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Agglomeration with the pros and cons of labor heterogeneity

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Agglomeration with the pros and cons of labor heterogeneity

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Abstract

Using a simple two-region model with the positive and negative effects of labor heterogeneity, we investigate the agglomeration pattern of entrepreneurs and the commuting pattern of heterogeneous workers. Labor heterogeneity is a source of productivity for e.g. high-tech industries as well as is an obstacle to e.g. mass production. As a result, we show that entrepreneurs tend to concentrate to a region hence regional labor markets are united with interregional commuting when (i) the commuting cost or (ii) the adjustment cost of labor heterogeneity is low, and when (iii) the input of heterogeneous labor is large. These results explain: the progress of urbanization with the decrease in commuting costs; the difference in the agglomeration tendency of industries.

JEL Classification: R11, R12, J61

Key words: labor heterogeneity, commuting cost, adjustment cost, urbanization

1. Introduction

In recent years, the effect of labor heterogeneity on urbanization has been regarded as an important issue because of the progress of agglomeration in the trend of globalization. The NEG literatures originating Krugman (1991) and Fujita et al. (1999) state that economic activities concentrate on cities because the decrease in transportation costs makes them possible to put together the plants and offices so as to benefit from the agglomeration economy. The evidence is the share of urban population keeps increasing in the world. Besides, as Jacobs emphasized in her books, the labor heterogeneity is the source of the productivity and the technological development in urban areas. Therefore, we should reveal the rolls of labor heterogeneity in the recent development of economic geography.

There have been numerous articles on the labor heterogeneity especially in recent years. For instance, Ottaviano and Peri (2006) and Bellini and Pinelli (2009) studied the effect of cultural heterogeneity on urban productivities in the United States and in Europe respectively, and Florida (2005) stressed that the cultural heterogeneity explains regional creativity. On the relation to agglomeration, Ottaviano and Prarolo (2009) studied the emergence of multi cultural cities in a two-city model with two cultural groups. In addition, Berliant and Fujita (2008, 2010) analyzed the knowledge diversity of workers and the effect on regional growth, and Berliant and Fujita (2011) shows the cultural separation among regions arises and the multiple cultures make knowledge productivity higher. Though these articles show the importance of labor heterogeneity, we observe some cases in which labor heterogeneity is an obstacle to production especially in mass production such as assembly plants. Sparber (2008) showed that the effect of racial variety on economic development can be positive or negative. In

addition, Sparber (2009) also investigated racial diversity and industrial productivities in the United States, and observed a positive effect on wages especially in legal services, computer manufacturing, computer software, and so on, while the labor heterogeneity does not play an important role in traditional sectors such as fabricated metal, raw durable manufacturing, mining, and so on.

In this paper, we analyze the agglomeration pattern of economic activities related with the benefit and the costs of labor heterogeneity. The remainder of this paper is organized as follows. In Section 2, we present a simple two-region model incorporating homogenous entrepreneurs and heterogeneous workers. In Section 3, we investigate the agglomeration pattern of entrepreneurs and interregional commuting patterns of workers. As a result, we show that entrepreneurs tend to concentrate to a region and regional labor markets are united with interregional commuting when the commuting cost or the adjustment cost of labor heterogeneity is low. Section 4 introduces homogenous workers into the above model, and explains the importance of labor heterogeneity. Finally, Section 5 concludes this paper.

2. The model

The model consists of two factors, K entrepreneurs and N workers. The entrepreneurs are homogenous, while workers are characterized by the continuum of horizontally differentiated types. We assume that each worker has labor amount $l(j)$, and the aggregate production function is given by

$$Y = cK^{1-\alpha}\int_0^N l(j)^{\alpha}\,dj\,. \tag{1}$$

This production function exhibits increasing returns to scale in variety. The precise explanation is in e.g. Ether (1982) and Behrens and Sato (2006). Assuming the

symmetry in the labor amount of each worker (i.e. $l(j) = l$), the profit maximization yields the wages of entrepreneurs and workers:

$$w_k = (1-\alpha)cN\left(\frac{l}{K}\right)^{\alpha}, \tag{2}$$

$$w_l = \alpha c\left(\frac{K}{l}\right)^{1-\alpha}. \tag{3}$$

Note that the wage of entrepreneurs is increasing in N because of the increasing returns to scale in variety, whereas that of workers is independent of N.

We introduce two regions, $r = 1,2$. Entrepreneurs are assumed to be freely mobile between regions, and the amount of entrepreneurs in region r is expressed as K_r. On the other hand, workers can not change the residential region, but can commute to the other region when the region of employment is different from the residential region. Assuming that each worker can not commute to two regions simultaneously (i.e. they can not provide labor service to the entrepreneurs in two regions), we rewrite the wages of entrepreneurs and workers as follows:

$$w_{kr} = (1-\alpha)c_r\frac{N_{(r)r}(l_{(r)r})^{\alpha} + N_{(s)r}(l^{\dagger}_{(s)r})^{\alpha}}{K_r^{\alpha}}, \tag{4}$$

$$w_{(r)r} = \alpha c_r\left(\frac{K_r}{l_{(r)r}}\right)^{1-\alpha}, \tag{5}$$

$$w^{\dagger}_{s(r)} = \alpha c_r\left(\frac{K_r}{l^{\dagger}_{(s)r}}\right)^{1-\alpha}, \tag{6}$$

where $l_{(r)s}$ is the worker who resides in region r and commute to region s, $N_{(r)s}$ is the number of the workers, and the superscript † means the values in the labor receiving region.

Considering the interregional commute, we assume commuting costs taking an "iceberg" from: $l^{\dagger}_{s(r)} = l_{(s)r}t$, $t \in [0,1]$. That is, by commuting from region *s* to region *r*, the initial amount of labor in region *s*, $l_{s(r)}$ shrinks to $l_{s(r)}t$. Therefore, the parameter *t* is thought as the easiness of the interregional commute. Such an iceberg form implies that the disposable wage of the commuter is also falls to $w_{s(r)} = w^{\dagger}_{(s)r}t$.

We introduce the adjustment cost of labor heterogeneity, because the labor heterogeneity provides not only the benefit but also the cost especially in mass production and assembly production. Concretely, we assume that $c_r = 1 - \gamma N_{(s)r}$, where $\gamma \in [0,1]$ means the degree of the negative effect. That is, the productivity is decreasing in the number of workers residing in the other region.

The factor distribution is defined as follows. First, letting *K* and θ be the total amount of entrepreneurs and the share of them locating in region 1 respectively, we have

$$\begin{aligned} K_1 &= \theta K, \\ K_2 &= (1-\theta)K. \end{aligned} \tag{7}$$

Second, letting *N* and λ be total number of number of workers and the share of region 1, and letting n_r be the share of workers who work in the residential region, we have

$$\begin{aligned} N_{(1)1} &= n_1\lambda N, & N_{(1)2} &= (1-n_1)\lambda N, \\ N_{(2)2} &= n_2(1-\lambda)N, & N_{(2)1} &= (1-n_2)(1-\lambda)N. \end{aligned} \tag{8}$$

Finally, choosing unit such that $l_{(r)s} = 1$, $K = 1$, $N = 1$, we derive the fundamental wage equations:

$$w_{k1} = (1-\alpha)[1-\gamma(1-n_2)(1-\lambda)]\frac{n_1\lambda + (1-n_2)(1-\lambda)t^{\alpha}}{\theta^{\alpha}}, \tag{9}$$

$$w_{k2} = (1-\alpha)[1-\gamma(1-n_1)\lambda]\frac{n_2(1-\lambda) + (1-n_1)\lambda t^{\alpha}}{(1-\theta)^{\alpha}}, \tag{10}$$

$$w_{(1)1} = \alpha[1-\gamma(1-n_2)(1-\lambda)]\theta^{1-\alpha}, \tag{11}$$

$$w_{(1)2} = \alpha[1-\gamma(1-n_1)\lambda](1-\theta)^{1-\alpha}t^{\alpha}, \tag{12}$$

$$w_{(2)2} = \alpha[1-\gamma(1-n_1)\lambda](1-\theta)^{1-\alpha}, \tag{13}$$

$$w_{(2)1} = \alpha[1-\gamma(1-n_2)(1-\lambda)]\theta^{1-\alpha}t^{\alpha}. \tag{14}$$

3. The location analysis

3.1 Commuting patterns of workers

This section considers the choice of commute, taking the location of entrepreneurs as given. First, workers in region 1 work in region 1 when $w_{(1)1} > w_{(1)2}$, and they commute to region 2 when $w_{(1)1} < w_{(1)2}$. The condition $w_{(1)1} > w_{(1)2}$ is rewritten as

$$n_1 < f_{n1}(n_2) \equiv \frac{1}{\gamma\lambda}\left[\left(\frac{\theta}{1-\theta}\right)^{1-\alpha}\frac{1-\gamma(1-\lambda)(1-n_2)}{t^{\alpha}} - (1-\gamma\lambda)\right]. \tag{15}$$

In the same way, workers in region 2 work in region 2 when $w_{(2)2} \geq w_{(2)1}$, and the condition is given by

$$n_1 > f_{n2}(n_2) \equiv \frac{1}{\gamma\lambda}\left[\left(\frac{\theta}{1-\theta}\right)^{1-\alpha}\left(1-\gamma(1-\lambda)(1-n_2)\right)t^{\alpha} - (1-\gamma\lambda)\right]. \tag{16}$$

We can easily see that $fn_1(n_2) > fn_2(n_2)$.

Figure 1 shows the functions, $f_{n1}(n_2)$ amd $f_{n2}(n_2)$, and the share of workers who decide to work in the home region, n_1^* and n_2^*. The commuting pattern is classified into three cases: (i) non-commuting, (ii) semi-commuting, (iii) full-commuting. First, the non-commuting pattern occurs in the condition of $f_{n1}(1) > 1$ and $f_{n2}(1) < 1$, which is

rewritten as $1-\theta_1 \le \theta < \theta_1$, $\theta_1 \equiv 1/(1+t^{\alpha/(1-\alpha)})$. In this case, all the residents decide to work in the home region, so we have

$$\begin{cases} n_1^* = 1 \\ n_2^* = 1 \end{cases} \tag{17}$$

Secondly, the pattern of semi-commuting to region 1 occurs when $f_{n2}(1) > 1$ and $f_{n2}(0) < 1$. Therefore we have

$$\begin{cases} n_1^* = 1 \\ n_2^* = n_2^S \equiv \dfrac{1}{\gamma(1-\lambda)}\left[\left(\dfrac{1-\theta}{\theta}\right)^{1-\alpha}\dfrac{1}{t^\alpha} - (1-\gamma(1-\lambda))\right] \end{cases} \tag{18}$$

for $\theta_1 \le \theta < \theta_2 \equiv 1/\{1+[(1-\gamma(1-\lambda))t^\alpha]^{1/(1-\alpha)}\}$. The pattern of full-commuting to region 1 occurs when $f_{n2}(0) > 1$. That is,

$$\begin{cases} n_1^* = 1 \\ n_2^* = 0 \end{cases} \tag{19}$$

when $\theta \ge \theta_2$.

Figure 1. The commuting patterns

The pattern of commuting to region 2 is derided in the same way. (The figures are omitted from Figure 1.) The semi-commuting pattern is given by

$$\begin{cases} n_1^* = n_1^S \equiv \dfrac{1}{\gamma\lambda}\left[\left(\dfrac{\theta}{1-\theta}\right)^{1-\alpha}\dfrac{1}{t^\alpha} - (1-\gamma\lambda)\right] \\ n_2^* = 1 \end{cases} \tag{20}$$

for the case of $\theta_3 \le \theta < 1-\theta_1$, where $\theta_3 \equiv ((1-\gamma\lambda)t^\alpha)^{1/(1-\alpha)}/[1+((1-\gamma\lambda)t^\alpha)^{1/(1-\alpha)}]$, and

the full-commuting pattern is given by

$$\begin{cases} n_1^* = 0 \\ n_2^* = 1 \end{cases} \tag{21}$$

for the case of $\theta < \theta_3$.

3.2 Distribution of entrepreneurs

In this section, we analyze the location of entrepreneurs who move to a region with a higher wage. We take the following steps. First, we consider the wages of entrepreneurs in each region for the five commuting patterns: (i) non-commuting, (ii) semi-commuting to region 1, (iii) full-commuting to region 1, (ii') semi-commuting to region 2, and (iii') full-commuting to region 2. Then, we find the equilibrium location pattern that offers the highest wage of entrepreneurs.

For the non-commuting pattern, substituting $n_1 = 1$ and $n_2 = 1$ into equations (9) and (10), and solving $w_{k1} = w_{K2}$ for θ, we derive the distribution of entrepreneurs:

$$\theta = \theta^N \equiv \frac{\lambda^{1/\alpha}}{\lambda^{1/\alpha} + (1-\lambda)^{1/\alpha}}. \tag{22}$$

Before considering the semi-commuting patterns, we show the full-commuting patterns. Considering the pattern of the full-commuting to region 1 (i.e. $n_1 = 1$ and $n_2 = 0$), we can see that the wage of entrepreneurs in region 1 is higher than that in region 2:

$$w_{k1} = (1-\alpha)\left(1-\gamma(1-\lambda)\right)\frac{\lambda + (1-\lambda)t^\alpha}{\theta^\alpha} > w_{k2} = 0. \tag{23}$$

Therefore, we have $\theta = 1$. On the other hand, the full-commuting to region 2 (i.e. $n_1 = 0$ and $n_2 = 1$) yields

$$w_{k2} = (1-\alpha)\left(1-\gamma\lambda\right)\frac{1-\lambda+\lambda t^\alpha}{(1-\theta)^\alpha} > w_{k1} = 0, \tag{24}$$

thus we have $\theta = 0$.

Finally we consider the semi-commuting patterns. For the pattern of semi-commuting to region 1 (i.e. $n_1 = 1$ and $n_2 = n_2^{SC}$), the wages are expressed as

$$w_{k1} = (1-\alpha)\left(1-\gamma(1-\lambda)(1-n_2^S)\right)\frac{\lambda+(1-\lambda)(1-n_2^S)t^\alpha}{\theta^\alpha}, \qquad (25)$$

$$w_{k2} = (1-\alpha)\frac{(1-\lambda)n_2^S}{(1-\theta)^\alpha}, \qquad (26)$$

for the area of $\theta_1 \le \theta \le \theta_2$. To see the relation between the wages, we consider the relative wage in the cases of $\theta = \theta_1$ and $\theta = \theta_2$. First, substituting $\theta = \theta_1$ and n_2^S into equations (25) and (26), we have

$$\left.\frac{w_{k1}}{w_{k2}}\right|_{\theta=\theta_1} = t^{\alpha^2/(1-\alpha)}\frac{\lambda}{1-\lambda}, \qquad (27)$$

which is lower than 1 when

$$t < \tilde{t} \equiv \left(\frac{1-\lambda}{\lambda}\right)^{(1-\alpha)/\alpha^2}. \qquad (28)$$

On the other hand, when $\theta = \theta_2$, we can see that $w_{k1} > w_{k2} = 0$. The distribution of θ which equalizes the wages is given by the inverse function of

$$t = f_{t1}(\theta) \equiv \left(\frac{\left((1-\theta)/\theta\right)^{1-\alpha} - \gamma\lambda(1-\theta)}{1-\gamma(1-\lambda)\theta}\right)^{1/\alpha} \quad \text{for } t < \tilde{t}. \qquad (29)$$

This equation is derived from solving $w_{k1} = w_{k2}$ for t. In the same way, semi-commuting to region 2 (i.e. $n_1 = n_1^S$ and $n_2 = 1$) derives the wages as

$$w_{k1} = (1-\alpha)\frac{\lambda n_1^S}{\theta^\alpha}, \qquad (30)$$

$$w_{k2} = (1-\alpha)\left(1-\gamma\lambda(1-n_1^S)\right)\frac{1-\lambda+\lambda(1-n_1^S)t^\alpha}{(1-\theta)^\alpha} \qquad (31)$$

for the case of $1-\theta_1 \le \theta \le \theta_3$, and the distribution of θ equating the wages is given by the inverse function of

$$t = f_{t2}(\theta) \equiv \left(\frac{\left(\theta/(1-\theta)\right)^{1-\alpha} - \gamma(1-\lambda)\theta}{1-\gamma\lambda(1-\theta)} \right)^{1/\alpha}. \tag{32}$$

Figure 2 shows the results of the distribution of entrepreneurs for the case of $\lambda > 1/2$. The arrows mean the movement of entrepreneurs on the borders of commuting patterns. Note that the broken lines mean the distribution is unstable.

Figure 2. The distribution diagram (for the case of $\lambda > 1/2$)

Finally we compare the wages to show the equilibrium distribution of entrepreneurs. Since the distributions in the areas of semi-commuting, $f_{t1}^{-1}(t)$ and $f_{t2}^{-1}(t)$, are unstable, we focus on the cases of non-commuting and full-commuting. The wage of entrepreneurs in each case is given by

$$w_{k1}^F = w_{k1}\big|_{\theta=1} = (1-\alpha)\left(1-\gamma(1-\lambda)\right)\left(\lambda + (1-\lambda)t^{\alpha}\right), \tag{33}$$

$$w_{k2}^F = w_{k2}\big|_{\theta=0} = (1-\alpha)\left(1-\gamma\lambda\right)\left(1-\lambda+\lambda t^{\alpha}\right), \tag{34}$$

$$w_k^N = w_{kr}\big|_{\theta=\theta^s} = (1-\alpha)\left[\lambda^{1/\alpha} + (1-\lambda)^{1/\alpha}\right]^{\alpha}, \tag{35}$$

and we can see that

$$\frac{w_{k1}^F}{w_{k1}^N} = \frac{\left(1-\gamma(1-\lambda)\right)\left(\lambda + (1-\lambda)t^{\alpha}\right)}{\left[\lambda^{1/\alpha} + (1-\lambda)^{1/\alpha}\right]^{\alpha}} > 1 \tag{36}$$

when

$$t > t_1^* \equiv \left(\frac{\left(\lambda^{1/\alpha} + (1-\lambda)^{1/\alpha}\right)^{\alpha}}{\left(1-\gamma(1-\lambda)\right)(1-\lambda)} - \frac{\lambda}{1-\lambda} \right)^{1/\alpha}, \tag{37}$$

and

$$\frac{w_{k1}^F}{w_{k2}^F} = \frac{\left(1-\gamma(1-\lambda)\right)\left(\lambda+(1-\lambda)t^\alpha\right)}{\left(1-\gamma\lambda\right)\left(1-\lambda+\lambda t^\alpha\right)} > 1 \tag{38}$$

when $\lambda > 1/2$. The thick lines on $\theta = \theta^S$ and $\theta = 1$ in Figure 2 mean the equilibrium distribution of entrepreneurs. In the same way, $w_{k2}^F / w_k^N > 1$ derives the condition for the concentration on region 2:

$$t > t_2^* \equiv \left(\frac{\left(\lambda^{1/\alpha} + (1-\lambda)^{1/\alpha}\right)^\alpha}{\left(1-\gamma\lambda\right)\lambda} - \frac{1-\lambda}{\lambda} \right)^{1/\alpha} . \tag{39}$$

Figure 3. The distribution pattern

Figure 3 shows the classification of equilibrium distribution of entrepreneurs in $\lambda - t$ plain. Consequently, we have the following proposition:

Proposition1. *When the interregional commute is easy such that $t \geq t_r^*$, the entrepreneurs concentrate to a region with a larger share of workers. When the commute is difficult such that $t < t_r^*$, the entrepreneurs disperse among regions.*

When entrepreneurs disperse among regions, they hire only the workers residing in the home region, so the variety of workers are restricted, and they can not obtain large benefit from the variety effect. On the other hand, in this case, workers should not commute between regions, so the labor force does not shrink through interregional commuting. When commuting cost is sufficiently high, the benefit of dispersion (i.e. the restriction of commuting cost) exceeds the cost of dispersion (i.e. the restriction of

variety effect), thus the entrepreneurs disperse among regions. Contrary, when entrepreneurs concentrate to one region, they hire workers residing in both of regions. In this case, the entrepreneurs benefit from large varieties of workers, but incur loss from commuting costs of workers residing in the other region. When commuting cost becomes sufficiently low, the benefit of concentration exceeds the cost, and it leads the entrepreneurs to concentrate to one region. Intuitively, the decrease in commuting costs resulting from e.g. the progress in the commuting facilities unites regions (or cities) with interregional commuting and reorganizes them into a large city. Such an urban transition explains the formation of megalopolis for instance.

Note that the distribution pattern is similar to that in the new economic geography. For instance, Fujita et al. (1999) and the following numerous articles explained the tendency of agglomeration with the decrease in transportation costs of manufactured goods. This paper shows a similar result by presenting a simple model analytically tractable.

Finally let us confirm the relation between the concentration and the adjustment cost of heterogeneous workers, γ. We can easily see that t_r^* is increasing in γ, so the economy tends to disperse when the adjustment cost of heterogeneous workers increases. This result explains the difference in the agglomeration patterns of industries is affected by the adjustment costs relative to the importance of labor heterogeneity. Therefore, we can say that some assembly plants tend to disperse to rural regions and hire relatively homogenous workers because the cost of labor heterogeneity exceeds its benefit in mass production. To the contrary, some of industries including high-tech and software industries, head offices, research institutes, etc, have agglomeration tendency, because the heterogeneity of skilled workers is important and they can hire various

workers from various regions and countries by concentrating on some specific regions e.g. Silicon valley.

4. An extension: substitution for homogenous labor

In this section, we consider the substitution of heterogeneous workers for homogenous workers, as an extension of the model. Introducing homogenous workers, we rewrite the production function (1) as

$$Y_r = c_r K_r^{1-\alpha}\left(\eta\left[\int_0^{N_{(r)r}} l_{(r)r}(j)^{\alpha}\,dj + \int_0^{N_{(s)r}} l_{(s)r}(j)^{\alpha}\,dj\right] + (1-\eta)U_r\right), \tag{40}$$

where U_r is the amount of homogenous workers in region *r*, and η means the weight of heterogeneous workers. We assume that homogenous workers can not move between regions. To focus on the effect of η, we set $\gamma = 0$, $\lambda = 1/2$ and $U_r = 1$.

Letting w_{Ur} be the wage of homogenous workers, the wages of all the factors are given by

$$w_{k1} = (1-\alpha)\frac{\eta\left[n_1\lambda + (1-n_2)(1-\lambda)t^{\alpha}\right] + (1-\eta)}{\theta^{\alpha}}, \tag{41}$$

$$w_{k2} = (1-\alpha)\frac{\eta\left[n_2(1-\lambda) + (1-n_1)\lambda t^{\alpha}\right] + (1-\eta)}{(1-\theta)^{\alpha}}, \tag{42}$$

$$w_{(1)1} = \alpha\eta\theta^{1-\alpha}, \tag{43}$$

$$w_{(1)2} = \alpha\eta(1-\theta)^{1-\alpha}t^{\alpha}, \tag{44}$$

$$w_{(2)2} = \alpha\eta(1-\theta)^{1-\alpha}, \tag{45}$$

$$w_{(2)1} = \alpha\eta\theta^{1-\alpha}t^{\alpha}. \tag{46}$$

$$w_{U1} = \alpha(1-\eta)\theta^{1-\alpha}, \tag{47}$$

$$w_{U2} = \alpha(1-\eta)(1-\theta)^{1-\alpha}. \tag{48}$$

In the same way as the previous section, $w_{k1} = w_{K2}$ yields the distribution of entrepreneurs in the patterns of non-commuting and full commuting (for the case of $n_1 = 1$ and $n_1 = 0$):

$$\theta = \theta^{Nh} \equiv \frac{(\eta\lambda + 1 - \eta)^{1/\alpha}}{(\eta\lambda + 1 - \eta)^{1/\alpha} + (\eta(1-\lambda) + 1 - \eta)^{1/\alpha}}, \tag{49}$$

$$\theta = \theta^{Fh} \equiv \frac{(\eta(\lambda + (1-\lambda)t^{\alpha} + 1 - \eta)^{1/\alpha}}{\eta(\lambda + (1-\lambda)t^{\alpha} + 1 - \eta)^{1/\alpha} + (1-\eta)^{1/\alpha}}. \tag{50}$$

Note that the semi-commuting pattern disappears when $\gamma = 0$. Then, comparing the wages of entrepreneurs in the two patterns, we have $w_{K1}^{F} / w_{K1}^{N} > 1$ when

$$t > t^{**} \equiv \left(\frac{\left[(\eta\lambda + 1 - \eta)^{1/\alpha} + (\eta(1-\lambda) + 1 - \eta)^{1/\alpha} - (1-\eta)^{1/\alpha} \right]^{\alpha} - (\eta\lambda + 1 - \eta)}{1 - \lambda} \right)^{1/\alpha}. \tag{51}$$

Therefore, the entrepreneurs concentrate to one region when commuting is sufficiently easy such that $t > t^{**}$.

Finally, considering $dt^{**} / d\eta\big|_{\eta=1} = 1 - 2^{\alpha} < 0$ and $dt^{**} / d\eta\big|_{\eta=0} = 1$, we have

Proposition2. *When the weight of heterogeneous workers is large (small) enough, the agglomeration tendency of the entrepreneurs increases (decreases).*

That is, when η is sufficiently large, the increase in η reduces t^{**}, and entrepreneurs tend to concentrate to one of the two regions. On the other hand, when η is sufficiently small, the increase in η raises t^{**} and entrepreneurs tend to disperse in two regions because the (positive) effect of labor heterogeneity is small.

This result reinforces the last discussion about the difference in the agglomeration patterns of industries. That is, some industries such as high-tech or software industries have large agglomeration tendency because of the importance of labor heterogeneity as well as the minute adjustment costs.

5. Conclusion

This paper constructed a simple two-region model and investigates the relation between the benefit and the costs of labor heterogeneity. As a result, we showed that the economy tends to concentrate on some regions when (i) commuting cost is low, (ii) the adjustment cost of heterogeneous workers is low, and (iii) the weight of heterogeneous workers is large. The first result explains the formation of large cities with the expansion of suburbs: the decrease in commuting costs unites regional labor market and the increase in labor heterogeneity stimulates the concentration of economic activities. The second and the third results explain the difference in the agglomeration tendency of industries. That is, some industries such as assembly plants tend to disperse among regions (or countries) because the labor heterogeneity is not so important and it can be an obstacle to mass production. On the other hand, some industries such as high-tech industries and research institutes tend to concentrate to some specific regions, because the concentration of production makes it possible to obtain heterogeneous workers who are the source of the productivity.

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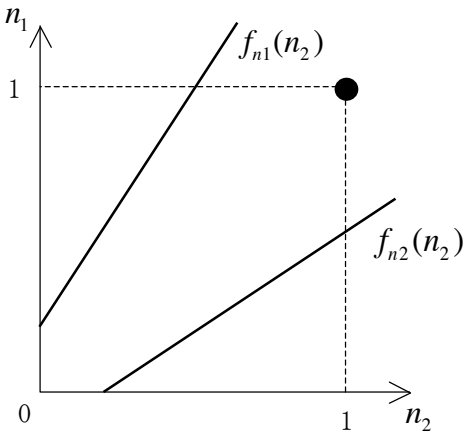
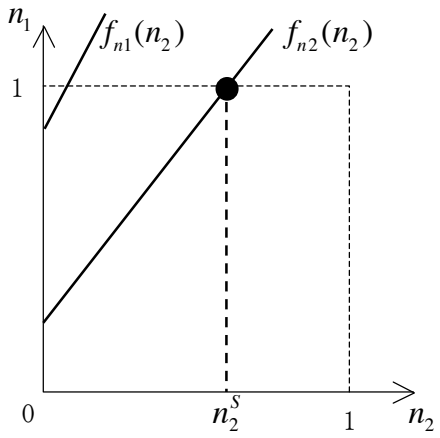
Figure 1. The commuting patterns

(i) $1-\theta_1 \le \theta < \theta_1$



(ii) $\theta_1 \le \theta < \theta_2$



(iii) $\theta_2 \le \theta$

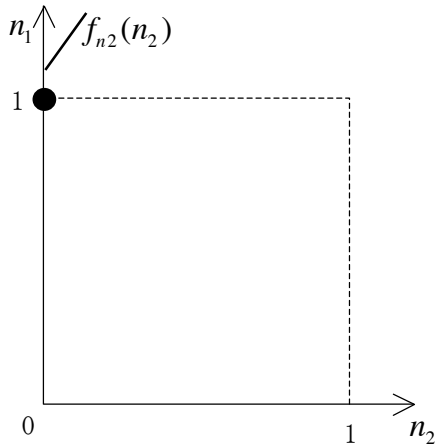


Figure 2. The distribution diagram (for the case of $\lambda > 1/2$)

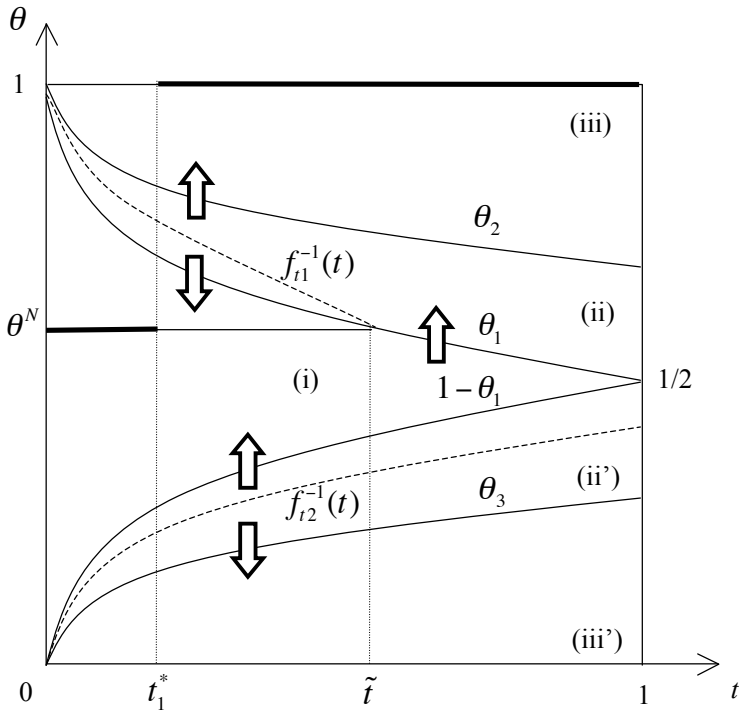
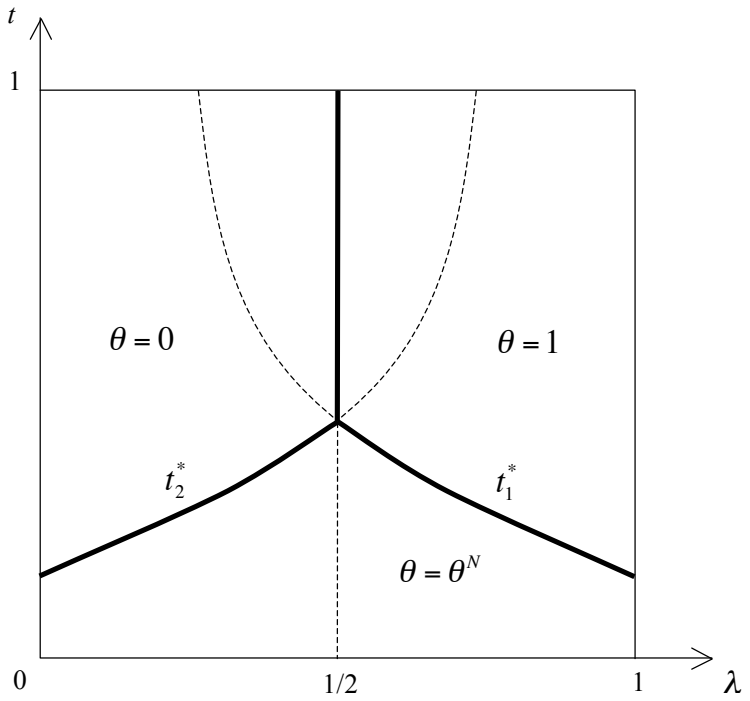



Figure 3. The distribution pattern