Correlation between coordination cost and spatial distribution of enterprises

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Abstract

It introduces the coordination cost to NEG model to analyze the impact of coordination cost on the spatial dispersion of enterprises. By solving the model and numeral simulation it finds that the enterprises' agglomeration in central place declines when the coordination cost reduce. As long as the coordination cost keeps a constant relates to diversity of worker's wage and product's substitution elasticity, the spatial distribution of enterprises will not be affected by trade freedom.

Keywords: coordination cost, trade freedom, enterprises' distribution

1 Introduction

As the development of information technology makes information transportation costless in a long distance and reduce the cost of coordination between enterprises, a growing number of firms choose to locate in periphery because of lower labour salary, lower price of resources and lower living cost, etc. Some spatial dispersion of production aims at taking advantage of differences in technologies, factor endowments, or factor prices across places[1]. The development of information and communication technology reduced the transportation and coordination costs[2]. The declines of transportation and coordination costs affect the firms' location choice[3]. Because of the revolution of information technology and the rise of location rent, the central places become less attractive[4][5]. There is a tendency that many enterprises prefer to leave the metropolitan region[6][7]. Information technology is one important motivation[8][9]. The development of information technology is a main factor to study the evolution of new economic geography[10] . Some scholar affirm that information technology would bring the spatial organization a radical revolution, just like what train and automobile did in the old time[11].

Based on the studies of information technology and coordination cost between enterprises, it introduces coordination costs to NEG model, to analyze the impact of information technology on the enterprises' spatial dispersion. The next part it constructs the model under the basic hypothesizes of NEG model. The second part it solves the mathematic model. The third part some numerical simulations are carried out and the model's economic implication are discussed. At last a conclusion of main results is made.

2 The model

The model is built based on the research of Masahisa Fujita and Toshitaka Gokan[2].There are two regions in the model, core A and periphery B, and two kinds of labours, skilled worker and unskilled worker whose populations are given. The skilled one is perfectly mobile between regions, but the unskilled one is definitely fixed. As normal NEG model there are two sectors, the modern sector (M) and the traditional sector (T). M produces continuum of varieties of horizontally differentiated good with increasing returns by using skilled and unskilled labour and the manufacturing service provided in the core area. It defines centralization as all enterprises locate in the same region A, dispersion as all enterprises locate in the same region B or separate. T sector produces homogeneous good with constant returns by using unskilled labour only. Preference is identical and described by a Cobb–Douglas utility:

$$U = Q^{\mu}\Upsilon^{1-\mu} / \mu^{\mu}(1-\mu^{\mu})^{1-\mu}, 0<\mu<1, \quad (1)$$

Q is the varieties' consumption of M sector's output, while Υ is the consumption of the T sector' output. M sector provides a continuum of differentiated varieties in size m, so Q is given by:

$$Q = \left[\int_0^m q(i)^{\rho} di\right]^{1/\rho}, 0<\rho<1, \quad (2)$$

$q(i)$ stands for the consumption of varieties, and $i \in [0,m]$. In (2), parameter ρ represents the inverse intensity of choice of varieties. When ρ close to 1, varieties are nearly perfectly substituted; when ρ decreases, desire over all varieties increases. $\sigma = \frac{1}{1-\rho}$ stands for the elasticity of substitution between any two varieties, which varies from 1 to $+\infty$. Since firms are

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continuum, each firm is negligible and the interactions between any two firms are zero, but they are affected by aggregate market condition. If Y represents consumer income, p^T is the price of traditional good, and $p(i)$ is the price of variety i, then the demand function and the price are:

$$\Upsilon = (1-\mu)Y / p^{\mathrm{T}}, \quad (3)$$

$$q(i) = \frac{\mu Y}{p(i)} \frac{p(i)^{-(\sigma-1)}}{P^{-(\sigma-1)}} = \mu Y p(i)^{-\sigma} P^{\sigma-1}, \; i \in [0, m], \quad (4)$$

The price index of the differentiated product P can be given by

$$P \equiv \left[\int_0^m p(i)^{-(\sigma-1)} di \right]^{-1/(\sigma-1)}, \quad (5)$$

Take (3) and (4) into (1) the indirect utility function can be got as:

$$v = YP^{-\mu}(p^{\mathrm{T}})^{-(1-\mu)}, \quad (6)$$

The assumption of technologies here is a little bit different from normal economic geography models. In T sector one unit of output requires $a_r \geq 1$ units of unskilled labour in both regions $r = A, B$.It assumes $a_A = 1$ and $a_B \geq 1$, which means unskilled workers in T sector in region A are more productive than in region B. L_A and L_B are the number of unskilled workers in region A and B respectively. To keep the symmetry between two regions, it assumes that both regions have the same amount of unskilled labour:

$$L_A = \frac{L_B}{\alpha_B} = \frac{L}{2}, \quad (7)$$

It assumes the output of the T sector can be costless traded across regions, thus its price is same in two regions. It can be chosen as a numeraire so that $p^{\mathrm{T}} = 1$. So the equilibrium wages for the unskilled are:

$$w_A^L = 1, \; w_B^L = 1/\alpha_B \leq 1, \quad (8)$$

Enterprise in M sector needs a fixed amount f of skilled labour. S is the total number of skilled workers. S_r represents the skilled worker in region r. The total number of firms in two regions can be given by $m = S / f$. Producing $q(i)$ units of variety i requires $l(i)$ units of unskilled labour. $l(i) = c_{rs} q(i)$, where $c_{rs} > 0$ is the firm's marginal labour requirement. The value of c_{rs} decreases with the effectiveness of the service provided by the core region. The effectiveness depends on the following two factors. First, longer distance affects the transfer of coordination, makes the coordination transferred to periphery less effective. Second, the agglomeration within the same region generates Marshallian externalities, which makes the firms in core region more effective in the supply of information and knowledge. When the firms locate in region A it has $c_{AA} = c(m_A)$, when they locate in region B, $c_{AB} = c(m_A)T_C$. T_C represents the coordination cost, when coordination is very difficult, the value of T_C is really great. The development of information technology will make the coordination much easier. When the enterprise locates in region A, the product function is $l(i) = c(m_A)q(i)$, whereas locates in region B, the efficiency of coordination is lower, so the firm needs more input.

As usual, the output of the M sector is shipped in a positive cost according to an iceberg technology (Samuelson): when one unit of the differentiated product is transported from region r to region s, only $1/\mathrm{T}_M$ ($\mathrm{T}_M > 1$) arrives at destination. Within every region transportation is costless. Hence, the price paid by a consumer located in region s is $p_r(i)T_M$.

w_r^H is the wage earned by skilled workers in region r. Then, with (7) and (8) the total income of region r is:

$$Y_r = m_r f w_r^H + L/2, \; r = A, B, \quad (9)$$

From (4), the total demand for variety i produced in region r can be expressed as:

$$q_r(i) = \mu Y_r p_r(i)^{-\sigma} P_r^{\sigma-1} + \mu Y_s \left[p_r(i)\mathrm{T}_M \right]^{-\sigma} P_s^{\sigma-1}\mathrm{T}_M, \quad (10)$$

P_r and P_s stand for the price of the differentiated good in regions r, s. M_{AA} means that information centre locates in region A, the firm also locates in region A. M_{AB} means that information centre locates in region A, the firm locates in region B. The profit of the firm $i \in \mathrm{M}_{AA}$ is as:

$$\pi_{AA}(i) = p_A(i)q_A(i) - w_A^H f - w_A^L c(m_A) q_A(i)$$

So the equilibrium price charged by firm i in region A is:

$$p_A^*(i) = \frac{w_A^L c(m_A)}{\rho}, \; i \in \mathrm{M}_{AA}, \quad (11)$$

Similarly, the profit of firm $i \in \mathrm{M}_{AB}$ is as follows:

$$\pi_{AB}(i) = p_B(i)q_B(i) - w_B^H f - w_B^L c(m_A) T_C q_B(i)$$

So the equilibrium price charged by the firm located in region B is

$$p_B^*(i) = \frac{w_B^L c(m_A) T_C}{\rho}, i \in \mathrm{M}_{AB}, \quad (12)$$

Comparing (11) and (12), it can be found that the equilibrium prices of the same variety produced in either region differ not only because of the wage differential of unskilled workers, but also because of coordination cost T_C. Combine (5), (7), and (8), regional price index can be determined as follows:

$$P_A = \left\{ m_{AA} \left(\frac{w_A^L c(m_A)}{\rho}\right)^{-(\sigma-1)} + T_M^{-(\sigma-1)} m_{AB} \left(\frac{w_B^L c(m_A) T_C}{\rho}\right)^{-(\sigma-1)} \right\}^{-1/(\sigma-1)}$$

$$P_B = \left\{ T_M^{-(\sigma-1)} m_{AA} \left(\frac{w_A^L c(m_A)}{\rho}\right)^{-(\sigma-1)} + m_{AB} \left(\frac{w_B^L c(m_A) T_C}{\rho}\right)^{-(\sigma-1)} \right\}^{-1/(\sigma-1)}$$

The first part of P_A means good produced in region A, the second part means good produced in region B but transported to region A. The first part of P_B is good produced in region A but transported to region B, the second part is good produced in region B. The equilibrium profits may be obtained as follows:

$$\pi_{AA}^* = k_1 \left[w_A^L c(m_A) \right]^{-(\sigma-1)} (Y_A P_A^{\sigma-1} + Y_B P_B^{\sigma-1} T_M^{-(\sigma-1)}) - w_A^H f$$

$$\pi_{AB}^* = k_1 \left[w_B^L c(m_A) T_C \right]^{-(\sigma-1)} (Y_A P_A^{\sigma-1} T_M^{-(\sigma-1)} + Y_B P_B^{\sigma-1}) - w_B^H f$$

Where $k_1 = \mu\sigma^{-\sigma}(\sigma-1)^{\sigma-1}$ is a positive constant. Hence, the free entrance condition is $\max\left\{\pi_{AA}^*, \pi_{AB}^*\right\} = 0$。

3 Results and discussion

In this part it analyzes the impact of trade costs T_M and coordination cost T_C on the distribution of firms in two regions under the given wage difference. It assumes $\theta = \frac{m_{AA}}{m}$, $\phi_C = (\frac{T_C}{\alpha_B})^{-(\sigma-1)}$, $\phi_M = T_M^{-(\sigma-1)}$. $\theta \in [0,1]$ denotes the quotient of centralized enterprises. ϕ_M indicates the trade integration between two regions, varies between 0 (trade forbidden) and 1(zero trade costs). For given $\alpha_B > 1$, ϕ_C is the coordination cost of two firms in different regions and varies from 0 (coordination forbidden) to $\alpha_B^{\sigma-1} > 1$ (zero coordination cost).

$w_A^L = 1$, $w_B^L = 1/\alpha_B \le 1$, so $\alpha_B = 1/w_B^L = w_A^L / w_B^L$, so the price can be expressed as:

$$P_A = \frac{c(m)}{\rho} m^{-1/(\sigma-1)} \left[\theta + (1-\theta)\phi_C\phi_M\right]^{-1/(\sigma-1)}, \quad (14)$$

$$P_B = \frac{c(m)}{\rho} m^{-1/(\sigma-1)} \left[\theta\phi_M + (1-\theta)\phi_C\right]^{-1/(\sigma-1)}, \quad (15)$$

w_r^H is the wage of skilled worker in region r. Through (7) and (8) total income of region r is $Y_A = m_A f w_A^H + L/2$, $Y_B = m_B f w_B^H + L/2$, where $m_A + m_B = m$.

So the profit is:

$$\pi_{AA}^* = \frac{\mu f}{\sigma S}\left[\frac{\theta S w_A^H + L/2}{\theta + (1-\theta)\phi_C\phi_M} + \frac{(1-\theta)S w_B^H + L/2}{\theta + (1-\theta)\phi_C\phi_M^{-1}}\right] - w_A^H f, \quad (16)$$

$$\pi_{AB}^* = \frac{\mu f}{\sigma S}\left[\frac{\theta S w_A^H + L/2}{\theta\phi_C^{-1}\phi_M^{-1} + (1-\theta)} + \frac{(1-\theta)S w_B^H + L/2}{\theta\phi_C^{-1}\phi_M + (1-\theta)}\right] - w_B^H f, \quad (17)$$

Formulation (16) and (17) can be used to determine the domains in case all the firms are centralized $(\theta^* = 1)$, all firms are dispersed $(\theta^* = 0)$, all the firms are centralized partly and dispersed partly $(0 < \theta^* < 1)$. It assumes that $w_B^H = \lambda_B w_A^H$, from $\pi_{AA}^* = 0$ it can be known:

$$w_A^H = \frac{\frac{L}{2A} + \frac{L}{2B}}{\frac{\sigma S}{\mu} + \frac{\theta S}{A} + \frac{(1-\theta)S\lambda_B}{B}}, \quad (18)$$

Where $A = \theta + (1-\theta)\phi_C\phi_M$, $B = \theta + (1-\theta)\phi_C\phi_M^{-1}$.

From $\pi_{AB}^* = 0$ it has:

$$w_A^H = \frac{\frac{L}{2\phi_C^{-1}\phi_M^{-1}A} + \frac{L}{2\phi_C^{-1}\phi_M B}}{\frac{\lambda_B\sigma S}{\mu} + \frac{\theta S}{\phi_C^{-1}\phi_M^{-1}A} + \frac{(1-\theta)S\lambda_B}{\phi_C^{-1}\phi_M B}}, \quad (19)$$

Submit (18) and A、B to (19) it has the following formulation:

$$\frac{\frac{1}{\theta\phi_C^{-1}\phi_M^{-1} + (1-\theta)} + \frac{1}{\theta\phi_C^{-1}\phi_M + (1-\theta)}}{\frac{\lambda_B\sigma}{\mu} + \frac{\theta}{\theta\phi_C^{-1}\phi_M^{-1} + (1-\theta)} + \frac{(1-\theta)\lambda_B}{\theta\phi_C^{-1}\phi_M + (1-\theta)}} = \frac{\frac{1}{\theta + (1-\theta)\phi_C\phi_M} + \frac{1}{\theta + (1-\theta)\phi_C\phi_M^{-1}}}{\frac{\sigma}{\mu} + \frac{\theta}{\theta + (1-\theta)\phi_C\phi_M} + \frac{(1-\theta)\lambda_B}{\theta + (1-\theta)\phi_C\phi_M^{-1}}}, \quad (20)$$

Solve the formulation θ can be expressed with ϕ_C and ϕ_M :

$$\theta(\phi_C,\phi_M)=\frac{(\mu-\sigma)\lambda_B\phi_C\phi_M^2+2\sigma\phi_C^2\phi_M-\lambda_B\mu\phi_C-\lambda_B\sigma\phi_C}{(\mu-\sigma\lambda_B-\sigma+\mu\lambda_B)\phi_C\phi_M^2+2\sigma\phi_C^2\phi_M+2\lambda_B\sigma\phi_M-(\lambda_B\mu+\lambda_B\sigma+\mu+\sigma)\phi_C}, \quad (21)$$

From (21) it has:

$$\frac{\partial\theta(\phi_C,\phi_M)}{\partial\phi_C}=\frac{2\mu\sigma\lambda_B^2(\phi_M^3-\phi_M)+2\mu\sigma\phi_C^2(\phi_M^3-\phi_M)+2\sigma^2\phi_M\left[-(\phi_C-\lambda_B\phi_M)^2-(\lambda_B-\phi_C\phi_M)^2\right]}{\left[(\mu-\sigma\lambda_B-\sigma+\mu\lambda_B)\phi_C\phi_M^2+2\sigma\phi_C^2\phi_M+2\lambda_B\sigma\phi_M-(\lambda_B\mu+\lambda_B\sigma+\mu+\sigma)\phi_C\right]^2}, \quad (22)$$

Because $\phi_M\in(0,1),\phi_C\in(0,a_B^{\sigma-1}),a_B\in(1,+\infty)$, $\mu\in(0,1)$, $\lambda_B\in(0,+\infty),\sigma\in(1,+\infty)$, so (22) is minus. So it has LEMMA 1:

LEMMA1: θ is a strictly decreasing function of ϕ_C, that is the agglomeration in core strictly decreases when coordination cost reduces.

It makes some numeral simulation according to the research of Strass-Kahn(2005)[12], Broda and Weinstein(2006)[13]. Set $\lambda_B=1,\mu=0.55,\sigma=6$. Let ϕ_M =0.2 and then 0.4. It has the following FIGURE 1 from the numeral simulation. θ is strictly decreasing along with ϕ_C. To the same curve, when the trade freedom is lower (ϕ_M =0.4), the elasticity of θ to ϕ_C is higher. It can be concluded from the numeral simulation that:

When the trade freedom is higher(ϕ_M =0.4), the elasticity of enterprises' distribution to coordination cost is higher. When the trade freedom is lower(ϕ_M =0.2), the elasticity of enterprises' distribution to coordination cost is lower. So PROPOSITION 1 can be concluded as:

PROPOSITION 1: the elasticity of the share of centralized enterprises to coordination cost is positively related to trade freedom.

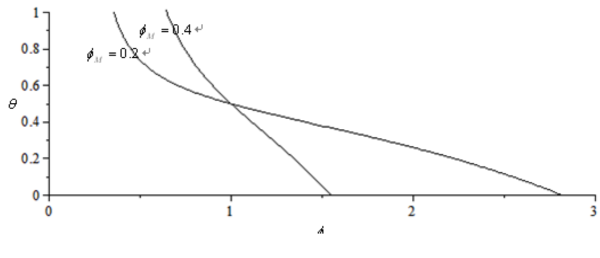

FIGURE 1 Relationship of θ and ϕ_C

Then some numeral simulation between θ and ϕ_M are made. Set $\lambda_B=1,\mu=0.55\ \ \sigma=6$. Let ϕ_C =0.5,0.9,1,1.1 and then 1.5, respectively, it has the figure 2 as bellow:

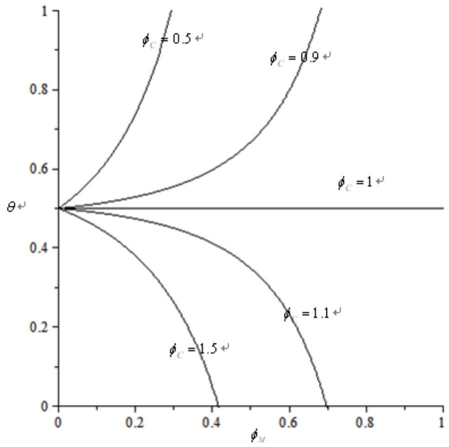

FIGURE 2 relationship of θ and ϕ_M

When ϕ_C =0.5, coordination cost is higher. When ϕ_M increase (trade cost decrease), enterprises tend to locate in core. ϕ_C =1 indicates that two region's share of enterprises are same, it has no relationship with ϕ_M . ϕ_C =1.5 means coordination cost is lower. Along with the decrease of trade costs, enterprises will locate in periphery. Under the same trade freedom, the higher the coordination cost is, the greater the agglomeration is.

Submit $\lambda_B=\phi_C$ to the formulation (21) it can be seen:

$$\theta^*\equiv\frac{\lambda_B}{1+\lambda_B}, \quad (23)$$

For (23), the value of θ is only related to the wage difference of skilled worker λ_B. $\lambda_B=(\frac{T_C}{\alpha_B})^{-(\sigma-1)}$,. $T_C=\alpha_B\lambda_B^\sigma$ So it has LEMMA 2:

LEMMA 2: when $\lambda_B=\phi_C$, that is $T_C=\alpha_B\lambda_B^\sigma$, the distribution of enterprises will not be affected by trade freedom. They will distribute in the quotient of $\theta^*\equiv\frac{\lambda_B}{1+\lambda_B}$, where a_B >1, λ >0, σ >1.

From lemma 1 and 2, for any $\phi_C < \lambda_B$, $\theta_{\phi_C} > \theta^*$, the agglomeration in region A is greater than θ^*. For any $\phi_C > \lambda_B$, $\theta_{\phi_C} < \theta^*$, the agglomeration in region A is smaller than θ^*. So it can be concluded that:

PROPOSITION 2: when $\lambda_B < \phi_C$,that is $T_C > \alpha_B \lambda_B^\sigma$, a higher trade freedom will make enterprises concentrate in periphery. When $\lambda_B > \phi_C$, that is $T_C < \alpha_B \lambda_B^\sigma$, a higher trade freedom will make enterprises concentrate in core.

As the same, set $\mu = 0.55, \sigma = 6$. Let ϕ_C =0.5,1,1.5 and λ_B =0.5、1、1.5 respectively. It has the below figure 3 which testified the proposition 2. When $\lambda_B = \phi_C$, θ is plane, has no relationship with ϕ_M, only be affected by λ_B. λ_B increase, enterprises will locate in core. When $\lambda_B \neq \phi_C$, Along with the increase of trade freedom, agglomeration elasticity will rise. When $\lambda_B < \phi_C$, trade integration will promote enterprises to aggregate in periphery. When $\lambda_B > \phi_C$, trade integration will make enterprises aggregate in core.

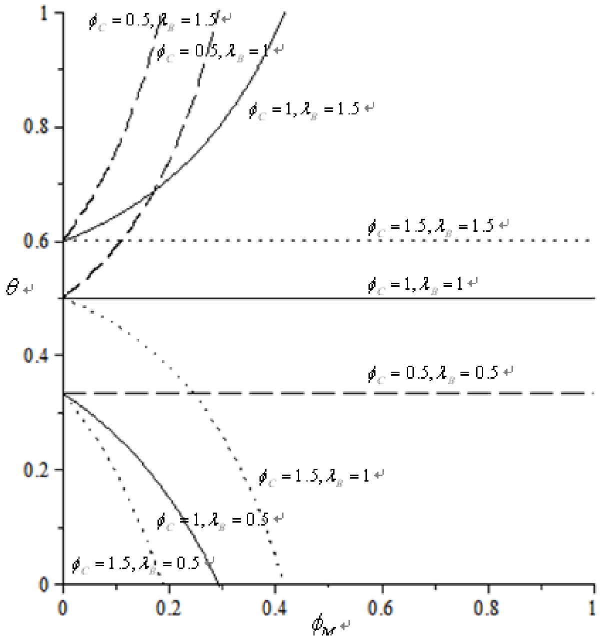

FIGURE 3. Relationship of θ and α_B , λ_B

σ is the substitution elasticity of diversity products. Because $\sigma = \frac{1}{1-\rho}$, $\sigma > 1$. When ρ is very close to 1, products can be substituted perfectly. When ρ is very close to 0, love of variety increases.

Aggregation in periphery has to fulfil the condition $\{T_C > \alpha_B \lambda_B^\sigma, \alpha_B > 1, \lambda_B > 0\}$. $\lambda_B > 1$, skilled worker in periphery have more wage than which in core, the bigger σ is, the larger $\alpha_B \lambda_B^\sigma$ is, aggregation in periphery can be triggered in a higher coordination cost. When $\lambda_B = 1$, coordination cost has no relationship with σ. When $0 < \lambda_B < 1$, the bigger σ is, the smaller $\alpha_B \lambda_B^\sigma$ is, aggregation in periphery only can be triggered in relative lower coordination cost.

4 Conclusions

The research constructs a new NEG model which introduces a coordination cost. After model solving and numeral simulation it finds the agglomeration in core is a strictly increasing function of coordination cost. Higher communication cost leads to more agglomeration in the core region. When the trade freedom is high, the centralization of enterprises is more elastic to coordination cost.

When coordination cost is a numeral only related to worker's wage difference and the variety substitution elasticity, the distribution of enterprise will be not affected by coordination cost. In a higher coordination cost, the increase of trade freedom will induce more aggregation in core. In a lower coordination cost, the increase of trade freedom will result to more aggregation in periphery.

When skilled worker in periphery have more wage, a higher substitution elasticity makes the aggregation in periphery can be triggered in a relative higher coordination cost. When the wages are same, coordination cost is independent to substitution elasticity. If skilled worker in periphery have less wage, a higher substitution elasticity makes aggregation in periphery will be triggered in a lower coordination cost.

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