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Abstract

This paper investigates the convergence of GDP per capita across Mongolia's twenty-two aimags and five regions[***].

According to international and domestic surveys, one third of the Mongolian population is living under the poverty line. Specifically, poverty is deeper in rural areas than in urban areas. Thus, one main objective of economic growth should be reducing the cross-regional income differences and maintaining real long-run per capita income growth. However, in Mongolia there is almost no research on regional economic development and regional income disparities.

This is the first time that the speed of convergence to the steady state has been estimated, using a Mongolian cross-regional data set (1989-2004). The results show that there is convergence across all Mongolian aimags and regions. The speed of convergence towards the steady state position is 3 percent in the Solow model and 4.3 percent in the Ramsey model. That is substantially higher than other convergence studies. The study also finds that migration has played an important role in the evolution of regional disparities.

Keywords: Convergence, GDP per capita, Speed of Convergence, Migration

JEL classification codes: O15, O18, O47

[***] In this paper, two different geographic levels are used: aimag (same like U.S states, Canadian provinence, Swedish counties and Japanese prefectures) and region (the country also divided into West, Khangai, Central and East regions and the Capital city Ulaanbaatar depending on living standards)

1. Introduction

There are significant differences between Mongolia and most other developing countries. Examples are, an expansive territory (1.566 million square kilometer), low population density (only 1.7 per square kilometer) and an economic structure influenced by a formerly centrally planed economy.

Stable economic growth is required for the long-run sustainable growth of the country. In the last decade of the centerally planed economy (1980-1989) Mongolia’s average economic growth was 6 percent, but during the first five years (1990-1994) of the transition it fell to minus 4.7 percent. Average economic growth improved to 4 percent between 1995 and 2004. The Mongolian economy path towards stable economic growth is uncertain.

According to international and domestic surveys, one third of the Mongolian population is living under the poverty line. Thus one main objective of economic growth should be reducing the cross-regional income differences and maintaining real long-run per capita income growth. This paper studies the convergence speed across Mongolian aimags in terms of per capita GDP.

Due to the transformation to the free market economy, the Government of Mongolia’s policy to reduce cross regional income differences has been almost lost and regional GDP per capita differences have increased. Widening differences in GDP by region caused migration which has made a dramatic influence on regional convergence. Although the period is short, the data set used in this study covers the 15 years of the transformation to the market economy since 1989.

The remainder of this paper is organized into four sections. The first section presents the theory and the methodology. The second section is concerned about data issues. The third section discusses the empirical analysis of regional convergence. The conclusion and some further discussion are in the last section.

2. Theory and Methodology

In growth empirics, convergence plays key role. Convergence refers to the process by which relatively poorer economies grow faster than rich ones. The definition of absolute convergence, in the long-run, says poorer regions or countries tend to grow faster than richer regions or countries in per capita terms. Accordingly, poor regions or countries will at last achieve the same level of per capita income as rich oneswhithout the inclusion of conditioning variables. Absolute convergence does not always hold[1]. For example, see Barro and Sala-i-Martin (2004, p.45, Figure 1.7). Enormous empirical literature shows that absolute convergence does hold if we consider the hypothesis of more homogeneous economies. In the first part of the study represents absolute convergence across Mongolian aimags and regions.

According to the neoclassical growth model, if regions or economies have relatively little differences subject to population growth, technological progress and the saving rate, then initially different regions or economies in terms of per capita income converge to the same steady state level. In this section we will consider the estimation of convergence coefficient β in which it is based on neoclassical growth theory as in Joakim Persson (1994).

Log-linearising the differential equations of a closed economy, Ramsey model with labor-augmenting technological progress yields the following convergence equation around steady state.

$$\ln \hat{y}(t) = e^{-\beta t} \cdot \ln \hat{y}(0) + (1 - e^{-\beta t}) \ln \hat{y}^{*} \qquad \beta > 0 \tag{6}$$

where, $\hat{y}$ is output per effective labor, $\hat{y}^{*}$ is the steady state level of output per effective labor, and β is the rate of covergence, which is determined by the parameters of technology and time preferences.

Equation (6) exhibits that $\ln \hat{y}(t)$ is a weighted average of the initial and steady state values, with the weight on the initial value declining exponentially at the rate β.

Rewriting per effective labor output in equation (6) into per capita output, setting $t = T$ and rearranging, yields for the average growth rate of per capita income or output as follows (please see the numerical appendix for more).

$$(1/T) \cdot \ln[y(T)/y(0)] = x + [(1 - e^{-\beta T})/T] \cdot \ln[\hat{y}^{*}/y(0)] \tag{7}$$

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[1] In the neoclassical framework, economies with different structural parameters tend to converge to different steady states in terms of per capita income as opposed to converge to same steady state. In this case, when each economy approach to their steady state, initially low per capita income economy tends to grow faster the further. This is the conditional covergence. Please see Mankiw, Romer, Weil (1992), Barro and Sala-i-Martin (2004), Mathur (2005) and so on.

where, x is the exogenous rate of labor-augmenting technological progress. Given x and $\hat{y}^*$, equation (7) shows inverse relation between initial per capita income and the average per capita income or output growth.

To derive the statistical model, change equation (7) to a discrete period. In equation (8) applies i to economy (please see the numerical appendix for more).

$$\ln[y_{i,t} / y_{i,t-1}] = a - (1 - e^{-\beta}) \cdot [\ln y_{i,t-1} - x \cdot (t-1)] + u_{i,t} \tag{8}$$

where, $u_{i,t}$ is the disturbance term and here we assume that convergence coefficient β is the same across economies and $a = x + (1 - e^{-\beta}) \cdot \ln \hat{y}^*$ [2].

The statistical model that is used for testing for β-convergence is given by equation (9). It is implied by equation (7) and (8). The average growth rate for economy i between two points in time, t_0 and $t_0 + T$, is given by,

$$(1/T) \cdot \ln(y_{i,t_0+T} / y_{i,t_0}) = c - [(1 - e^{-\beta T}) / T] \cdot \ln y_{i,t_0} + u_{i,t_0,t_0+T} \tag{9}$$

where, u_{i,t_0,t_0+T} is the error term and $c = x + [(1 - e^{-\beta T}) / T] \cdot [\ln \hat{y}^* + x \cdot t_0]$. The intercept is increasing in t due to technological progress. Controlled variables do not exist in equation (9), so it shows speed of absolute convergence.

3. Data sources

The data set for the empirical analysis of Mongolian economic growth was very difficult to collect. The basic data used here provided from National Statistical Office (NSO) of Mongolia. For the analysis of convergence speed, β, we calculated each aimag's GDP, because the data was not available from NSO of Mongolia and other sources.

[2] The level of technology does not influence the value of β in the Ramsey model.

(1). Data on GDP

I used here time series data for real GDP at constant 1995 price for the period 1989-2004 (Please see the real GDP in Appendix 1). Although there are some official data of GDP per aimag since 1998, the period is not sufficient to estimate convergence speed and also methodology has been changed for several times, so we calculated each aimag's GDP as follows

$$y_i = p \cdot x_i + (1-p) \cdot [w \cdot z_i + (1-w) \cdot q_i] \quad (10)$$

y_i : share of each aimag's GDP in GDP of Mongolia

p : share of industrial products in GDP of Mongolia

$1-p$: share of agricultural products in GDP of Mongolia

x_i : share of each aimag's indsutrial products in total industrial products

$[w \cdot z_i + (1-w) \cdot q_i]$: share of each aimag's agricultural products in total agricultural products

w : share of livestock products in agricultural products

$1-w$: share of field crop products in agricultural products

z_i : share of each aimag's livestock products in total live stock products

q_i : share of each aimag's field crop products in total harvest products

(2). Data on Population and Migration

The database of an aimag's population and migration pattern will be used for the study of regional convergence. To obtain per capita income, we used per aimag population data from the NSO of Mongolia. There is vast literatures concerned that migration contributes to convergence in per capita income. Thus the data on migration used for the study of regional convergence was obtained from the NSO of Mongolia (unpublished data) and Urban poverty and in-migration: Survey Report 2004.

4. Results of the Empirical Analysis

(1). β convergence

Due to the different methodology and the lack of data about aimags' GDP before 1998, each aimag's GDP per capita is calculated as in equation (10). Please see the results in Appendix 2. Appendix 2 shows the calculation of each aimag's GDP per capita for 22 Mongolian aimags and the capital city for the period 1989-2004. As shown in Appendix 2, mainly mining and field crops can be found in the developed aimags, border aimags and urban areas are richer than other aimags in per capita GDP. In 1989 the per capita GDP, in 1995 year prices, was 1621.4 thousand tugrug in the richest aimag, whereas it was about 91.6 thousand tugrug in the poorest aimag. In 2004 the per capita GDP differentials had narrowed.

As for Ulaanbaatar (capital city) per capita GDP is lower than before the transition level in 1989. It seems, the main reason of the lower per capita GDP is that the large amount of migration, relatively high informal sector and GDP is not perfectly reflected in an economy.

However, GDP per capita in Orkhon is the highest. The average growth of GDP per capita strongly depends on copper price in the world market. There are no big changes for other aimags. In case of natural disaster, due to the high propotion of agriculture to GDP, the average growth of GDP per capita tends to be lower.

Figure 1

As indicated in Figure 1, absolute convergence applies for the aimags of Mongolia. The relation between the aimags' average annual real GDP per capita growth rates from 1989 to 2004 is negatively related to the level of real GDP per capita in 1989. It is clear that data on across Mongolian aimags presents absolute convergence in which relatively homogenous economies tend to converge to the same steady state. Figure 1 shows that most aimags grew faster than relatively developed aimags and urban areas in terms of GDP per capita since 1989.

Based upon absolute convergence hypothesis, I have estimated convergence coefficient β using a regression. The results of the regression divided into five periods can be characterized as follows.

1. 1989-2004 years: Total period of analysis

2. 1989-1993 years: Begining of the market economy with negative growth

3. 1994-2004 years: The period, economic depression stopped and positive growth began

4. 1995-1999 years: First 5 years of positive growth

5. 2000-2004 years: Last 5 years of positive growth

Table 1

The high GDP per capita created by the copper mining of Orkhon aimag may cause distortion in the convergence coefficients and the dispersion. Therefore, I estimated two sapmles. In the first sample Orkhon aimag has been excluded from the sample, in the second sample Orkhon aimag has been included in the sample. According to the estimation results, there are no big differentials between coefficients. In order to involve all aimags in the study, I present the results with Orkhon aimag.

Table 1 presents the estimates of convergence speed β in the form of equation (9). The regression equation (9) is estimated using nonlinear least square for the entire sample period. The estimation of equation (9) for the 3 subperiods is a seemingly unrealted regression. Standard errors are given within parentheses. The estimated constant coefficient is not reported.

The full sample period 1989-2004, the positive growth period 1994-2004, and the first five years of positive growth period 1995-1999 show a positive and significant β coefficient. However, the begining of the market economy period 1989-1993, the last five years of positive growth period 2000-2004 shows an insignificant β coefficient and also a very low determination coefficients. To compare SUR with nonlinear least square methods with regard to 3 subperiods, the esimated β for the period 1995-1999, the estimation method SUR is higher than least square method and for the other periods vice versa.

For the longest sample period, 1989-2004, the estimation of β is 0.43(0.009). As mentioned above, for the period 1989-1993 the β coefficient is negative and statistically insignififcant. However, it is possible to explain a divergence in the period 1989-1993, the gap between rich and poor aimags has tended to widen. This is closely related to the economic recession and its transition to a market economy. As a consequence of the boom of the gold, copper and other minerals prices in 2004, the growth rate was high at 10.6 percent. It seems that due to this temporary high growth, β convergence is statistically insignificant for the period 2000-2004.

If the three periods are restricted to have the same β but individual constants, then the joint estimate of β is 0.017(0.011). The Wald statistic is 6.44, with a p -value 0.04. The p -value comes from a χ^2 distribution with 2 degrees of freedom. The Wald statistic test rejects the hypothesis that β is the same for the subperiods.

We have also done similar studies for the Mongolian regions. Due to the government policies on living standards, Mongolia is divided into five regions. The region's average growth rate of GDP per capita between 1989 and 2004 is plotted against the log of the region's average GDP per capita in 1989 in figure 2. The negative relation is clear (the correlation coefficient is -0.74). In other words, figure 2 confirms that there is absolute convergence across the five regions.

Figure 2

The statistical model of the convergence speed in equation (9) is extended to include regional dummies. Table 2 shows nonlinear least squares and SUR estimates with regional dummy variables.

Table 2

According to the estimation results with the regional dummy variables, the estimations of β are the same for the aimag's results during periods 1989-2004, 1994-2004 and 1995-1999. They also show a positive and significant β coefficient. The periods 1989-1993 and 2000-2004 show an insignificant β coefficient. However, the determination coefficients are higher than previous results. Speed of convergence with regional dummy variables is typically slower than without conditioning any other variables. For example, for the full sample period 1989-2004, the estimation of the β coefficient is 0.039(0.009).

As with Table 3, the last row restricts the β coefficients to have the same 3 subperiods. The joint estimate of β for the three subperiods is 0.015(0.009) and the Wald statistic is 7.761 with a p value of 0.021. The hypothesis of equal speeds of convergence for the subperiods is however still rejected by a Wald statistic test.

(2) Convergnce and migration

The neoclassical model views migration flows as an equilibrating tool to contract income differentials, given people tend to move from low income regions to high income regions in search for higher salaries. Income growth offers a significant incentive for net migration (Lowry, 1966; Richardson, 1973; Lande and

Gordon, 1977). It could be also argued that income differentials are among major determinants of migration and the existence of regional differences in income is likely to be self-corrected through the migration effect (Dunlevy and Bellante, 1983). Therefore, migration is one of the main factors which highly affects the regional convergence.

In the developed world, Mongolia is known for its nomadic life style and urbanization only truly started in the begining of the 1950's. Like most developing countries people tend to move from rural to urban areas. There is three main reason to migrate from rural to urban areas: 1) Regional income disparity-People move to urban areas to increase their income, 2) Eduction-People want to obtain higher eduction to access higher future income, 3) Natural disaster-People who lose their herds in natural disaster (herds are the only source of their income) move to an urban area in search for a job.

In growth theory migration affects regional convergence. As consequently migration speeds up convergence in regional incomes transition toward their steady-state. Based on this theoretical framework I present migration and its impact on convergence speed in the case of Mongolian aimags.

Figure 3 shows the relation between the net migration rate for 1989-2004 and the log of per capita GDP in 1989. The scatter plot depicts a positive relation between net migration and per capita GDP (correlation coefficient 0.65). The main point is that only Ulaanbaatar and Orkhon have the positive net migration (the average annual net migration is 1.9 percent and 2.1 percent, respectively). In general, all other aimags with lower per capita GDP in 1989 experienced a negative average annual net migration rate in the period 1989-2004. Therefore, it is clear from figure 3 that the flows of migration are from other aimags to Ulaanbaatar and Orkhon. The Western region (five most western aimags) has a notably higher negative net migration rate. Specifically, Bayan-Oglii, Uvs, and Zavkhan aimags have higher negative net migration rates as seen in the lower left of figure 3. (Please see the catergory of regions in Appendix 3).

Figure 3

Convergence speed towards a steady state position is higher in the model with migration. To get a value of sensitivity for net migration to per capita GDP differentials across Mongolian aimags, the following statistical model is estimated,

$$m_{i,t_0,t_0+T} = c + d \ln y_{i,t_0} + v_{i,t_0,t_0+T} \qquad (11)$$

where m_{i,t_0,t_0+T} is the average annual net migration rate for aimag i between time t_0 and t_0+T. The rate is calculated as the share of net migration to population. If $m_{i,t_0,t_0+t} > 0$, then immigration is larger than emigration. The coefficient d measures the percentage change in population, through net migration, of a one percent change in per capita GDP, holding constant the effect of GDP on fertility and mortality. v_{i,t_0,t_0+T} is the error term.

Table 3 presents Non-linear least square and SUR estimation results in equation (11). The estimated constants, logarithm of per capita GDP (explanatory variable) and determination coefficients are displayd in table 3.

Table 3

Table 3 shows positive explanatory variable coefficients that is same for depicted in figure 3. The estimated explanatory variable is 0.097(0.003) for the full sample period 1989-2004. This means that one percent increase in an aimag's per capita GDP raises net migration (aimag's annual rate of population growth) by 0.097 percentage points.

The coefficient d is significant except for the periods 1989~1993 and 2000~2004. If the three subperiods are restricted to have the same net migration coefficient d, then the joint estimate d is 0.012(0.003). The Wald statistic is 5.107 with a p value 0.021. Thus the Wald statistic does not reject the hypothesis that d is the same for the three subperiods. The p-value comes from a χ^2 distribution with 2 degrees of freedom.

The speed of convergence towards the steady state tends to be higher in the model with migration. In this case, I have predicted that migrant's human capital is lower than the domestic economy. Based on this prediction I estimated convergence coefficient β from the regression model augmented with the net migration as shown in equation (12). This form of regression is also argued in Braun's (1993) assumption with diminishing returns to scale. It is derived from the system with four differential equations during the transtion to the steady state.

$$(1/T)\cdot \ln(y_{i,t_0+T} / y_{i,t_0}) = c - [(1-e^{-\beta T})/T]\cdot \ln y_{i,t_0} + \xi \cdot m_{i,t_0,t_0+T} + u_{i,t_0,t_0+T} \qquad (12)$$

Equation (12) is one of the system equations and should be estimated with the instrumental variable method. However, due to lack of the appropriate additional variables (for example; level of education, natural disaster and so on) for the estimation of annual net migration rate we used the nonlinear least square method. Consequently, there is a possible simultaneous causality bias problem in the regression.

Table 4 shows estimation results of convergence coefficients augmented with the net migration rate as an explanatory variable in equation (12).

Table 4

For the full sample period 1989-2004, estimated convergence coefficient β is 0.069(0.011). As compared with table 1 and table 2, only the full sample period has a higher β coefficient than other periods. Note that, according to the estimated coefficients of regression with a net mirgration rate, significant levels are lowering in all sample periods except for 1989-2004. Hence, the impact of net migration on the convergence speed is somewhat ambiguous. For the period 1995-1999, estimated results of the regression with net migration rate, shown in table 3, are lower than the regression shown in table 1 by the SUR estimation method. As in growth theory, however, for the sample period 2000~2004, regression results with net migration rate is higher by SUR estimation.

We have also run the regressions that use net migration rate and regional dummies as explanatory variables. Table 5 displays the regression results. For the full sample period 1989~2004, the convergence coefficient is the highest 0.076(0.038) and significant at the level of 10%. The determination coefficient is the highest 0.60, compared with others.

Table 5

This results discussed above imply that if we include the net migration rate and regional dummies in the convergence equations, the estimated β coefficient shows that the GDP per capita converges more rapidly to the steady state position.

5. Concluding remarks

This paper investigates convergence in real GDP per capita across twenty-two Mongolian aimags (5 regions) for the period 1989-2004 and estimates speed of convergence towards the steady state position with and without net migration rate and regional dummies.

The convergence coefficient with regard to the Solow model is also estimated. According to my previous study, the estimated coefficient of capital share, α, was about 0.74. The average annual rate of capital depreciation is about 6 percent, average annual growth rate of the labor force is 2.5 percent and theoretically the technological progress corresponds to the long-run growth of GDP. Thus the growth of technological progress is 2.89 percent. Therefore, the speed of convergence can be estimated as follows:

$$\beta = (1-\alpha)(x+n+\delta) = 0.029$$

In other words, the speed of concvergence towards the steady state position is 3 percent in the Solow model. Two thirds of convergence is about 14 years. It indicates the number of years that would take to reduce by two thirds the gap between the logarithm of initial and the steady state GDPs.

The convergence coefficient in the Solow model is 1 percentage point lower than in the Ramsey model and 4 percentage points lower compared to the Ramsey model with net mirgartion rate. In accordance with other studies, regional convergence as well as cross-country convergence coefficient is relatively low. In the case of Mongolia however the convergence coefficient is substantially higher at 4.3 percent in the Ramsey model and almost the same with Joakim Persson (1994) 2.9 percent in Solow model[3].

For further research, to make a clear regional convergence, there needs to be more reasonable variables such as sector shocks[4]. Also other parameters should be estimated such as education and natural disasters, (People tends to move to obtain higher education and also due to the natural disaster in Mongolia) in the equation of net migration regression.

[3] The estimated speed of regional convergence is around 2 percent in Barro and Sala-i-Martin (1991) and around 3 percent in Persson (1994) across Swedish counties.

[4] For example, if in somewhere newly discovered copper deposit, as consequently given aimag’s growth rate of GDP per capita should be high. This shock have an more effect on the GDP of that aimags relative to the GDP of other aimags.

Numerical Appendix

The standard closed Ramsey model with labor augmenting technological process.

Households are assumed to maximize their utility (A.1) subject to the constraint imposed by (A.2)

$$\max \int_0^{\infty} u[c(t)] \cdot e^{nt} \cdot e^{-\rho t} dt \tag{A.1}$$

where, c, $u(c)$, e^{nt} and ρ, consumption per person, household's utility, family size and rate of time preference respectively at time t. Here we note that the household's net assets per person by a, the labor income by w and the asset income by ra.

$$\dot{a} = w + ra - c - na \tag{A.2}$$

$$\lim_{t \to \infty} \left\{ a(t) \cdot \exp\left(-\int_0^t [r(v) - n] dv \right) \right\} \geq 0 \tag{A.3}$$

Inequality (A.3) rule out Chain letter possibilities.

To solve for the consumption function, we need to use above equations. Using the Euler equation we can calculate per capita consumption growth as follows:

$$\dot{c} / c = 1/\theta \cdot (r - \rho) \tag{A.4}$$

If we define *effective labor* as the product of labor and the level of technology, $\hat{L} = L \cdot A(t)$, then we can write profit maximization condition for the competitive firm as:

$$f'(\hat{k}) = r + \delta \tag{A.5}$$

where, $\hat{k} = K / \hat{L}$ (capital stock per unit of effictive labor), δ is the depreciation rate of capital stock. If profit equals zero, wage rate equals the marginal product of labor corresponding to the value of $\hat{k}$ that satisfies (A.5).

$$(f(\hat{k}) - \hat{k} \cdot f'(\hat{k})) \cdot e^{xt} = w \tag{A.6}$$

where x is the exogenous rate of labor-augmenting technological progress. $\dot{a}$ is derived from household budget constraint as given in equation (A.2). If we note that $a = k$, $\hat{k} = ke^{-xt}$ and also use the conditions r and w in equations (A.5) and (A.6), we can get growth of capital stock per effective labor:

$$\dot{\hat{k}} = f(\hat{k}) - \hat{c} - (x + n + \delta) \cdot \hat{k} \tag{A.7}$$

where, $\hat{c} = C / \hat{L} = ce^{-xt}$ and the initial capital stock per effecitve labor $\hat{k}(0)$ is given. Equation (A.7) is resource constraint for the overall economy. From the household optimization problem c grows in accordance with equation (A.4). If we use the conditions $r = f'(\hat{k}) - \delta$ and $\hat{c} = ce^{-xt}$, we get:

$$\dot{\hat{c}} / \hat{c} = \dot{c} / c - x = (1/\theta) \cdot (f'(\hat{k}) - \delta - \rho - \theta x) \tag{A.8}$$

Equation (A.7) and (A.8) creates a system of two differential equations in $\hat{c}$ and $\hat{k}$. This system, together with the inintial condition, $\hat{k}(0)$, and transversality condition, determines the time paths of $\hat{c}$ and $\hat{k}$. To determine the speeds of convergence we need to log-linearize equations (A.7) and (A.8) around steady state position. The results can be written as follows:

$$\ln \hat{y}(t) = e^{-\beta t} \cdot \ln \hat{y}(0) + (1 - e^{-\beta t}) \ln \hat{y}^* \qquad \beta > 0 \tag{A.9}$$

where β is speed of convergence.

If we setting t to T in equation (A.9) and substract $\ln \hat{y}(0)$ from both sides we get:

$$\ln \hat{y}(T) - \ln \hat{y}(0) = (e^{-\beta T} - 1) \cdot \ln \hat{y}(0) + (1 - e^{-\beta T}) \cdot \ln \hat{y}^*$$

Hence,

$$\ln[\hat{y}(T) / \hat{y}(0)] = (1 - e^{-\beta T}) \cdot [\ln \hat{y}^* - \ln \hat{y}(0)] = (1 - e^{-\beta T}) \cdot \ln[\hat{y}^* / \hat{y}(0)] \qquad \text{(A.10)}$$

where, $y(t) = \hat{y}(t)e^{xt}$. Therefore $\ln y(T) = \ln \hat{y}(T) + xT$ and $\ln y(0) = \ln \hat{y}(0)$.

So

$$\ln[\hat{y}(T) / \hat{y}(0)] = \ln y(T) - \ln y(0) - xT = \ln[y(T) / y(0)] - xT \qquad \text{(A.11)}$$

If we substitute equation (A.11) into left side of equation (A.10) and divide both sides by T, we obtain equation (A.12).

$$(1/T) \cdot \ln[y(T) / y(0)] = x + [(1 - e^{-\beta T}) / T] \cdot \ln[\hat{y}^* / y(0)] \qquad \text{(A.12)}$$

Rearranging equation (A.12) we can get following equations:

$$\ln y(t) = xt + (1 - e^{-\beta t}) \ln \hat{y}^* + e^{-\beta t} \ln y(0) \qquad \text{(A.13)}$$

$$\ln y(t-1) = x(t-1) + (1 - e^{-\beta(t-1)}) \ln \hat{y}^* + e^{-\beta(t-1)} \ln y(0) \qquad \text{(A.14)}$$

Here we normailize the initial level of the technological progress, $A(0)$, to one.

Rewriting equation (A.14) with regard to $\ln y(0)$ we can get following equation:

$$\ln y(0) = e^{\beta(t-1)} \cdot \ln y(t-1) - e^{\beta(t-1)} \cdot x(t-1) - e^{\beta(t-1)} \ln \hat{y}^* + \ln \hat{y}^* \qquad \text{(A.15)}$$

Here we substitute equation (A.15) into equation (A.13) and rearrange equation.

$$\ln y(t) = xt + (1 - e^{-\beta t}) \ln \hat{y}^* + e^{-\beta} \cdot \ln y(t-1) - e^{-\beta} \cdot x(t-1) - e^{-\beta} \ln \hat{y}^* + e^{-\beta t} \ln \hat{y}^*$$

$$= x + x(t-1) + e^{-\beta} \ln y(t-1) - e^{-\beta} \cdot x(t-1) + (1 - e^{-\beta}) \ln \hat{y}^* \qquad \text{(A.16)}$$

Also substract $\ln y(t-1)$ both sides of equation (A.16) and make some simple calcultion we obtain following equation:

$$\ln[y(t)/y(t-1)] = x + (1-e^{-\beta})\ln\hat{y}^* - (1-e^{-\beta})\ln y(t-1) + (1-e^{-\beta})\cdot x(t-1)$$

$$= a - (1-e^{-\beta})[\ln y(t-1) - x(t-1)] \tag{A.17}$$

where $a = x + (1-e^{-\beta})\ln\hat{y}^*$.

To derive the statistical model, we need to consider a discrete period version of equation (A.17) that applies to economy i and is augmented by a disturbance term,

$$\ln[y_{i,t}/y_{i,t-1}] = a - (1-e^{-\beta})\cdot[\ln y_{i,t-1} - x\cdot(t-1)] + u_{i,t} \tag{A.18}$$

where $u_{i,t}$ is the disturbance term. Here we will make the assumption that the economies are equal with respect to technology and preferences, which implies that β is the same across economies.

If we note that inintial period is t_0, time interval is T and the average growth rate for economy i between two points in time t_0 and t_0+T, is given by,

$$(1/T)\cdot\ln(y_{i,t_0+T}/y_{i,t_0}) = c - [(1-e^{-\beta T})/T]\cdot\ln y_{i,t_0} + u_{i,t_0,t_0+T} \tag{A.19}$$

where $c = x + [(1-e^{-\beta T})/T]\cdot[\ln\hat{y}^* + x\cdot t_0]$.

Appendix 1

Real GDP 1989~2004

(billion tugrug, at constant 1995 price)

Period	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
realGDP	651.5	635.1	576.4	521.6	505.9	517.6	550.3	563.2	585.7	606.4	625.9	632.5	639.7	664.9	701.8	776.1

Source：National Statistical Office of Mongolia

Appendix 2 GDP per capita of aimags (thousand tugrug, at constant 1995 price)

	Aimag	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	Arkhangai	91.6	98.3	120.	106.1	54.6	99.4	134.7	171.4	153.6	155.8	178.2	184.3	217.5	221.8	184.9	177.8
2	Bayan-Olgii	108.6	108.6	107.	106.5	70.0	95.5	131.4	155.7	139.9	114.5	115.0	111.2	109.6	128.9	126.2	116.7
3	Bayankhongor	110.1	112.7	136.	126.0	89.8	143.5	194.4	232.5	216.0	208.7	222.5	202.7	158.8	125.8	140.9	138.3
4	Bulgan	133.0	144.5	192.	153.2	85.4	160.8	224.7	253.8	230.0	226.7	249.3	250.9	274.2	302.4	309.0	298.4
5	Gobi-Altai	121.7	126.2	158.	139.9	75.5	136.3	206.1	266.3	227.8	212.7	232.8	217.6	200.4	156.6	199.6	219.3
6	Dornogobi	107.6	105.8	133.	121.6	91.6	95.0	140.5	176.8	163.6	160.1	177.7	162.9	151.8	182.7	185.2	170.1
7	Dornod	319.3	272.8	233.	192.6	113.8	104.0	91.6	117.4	104.4	91.2	107.2	97.6	107.9	137.6	173.3	140.2
8	Dundgobi	124.8	133.0	176.	171.4	90.4	164.4	237.3	311.4	289.1	292.2	298.7	178.2	206.8	270.9	287.8	296.4
9	Zavkhan	166.7	162.3	175.	149.2	53.1	121.6	174.0	214.2	188.8	179.7	180.7	157.9	136.9	163.9	181.1	202.3
1	Uvurkhangai	133.8	131.1	150.	145.3	74.9	141.3	204.4	244.0	215.5	249.4	242.5	176.6	164.9	166.8	188.1	173.8
1	Umnugobi	106.8	114.4	149.	130.8	70.1	144.6	206.6	265.5	268.2	253.5	264.1	230.5	195.7	182.5	244.6	356.0
1	Sukhbaatar	107.7	107.4	141.	131.6	71.9	119.6	173.1	191.2	179.1	178.7	208.1	194.9	199.7	266.0	274.5	265.2
1	Selenge	380.6	367.5	575.	197.1	153.7	191.9	284.0	263.4	378.8	385.1	373.8	305.9	390.3	495.4	526.4	463.7
1	Tuv	142.4	146.9	205.	187.3	107.4	193.1	280.0	342.3	409.0	514.8	510.9	516.7	566.3	656.0	588.4	248.9
1	Uvs	132.8	125.4	139.	116.7	78.1	118.5	152.6	176.7	165.5	163.9	181.6	165.4	168.9	198.2	208.9	228.8
1	Khovd	121.4	126.5	129.	112.5	51.4	116.1	165.3	189.8	160.5	145.9	155.7	149.9	134.6	146.7	162.1	170.1
1	Khubusgul	112.0	118.8	128.	111.7	57.6	106.3	139.1	173.6	157.9	148.5	164.5	142.5	125.5	158.4	174.5	173.8
1	Khentii	150.7	154.2	174.	159.5	73.1	106.0	139.6	170.9	158.4	161.6	175.4	179.9	184.1	240.8	250.3	244.9
1	Darkhan-Uul(*)	797.4	665.1	332.	255.3	265.2	265.3	225.7	228.9	172.1	181.6	164.5	196.8	200.8	196.3	193.1	211.2
2	Ulaanbaatar	609.6	561.8	399.	370.1	298.0	256.0	205.6	202.9	217.2	257.4	248.0	245.2	263.3	242.9	246.9	282.8
2	Orkhon(*)	1621.	1492.	574.	1176.	2973.	2403.	2323.	1615.	1863.	1522.	1588.	1837.	1504.	1351.	1455.	2231.
2	Gobisumber(*)	0.0	0.0	39.3	41.0	116.3	149.8	110.9	115.2	114.6	137.4	214.0	229.5	308.8	267.7	305.6	355.9

(*) Darkhan-Uul, Orkhon and Gobisumber established in 1994.

Appendix 3

Mongolian regions

Western region	Khangai region	Central region	Eastern region	Capital city
1 Bayan-Ulgii 2 Govi-Altai 3 Zavkhan 4 Uvs 5 Khovd	6 Arkhangai 7 Bayankhongor 8 Bulgan 9 Orkhon 10 Ovorkhangai 11 Khovsgol	12 Gobisumber 13 Darkhan-Uul 14 Dornogobi 15 Dundgovi 16 Omnogobi 17 Selenge 18 Tov	19 Dornod 20 Sukhbaatar 21 Khentii	22 Ulaanbaatar

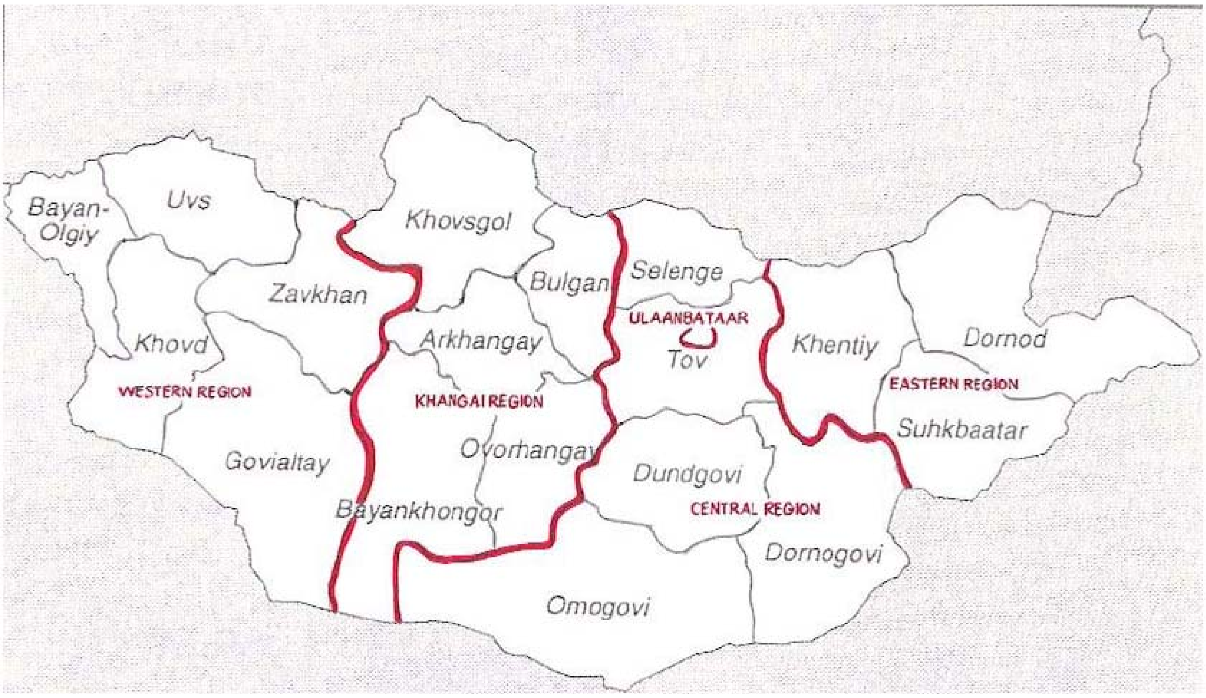

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Figure 1

Convergence of per capita GDP across Mongolian aimags

(1989 per capita GDP and annual growth rate of GDP from 1989 too 2004)

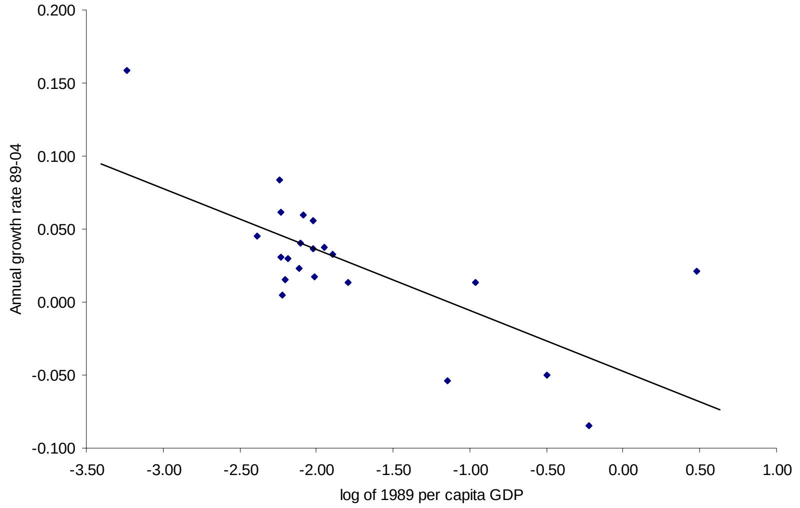

Figure 2

Convegence of per capita GDP across Mongolian regions

(1989 per capita GDP and annual growth rate of GDP from 1989 to 2004)

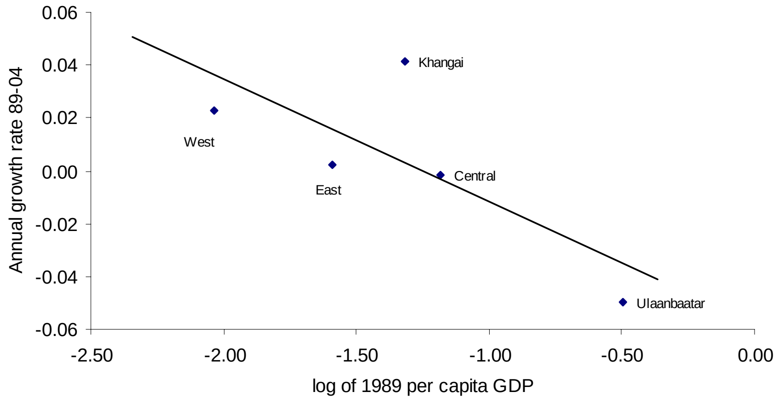

Figure 3

Relation between migration and aimags' per capita GDP (1989~2004)

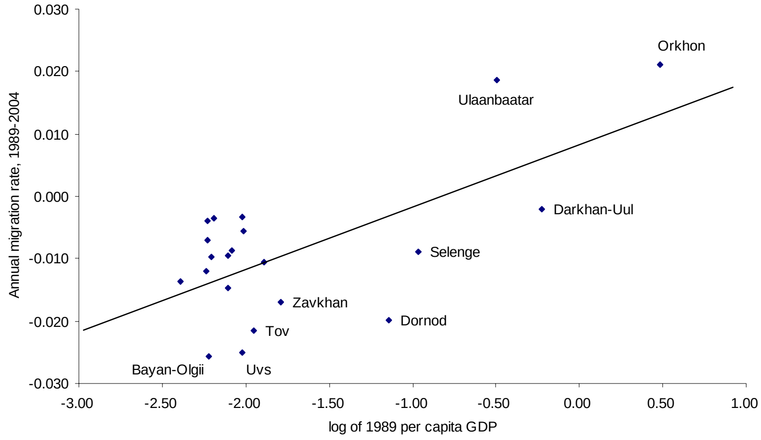

Table 1

Test for convergence speed β : Mongolian aimags

Period	LS		SUR	
	β	R^2	β	R^2
1989~2004	0.043*** (0.009)	0.41	-	-
1989~1993	-0.007 (0.022)	0.05	-0.012 (0.020)	0.002
1994~2004	0.023** (0.009)	0.21	-	-
1995~1999	0.038** (0.015)	0.21	0.049** (0.018)	0.19
2000~2004	0.020 (0.021)	0.04	0.012 (0.021)	0.03
Equality of coefficients [3 subperiods](note)	β restricted		0.017 (0.011)	-
	Wald statistics (p value)		6.444 (0.0399)	-

Note: 3 subperiods are 1989~1993, 1995~1999, 2000~2004 years. Standard errors in parentheses.

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 2

Test for convergence speed β : Mongolian aimags (with regional dummy variables)

Period	LS		SUR	
	β	R^2	β	R^2
1989~2004	0.039*** (0.009)	0.48	-	-
1989~1993	-0.008 (0.025)	0.20	-0.017 (0.019)	0.19
1994~2004	0.019* (0.009)	0.33	-	-
1995~1999	0.044** (0.015)	0.42	0.044** (0.016)	0.34
2000~2004	0.012 (0.024)	0.13	0.024 (0.021)	0.12
Equality of coefficients [3 subperiods](note)	β restricted		0.015 (0.009)	-
	Wald statistics (p value)		7.761 (0.0206)	-

Note: 3 subperiods are 1989~1993, 1995~1999, 2000~2004 years. Standard errors are in parentheses.

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 3

Cross-Aimags Net migration Regression (1989~2004)

Period	LS			SUR		
	Constant	Log GDP	R^2	Constant	Log GDP	R^2
1989~2004	0.008 (0.005)	0.097*** (0.003)	0.42	-	-	-
1989~1993	0.015 (0.011)	0.009 (0.005)	0.12	-0.065** (0.028)	0.012** (0.005)	0.12
1994~2004	0.008 (0.007)	0.011** (0.004)	0.27	-	-	-
1995~1999	0.012* (0.006)	0.012*** (0.004)	0.35	-0.065*** (0.016)	0.011*** (0.003)	0.34
2000~2004	-0.007 (0.01)	0.005 (0.006)	0.04	-0.034 (0.026)	0.003 (0.004)	0.03
Equality of coefficients [3 subperiods](note)	d restricted			-	0.012*** (0.003)	-
	Wald statistics (p value)			-	5.107 (0.077)	-

Note: 3 subperiods are 1989~1993, 1995~1999, 2000~2004 years. Standard errors are in parentheses.

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 4

Migration and Convergence

Period	LS			SUR		
	β	Net migration rate	R^2	β	Net migration rate	R^2
1989~2004	0.069*** (0.011)	1.118 (0.71)	0.48	-	-	-
1989~1993	-0.002 (0.024)	0.56 (0.9)	0.03	-0.007 (0.022)	0.360 (0.818)	0.02
1994~2004	0.019 (0.010)	-0.027 (0.51)	0.23	-	-	-
1995~1999	0.027 (0.018)	-0.72 (0.89)	0.23	0.037 (0.021)	-0.73 (0.817)	0.22
2000~2004	0.024 (0.021)	0.70 (0.78)	0.08	0.017 (0.021)	0.705 (0.725)	0.07

Stand errors are in parentheses.

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 5

Migration and Convergence (with regional dummy variables)

Period	LS			SUR		
	β	Net migration rate	R^2	β	Net migration rate	R^2
1989~2004	0.076* (0.038)	2.134** (1.019)	0.60	-	-	-
1989~1993	-0.009 (0.026)	-0.204 (1.064)	0.20	-0.017 (0.019)	-0.230 (0.822)	0.19
1994~2004	0.019 (0.014)	-0.055 (0.677)	0.33	-	-	-
1995~1999	0.023 (0.020)	-1.647 (0.958)	0.52	0.035** (0.017)	-1.646** (0.751)	0.50
2000~2004	0.015 (0.026)	1.489 (1.191)	0.21	0.013 (0.022)	1.672 (0.979)	0.20

Standard errors are in parentheses

*** significant at 1%, ** significant at 5%, * significant at 10%