地域硏究, 第14卷 第2號
1998年 12月 pp. 65~75

Human Capital, Agglomeration Economies and Regional Economic Growth

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1. Introduction

Human capital is widely recognized as one of the main sources for economic growth . With this recognition many researchers (Jorgenson and Fraumeni, 1993; Findlay and Rodriquez, 1981; Garcia-Mila and McGuire, 1992; among others) have measured the impact of investment in human capital on economic growth and have modeled economic growth. Mankiw, Romer and Weil(1992) demonstrated that the pioneering Solows neoclassical model does explain well international variations in per capita income if the importance of human capital is acknowledged. Their outcome implies in the regional context that human capital must be included in modeling so that the model represents regional growth more realistically. Human capital can easily be embodied in the regional model since most theories of regional growth have evolved from the Solows model. Strangely enough, however, the literature shows that researchers have paid little attention to the importance of human capital in regional growth. Consequently, this tendency leads to the fact that regional models do not present sufficient understanding of regional growth.

The main purpose of this paper is to improve general understanding of regional growth by building a model which takes into account human capital in a simple partial equilibrium framework. The paper is designed as follows. Section 2 describes the model structure and growth of a regional economy. To reflect the role of human capital in regional growth, labor is divided into two groups, educated labor and uneducated labor. Section 3 explores regional growth with consideration to the role of the educational facility. Section 4 extends the result obtained in section 3 to investigate the impact of the presence of agglomeration economies on regional growth. Finally, section 5 contains a summary and suggests future research.

2. The Model

A national economy is considered consisting of small and many regions. Each regional economy produces a single output with capital (K_t), educated labor (E_t) and unducated labor (N_t) via a constant return Cobb-Douglas production function,

$$Y_t = AE_t^{\alpha} N_t^{\beta} K_t^{1-\alpha-\beta} , \qquad (1)$$

where A is the regional productivity index, and the subscript "t" refers to time.

Under the assumption of a competitive market, each firm employs factors such that the value of an input's marginal value product is equal to the factor price. Each factor price is thus expressed as follows:

$$w_{Et} = \frac{\partial Y_t}{\partial E_t} , \quad w_{Nt} = \frac{\partial Y_t}{\partial N_t} , \quad r_{Kt} = \frac{\partial Y_t}{\partial K_t} , \qquad (2)$$

w_{it} : labor i's wage rate (i=E,N),

r_{Kt} : capital returns.

Since regions are open, factors are mobile across regions. With regard to factor mobility, it is assumed that capital is perfectly mobile, while labor is partially mobile. Thus, marginal returns to capital is identical across regions,

$$\bar{r} = r_{Kt} , \qquad (3)$$

where $\bar{r}$ is national average capital return.

The labor of a region grows due to two components, natural growth and migration, whereby the natural growth rate of the population is assumed to be zero. This assumption is based on the general observations that the natural growth rate sharply declines as the economy develops (Alonso, 1980). Labor basically moves in response to wage differences between regions. Here, the number of migrants is assumed to be determined by wage differences, the size of the region's labor force, and a labor movement sensitivity index. The movement sensitivity index represents the various movement barriers such as language, culture, etc. With these two assumptions labor growth in each region is expressed as follows:

$$\overset{\circ}{E}_t = q_1(w_{Et} - \bar{w}_E)E_t , \qquad (4)$$

$$\overset{\circ}{N}_t = q_2(w_{Nt} - \bar{w}_N)N_t , \qquad (5)$$

$\overset{\circ}{x}$:growth of x (dx/dt),

q_i :labor i's movement sensitivity index,

$\bar{w}_i$: labor i's national average wage rate(i=E,N).

Using equation (3), the regional production function is expressed in terms of two factors which are educated labor and uneducated labor.

$$Y_t = \bar{A} E_t^{\sigma} L_t^{\rho} \tag{1-1}$$

$$\bar{A} = A \circ \left(\frac{1-\alpha-\beta}{\bar{r}} \right)^{\frac{1-\alpha-\beta}{\alpha+\beta}},$$

$$\sigma = \frac{\alpha}{\alpha+\beta}, \quad \rho = \frac{\beta}{\alpha+\beta}.$$

Equations (4) and (5) can be reduced to one equation by introducing a new variable consisting of the ratio of educated labor to uneducated labor, $k_t (= E_t / N_t)$. Thus, the growth rate of is the difference between growth rates of k_t educated labor and uneducated labor,

$$\frac{\overset{\circ}{k_t}}{k_t} = \frac{\overset{\circ}{E_t}}{E_t} - \frac{\overset{\circ}{N_t}}{N_t}. \tag{6}$$

Inserting equations (4) and (5) into (6),

$$\frac{\overset{\circ}{k_t}}{k_t} = \theta(k_t)$$

$$= \{\sigma q_1 \bar{A} k_t^{-\rho} - q_1 \bar{w}_E\} - \{\rho q_2 \bar{A} k_t^{\sigma} - q_2 \bar{w}_N\}. \tag{7}$$

As shown in Figure 1, there exists a stationary equilibrium point, k^* such that for $\frac{\overset{\circ}{k_t}}{k_t} = 0$. At k^*, both educated labor and uneducated labor grow at a constant regional rate. Also, this equilibrium point is locally stable.

$$\left. \frac{d\theta(k)}{dk} \right|_{k=k^*} < 0. \tag{8}$$

The phase diagram indicates that a stable regional growth equilibrium is always achieved through factor mobility across regions. Moreover, there exists a unique growth path which converges toward the equilibrium (k^*)for any initial point (k_o). In equilibrium, per capita regional output (y^*) and output per educated labor and uneducated labor(y_i^* : i = E,N) are,

$$y^* = y_E^* + (y_N^* - y_E^*)\left(\frac{1}{k^* + 1}\right),$$

$$y^*_E = \bar{A}(k^*)^{-\rho}, \; y_N^* = \bar{A}(k^*)^{\sigma}. \tag{9}$$

This kind of result can be easily found in various neoclassical regional growth models (Smith, 1975; Rabenau, 1979, 1985; Dentronos, 1982; Miyao, 1987), even though the factors employed and points are somewhat different.

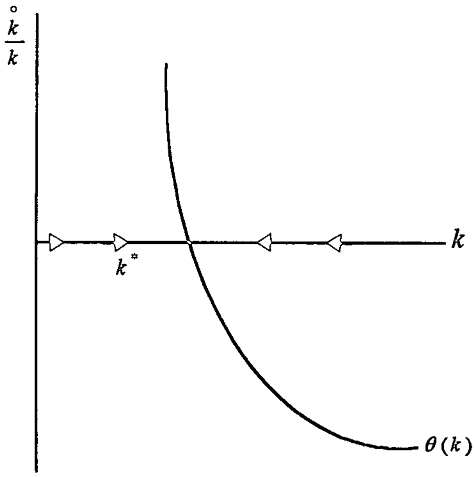


Figure 1. Rgional Growth Equilibrium Point

3. Regional Growth Considering Educational Facilities

Labor learns skills and acquires knowledge mostly in educational facilities and becomes educated labor which results in productivity improvement of a economy. This indicates that the educational facility plays a essential role in regional growth. Generally speaking, a region with an educational facility can produce more and has a better chance of retaining educated labor in the region than regions without such a facility. That is to say, educational facilities have an essential effect on the growth of an educated labor force in a region. This generality illustrates that educational facilities must be included in a model in order for the model to present sufficient understanding of regional growth. Thus this section explores regional growth taking into consideration the educational facility that a region retains.

The educated labor force of a region is determined by two components. The first component is interregional labor movement resulting from the wage differences, as in equation (4). The second component is the educational facility that a region retains as mentioned above. To link an educational facility to regional economic growth, it is assumed that the educational facility size of a region is positively related to the regional output scale. This assumption is based on recent findings(Kim, 1997) that high regional output scale results in large regional government expenditure due to taxation, which in turns facilitates efforts by the regional government to spend more on education. Eventually, more spending on education provides an increase in the volume(or number) of educational facilities which in turns means that the region can produce more educated labor. In short, a region producing a high level of output can produce and retain more educated labor as well. Taking these two components into account, the growth of educated labor in a region is expressed,

$$\overset{\circ}{E}_t = \phi(Y_t)E_t + q_1(w_{Et} - \bar{w}_E)E_t, \quad (10)$$

$$\overset{\circ}{N}_t = q_2(w_{Nt} - \bar{w}_N)N_t.$$

where $\phi(Y_t)$ is an educational facility size which is a function of regional output.

The first term of the equation (10), $\phi(Y_t)E_t$, indicates the contribution of regional output scale to the accumulation of educated labor in the region. The second term of the equation represents the change of educated labor resulting from migration. For the sake of simplicity, it is assumed that regional education facility size is linearly related to regional output.

$$\phi(Y_t) = \gamma Y_t, \ \gamma \ \text{: constant.} \quad (11)$$

Since the regional production function is expressed by two factors, E_t and N_t, the dynamic growth path of a regional economy is given by two equations of $\frac{\overset{\circ}{E}_t}{E_t} = 0$ and $\frac{\overset{\circ}{N}_t}{N_t} = 0$. A standard procedure in exploring the growth path is to determine the location of all (N, E) for which $\frac{\overset{\circ}{E}}{E} = 0$ and $\frac{\overset{\circ}{N}}{N} = 0$.

To do this, we define,

$$\psi(N_t, E_t) = \{(N, E) : \tfrac{\overset{\circ}{E}}{E} = 0\}, \quad (12)$$

$$\varphi(N_t, E_t) = \{(N, E) : \tfrac{\overset{\circ}{N}_t}{N_t} = 0\}.$$

To draw the loci $\frac{\overset{\circ}{E}}{E} = 0$ and $\frac{\overset{\circ}{N}}{N} = 0$, differentiation of (12) leads to

$$\left.\frac{dE}{dN}\right|_{\frac{\overset{\circ}{E}}{E}=0} = (-)\frac{\frac{\partial\psi}{\partial N}}{\frac{\partial\psi}{\partial E}}, \quad \left.\frac{dE}{dN}\right|_{\frac{\overset{\circ}{N}}{N}=0} = (-)\frac{\frac{\partial\varphi}{\partial N}}{\frac{\partial\varphi}{\partial E}}. \quad (13)$$

The shape of the steady-state of educated labor has the following characteristics:

$$\left.\frac{dE}{dN}\right|_{\frac{\overset{\circ}{E}}{E}=0} \begin{Bmatrix} - \\ \infty \\ + \end{Bmatrix}, \text{ as } E \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} \frac{(1-\sigma)q_1}{\gamma}. \quad (14)$$

From equation (13), when E approaches zero and infinite, the locus slope of the steady-state of educated labor is,

$$\lim_{E \to 0} \left.\frac{dE}{dN}\right|_{\frac{\overset{\circ}{E}}{E}=0} = 0, \quad \lim_{E \to \infty} \left.\frac{dE}{dN}\right|_{\frac{\overset{\circ}{E}}{E}=0} = -\infty. \quad (15)$$

Using equations (14) and (15), the shape of the steady-state of educated labor growth $(\frac{\overset{\circ}{E}_t}{E_t}=0)$ is obtained. Similarly, the locus of the steady-state of non-educated labor growth $(\frac{\overset{\circ}{N}_t}{N_t}=0)$ is determined by the following condition:

$$\left.\frac{dE}{dN}\right|_{\frac{\overset{\circ}{N}}{N}=0}=c>0 \quad , \quad c\ :\ \text{constant.} \qquad (16)$$

To explore the growth of a regional economy, a phase diagram is constructed by expressing the two dynamic equations in the N-E space. As shown in Figure 2, the two loci of $\frac{\overset{\circ}{E}_t}{E_t}=0$ and $\frac{\overset{\circ}{N}_t}{N_t}=0$ divide the N-E plane into four parts for which the sign $\frac{\overset{\circ}{E}_t}{E_t}$ and $\frac{\overset{\circ}{N}_t}{N_t}$ is constant. The motion of the system in each part is determined by the following derivative conditions:

$$\frac{\partial(\overset{\circ}{E}/E)}{\partial E}>0\ ,\quad \frac{\partial(\overset{\circ}{N}/N)}{\partial N}>0 \qquad (17)$$

This completes the analysis of the phase diagram. Arrows shown in each part indicate the direction a path takes. To illustrate the phase diagram shown in Figure 2, first, the growth equilibrium point, (N^*, E^*), is characterized as a saddle point so that the equilibrium point can be reached only along a branch. The branch is represented by a so-called locus of minimum threshold of growth. The existence of the locus of minimum threshold illustrates that a region must overcome the minimum threshold to grow, otherwise it decays. This implies that the direction of regional growth depends on the initial condition, (N_o, E_o), of an economy. That is to say, a region below the locus of minimum threshold is dying since the growth path of the economy ultimately leads the region to (N, E)=(0,0). When a regional economy initially lies above the locus of minimum threshold, it will grow. A regional economy is not thus necessarily converging on a stationary equilibrium point through factor movement. This result is different from the one obtained in the previous section.

The fact that the equilibrium point is a saddle point even when regional production exhibits constant returns sharply contrasts results with existing regional growth models. Those models suggest that whether a growth equilibrium point is stable or not depends on the production function that a region provides (Niehans, 1963; Smith, 1975; Rabenau, 1979; Dentrinos, 1982; Miayo, 1987; among others). Specifically, when the regional production function represents increasing returns, a regional growth equilibrium is a saddle point. When regional production function is characterized as constant returns or decreasing returns, the region has a stable growth equilibrium point. Thus the paper shows that the characteristics of regional growth tends to be determined by the role of an educational facility that a region keeps rather than technical characteristics of production function which a region provides.

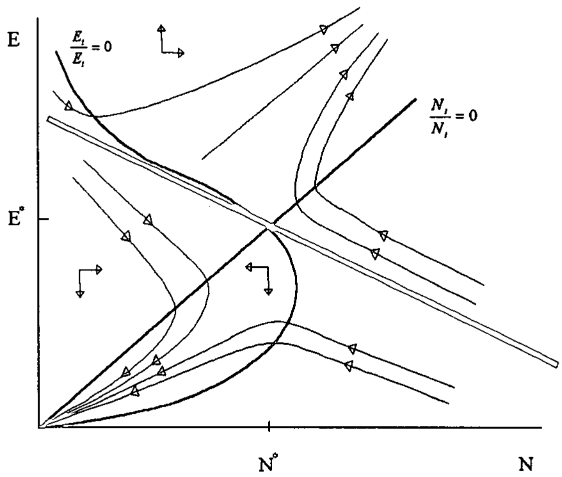


Figure 2. Phase Diagram Of Regional Growth

4. Agglomeration Economies and Regional Economic Growth

Many regional models have suggested that the presence of agglomeration economies determines the characteristics of a growth equilibrium point, i.e., stable and unstable. However, the previous section showed that a growth equilibrium point is not stable even when regional production function exhibits constant return to scale. If so, what is the effect of agglomeration economies on regional growth? This question will be answered in this section. This section investigates the effect of agglomeration economies on regional growth extending the result of the previous section. It is assumed that regional output is produced with variable agglomeration economies with a productivity index, $A(E_t)$. This productivity index represents the average labor productivity of the region and varies depending only upon the size of the educated labor. Specifically, it takes the form,

$$A(E_t) = \frac{aE_t^2}{(b+E_t)^2}, \quad a,b>0 \tag{18}$$

The productivity index is based on the productivity index form of Rabenau (1985) and Kim (1992). That is, agglomeration economies of a region which varies according to educated labor are rising throughout but bounded from above.

The regional production function (1-1) is thus re-expressed to take agglomeration economies into consideration,

$$Y_t = \tilde{A}_t E_t^{\sigma} L_t^{\rho}, \quad (1\text{-}2)$$

$$\tilde{A}_t = A(E_t) \circ \left(\frac{1-\alpha-\beta}{\bar{r}} \right)^{\frac{1-\alpha-\beta}{\alpha+\beta}}$$

In modeling regional growth, the presence of agglomeration economies under the competitive market is represented by parametric external economies of scale (Chipman, 1970). It implies that there are constant returns to scale to the individual firm but increasing returns to scale to the region as a whole. Specifically speaking, each firm's production function is characterized $\frac{\partial \tilde{A}(E_t)}{\partial E_{it}} = 0$ by which means that each firm in a region experiences constant returns to scale regardless of the presence of regional economies of scale. Thus each firm's production function in the region is expressed as follows:

$$Y_{it} = \tilde{A}(E_t) E_{it}^{\sigma} N_{it}^{\rho}, \quad (1\text{-}3)$$

Y_{it} : production of each individual firm i in the region,

$E_{it}(N_{it})$: the number of educated (non-educated)labor employed in individual firm i in the region.

To explore the impact of agglomeration economies on the long term equilibrium, consider the phase diagram and specifically the two loci of and . Each locus shifts when educated labor increases. The direction of this shift is found by the following conditions:

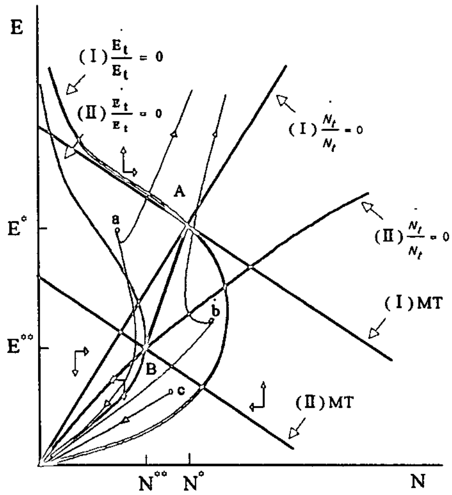
$$\left. \frac{dN}{dA} \right|_{\frac{\mathring{E}}{E}=0} = (-)\frac{\partial \psi / \partial A}{\partial \psi / \partial A} < 0, \quad (19)$$

$$\left. \frac{dN}{dA} \right|_{\frac{\mathring{N}}{N}=0} = (-)\frac{\partial \varphi / \partial A}{\partial \varphi / \partial N} < 0.$$

The shifts of these two loci are bounded by educated labor, since the productivity index has an upper limit as in equation (18). The locus of $\frac{\mathring{E}}{E} = 0$ shifts leftward with a limit. At the same time, the locus of $\frac{\mathring{N}}{N} = 0$ shifts rightward with a limit. As shown in Figure 3, there is a locus of points of intersection of $\frac{\mathring{E}}{E} = 0$ and $\frac{\mathring{N}}{N} = 0$ which represents the lay between equilibria corresponding to each E_t. Here, this is called the agglomeration locus of equilibrium points, depicted as AB in the phase diagram. This illustrates that with rising E_t, the equilibrium point shifts along this agglomeration locus of equilibrium points. The point A, (N^*, E^*), represents the equilibrium with initial productivity index $A(E_o)$, and the point B, (N^{**}, E^{**}), given by the extremal loci of $\frac{\overset{\circ}{E}}{E}=0$ and $\frac{\overset{\circ}{N}}{N}=0$.

The shifts of the two loci of $\frac{\overset{\circ}{E}}{E}=0$ and $\frac{\overset{\circ}{N}}{N}=0$ due to the presence of agglomeration economy subsequently generate the shift of the locus of minimum threshold downward. The MT(I) and MT(II) in the phase diagram represents the locus of minimum threshold with initial and extreme values in productivity index, respectively. Next, consider the impact of agglomeration economies on the economic growth paths. The presence of agglomeration economies affects the growth paths, since the productivity index function is entered in two dynamic equations of $\frac{\overset{\circ}{E}}{E}$ and $\frac{\overset{\circ}{N}}{N}$. Their impact on the growth paths is similar to the shift of the equilibrium point along the agglomeration locus of equilibrium points for each E_t, i.e., the growth paths change when E_t rises.

The phase diagram shows that the presence of agglomeration economies does not always lead the region to growth since there still exists the minimum threshold in the presence of agglomeration economies. The impact of agglomeration economy on regional growth only lowers the minimum threshold. Thus, a region like "a" or "b" which is below the initial minimum threshold can grow due to agglomeration economies. On the other hand a region like "c", far below the minimum threshold, decays despite of the existence of agglomeration economies.



(I) : with E_0, (II) : with E_s, MT : Minimum Threshold

Figure 3. Regional Growth under Agglomeration Economies

5. Summary

This paper has modeled the growth of a regional economy taking human capital into consideration. When labor is separated into educated labor and uneducated labor, it appears that a regional economy converges toward a stable equilibrium point. This result is very similar to that of existing neoclassical growth models. However, when the role of the educational facilities is considered, regional growth becomes unstable showing the existence of a minimum threshold. This indicates that a region must overcome it in order to grow, otherwise it decays. Moreover, the impact of agglomeration economies on a regional economy has been analyzed through phase diagram. It appears that their impact only lowers the minimum threshold. These results illustrate that educational facilities a region retains is the most crucial factor in determining the characteristics of regional growth.

Finally, this paper has modeled regional growth in a simple partial equilibrium framework. A general equilibrium framework presents better understanding of reality (Kelley and Williamson 1984). A single region model must be thus extended to a multi-regional growth model in a general equilibrium framework. When the model is constructed, it should at least be based upon a two-sector two-region economy. In this manner, meaningful results can be obtained as to impacts of education and educational facilities on a regional economy and the national economy.

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ABSTRACT

Education is widely recognized one of main sources for growth. This paper attempts to incorporate the general recognition into formal regional growth model. The model structure is largely neoclassical. It produces a single good with the two factors, educated labor and non-educated labor, via a constant return production function. Each factor is partially mobile migrating to the region with the higher real wage. The educated labor in a region is accumulated by two sources, migration and physical education capital, while the non-educated labor is by only migration.

The paper shows that regional growth equilibrium is characterized as a saddle point. This indicates the presence of the minimum threshold size that must be overcome before a region may grow. It contrasts sharply with results obtained in regional growth models. The paper suggests that regional growth is determined less by the technical characteristics of regional production function but by the stock combination of educated labor and non-educated labor. Based on this result, the impact of agglomeration economies on regional growth is explored. It is by phase diagram demonstrated that the presence of agglomeration economies do not always lead a region to growth since there still exists the minimum threshold even in the presence of agglomeration economies.