Migration among Multicities

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Abstract—This paper proposes a simple model of economic geography within the Dixit-Stiglitz-Iceberg framework that may be used to analyze migration patterns among three cities. The cost–benefit tradeoffs affecting incentives for three types of migration, including echelon migration, are discussed. This paper develops a tractable, heterogeneous-agent, general equilibrium model, where agents share constant human capital, and explores the relationship between the benefits of echelon migration and gross human capital. Using Chinese numerical solutions, we study the manifestation of echelon migration and how it responds to changes in transportation cost and elasticity of substitution. Numerical results demonstrate that (i) there are positive relationships between a migration's benefit-and-wage ratio, (ii) there are positive relationships between gross human capital ratios and wage ratios as to origin and destination, and (iii) we identify 13 varieties of human capital convergence among cities. In particular, this model predicts population shock resulting from the processes of migration choice and echelon migration.

Keywords—Dixit-Stiglitz-Iceberg framework, elasticity ,echelon migration, trade-off

I. INTRODUCTION

FOLLOWING the pioneering work of Harris and Todaro[1], economists have studied the various scenarios of migratory movement, such as the multi-country model described by the Dixit-Stiglitz structure[2]. There are many types of migration, including seasonal migration[3], [4], return migration[5], [6], chain migration[7], and intercounty and interstate migration[8], among others.However, there is as yet no spatial-economics model that explains migration among cities.

Generally in China, cities may be distinguished on the basis of their populations and economic functions. Each successively "higher-tiered" urban center adds higher-ordered economic functions, such as cultural or household amenities and business services. While a smaller city may have only grocery stores, gas stations, and basic restaurants, the upper end of urban areas generally offers a full range of services, including sophisticated financial advisors, patent attorneys, and business consultants, according to researchers studying urban rankings. According to Linda Harris Dobkins and Yannis M. Ioannides[9], larger cities are more likely to locate near other cities, and older cities are more likely to have neighbors, while distance from the nearest higher-tiered city is not always a significant determinant of size and growth. City size in an open spatial economy is determined by two interacting forces: wage rate and concentration of economic activities. Holding other variables constant, wage rates increase with the size of the city.

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However, the growth of a city will be limited by the physical consequences of the concentration amongst its economic activities. Holding wage levels constant, higher land prices decrease the welfare of the city residents[10]. Under a monopolistic-competition model, an economy within an integrated city equilibrium yields a primacy trap wherein population growth alone does not result in the formation of new cities[11]. It has been demonstrated that as an economy's population increases gradually, urban systems self-organize into highly regular hierarchical systems, á la Christaller[12]. The possibility of migration can change the both the composition of human capital and its development because heterogeneous agents accumulate skills in response to economic incentives. Migration distorts these incentives and the accumulation of human capital, which slows down, or even hinders, economic development[13]. In a continuous spatial economy consisting of pure-exchange local economies, agents are allowed to change their locations over time as a response to spatial income differentials[1]. In a dynamic framework, where migrations are temporary, the size of the migrant population in temporary residence depends on the duration of the migration. Optimal migration durations can be calculated. If migrations are temporary, the optimal migration duration may decrease as the wage differential increases[14].

Our research introduces heterogeneity of return to unit human capital in different rank city and preference for variety in consumption within the Dixit-Stiglitz-Iceberg framework to study echelon migration and human capital convergence. The article is organized as follows: section 2 describes the assumptions of the model; the equilibrium is analyzed in section 3; my principal results are presented in section 4; and section 5 presents my primary conclusions.

II. MODEL SETUP

The monopolistic competition model presented by Dixit and Stiglitz[15] was based on an assumption about market structure that avoids the problem of price-taking behavior in the presence of increasing returns to scale. This model still represents the basic research method used to study spatial economics.

The Dixit-Stiglitz model uses specific functional forms to identify consumer preferences, allowing for a "preference for variety." To completely eliminate every producer's market power, it is assumed that the range of goods is continuous, and each producer is infinitely small. With monopolistic competition, consumers discern between different varieties, and products from different producers offer imperfect substitutes. Goods can be traded between regions, and after trade liberalization, shipping costs take the usual "iceberg" form, as per Krugman[16]. That is, $\tau > 1$ units must be

transported from region i to region j in order for one unit to arrive. This assumption of proportional transportation costs is clearly unrealistic, but it simplifies the analysis greatly.

A. Preferences and Endowments

There are three rankings for cities within an economic region in our model: rank 1 (small town), rank 2 (prefecture-level city), and rank 3 (provincial capital). Economic development increases with city size, i.e., the per capita GDP of a rank 1 city ≤ per capita GDP of a rank 2 city ≤ per capita GDP of a rank 3 city. See Fig.1. Assume that agents prefer to work in areas with higher incomes, migrating from cities with low rank to cities of higher rank, and further, assume that migration costs between these cities are too small to block migration. Finally, the manufacturing sector produces many differentiated varieties, with increasing returns-to-scale technology under conditions of monopolistic competition, subject to iceberg transportation costs, such that $\tau > 1$ units have to be shipped between regions in order for one unit to arrive.
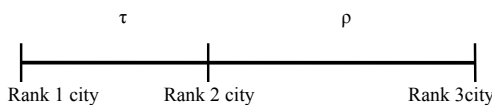

Fig.1 Distribution of cities

Our analysis covers three separate types of migration: neighboring migration, echelon migration, and jump migration. Here, neighboring migration refers to the movement of an agent to a neighboring city as a permanent resident. Echelon migration is relocation from a rank 1 to a rank 2 city, then after an optimal migration duration, to a rank 3 city. In jump migration, the agent migrates directly from a rank 1 city to a rank 3 city without optimal migration durations within a rank 2 city. Unlike other migrants, echelon migrants enjoy the advantage of receiving information about labor market opportunities from their networks, as well as assistance in finding a job. An echelon migrant might also reduce his or her accommodation expenses by sharing housing with members of that network. The equivalent value of such benefits also diminishes the expenses necessary to maintain a baseline consumption level, as required expenses that reach a certain utility level are likely to be lower for echelon migrants than for single-move migrants. Here, we introduce an "iceberg" transportation cost into the monopolistic competition model. If one unit of goods produced in a rank 1 city should be sold, $\tau(>1)$ unit goods in a rank 2 city and τ-1 unit goods "melt" in transportation, where τ is the "iceberg" cost between a rank 1 and rank 2 city. Similarly, $\rho(>1)$ is "iceberg" cost from rank 2 to 3 city. So, "iceberg" transportation cost between a rank 1 city and a rank 3 city is $\tau\rho$.

B. Household and firm

There are income inequalities among cities in China, where human capital comprises the primary influence upon urban

residents' income [1]. According to the Dixit-Stiglitz monopolistic model, each firm only produces one kind of goods, with increasing returns to scale. There are entry and exit barriers that yield zero profits in equilibrium. There are so many firms that each does not directly influence every other firm, but by elasticity of substitution between differentiated goods, they indirectly influence every other firm's production, hence every firm is competitive. Suppose that individuals in each city differ in their degree of return-to-unit human capital. Assume further that an agent's wages depend on his human capital, where agent j's income is wh_j. Here, w is unit of human capital wage, and h_j is its human capital. Because most Chinese rural laborers have little education, and their incomes are lower than urban workers, they live at subsistence levels. Now, assume that the human capital hj of echelon migration in each city is a constant, and that persons in a rank 1 city can only consume the goods of city 1, persons in a rank 2 city can consume goods of their local city and goods of a rank 1 city; while persons in a rank 3 city can consume local urban goods, or goods of rank 1 and 2 cities. This reflects the agglomeration effect of urban scales. Human capital can be expressed as a function of income[2]. Now, let us turn to the decisions of households and firms. The former are composed of one individual and have the following utility functions, where consumption utility and budget constraints are as follows:

agent's utility function of rank 1 city:

$$u_j = [\int_0^{N_1} c_j(i)^{\frac{\sigma-1}{\sigma}} di]^{\frac{\sigma}{\sigma-1}} \qquad (1)$$

agent's utility function of rank 2 city:

$$u_j = [\int_0^{N_1+N_2} c_j(i)^{\frac{\sigma-1}{\sigma}} di]^{\frac{\sigma}{\sigma-1}} \qquad (2)$$

agent's utility function of rank 3 city:

$$u_j = [\int_0^{N_1+N_2+N_3} c_j(i)^{\frac{\sigma-1}{\sigma}} di]^{\frac{\sigma}{\sigma-1}} \qquad (3)$$

agent's budget constraint in rank 1 city:

$$\int_0^{N_1} p_1(i)c_j(i)di = w_1 h_j \qquad (4)$$

agent's budget constraint in rank 2 city:

$$\int_0^{N_1+N_2} p_2(i)c_j(i)di = w_2 h_j \qquad (5)$$

agent's budget constraint in rank 3 city:

$$\int_0^{N_1+N_2+N_3} p_3(i)c_j(i)di = w_3 h_j \qquad (6)$$

Where $p(i)$ is the price of goods, i,$c_j(i)$ is consumed good i by consumer j, N_i(i=1,2,3) are goods varieties produced in city i,σ, and (>1) is elasticity of substitution between differentiated goods. CES utility function is characterized as the "preference for variety effect" function. Thus, at the same level of expenditure, the more goods variety, and the higher the utility. Assume wages per human capital in all three ranked cities are different and that $w_1 < w_2 < w_3$.

[1] Seth M. Hauser and Yu Xie,"Temporal and regional variationin earnings inequality: urban China in transition between 1988 and 1995",Social Science Research, 2005,34(1),44–79.

[2] István Tamás Kónya,"Essays on immigration,culture and international trade," Northwestern university; dissertation; June 2001.

With utility maximization, with (1) and (4), we can get goods i's demand function of agent j in rank 1 city (7). With (2) and (5), we can get goods i's demand function of agent j in rank 2 city (8). With (3) and (6), we can get goods i's demand function of agent j in rank 3 city (9). Thus, goods i's total demand in a city can be given with (10), (11) and (12).

$$c_j(i) = [\frac{p_1(i)}{P_1}]^{-\sigma} \frac{w_1 h_j}{P_1}, \ i \in [0, N_1] \tag{7}$$

Goods i's demand function of agent j in rank 2 city is:

$$c_j(i) = [\frac{p_2(i)}{P_2}]^{-\sigma} \frac{w_2 h_j}{P_2}, \ i \in [0, N_1 + N_2] \tag{8}$$

Goods i's demand function of agent j in rank 3 city is:

$$c_j(i) = [\frac{p_3(i)}{P_3}]^{-\sigma} \frac{w_3 h_j}{P_3}, \ i \in [0, N_1 + N_2 + N_3] \tag{9}$$

Total demand of goods i in rank 1 city is:

$$c(i) = [\frac{p_1(i)}{P_1}]^{-\sigma} \frac{w_1 H_1}{P_1}, \tag{10}$$

where, H_1 is the aggregate amount of human capital in rank 1 city.

Total demand of goods i in rank 2 city is:

$$c(i) = [\frac{p_2(i)}{P_2}]^{-\sigma} \frac{w_2 H_2}{P_2}, \tag{11}$$

where, H_2 is the aggregate amount of human capital in rank 2 city.

Total demand of goods i in rank 3 city is:

$$c(i) = [\frac{p_3(i)}{P_3}]^{-\sigma} \frac{w_3 H_3}{P_3}, \tag{12}$$

where H_3 is the aggregate amount of human capital in rank 3 cities.

Here, P_1 is real price index in rank 1 city:

$$P_1 = [\int_0^{N_1} p_1(i)^{1-\sigma} di]^{\frac{1}{1-\sigma}}. \tag{13}$$

P_2 is real price index in rank 2 city:

$$P_2 = [\int_0^{N_1+N_2} p_2(i)^{1-\sigma} di]^{\frac{1}{1-\sigma}}. \tag{14}$$

P_3 is real price index in rank 3 city:

$$P_3 = [\int_0^{N_1+N_2+N_3} p_3(i)^{1-\sigma} di]^{\frac{1}{1-\sigma}}. \tag{15}$$

In Eqs. (10)–(12) and Eqs. (13)–(15)[3], H_1, H_2 and H_3, respectively, are gross human capital in rank 1, 2, and 3 cities; and P_1, P_2 and P_3 are the real price indexes in rank 1, 2, and 3 cities, respectively. This implies that the influence of industrial goods variety on the price index depends on elasticity of substitution between differentiated goods σ. The smaller the elasticity of substitution between differentiated goods is, with industrial goods variety increasing, the greater the descending range of the price index is. Next, we turn to firms. Since they are presumed to be infinitesimal, they each set their own prices, and their decisions do not affect the aggregate price index. Production input takes the form of efficiency units of human

capital. In order to produce, a firm pays a variable cost of βw_i (i=1,2,3) per unit of output, and a fixed cost of αw_i. Thus, the cost functions in three cities are expressed as:

$$TC_1 = (\alpha + \beta q_1)w_1; \tag{16}$$

$$TC_2 = (\alpha + \beta q_2)w_2; \tag{17}$$

$$TC_3 = (\alpha + \beta q_3)w_3; \tag{18}$$

where q_i is the total quantity of goods produced by the firm.

C. Urban goods supply

Assume that in every urban economy, there are many industrial goods producers. N shows the potential variety of goods, where each industrial good serves one kind of consumer. Because there are so many producers of industrial goods, we can assume that a continuous variable i, shows the differentiated varieties of goods, where i [0,N]. Assume that each firm produces with scale economics, not scope economics. A firm's production depends on a single factor, labor. In the Dixit-Stiglitz framework, good i's production function shows:

$$L(i) = \alpha + \beta x(i) \tag{19}$$

Eq.(19) reflects the relationship between labor input and output in the i industrial goods production. $L(i)$ is the labor force in production, $x(i)$ is output of goods i, α is fixed-labor cost, and β is marginal labor cost.

All consumers share the same industrial goods demand function in Eq. (10). By choosing an appropriate measurement unit, constants can be omitted. Hence, a consumer's demand function is:

$$x(i) = p(i)^{-\sigma} \tag{20}$$

Profit maximization of a firm in a rank 1 city satisfies the following conditions:

$$\max \{ p_1(i)x(i) - w_1[\alpha + \beta x(i)] \}, \tag{21}$$

constrained by (19).

Formally, substitute $kp(i)$-σ into pq-TC, and rearrange the first order condition to get:

goods price in rank 1 city: $p_1(i) = \frac{\sigma}{\sigma - 1} \beta w_1$. $\tag{22}$

In (22), we see that the goods price has no relationship with type of goods. This is because industrial goods production in a rank 1 city has the same production function, and faces the same demand constraints as other ranks. Since the industrial goods price in a rank 1 city are the same, we can omit i and rewrite (22):

goods price in rank 1 city: $p_1 = \frac{\sigma}{\sigma - 1} \beta w_1$. $\tag{23}$

Thus, relationships in rank 2 cities and rank 3 cities are:

goods price in rank 2 city: $p_2 = \frac{\sigma}{\sigma - 1} \beta w_2$; $\tag{24}$

goods price in rank 3 city: $p_3 = \frac{\sigma}{\sigma - 1} \beta w_3$. $\tag{25}$

It is well-known that firms apply a constant markup marginal cost that is a decreasing function of demand elasticity. That

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[3] All calculation processes can be aquired from the corresponding author.

optimal price is the same for all regions, and is also independent of the index i, since goods are completely symmetric. We can count the goods on an arbitrary scale, so we set units in such a way that $\beta\sigma/(\sigma-1)=1$, to simplify notation. There are no barriers to entry by additional firms. Since firms are infinitesimal, entry continues till it drives profits to zero. The zero profit condition pins down firm size, as shown below:

$$q_1 = q_2 = q_3 = \alpha\sigma. \tag{26}$$

Here, I have used the fact that $\sigma/(\sigma-1)\beta=1$. Finally, factor markets are clear in all cities. Using (15) and $\sigma/(\sigma-1)\beta=1$, and using m for the city index, we get $H_m = N_m(\alpha + \beta q) = N_m\alpha\sigma$, m=1,2,3. Rearranging for Nm, we find that the number of firms in a rank m city is given by:

$$N_m = H_m/\alpha\sigma, \tag{27}$$

where, m=1,2,3.

D. Goods market clearing

Assuming that all firms in a city establish the same price, the unit human capital wage in a rank 1 city is w_1, the unit human capital wage in a rank 2 city can be $w_1\tau$, and the unit human capital wage in a rank 3 city can be $w_1\tau\rho$. Goods quantity produced in city m is given by (23). The simplified (13)–(15) price index is as follows:

goods price index in rank 1 city is:

$$P_1^{1-\sigma} = \frac{H_1}{\alpha\sigma}w_1^{1-\sigma} \tag{28}$$

goods price index in rank 2 city is:

$$P_2^{1-\sigma} = \frac{H_1}{\alpha\sigma}(w_1\tau)^{1-\sigma} + \frac{H_2}{\alpha\sigma}w_2^{1-\sigma} \tag{29}$$

goods price index in rank 3 city is :

$$P_3^{1-\sigma} = \frac{H_1}{\alpha\sigma}(w_1\rho\tau)^{1-\sigma} + \frac{H_2}{\alpha\sigma}(w_2\rho)^{1-\sigma} + \frac{H_3}{\alpha\sigma}w_3^{1-\sigma} \tag{30}$$

where Hm is the average human capital in rank m city and Pm is the goods price in rank m city, m=1,2,3. Demand for good i comes from both cities. Because part of the good "melts" in transportation, a unit of demand for a good from another city (1 unit) requires the sending of τ units.

With this in mind, substitute the pricing equation (19) into (13), equating it with supply in (22); substitute the pricing equation (20) into (14), total up demand of two cities, equalize it and supply in (22); substitute the pricing equation (21) into (15), total up demand of all three cities, and equalize it with supply in (22). So, a three urban goods market clearing condition is:

goods market clearing in rank 1 city is:

$$\alpha\sigma = \frac{w_1^{1-\sigma}H_1}{P_1^{1-\sigma}}; \tag{31}$$

goods market clearing in rank 2 city is:

$$\alpha\sigma = \frac{(\tau w_2)^{-\sigma}\tau w_1 H_1}{P_1^{1-\sigma}} + \frac{w_2^{1-\sigma}H_2}{P_2^{1-\sigma}} \tag{32}$$

goods market clearing in rank 3 city is :

$$\alpha\sigma = \frac{(\rho\tau w_3)^{-\sigma}\rho\tau w_1 H_1}{P_1^{1-\sigma}} + \frac{(\rho w_3)^{-\sigma}\rho w_2 H_2}{P_2^{1-\sigma}} + \frac{w_3^{1-\sigma}H_3}{P_3^{1-\sigma}} \tag{33}$$

Given every city's human capital, the two equations determine wage, and in turn price demand.

III. CONDITION OF ECHELON MIGRATION

Using survey data from China, income gaps significantly influence migration decisions. When an income gap reaches a certain level, the reaction of the migration probability to the income gap is different between sexes [17]. According to the Harris-Todaro theory [1], migration responds to differences in benefits between cities. It is well known that a homothetic utility function's indirect utility is proportional to "real" income, where income is deflated by the true price index, P. Since utility is ordinal, we can set the factor of proportionality to one, considering migration cost is fixed. Assume that migration responds to cost–benefit tradeoff between cities. Since income is deflated by the true price index P, person j wants to move from the original place to the destination if the benefit is greater than the moving cost D. For an individual, the critical condition of migration is that moving cost D equals migration benefits B. So, migration benefit is:

$$B_1 = \frac{w_2 h_j}{P_2} - \frac{w_1 h_j}{P_1} \tag{34}$$

$$B_2 = \frac{w_3 h_j}{P_3} - \frac{w_2 h_j}{P_2} \tag{35}$$

where B_1 and B_2 are migration benefits from rank 1 to 2 cities, and migration benefits from rank 2 to 3 cities, respectively.

The model's predictions are driven largely by the fact that the left hand side (the gain from moving) is increasing in hj, while the right hand side remains constant. Thus, people with more human capital have more incentives to migrate. Assume migrants from a rank 1 to 2 city have optimal migration durations in the rank 2 city, then the total benefits of migration to a rank 3 city are more than B_1+B_2. That is, when $\zeta>1$, we have

$$B_3 = \left(\frac{w_3 h_j}{P_3} - \frac{w_2 h_j}{P_2}\right) + \zeta\left(\frac{w_2 h_j}{P_2} - \frac{w_1 h_j}{P_1}\right)$$
$$> \left(\frac{w_3 h_j}{P_3} - \frac{w_1 h_j}{P_1}\right) \tag{36}$$

where B_3 is echelon migration benefits, ζ (>1) is an adjustment parameter, and shows the benefit of echelon migration is more than jump migration, and h_j is a constant for each migrant. Assume that migration costs between cities are constant. Persons with high human capital have more motivation to outmigrate. The larger the average wage difference between cities is, the greater the migration benefits are. Without migration motivation, goods markets and labor markets are clear. To show migration benefit, the gross human

capital ratio between cities of different ranks can be determined by inserting (28) and (29) into (32), solving (37). Inserting Eqs. (28)–(30) into Eq. (33), we get (38):

$$H_2/H_1 = x^{1-2\sigma} - (x\tau)^{1-\sigma} ; \tag{37}$$

$$H_3/H_1 = (x/y)^{1-2\sigma} - (x/y)^{1-2\sigma}(y)^{-\sigma}\rho^{1-\sigma} \tag{38}$$

Eqs. (37) and (38), thus, give:

$$H_3/H_2 = \frac{H_3/H_1}{H_2/H_1} = \frac{x^{1-2\sigma} - x^{1-2\sigma}(y)^{-\sigma}\rho^{1-\sigma}}{\left(x^{1-2\sigma} - (x\tau)^{1-\sigma}\right)y^{1-2\sigma}}$$

$$= \frac{x^{-\sigma} - (xy)^{-\sigma}\rho^{1-\sigma}}{\left(x^{-\sigma} - \tau^{1-\sigma}\right)y^{1-2\sigma}} \tag{39}$$

For simplicity, the calculation process is omitted. (34)–(39) gives:

$$B_1 = h_j{}^{1-\sigma}\sqrt{\frac{\alpha\sigma}{H_1}}\left(\frac{1}{{}^{1-\sigma}\sqrt{x^{1-2\sigma}}} - 1\right) \tag{40}$$

$$B_2 = {}^{1-\sigma}\sqrt{\frac{\alpha\sigma}{H_1}}\left(\frac{y}{{}^{1-\sigma}\sqrt{(x/y)^{1-2\sigma}\,y^{1-\sigma}}} - \frac{1}{{}^{1-\sigma}\sqrt{x^{1-2\sigma}}}\right)h_j$$

$$= {}^{1-\sigma}\sqrt{\frac{\alpha\sigma}{H_1}}\left(\frac{1}{{}^{1-\sigma}\sqrt{(x/y)^{1-2\sigma}}} - \frac{1}{{}^{1-\sigma}\sqrt{x^{1-2\sigma}}}\right)h_j \tag{41}$$

$$B_3 = {}^{1-\sigma}\sqrt{\frac{\alpha\sigma}{H_1}}\left(\frac{y}{{}^{1-\sigma}\sqrt{(x/y)^{1-2\sigma}}} - \frac{1}{{}^{1-\sigma}\sqrt{x^{1-2\sigma}}}\right)h_j$$

$$+ \zeta h_j\left(\frac{1}{{}^{1-\sigma}\sqrt{x^{1-2\sigma}}} - 1\right){}^{1-\sigma}\sqrt{\frac{\alpha\sigma}{H_1}} \tag{42}$$

IV. SIMULATION

Because of dynamic human capital externality and congestion diseconomies, large-scale migration can create benefits[4]. Echelon migration yields more total benefits than the total benefits of jump migration. Assume all agents suffer from a "money illusion," their migration decisions only depend on the nominal value of money, not its real value[5]. Defining the critical wage in a rank 1 city as x, when wages in a rank 1 city are lower than x, an agent in that rank 1 city will migrate from that rank 1 city and into a rank 2 city. Defining wages in the rank 2 city as 1, and the critical wage in a rank 3 city as y, then $0<x<1<y<2$[6]. Numerical values of x and y can be seen in table 1.

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[4] Luisito Bertinelli and Duncan Black.Urbanization and Growth.Journal of Urban Economics .2004 (56): 80–96.

[5] Because most peasents with low education and income know and feel little about inflation and deflation, we can assume most of them consider nominal wage in China.

[6] According to "Urban residents' income and expenses, savings and residential housing area statistics 2005 in Chinese 287 above prefecture-level cities (not including prefecture-administered counties,prefectures) ( ) ( ) ( ) ( ) (Chinese urban yearbook 2006)",in the provincial administration system, wages in provincial capital are higher than those in prefecture-level cities.In the whole country,per capita wage in Beijing, Shanghai, Guangzhou, Hangzhou, and Ningbo exceeds 3 ten thousand yuan. Wage ratio between prefecture-level city wage and their own provincial capital almost less than 1 more than 0, wage ratio

In Fig.2 and Fig.3, when x and y are small, the smaller the elasticity of substitution between differentiated goods σ, and the greater the variety of goods, the larger $B_1(x)$ and $B_2(x,y)$.When x and y increase, wages in the rank 1 and 2 cities continuously approach the rank 3 city wage. As they approach 2 times that of the rank 2 city, the migration benefit is near to 0.

TABLE I
NUMERICAL VALUES OF X AND Y

x	0.1	0.15	0.2	0.25	0.3
y	1.1	1.15	1.2	1.25	1.3
x	0.35	0.4	0.45	0.5	
y	1.35	1.4	1.45	1.5	
x	0.55	0.6	0.65	0.7	0.75
y	1.55	1.6	1.65	1.7	1.75
x	0.8	0.85	0.9	0.95	
y	1.8	1.85	1.9	1.95	

Labor force inflow has a positive effect on local wage growth[7]. From Fig.4 and Fig. 5, when x and y's numerical values are small, elasticity of substitution between differentiated goods is reduced. The bigger $B_1(x)$ and $B_2(x,y)$; when x and y's numerical values increase, $B_3(x,y)$ tends to converge to a numerical value (>0).This implies that as wages among cities approach 0, the migration benefit becomes smaller. The smaller elasticity of substitution between differentiated goods, the greater the migration benefit is, and vice versa.

Theorem 1: In the D-S framework, the benefit of echelon migration increases with gross human capital in the original region. That is to say, the higher gross human capital is in the original city, the more the migration benefit is.

Past research shows that migration between administrative districts of different ranks offers a perspective to study urbanization stages[8]. The spatial flow of human capital is pre-condition of spatial production agglomeration. Because human capital is attached to its owner, capital flows with its owner. So the relative human capital volume between cities can illustrate the urbanization process. Hence, human capital convergence classification depends on H_2/H_1, H_3/H_1 and H_3/H_2. If an agent in the initial stage between cities does not migrate, from eqs. (37)–(39), we know how the nominal wage ratio influences human capital distribution between cities.

Here, the transportation cost in urbanization plays an important role in the spatial distribution process. Lower transportation costs can increase the probability of agglomeration. High transportation cost obstruct goods flowing

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in Beijing, Shanghai and provincial capital are more than 1 and less than 2.If rank 1 city is prefecture-level city, rank 2 city is provincial capital, rank 3 city is Beijing, Shanghai.Then, except several prefecture-level cities, most cities satisfy the relationship.

[7] Zhong xiaohan,"labour force flow and wage difference", Chinese social science,2006,1:34-46.

[8] Marc Antrop,"Landscape change and the urbanization process in Europe" ,*Landscape and Urban Planning*, 2004,67 (1-4) ,9–26.

between cities, and produces a heterogeneous spatial distribution.

A. Human Capital Comparison between Rank 2 and 1 Cities

With (37), we illustrate Fig.6 and Fig.7. From Fig. 6, the smaller σ is, $\tau(>1)$ is a constant, where the value of H_2/H_1 is near to 1. This implies, with transportation costs fixed, and elasticity of substitution between differentiated goods becomes smaller, gross human capital in rank 1 and 2 cities is almost equal. In other words, the more the variety of industrial goods, the weaker the migration motivations that obstruct urbanization are. From Fig. 7, with σ fixed, $\tau(>1)$ becomes smaller, and the gross human capital ratio between rank 1 and 2 cities becomes smaller. In other words, transportation cost changes influence migration motivations from a rank 1 city weakly. In Figs. 6 and 7, when wages in rank 1 and 2 cities approach each other, gross human capital in the two cities approaches equality. This implies that a wage difference between rank 1 and 2 cities can weaken migration motivations.

B. Human Capital Comparison between Rank 3 and 1 Cities (H_3/H_1)

With (38), we create Fig. 8 and Fig. 9. The smaller σ, ρ (>1) is a constant, and the value of H_3/H_1 is near to 1. This implies, with transportation costs fixed, that when elasticity of substitution between differentiated goods declines, gross human capital in rank 1 rank 3 cities is almost equal. In other words, the more variety in industrial goods, the weaker motivation is for jump migration. In Fig. 9, with σ fixed, as $\rho(>1)$, gross human capital in rank 1 city 3 cities is almost equal. In other words, the smaller the transportation cost, the weaker motivation is for jump migration. In Fig. 8 and Fig. 9, wages in a rank 1 city are almost equal to the rank 2 city wages, and wages in the rank 3 city are almost equal to twice the wages the in rank 2 city. Gross human capital in the rank 1 and 3 cities is almost equal. This implies that echelon migration continues from the rank 1 city though rank 2 city to rank 3 city, and as the wage difference between rank 1 and 2 cities becomes smaller, wages in the rank 3 city are almost twice the wages in the rank 2 city.

C. Human Capital Comparison between Rank 3 and 2 Cities (H_3/H_2)

With (39), we yield the numerical values in Fig. 10 and Fig. 11. As shown, when σ becomes small, τ and $\rho(>1)$ are constant, and the value of H_3/H_2 is near to 1. This implies that with transportation costs fixed, when elasticity of substitution between differentiated goods becomes smaller, gross human capital in rank 2 and 3 cities is almost equal. In other words, the more variety in industrial goods, the weaker migration motivation is, and urbanization slows. From Fig.11, with σ fixed, the greater τ and $\rho(>1)$ are, gross human capital between rank 2 and 3 cities approaches equality. In other words, the higher transportation cost is, the weaker migration motivation is, and the slower urbanization pace is. In Figs.10 and 11, the wage ratio in rank 1 and 2 cities approaches 0, wages in the

rank 3 city approach wages in the rank 2 city, and gross human capital in rank 2 and 3 cities are almost equal.
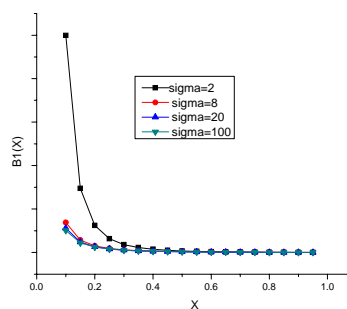

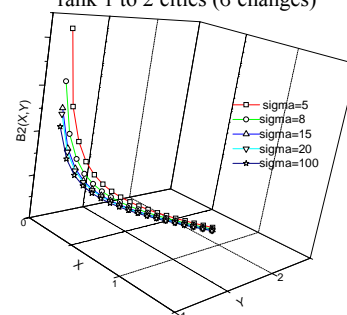Fig.2 Relationship between migration benefits and wage ratio from rank 1 to 2 cities (σ changes)

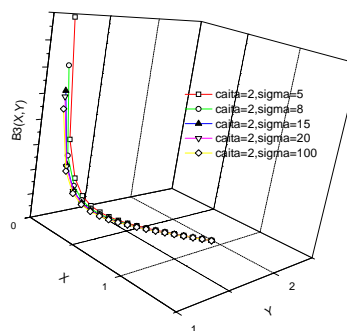Fig.3 Relationship between migration benefits and wage ratio from rank 2 to 3 cities (σ changes)

Fig.4 Relationship between migration benefits and wage ratio (σ changes)
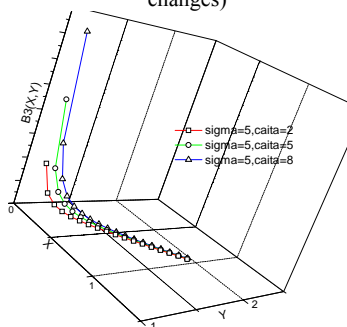

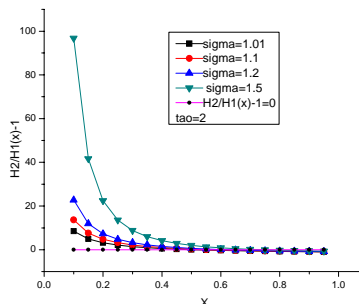Fig.5 Relationship between migration benefits and wage ratio (ζ changes)

Fig.6 Relationship between gross human capital ratio and wage ratio in rank 1 and 2 cities (σ changes)
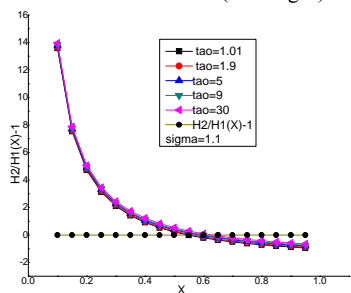

Fig.7 Relationship between gross human capital ratio and wage ratio in rank 1 and 2 cities (τ changes)
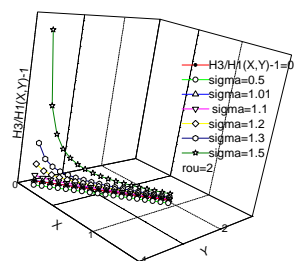

Fig.8 Relationship between gross human capital ratio and wage ratio in rank 1 and 3 cities (σ changes)
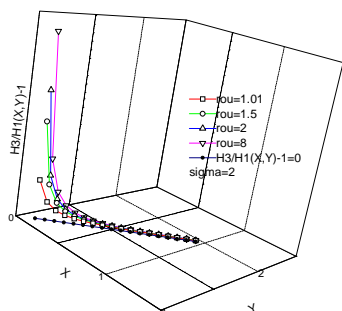

Fig. 9 Relationship between gross human capital ratio and wage ratio in rank 1 and 3 cities (ρ changes)
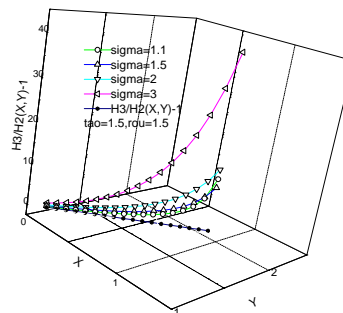

Fig.10 Relationship between gross human capital ratio and wage ratio in rank 2 and 3 cities (σ changes)
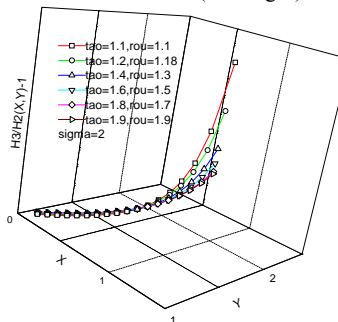

Fig.11 Relationship between gross human capital ratio and wage ratio in rank 2 and 3 cities (τ and ρ changes)

Above research shows that the smaller the elasticity of substitution between differentiated goods, the stronger is the demand preference of differentiated varieties. The stronger industrial differentiated varieties preference, and the higher human capital agglomeration to cities with higher rank is, the stronger the urban agglomeration effect, which benefits human capital volume in cities with higher ranks. There are 13 kinds of human capital convergence among cities. See Table 2. Income gap may be not a unique variable that determines echelon migration velocity. Other factors, such as educational chance and amenities, may contribute to human capital convergence. The number of cities within the different ranks is also a measure of healthy economic development.

Above all, because H_2/H_1, H_3/H_1 and H_3/H_2 can be more than 1, equal to 1 and less than 1, we get:

Theorem 2: In D-S framework, stage equilibrium exists in echelon migration. The human capital convergence among cities is influenced by transportation costs and elasticity of substitution between differentiated goods.Rich human capital in a small town can serve a medium city and a big city's expansion. The rapid growth of medium cities and big cities create benefits for echelon migration and lead to human capital agglomeration. The higher the destination's urban wage, the smaller the elasticity of substitution between differentiated goods. Differentiated varieties-of-goods demand promotes urban production agglomeration. However, urban human capital convergence can develop urban economy and encourage residents in cities with low rank to outmigrate.The influence of migration on the regional structure contributes to agglomeration because of the presence of increasing returns, and fosters regional convergence. Furthermore, the size of

agglomerations, when they occur, increase with the taste for variety and the scale of the manufacturing population, and decreases with transportation costs[18]. There are potential population growth shocks under 13 kinds of human capital convergence among cities. Population growth shocks (irrespective of their aggregate or disaggregate form) depict spatial movement that is deemed to contribute to economic growth fluctuations, depending upon their convergence properties to the long-run level [19]. Population growth shocks will also distort the process of urbanization, that is, the process of spatial movement of a population towards towns and cities, and their resulting expansion. The factors that commonly contribute to spatial movements of this kind include intrinsic population growth in urban areas and a resulting expansion along the periphery. Likewise, urbanization provides spatial dimension benefits and positive externalities arising from economies of scale, as well as agglomeration of economies in the utilization of resources, technology and public services.

TABLE II
HUMAN CAPITAL CONVERGENCE AMONG CITIES

H_2/H_1	H_3/H_1	H_3/H_2	human capital convergence
<1	<1	<1	①②③
		=1	①②③
		>1	①②③
	=1	>1	①②③
	>1	>1	①②③
=1	<1	<1	①②③
	=1	=1	①②③
	>1	>1	①②③
>1	<1	<1	①②③
	=1	<1	①②③
	>1	<1	①②③
		=1	①②③
		>1	①②③

Notice: Circle size respectively shows gross human capital ratios in three differently ranked cities. The circled number shows the ranks of cities.

V. SUMMARY AND CONCLUSIONS

This article fully specifies and formally solves a three-city model of echelon migration with three ranked cities within the Dixit-Stiglitz-Iceberg framework. How to create echelon migration and how echelon migration responds to changes in transportation cost and elasticity of substitution are analyzed. Numerical calculations illustrate the relationship between migration benefit-and-wage ratio, the relationship between gross human capital ratio and wage ratio in the origin and destination. These results yield several policy implications: (i) transportation costs between cities of different rank is influenced by roadway quality, vehicle type, and communication. In any future work, technological improvements should be considered in the model. (ii) interregional competition and protectionism within fragmented regional markets should also be considered by urban governments. Market fragmentation deters production specialization in accordance with patterns of comparative advantage, and discourages producers from taking advantage economies of scale. This leads to the discontinuity of the domestic market and distortion of regional production against patterns of comparative advantage.

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