S_{sus} > \phi^M_{sus}$. It means that increase in the share of multiplant firms makes the sustain point decreased, as in Figure 4.

[13] The parameters specified is the same with the other figures except $m_r = 0.3$.

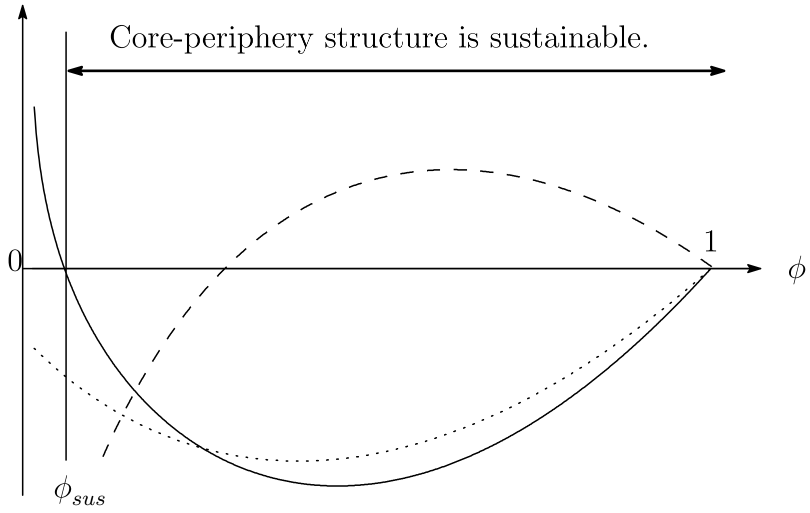

Figure 4: Sustain point and the share of multi-plant firms

In order to clarify the sign of the derivative at $\phi = \phi_{sus}^S$, we simply take the difference of $\Theta(0,\phi)$ and the derivative of $\Theta(m_r,\phi)$ evaluating at $m_r = 0$ as,
$\Theta(0,\phi) - \frac{d}{dm_r}\Theta(m_r,\phi)\Big|_{m_r=0} = \left(1-\frac{\mu}{\sigma}\right) - \phi(1-2\phi)\left(1+\frac{\mu}{\sigma}\right) - \left(\phi^{-\frac{\mu}{\sigma-1}}(1-\phi)\left(1-\frac{\mu(\sigma+1)}{\sigma(\sigma-1)}\right) - 2\phi\right).$
Observing the equation, as ϕ approaches to 0, the first term remains to be constant, $1-\frac{\mu}{\sigma}$, the second converges to 0 and the third term to $-\infty$. In total, the terms converges to $-\infty$. On the other hand, as ϕ approaches to 1, the sum of first and second terms converge to 2, and the third term to -2. In total, the terms converges to zero. Thus we have $\Theta(0,\phi) < \frac{d}{dm_r}\Theta(m_r,\phi)\Big|_{m_r=0}$, $\forall \phi \in (0,1)$. ■

Appendix IV

The proof of Proposition 2

Proof. Solving for the nominal wage differential between single-plant and multiplant equal to one, and without evaluating m_1, we could obtain the following equation from (27) for the given fixed cost differential, $\Gamma = (1+\alpha)$,

$F(m_1) \equiv \frac{\omega_1^S}{\omega_1^M} - 1 = \frac{W_1^S}{W^M} - 1 = \frac{\Omega_1}{\Omega_2}$,

where $\Omega_1 \equiv \alpha(1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_1 - (1-\phi)\left(1-\frac{\mu}{\sigma}\right) + 2\alpha\phi$, and $\Omega_2 \equiv (1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_1 + \left(1+\frac{\mu}{\sigma}\right)\phi + \left(1-\frac{\mu}{\sigma}\right)$. The sign of $F(m_1)$ is of interest. If $F(m_1) > 0$, all firms are single plant and if $F(m_1) < 0$, all firms are multiplant. When there is $m_1 \in [0,1]$ such that

$F(m_1) = 0$, some firms are multiplant. A simulation of $F(m_1)$ is in Figure 5,[14] which has the correspondence with Figure 1 and there is a range of $m_1 \in [0, 1]$. Since $\Omega_2 > 0$, $\forall m_1 \in [0, 1]$, we could focus on the sign of numerator, Ω_1. Solving Ω_1 for m_1, then we have a solution for $m_1 \in [0, 1]$ as $m_1 = \frac{\left(1-\frac{\mu}{\sigma}\right)}{\alpha\left(1+\frac{\mu}{\sigma}\right)} - \frac{2\phi}{(1-\phi)\left(1+\frac{\mu}{\sigma}\right)}$, which is unique for any given ϕ and guarantee $\omega_1^S = \omega_1^M$. Note that $\frac{d}{d\phi} m_1 = -\frac{2}{(1-\phi)^2\left(1+\frac{\mu}{\sigma}\right)} < 0$ and $\frac{d}{d\alpha} m_1 = -\frac{1-\frac{\mu}{\sigma}}{\alpha^2\left(1+\frac{\mu}{\sigma}\right)} < 0$. In a different way, solving Ω_1 for ϕ, then we have the function of $\phi(m_1)$ as $\phi(m_1) = 1 - \frac{2\alpha}{\left(1-\frac{\mu}{\sigma}\right)-\alpha m_1\left(1+\frac{\mu}{\sigma}\right)+2\alpha}$ with $\phi(0) = \frac{1-\frac{\mu}{\sigma}}{1-\frac{\mu}{\sigma}+2\alpha}$ and $\phi(1) = \frac{\left(1-\frac{\mu}{\sigma}\right)-\alpha\left(1+\frac{\mu}{\sigma}\right)}{(1+\alpha)\left(1-\frac{\mu}{\sigma}\right)}$, which we have in (30) and (31) as the critical values for different organization configuration. $\frac{d}{dm_1}\phi(m_1) = -\frac{2\alpha^2\left(1+\frac{\mu}{\sigma}\right)}{\left(\left(1-\frac{\mu}{\sigma}\right)-\alpha m_1\left(1+\frac{\mu}{\sigma}\right)+2\alpha\right)^2} < 0$. ■

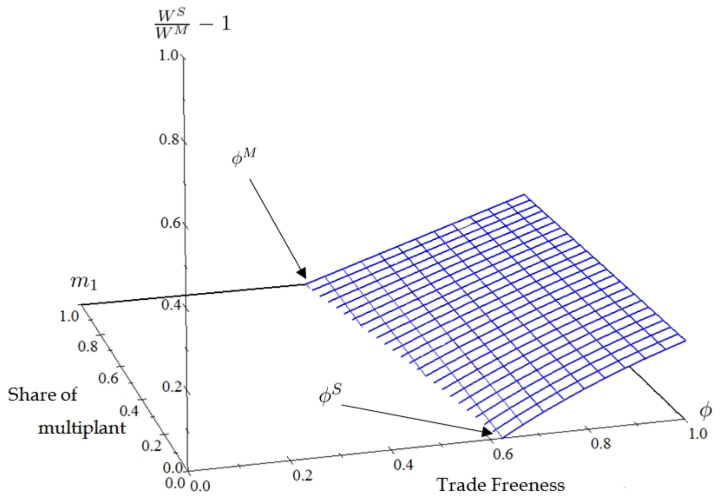

Figure 5: Intermediate value of share of multiplant

Appendix V

The proof of Proposition 3

Proof. Solving for the nominal wage differential between single-plant and multiplant equal to one, and without evaluating m_1 and specifying the fixed cost difference in Γ, we could obtain the following equation from (27),

$$G(m_1) \equiv \frac{\omega_1^S}{\omega_1^M} - 1 = \frac{W_1^S}{W^M} - 1 = \frac{\Omega_3}{\Omega_4},$$

where $\Omega_3 \equiv (1-\phi)\left(1+\frac{\mu}{\sigma}\right)(1-\Gamma)m_1 + \left(1+\frac{\mu}{\sigma}\right)\phi + \left(1-\frac{\mu}{\sigma}\right) - 2\Gamma\phi$, and $\Omega_4 \equiv (1-\phi)\left(1+\frac{\mu}{\sigma}\right)m_1 + \left(1+\frac{\mu}{\sigma}\right)\phi + \left(1-\frac{\mu}{\sigma}\right)$. If $G(m_1) > 0$, all firms are single plant and if $G(m_1) < 0$, all

[14] We set the parameters as $\alpha = 0.2$. The other two parameters, σ and μ, are the same as before.

firms are multiplant. Note that $\Omega_4 = \Omega_2 > 0 \; \forall m_1 \in [0,1]$. From the equation, it is obvious that for given Γ and ϕ, $G(m_1)$ is continuous. So we could focus on the sign of numerator, Ω_3. Solving $\Omega_3|_{m_1=0} \leq 0$ for α yields the equation in (28). If $\alpha \leq \frac{1}{2}\phi^{b-1}(1-\phi)\left(1-\frac{\mu}{\sigma}\right)$ holds, $\Omega_3|_{m_1=0} \leq 0$, otherwise $\Omega_3|_{m_1=0} > 0$ and there is no possible multiplant organization. Solving Ω_3 for m_1, then we have a solution for $m_1 \in [0,1]$ as $m_1 = \frac{2\Gamma\phi - \phi\left(1+\frac{\mu}{\sigma}\right) - \left(1-\frac{\mu}{\sigma}\right)}{(1-\phi)(1-\Gamma)\left(1+\frac{\mu}{\sigma}\right)}$, which is unique for any given ϕ and guarantee $\omega_1^S = \omega_1^M$. Note that $\frac{d}{d\alpha}m_1 = -\frac{\left(1-\frac{\mu}{\sigma}\right)\phi^b}{\left(1+\frac{\mu}{\sigma}\right)\alpha^2} < 0$. A simulation of $G(m_1)$ is depicted in Figure 6,[15] which has the correspondence with Figure 3 and shows two separated ranges of $m_1 \in [0,1]$. ■

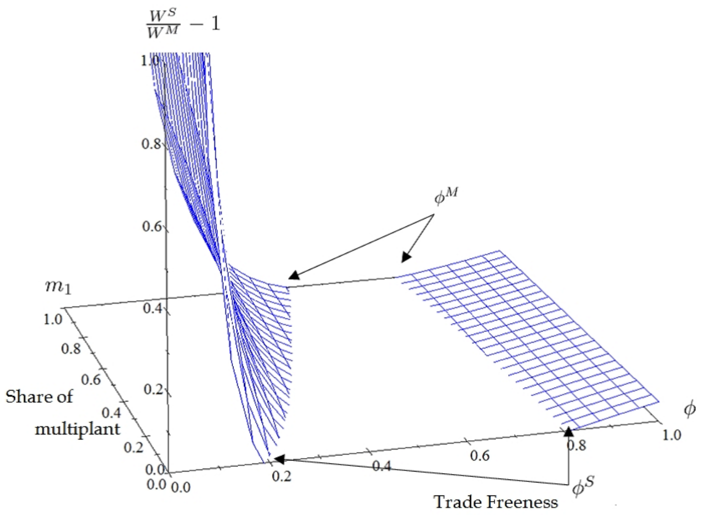

Figure 6: Intermediate value of share of multiplant

[15]We set the parameters as $\alpha = 0.06$ and $b = 2$. The other two parameters, σ and μ, are the same as before.