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Regional Growth in Japan*

Etsuro Shioji
Universitat Pompeu Fabra†

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† Balmes, 132. Barcelona. E–mail: shioji@upf.es

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Abstract

I study the role of internal migration in income convergence across regions in Japan. Neoclassical theory predicts that migration should have been an important source of convergence. Regression results, however, suggest that migration did not contribute to convergence. I investigate the possibility that this discrepancy is explained by taking into account the effects of migration on population composition, especially on educational attainment. I propose an empirical approach to quantify this "educational composition effect". It is shown that, although this effect did slow down convergence, its magnitude was too small to account for the discrepancy between theory and empirics.

1 Introduction

This paper studies the role of internal migration in convergence of per-capita incomes across regions in postwar Japan. Barro and Sala-i-Martin (1992b) showed that there was a tendency toward convergence across regions in Japan. They estimated the "speed of convergence" (the rate at which poorer regions catch up with wealthier regions) to be about two to three percent per year. This result is consistent with numerous other studies[3].

Barro and Sala-i-Martin (1992b) used only one type of measures of output and labor, and did not take into account changes in regional price differentials. The first part of the paper investigates whether their results are robust to uses of different measures of output and labor input, and whether using a regional price index changes their results in any significant ways. It turns out that the results are robust, at least qualitatively.

The second part of the paper studies the role of migration in this convergence. I will argue that there are two important channels through which migration could affect convergence: a quantity effect and a composition effect. Migration could affect regional incomes through changing the quantity of labor input. Migration could also affect regional incomes through changing educational and demographic composition of the regional labor force.

I first abstract from the heterogeneity of labor, and concentrate on the quantity effect of migration. It is shown that there is a discrepancy between what theory predicts (in the absence of labor heterogeneity) and the regression results. Neoclassical theory predicts

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[3]For example, Barro (1991), Mankiw, Romer and Weil (1992), etc. showed that, once we hold constant the effects of such variables as investment rates, there is a tendency toward convergence across countries in the world. On the other hand, using regional data from other countries, Barro and Sala-i-Martin (1991, 1992a), Cashin (1993), Hofer and Woergoetter (1993), Persson (1994), etc. showed that we can often find a tendency toward convergence, even if we do not hold constant effects of investment rates etc. Barro and Sala-i-Martin (1995) offer a survey and some further investigation in this literature.

that migration should have been an important force behind convergence. On the other hand, regression results suggest that migration was either irrelevant for regional growth, or even working against convergence.

It is possible that this discrepancy between theory and empirics is due the composition effect of migration. This is why it is potentially important to extend the preceding analyses to take into account the heterogeneity of labor. I do this in the rest of the paper. First, I show that migration has indeed changed the composition of regional population. Especially, its effect on educational attainment was working in the direction of slowing down convergence: migration tended to redistribute more productive workers (in terms of education) from sending regions to receiving regions. As the receiving regions tended to be wealthier than the sending regions, this is likely to have contributed to weakening of convergence. To study the magnitude of this "educational composition effect", I propose a regression analysis framework, based on a neoclassical model extended to incorporate labor heterogeneity. It is shown that the size of the effect was too small to account for the discrepancy between theory and empirics.

The rest of the paper is organized as follows. In the next section Japanese regional convergence is studied using different measures for output, labor input, and deflator. Section 3 shows the discrepancy between the estimated effect of migration on income convergence and the prediction of neoclassical theory. In section 4, effects of migration on regional demographic composition are investigated. Section 5 is the central part of the paper in which I investigate whether the "educational composition effect" (the effect of migration on regional incomes that works through changing regional educational composition) was large enough to account for the discrepancy between theory and empirics. Section 6 provides some concluding comments and suggestions for future research.

2 Convergence: Further Studies

In this section I will quickly review the notions of convergence and then investigate whether the result of Barro and Sala-i-Martin (1992b) on convergence across the Japanese regions is robust to changes in measures of income, population, and prices.

Concepts

Two notions of convergence, both of which were introduced by Barro and Sala-i-Martin (1992a), are most commonly used in the literature. The first is σ-convergence, which means that dispersion of per-capita incomes shrinks over time. The second is β-convergence, which means that poorer economies tend to grow faster than wealthier ones.

Various growth models predict β-convergence. One of them is the neoclassical growth model of Solow (1956), Swan (1956), Ramsey (1928), etc. Below, I will review the case of the Solow–Swan model. This exposition is based on Barro and Sala-i-Martin (1995), but it differs from theirs in that I allow the rate of technological progress and population growth rates to vary over time, following some deterministic, stable processes. Assume that the production function is Cobb-Douglas, and the savings rate is fixed:

$$Y_t = K_t^{\alpha} \cdot (A_t \cdot L_t)^{1-\alpha} , \quad (1)$$

$$I_t = S_t = s \cdot Y_t , \quad (2)$$

and $$\dot{K}_t = I_t - \delta \cdot K_t . \quad (3)$$

In the above, Y_t is output at time t, K_t is capital stock, A_t is the level of technology that grows at an exogenous but time-varying rate g_t, L_t is labor which grows at an exogenous but time-varying rate n_t, S_t is the savings, I_t is investment, s is the savings rate, and δ is the exogenous and fixed depreciation rate. Defining output per efficiency unit by

$$\tilde{y}_t \equiv \frac{Y_t}{A_t \cdot L_t},$$

it can be shown that, around the steady state, $\tilde{y}_t$ follows the following:

$$\ln \dot{\tilde{y}}_t \approx -b\cdot[\ln \tilde{y}_t - \ln \tilde{y}^*] - \alpha\cdot(g_t-g^*) - \alpha\cdot(n_t-n^*)\,. \tag{4}$$

In the above, g^* and n^* are the steady state values of g_t and n_t, respectively. The parameter b, the theoretical "speed of convergence", is equal to $(1-\alpha)\cdot(g^*+n^*+\delta)$, and $\tilde{y}^*$, the steady state value of $\tilde{y}$, is equal to $\left[\frac{g^* + n^* + \delta}{s}\right]^{-\alpha/(1-\alpha)}$. Integrating this equation between time 0 and T, and dividing both sides by T, we get

$$\frac{1}{T}\cdot[\ln \tilde{y}_T - \ln \tilde{y}^*] = \frac{e^{-bT}}{T}\cdot[\ln \tilde{y}_0 - \ln \tilde{y}^*]$$
$$- \alpha\cdot\frac{e^{-bT}}{T}\cdot\int_0^T e^{bt}\cdot(g_t-g^*)\,dt - \alpha\cdot\frac{e^{-bT}}{T}\cdot\int_0^T e^{bt}\cdot(n_t-n^*)\,dt\,. \tag{5}$$

Using the approximation that g_t and n_t were roughly constant between time 0 and T, that is, $g_t \approx \bar{g}_{0,T}$, and $n_t \approx \bar{n}_{0,T}$, (for $0 \le t \le T$) and rearranging, (5) can be rewritten as

$$\frac{1}{T}\cdot[\ln \tilde{y}_T - \ln \tilde{y}_0] \approx -\left(\frac{1-e^{-bT}}{T}\right)\cdot[\ln \tilde{y}_0 - \ln \tilde{y}^*]$$
$$- \alpha\cdot\frac{1}{b}\cdot\left(\frac{1-e^{-bT}}{T}\right)\cdot[(\bar{g}_{0,T}-g^*)+(\bar{n}_{0,T}-n^*)]\,. \tag{5'}$$

This can be rewritten in terms of output per labor, $y_t \equiv Y_t/L_t$, as

$$\frac{1}{T}\cdot[\ln y_T - \ln y_0] \approx -\left(\frac{1-e^{-bT}}{T}\right)\cdot[\ln y_0 - \ln \bar{y}^*] - \frac{e^{-bT}}{T}\cdot \ln A_0$$

$$+ \bar{g}_{0,T} - \alpha\cdot\frac{1}{b}\cdot\left(\frac{1-e^{-bT}}{T}\right)\cdot[(\bar{g}_{0,T}-g^*)+(\bar{n}_{0,T}-n^*)] \; . \tag{6}$$

As the value of b has to be positive, equation (6) predicts a negative relationship between initial per-capita income and its subsequent growth rate, holding constant $\bar{y}^*$ and some other variables. A typical exercise is to run the following "convergence regression":

$$\frac{1}{T}\cdot[\ln y_T - \ln y_0] = -\left(\frac{1-e^{-\beta T}}{T}\right)\cdot \ln y_0 + \text{const.} + \text{error term}. \tag{7}$$

The parameter β is an empirical counterpart of b. If it is estimated to be significantly positive, it can be concluded that there is a significant tendency toward (β-) convergence. When there are sufficient reasons to believe that $\bar{y}^*$ is different across regions, some regressors such as investment rates are added to control for its difference.

Application to the Japanese Data

Barro and Sala-i-Martin (1992b) tested the hypothesis of β-convergence on the Japanese regional data, and concluded that those regions were converging at two to three percent per year. They used only per-capita prefectural income deflated by a national deflator as a measure of y_t in equation (7). In this section, I will investigate if their results are robust to uses of different measures.

All data sources are in the Appendix, and a simple map of Japan is provided in Figure 1. Japan consists of 47 prefectures. I excluded Okinawa (47 in the map of Figure 1) from all regressions because of missing values. Because some prefectures are small, commuting becomes an issue. That is, although the data concerning labor inputs are for the residents of the regions, they might not proxy very well the amount of labor input that contributes to production of the regions, because some of the residents might be crossing borders to work in other regions. This problem is particularly serious for Tokyo and Osaka areas. For example, "daytime population " of Tokyo is about 118 percent of its "night–time population" i.e. the number of residents (Barro and Sala-i-Martin (1992b)). To counter this problem, I created two greater regions by combining several prefectures[4]. Specifically, I combined Saitama (12), Chiba (13), Tokyo (14), and Kanagawa (15) and treated it as a single region ("Greater Tokyo"). Also, I combined Shiga (25), Kyoto (26), Osaka (27), Hyogo (28), and Nara (29) and treated it as a single region ("Greater Osaka"). As a result, the sample size shrank to 39.

I try three different types of measures for regional output: prefectural income, GDP, and consumption. Prefectural income series is superior in the sense that this series has undergone relatively few and minor definitional changes, and hence comparability across time is high. On the other hand, it measures income of the residents. This means that it excludes income (especially capital income) that originates within the region that goes to residents of other regions, while including income of the residents that originates from other regions. Hence it is not strictly a measure of output produced within a region. GDP is a superior index in that regard, because it measures output produced within a region[5]. A problem with this series has been that it had undergone some major definitional changes. However, recently, the Economic Planning Agency (1991) of Japan estimated a new series for the period of 1955 to 1974 that maintains comparability with the series after 1975. I will use this new series in this paper. A potential problem with the GDP series is that it tends to contain large transitory components, such as region specific productivity shocks. Also, different regions might have different degrees of sensitivity to business cycles, due to

[4]Barro and Sala-i-Martin (1992b) did not take this approach. Hence, some caution is required when comparing their results to mine.

[5]Prefectural Income is constructed in the same way as National Income in the National Account. Hence, it differs from GDP in (i) that it includes net factor income from outside, (ii) that it excludes depreciation, and (iii) that it excludes indirect taxes minus subsidies.

differences in their industry mix, which could amplify the size of the transitory components in GDP. Presence of such transitory components is known to produce an upward bias in the estimated speed of convergence. In that sense, consumption might be a better proxy. According to the permanent income hypothesis, consumption should reflect long-run movements in income. A problem with this series is that, like the income series, it reflects income of the residents, not output produced within the region. Also, it includes not only non-durables but also durable goods consumption, which might not necessarily reflect the permanent income. For consumption, too, I will use the newly estimated series of Economic Planning Agency (1991) for the period of 1955 to 1974.

I use three alternative measures of labor input: population, adult population (not at school), and labor force. Population is an index that has been used most often, but it might not capture changes in labor input very well, if the labor force participation rate varied substantially across time and across regions. Adult population measures number of people over 15, and excludes people attending school. It's a measure of population that can potentially work. Its major advantage is that there is data on its educational composition, which will be used later. Labor force measures the amount of inputs more closely, although it might contain larger business cycles components (because participation rates fluctuate over business cycles) and measurement errors, which could be a source of an upward bias in the estimated speed of convergence.

I use two measures of prices. One is a common deflator (the National CPI), which was used in Barro and Sala-i-Martin (1992b). A potential problem with this series is that it ignores changes in the regional price differentials, which could affect the speed of convergence. That is why I will use the regional CPI[6] as an alternative deflator, and

[6]Regional CPI measures CPI in the capital of each prefecture. Hence, it is not a perfect price index for a region as a whole, but it is expected to measure regional costs of living a lot more closely than the national price index. The regional CPI excludes imputed rents. Persson (1994) studied convergence across counties in Sweden, taking into account changes in regional housing costs (but not other types of costs of living).

compare the results with the case of a common deflator.

σ–convergence

Figure 2 plots the standard deviations of the log of GDP per worker for every five years between 1955 and 1990. The upper line uses the common deflator, and the lower line uses the regional CPI. Three messages emerge from this figure. First, there was a tendency toward (σ-) convergence, though the process was a bit erratic. Secondly, the use of the regional CPI lowers the dispersion within each year. Thirdly, and most importantly, the use of the regional CPI does not change the patterns of changes in the dispersion over time in any significant way.

Figure 3 compares three different measures of output: prefectural income, GDP, and consumption. All of them are divided by labor force, and deflated by the regional CPI. The figure shows that the three series exhibit globally similar patterns over time. The GDP series exhibits the largest within-year dispersion, which is probably because it contains large transitory components. The consumption series exhibits the smallest within-year dispersion, which suggests that it contains a much smaller transitory component due to consumption-smoothing. Also, its movement over time is a lot less erratic than the case of the other two series. The income series exhibits the weakest tendency toward convergence.

β–convergence

Figure 4 shows the long-run tendency toward β-convergence graphically. In this figure, the growth rate of GDP, divided by labor force and deflated by the regional CPI, between 1955 and 1990 is plotted against its initial value[7]. There is a clear downward relationship.

In Tables 1-A, 1-B and 1-C, I report the results of the cross–sectional regression

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[7]Throughout the paper, the growth rate refers to the log difference, and is annualized by dividing by the number of years. The initial values are also defined in logs.

that corresponds to equation (6). The method is NLLS. Only the estimated β, its t-statistic (based on the White's heteroscedastic-consistent standard errors, shown inside the round parentheses), and the adjusted R squared (in the squared parentheses)[8] are reported. These three tables correspond to different output measures: Table 1-A uses prefectural income, 1-B uses GDP, and 1-C uses consumption. Constant terms are included in all the regressions but omitted from the tables (this is true throughout this paper). Also, two additional variables – the shares of the primary and the secondary industries in total output in the initial year of each period – are included on the right-hand-side. This is to control for the possibility that regions might have temporarily experienced different rates of technological progress (terms that involve $\bar{g}_{0,T}$ in equation (6)) due to differences in industrial mix[9]. Their estimated coefficients are omitted to save space. The five columns in each table correspond to five different sample periods. In the first column, the initial year ("0" in equation (7)) is 1960 and the terminal year ("T" in equation (7)) is 1990. In the next three columns, regression results for the three sub-periods: 1960–70, 1970–80, and 1980–90 are reported. In the last column, titled "restricted", I restrict the β coefficient for the above three sub-periods to be the same, and use 3SLS to simultaneously estimate equation (7) for the three periods, allowing each period to have different constant terms, and different coefficients for the industrial variables. I test this restriction using Likelihood Ratio test, and if the restriction is not rejected, indicate it by "*".

In the rows indicated by (i) in Tables 1-A, B and C, I divide the output measures by population, and deflate by a common deflator. In the second rows, indicated by (ii), the regional CPI is used instead of the common deflator. In the third rows, (iii), I use adult

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[8]For the "restricted" case, the R-squared for each period is omitted to save space. In most cases, it was very similar to the R-squared for the unrestricted regression.

[9]Barro and Sala-i-Martin (1992a and b) constructed a "structural variable" using the data on one-digit industrial mix to control for this possibility. My approach is less restrictive, although it controls for only very crude differences in industrial mix. I would like to thank Yosuke Takeda for suggesting this alternative approach. The inclusion of these variables would be inconsequential to the estimated β if they were uncorrelated with the initial income. In reality, however, they are rarely uncorrelated.

population instead of total population, and deflate by the regional CPI. In the last rows, (iv), I divide the output measures by labor force, and deflate by the regional CPI.

The tables, in general, support the convergence result. Only in two cases, the estimated β is significantly negative at the 5% level (rows (i) in Tables 1-A and 1-B, for the period of 1980-90). The tendency toward convergence was the weakest in the 80s. The estimated β tends to be smaller when income is used, and larger when consumption is used.

Comparing rows (i) and (ii) reveals that the estimated β is generally larger when the regional CPI is used than when the common deflator is used. This is an expected result because deflating by the regional CPI reduces the initial income differential to the extent that the prices are positively correlated with income across the regions, while it does not affect estimated relative growth rates when prices change at the same rate across regions, as was illustrated by Persson (1994). Persson reports similar but somewhat stronger results for counties in Sweden. Next, comparing rows (ii) and (iii), it is found that using adult population in place of total population tends to raise the estimated β for the 60s and the 80s, but lowers it for the 70s. Finally, comparing rows (iv) with (ii) or (iii), it is found that using labor force instead of (adult) population increases the value of β except for the period of 1970-80. The value for the period 1980-90 turns significantly positive at the 10% level in all three cases. This is probably because the labor force series contains larger temporary components.

The main conclusion from this section is that the convergence result of Barro and Sala-i-Martin is robust to uses of different measures of output, labor input and prices.

3 Migration: Quantity Effect

The rest of the paper focuses on the role of internal migration in this β-convergence. What characterizes the regional development of postwar Japan is a large and continuous migration from poorer regions to wealthier regions. For example, the total population of "Greater Tokyo" in 1954 was 15.09 million. Net migration into this area in each period was: 1954–59: +1.72 million, 1960–69: +3.31 million, 1970–79: +1.16 million, 1980–89: +1.13 million. By 1990 its population had grown to 31.80 million.

Migration could affect regional growth in two important ways. First, it changes the amount of labor input in a region (**quantity effect**). Secondly, it could change educational and demographic composition of the labor force (**composition effect**). In this section, I will abstract from the heterogeneity of labor and focus on the quantity effect of migration. I will first discuss how large the effect should be from the viewpoint of neoclassical theory, and then contrast it with regression results.

As a measure of output per labor input, from this section on, I will use prefectural income per adult. Income is used because it is expected to be correlated better with expected earnings of migrants in their destination region than GDP would. Note that a part of GDP goes to owners of capital, who might be living outside the region. Adult population is used because there is data on its educational composition from an early period (1960).

Migration in Solow–Swan Model

According to traditional neoclassical theory, when workers move from poorer to wealthier regions, this should contribute to a faster (β-)convergence. This is because of decreasing to returns to labor in the production function in equation (1). To illustrate this point, I will assume that the growth rate of labor input, n_t, depends on $\ln y_t$ in the following way:

$$n_t = \lambda \cdot \ln y_t + \pi_1 \cdot X_{0,T}' , \tag{8}$$

where λ is a positive constant, π_1 is a vector of parameters, and $X_{0,T}$ is a vector of exogenous variables that affect n_t. Then, equation (4) on page 5 is rewritten as

$$\ln^{\cdot} \tilde{y}_t = -(b+\alpha\cdot\lambda)\cdot[\ln \tilde{y}_t - \ln \tilde{y}^*] + \pi_2 \cdot Z_{0,T}' , \tag{9}$$

where π_2 is a vector of parameters and $Z_{0,T}$ is a vector of exogenous variables that includes the variables in the vector $X_{0,T}$. Note that this is very similar to equation (4), except that "b" is replaced by "$b+\alpha\cdot\lambda$". Hence an equation analogous to equation (6) can be derived, with the theoretical speed of convergence being $(b+\alpha\cdot\lambda)$ instead of b. This implies that the speed of convergence in this case can be decomposed into two parts:

$\alpha\cdot\lambda$: contribution of migration to convergence,

and b: contribution of other causes.

The estimated β is now interpreted as an estimate for $b+\alpha\cdot\lambda$, rather than b.

The question is, how large is the contribution of migration ? Note that the parameter α is equal to (1 – the share of labor). Barro and Sala-i-Martin (1995) estimated α for Japan to be 0.42 (p.380). I will use this value in the following. The parameter λ has to be estimated from the data. Integrating equation (8) with respect to time, using equation (9), it can be shown that

$$\frac{1}{T}\cdot(\ln L_T - \ln L_0) = \lambda\cdot\tilde{b}^{-1}\cdot\frac{1-e^{-\tilde{b}T}}{T}\cdot\ln y_0 + (\text{exogenous terms}), \tag{10}$$

where $\tilde{b} \equiv b + \alpha\cdot\lambda$. Hence, I first regress the net migration rate (a proxy for the left-hand-side) on the log of initial income per adult. Its coefficient is my estimate for

$\lambda \cdot \bar{b}^{-1} \cdot \frac{1-e^{-\bar{b}T}}{T}$. Using the estimated β from row (iii) in Table 1-A as an estimate for $\bar{b}$, and using the appropriate values for T, the estimated value for λ is derived. Using this estimated λ together with $\alpha = 0.42$, the contribution of migration to the speed of convergence $= \alpha \cdot \lambda$ is derived. The results of this calculation is summarized in Table 2. For the 60s, according to this calculation, migration raised the speed of convergence by 2.1 %, which exceeds the actually estimated speed of convergence. For the 70s, its contribution goes down to about 0.7 %, because the sensitivity of migration to income experienced a large reduction[10]. For the 80s, its contribution is 0.5 %. Those numbers are not small when we consider that, on average, the estimated speed of convergence is two to three per cent.

Hence, the theoretical prediction is that migration must have been an **important**, if not dominant, cause of convergence in Japan.

Regression Approach

Next I try to measure the importance of migration through regressions, without imposing strong theoretical restrictions. In the previous section, I showed (equation (6)):

$$\frac{1}{T} \cdot [\ln y_T - \ln y_0] \approx -\left(\frac{1-e^{-bT}}{T}\right) \cdot [\ln y_0 - \ln \bar{y}^*] - \alpha \cdot \frac{1}{\bar{b}} \cdot \left(\frac{1-e^{-bT}}{T}\right) \cdot (\bar{n}_{0,T} - n^*) + \text{other terms.}$$

This suggests including the net migration rate linearly on the right-hand-side of the convergence regression. If theory is right, the estimated coefficient on the net migration rate should be around $-\alpha \cdot \frac{1}{\bar{b}} \cdot \left(\frac{1-e^{-bT}}{T}\right)$. If $\alpha = 0.42$, and $\dot{b} = 0.02$, this value is about -0.38 for $T = 10$, and about -0.32 for $T = 30$. Hence, theoretically speaking, a 1 % increase in the migration rate should reduce the growth rate by 0.3 to 0.4 %. Also, the empirical speed

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[10] Economic Planning Agency (1995) attributes this reduction to reduction of the share of young adults, who have a large propensity to migrate, in the total population. As the baby boomers got older and less mobile, the overall propensity to move went down.

of convergence, β, becomes an estimate for the speed of convergence net of the contribution of migration, b. Hence, it should be lower than in the case where the net migration rate is excluded from the right-hand-side.

Barro and Sala-i-Martin (1992b) estimated similar equations, and did not find any significant negative effect of migration on regional growth. Their result is confirmed by the regression results in Table 3. This table reports the results of the convergence regressions with the net migration rate included as an additional regressor. To take into account possible endogeneity of the net migration rate[11], I use past net migration rates or population growth rates as instruments, following Sala-i-Martin (1990)[12][13], who studied the US data. In none of the cases reported, the estimated coefficient on the net migration rate is significantly negative. In fact, the point estimates are all positive, and, for the periods other than 1970-80, it is significant at the 10 % level (although this significance result turned out to be not so robust to slight specification changes). Moreover, compared with row (iii) of Table 1-A (which uses the same measure of y_t as I do here), the point estimates

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[11]A region that experienced a faster growth in the level of technology (a larger $\bar{g}_{0,T}$) between time 0 and T should attract more migrants, other things being equal. A faster technological progress should also affect the growth rate of income per labor positively. If this effect is not completely controlled for by the industrial variables in the regression, it could produce a positive correlation between the error term and the migration rate, biasing the estimated coefficient upwards.

[12]If the technology shocks are uncorrelated across time, the past migration rate should not be correlated with the shocks between time 0 and T, as long as the shocks were not anticipated before time 0. On the other hand, migration is known to be highly correlated across time. So the past migration could serve as a good instrument.

There could be a problem with this approach if the productivity shocks are serially correlated. Migration in the period just before the current one is partly driven by technological changes in that period. Hence, if technological changes are serially correlated, the migration rate from that period is likely to be correlated with today's technological change. Hence, it is desirable to avoid using the migration rate in the "near past", and to use the ones from a sufficiently distant past. This is why I am avoiding using the migration rate from the ten years period directly before the current one as an instrument.

[13]Unfortunately, data on migration starts only from 1954. So in most cases I used the past population growth rates as proxies for the migration rates. I also tried adding the population density as instruments, as in Barro and Sala-i-Martin (1992b), but it did not change the qualitative results much.

for β are actually larger, not smaller.

Hence, the regression results indicate that migration was at best **irrelevant**[14], or perhaps even working against convergence.

Why the Discrepancy ?

It is possible that this discrepancy between theory and empirics is due to the fact that I ignored the composition effect of migration in deriving the theoretical prediction. I will pursue this possibility in the next two sections.

[14]This result is consistent with Tabuchi (1988), who showed that, using the Japanese data, migration does not Granger-cause income growth. It is in contrast with Blanchard and Katz (1992), who argued, using the US data, that migration was a major mechanism through which equilibrium in regional relative wage is restored.

4 Determinants of Population Composition

In this section, I study the possibility that migration has affected regional population composition in the following three aspects: (1) educational attainment, (2) school enrollment rate, and (3) age distribution. Using, mainly, the Population Census data, I will estimate these effects with OLS. The periods used here are 1960–70, 1970–80 and 1980–90, because the Census data on educational attainment is available in a consistent manner for the years 1960, 70, 80 and 90. I also report the case where all the coefficients other than the constants are restricted to be the same across the three periods, and the case in which the whole period of 1960–90 is treated as a single period.

In this section, all the variables other than the net migration rate are in logs. The "-0" after the series names indicates that it is evaluated at the initial year of the period. Likewise, "-d" indicates annualized growth rate (log differences).

4–1: Immigration raises the average educational attainment

First, it will be shown that Japanese internal migration tended to raise the level of education of receiving regions throughout the 60s, 70s and 80s. Two indicators of educational attainment will be considered. The first is the share of four–year university graduates in the adult population (over 15, not at school) (in logs), which will be called UNIV. The second is the share of two–year college and\or high school graduates, in the adult population who did not go to four–year universities (in logs), called HIGH.

In Table 4a I regress the average annual growth rates of UNIV (UNIV-d) on the net migration rate (MIGRATE) and other possible determinants. The first regressor on the right-hand-side is the initial value of UNIV (UNIV-0), whose coefficient is expected to be negative (see footnote 15)[15]. The second variable, GOUNIV-0, is the log of the share of high school graduates in a prefecture who go on to higher education (in any prefecture), evaluated at the initial year. Its coefficient is expected to be positive. The third variable, OLD-0, is the log of the share of population above 60 in adult population (not at school), evaluated at the initial year. In Japan, each generation tends to be better educated than the preceding generations, as in many other countries. So, a prefecture with a relatively high share of older people in the initial year will experience a more rapid growth of UNIV, as these people are replaced by younger people. Hence, coefficient on this variable is expected to be positive. Table 4b shows the result of similar regressions for HIGH. The left-hand-side is HIGH–d, and on the right-hand-side, the initial value of UNIV is replaced by that of HIGH (HIGH–0). GOUNIV-0 is excluded.

Most of the coefficients have expected signs: UNIV–0 and HIGH–0 have very significant negative effects on subsequent growth. GOUNIV-0 has significantly positive coefficients (except for one case). OLD–0 has expected positive coefficients in the UNIV-d regressions, but its effects on HIGH-d vary across periods. Most importantly, MIGRATE has highly significantly positive coefficients in all cases.

Data on educational attainment of labor force is available for the years 1970, 80 and 90. I ran regressions very similar to the ones above, using this labor force data. The estimated effect of migration on educational attainment turned out to be quite similar, except that the coefficient on MIGRATE in the HIGH-d regression went down somewhat.

Thus, it can be concluded that Japanese internal migration tended to raise

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[15]UNIV-0 is included for two reasons. First is to account for measurement errors and temporary components, which work to induce "convergence bias" in UNIV. Secondly, note that UNIV is bounded from above by 1. It cannot keep growing exponentially. In fact, as UNIV rises over time it becomes more and more difficult for it to grow at the same rate as before. To give an illustration, suppose that a prefecture started with an initial UNIV of near zero. Sending several youths to universities could generate a near infinite growth of UNIV in four years. From the next year, however, it has to produce a lot more students to achieve the same growth rate of UNIV. As UNIV approaches 100 per cent, there will be no way of getting near infinite growth. Both of the two arguments above suggest that coefficients on UNIV–0 should be negative.

educational attainment of receiving regions relative to that of source regions. This result is consistent with the study of Borjas et. al. (1992) on the US micro data, which found that internal migrants tended to be better-educated than non-movers.

4–2 Immigration raises the school enrollment rate

Table 5 shows that migration tends to have a positive effect on the school enrollment rate of receiving regions. This table studies the determinants of ENROLL, the number of people above 15 still enrolled in school, as a share of the total population above fifteen (in logs). The left-hand-side variable in the regression is its growth rate, ENROLL–d. On the right-hand-side, the initial value of ENROLL, ENROLL–0 is included for the same reason as UNIV–0 was included in Table 4a. GOUNIV-0, whose coefficient is expected to be positive, is included as well. Also included is YOUTH–0, which is (the log of) the share of people below 15 in the total population, evaluated at the initial year. Relatively larger share of younger people is likely to mean that there will be more students in the population above 15 later. Hence the coefficient on this is expected to be positive. The last right-hand-side variable is MIGRATE.

In Table 5, the coefficients on ENROLL–0, GOUNIV-0, and YOUTH-0 have expected signs and are significant. The coefficients on MIGRATE are positive and significant. Hence, it can be concluded that immigration tends to raise school enrollment. There seem to be two reasons for this. One is that, as Table 4 suggests, migration moves parents with higher education. If their children tend to stay in schools longer, as seems to be the case, migration should increase the regional school enrollment. Secondly, some migrants could actually be students seeking better educational opportunities. Higher educational institutions in Japan are heavily concentrated in the Greater Tokyo and Greater Osaka areas. The above result could be a direct consequence of those new students moving to urban areas.

4–3 Immigration has ambiguous effects on the share of youths

In the next three sub–sections, the effects of migration on age distribution will be examined. First, I study the effect of migration on the share of youths.

In Table 6, determinants of the share of population below 15 in the total population (in logs), denoted YOUTH, is studied. The left-hand-side variable is YOUTH–d, the growth rate of YOUTH. The right-hand-side variables are YOUTH–0, the initial value of YOUTH, the initial value of OLDER, defined as the log [(population between 5 and 15) / (population between 0 and 15)]), and MIGRATE. OLDER-0 is included to capture the fact that the older half of the youths will not be counted as youths at the end of the period, namely ten years later. Hence, the larger the share of older youths now, the lower will be the number of youths ten years later.

Table 6 shows that YOUTH–0 and OLDER-0 have coefficients with expected signs and are significant. Coefficient on MIGRATE is significantly positive for the 70s but is significantly negative for the 80s. In the 1960-90 regression, MIGRATE has a positive coefficient, but it is small and is insignificantly different from zero. Hence, it is concluded that, overall, immigration might have contributed to increasing the share of the youths, but the effect was small and varied a lot across the periods.

4–4 Immigration increases the share of younger adults

Next, I study if migration affects the share of the younger part of adults, holding constant its effects on the youths. I denote by YA (the log of) the share of those younger adults, defined as the population between 15 and 30, as a share of total population over 15. Hence, YA measures the share of relatively younger people among those who were not counted as youths in the previous sub-section. In Table 7, I regress the growth rate of YA, denoted YA-d, on possible candidates of its determinants. The first is YA-0, the initial value of YA. The second is UPPER-0, the number of people between 20 and 30, as a share of people between 15 and 30, evaluated at the initial year. Its coefficient is expected to be negative, for the same reason as OLDER-0 in Table 6 was expected to have a negative sign. The third regressor is YOUTH-0, as was defined in the section 4-3. If there are many people under 15 in a region, in ten years, there will be a lot of younger adults. Hence, the coefficient on YOUTH-0 is expected to be positive. The last regressor is MIGRATE.

Table 7 shows that immigration significantly increases the share of younger adults among all the adults. All the other coefficients have the expected signs and are mostly significant. The conclusion is that immigration increases the share of younger adults.

4–5 Immigration reduces the share of older people

Finally, it will be shown that migration reduces the share of older people in the adult population in the receiving regions.

It is often said that many of adult males in Japan abandoned agricultural areas in the 50s and the 60s, leaving only their wives and elderly parents on the farmlands (called 3–chan agriculture[16]). This conventional view is verified in the regressions reported in Table 8. AGED is defined as the share of the population above 60 in the population over 30 (in logs). The left-hand-side variable, AGED–d, is the log difference of AGED. The first right-hand-side variable is AGED–0, the initial value of AGED. The second variable, YOUNGER-0, is defined as the ratio of the population between 50 and 60 to the population over 60 (in logs, evaluated at the initial year). People between the age of 50 and 60 are obvious candidates for becoming people above 60 by the end of the period, namely ten years later. Hence, the higher this ratio is, the higher will be the growth of AGED.

One puzzling result in Table 8 is that the coefficients on AGED–0 are often positive and significant. It might be that AGED–0 is proxying some effect missing from my specification. The coefficients on YOUNGER-0 are always positive and significant, as expected. Most importantly, coefficients on MIGRATE are significantly negative in all cases. This is consistent with the majority of the internal migration literature, which finds that migrants tend to be younger than non-movers (Greenwood (1975)).

[16]This terminology refers to grandpa (jee–chan), grandma (bah–chan) and mom (kah–chan).

5 Migration: Educational Composition Effect

It was shown in the previous section that migration has improved relative educational attainment of receiving regions. As more educated people are expected to be more productive, this should improve the average labor productivity of receiving regions relative to that of source regions. As was shown in section 3, receiving regions tend to be wealthier regions. Hence, migration, through its composition effect on educational attainment, is likely to contribute to slowing down the convergence.

In the previous section, it was also shown that migration increases the share of younger people and students, and reduces that of older people in receiving regions. All of these groups of people can be characterized by low labor force participation rates and low productivity. Hence, it is not clear if migration, through its effect on age distribution, contributes to raising or lowering the average output per capita of receiving regions.

In this section, I focus on the effect of migration on regional growth that works through changing regional educational attainment. I will call this "educational composition effect". The effect of migration that works through changing age distribution will be examined on another occasion, because it requires far more detailed data. The question I would like to ask is: was the educational composition effect large enough to offset the quantity effect of migration ? As I showed in section 3, theoretically speaking, the quantity effect should contribute substantially to convergence. However, according to the regression results, migration was either irrelevant or even working against convergence. I pursue the possibility that the educational composition effect, which contributes to slowing down convergence, was large enough to offset the quantity effect, resulting in a zero or even positive net effect.

Theoretical Background

The question is how to quantify the educational composition effect. I propose a regression analysis approach that is based on an extended Solow–Swan model which incorporates labor heterogeneity. Consider a regional production function of the following form:

$$Y_t = K_t^{\alpha} \cdot \{A_t \cdot [q_{1t} N_{1t} + q_{2t} N_{2t} + \cdots + q_{mt} N_{mt}]\}^{1-\alpha}$$

$$= K_t^{\alpha} \cdot N_t^{1-\alpha} \cdot (A_t \cdot Q_t)^{1-\alpha},$$

$$\text{where } N_t \equiv \sum_{i=1}^{m} N_{it}, \text{ and } Q_t \equiv q_{1t} \frac{N_{1t}}{N_t} + q_{2t} \frac{N_{2t}}{N_t} + \cdots + q_{mt} \frac{N_{mt}}{N_t}. \quad (11)$$

In equation (11), A_t is the level of (disembodied) technology, while q_{it}'s are the productivity that is embodied in each worker's body, which are assumed to differ across m groups within regional population[17]. The number of people in group i is denoted by N_{it}, and their productivity is q_{it}. Q_t measures the average quality of labor. As I have discussed earlier, migration could change per–capita output through two channels, changes in N_t (<u>quantity effect</u>), and changes in the shares of people with different productivities (N_{it}/N_t), and thus the average quality of the population, Q_t (<u>composition effect</u>). If the shares of people with higher q's are increased, per–capita output will also increase.

I assume that the adult population (not at school) consists of four groups with different levels of quality (i.e., m = 4), which correspond to four different levels of educational attainment for which the data is available: <1> Elementary and Junior High School (normally 6 to 9 years of education), <2> High School (12 years), <3> 2-year Colleges (14 years), and <4> Universities and higher (over 16 years)[18]. I hereby assume

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[17]This functional form amounts to assuming that workers with different educational levels are perfect substitutes in production, except that they have different productivity.

[18]The sum of those four does not add up to the total. The discrepancy is a combination of people with zero education and people with no data on their educational attainment. Wage data was not available for either of them. In what follows, these people are included in group <1>. Their population share was so small that this decision should

that their relative productivity (q_{jt}/q_{it} for all i and j) stayed constant within the sample period[19]. Then, equation (11) can be written as

$$Y_t = K_t^{\alpha} \cdot N_t^{1-\alpha} \cdot (A_t \cdot q_{1t} \cdot E_t)^{1-\alpha}$$

$$\text{where } E_t \equiv \frac{Q_t}{q_{1t}} = [\frac{N_{1t}}{N_t} + \theta_2 \cdot \frac{N_{2t}}{N_t} + \theta_3 \cdot \frac{N_{3t}}{N_t} + \theta_4 \cdot \frac{N_{4t}}{N_t}],$$

$$\text{and where } \theta_i \equiv \frac{q_{it}}{q_{1t}} \text{ for i = 2, 3, and 4.} \qquad (11')$$

I will call E_t the educational composition of the regional population. Note that the composition effect of migration affects only E_t and not q_{1t}. To compute the θ_i's above, I assume that their relative wages are proportional to their relative productivity. This should be the case if the production function takes the above form and the labor market is perfectly competitive. I computed the relative wage of each of them using the "Basic Survey of the Wage Structure" for the period of 1980-90[20]. I estimated the productivity of each educational group relative to group <1> to be: $\theta_2 \approx 1.017$, $\theta_3 \approx 1.013$, and $\theta_4 \approx 1.209$[21]. Note that all the groups other than <4> have very similar productivity.

If the production function is of the form in equation (11'), instead of (1) in page 4, then the "convergence equation" in equation (6) of page 6 is replaced by (using the approximation that q_{1t} and E_t grow at some constant rates between time 0 and T):

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not influence the results in any significant way. According to the Census of Population, during my sample period, the shares of those groups of people in the total population over age 15 were: 2.2 % (1960), 0.7 % (1970), 0.5 % (1980), and 1.6 % (1990).

[19]In reality, the relative wage across educational groups have changed over time in Japan, though not as drastically as in the US. See Katz and Revenga (1989). This assumption is justified because I am specifically interested in the effects of changing educational composition.

[20]The data is monthly contractual earnings (total) of male workers for industries covered, and it's from all sizes of enterprises. I took averages over the ten years.

[21]This construction of the educational quality variable with θ_i's fixed across time is similar to the way Mulligan and Sala-i-Martin (1994) constructed their "fixed-weight" measure of human capital for the US regions.

$$\frac{1}{T}\cdot[\ln y_T - \ln y_0] \approx -(\frac{1-e^{-bT}}{T})\cdot[\ln y_0 - \ln \bar{y}^*] - \frac{e^{-bT}}{T}\cdot(\ln A_0+\ln Q_0)$$

$$+ [1-\alpha\cdot\frac{1}{b}\cdot(\frac{1-e^{-bT}}{T})]\cdot[\bar{g}_{0,T} + \bar{\gamma}_{1,0,T} + \bar{\gamma}_{E,0,T}] - \alpha\cdot\frac{1}{b}\cdot(\frac{1-e^{-bT}}{T})\cdot\bar{n}_{0,T}. \quad (12)$$

In the above, $\bar{\gamma}_{1,0,T}$ is the growth rate of q_{1t} between time 0 and T, and $\bar{\gamma}_{E,0,T}$ is the growth rate of E_t between time 0 and T.

Estimating the Educational Composition Effect

The educational composition effect means that migration changes the term $\bar{\gamma}_{E,0,T}$, the growth rate of E_t in equation (12), and thus changes the growth rate on the left-hand-side. To estimate the extent of this effect, we need to ask two questions: (i) How strong is the effect of migration on the growth rate of the "educational composition variable", E_t ? and (ii) How strongly do changes in the growth rate of E_t translate into changes in income growth ? To investigate the first question, I regress the growth rate of the "educational composition variable", E_t, on its determinants, including the net migration rate, and study the size and significance of the coefficient on the migration rate. To answer the second question, equation (12) gives a key. According to this equation, the effect of the growth rate of the "educational composition variable" on income growth is given by the coefficient $[1-\alpha\cdot\frac{1}{b}\cdot(\frac{1-e^{-bT}}{T})]$. Unfortunately, we do not know the value of b, the "true" speed of convergence (net of the effects of migration). However, assuming that b is positive (which is required for stability), this coefficient takes a value between $1-\alpha$ and 1. Hence, we know that, the growth rate of E_t translates into the growth rate of income at most one-to-one. For example, for $\alpha = 0.42$, $b = 0.02$, and $T = 10$, this coefficient would be 0.62.

Going back to the first question, in Table 9, I study the determinants of the growth rate of E_t, the "educational composition variable". Given that, in the construction of E_t, the weights given to the first three educational groups are similar ($\theta_2 \approx \theta_3 \approx 1$), most of variations in E_t should come from variations in N_{4t}/N_t, the share of university graduates. Hence, it is expected that a set of regressors similar to the one used in Table 4-a could be used to explain E_t. Hence, I regressed the growth rate of E_t (ln E-d) on four variables, its initial value in logs (ln E-0), GOUNIV-0 (the share of high school students proceeding to higher education, in the initial year, in logs), OLD-0 (the share of people over 60 in the adult population, in the initial year, in logs), and the net migration rate. As expected, the net migration rate has significant positive influence on the growth rate of the "educational composition", and its coefficients range from 0.006 to 0.022. Given that the growth rate of E_t translates into the growth rate of income by at most one-to-one, this means that <u>a 1 % increase in net migration rate, through its educational composition effects, increases the growth rate of income by at most 0.022 %</u>[22]. I also performed similar studies using the educational attainment data of labor force rather than adult population (for 1970 onwards), and obtained similar results. The largest coefficient on MIGRATE was 0.025.

Is this effect large enough to fill the gap between theory and empirics ? As was already discussed in section 3, theory suggests that a 1 % increase in net migration rate should <u>decrease</u> the per-capita growth rate by about 0.3 to 0.4 %. Regression results in Table 3 indicate that a 1 % increase in net migration rate <u>increases</u> the growth rate by 0.5 to 1 %. The gap is about 0.8 to 1.4 %. It is clear that the introduction of the educational composition effect, whose maximum effect is 0.022 %, comes nowhere close to resolving the problem. The conclusion is that, although this effect works in the direction toward resolving the problem, its magnitude is just too small to account for the difference between theory and empirics.

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[22]Here I discuss about the other variables in table 9. Coefficients on ln E-0 are significantly positive except for the period of 1980-90, which is the other way round from the coefficients on UNIV-0 in table 4-a. This change is not surprising because the educational composition variable can be considered as a highly non-linear transformation of UNIV. Coefficients on GOUNIV-0 are positive, as expected, but insignificantly so for the period of 1960-70. Coefficients on OLD-0, which were expected to be positive, turned out to be insignificant in most cases. It is significantly positive only for the period of 1960-90.

Robustness

It is possible that relative wages do not fully reflect relative productivity differentials across different educational groups. If so, it would lead to an underestimation of the strength of the educational composition effect. To evaluate the possible extent of this underestimation, I go to the other extreme and assume that there are huge productivity differentials among the groups with different educational attainment. In practice, I assume that: $\theta_2 = 2$, $\theta_3 = 2$, and $\theta_4 = 4$. I redid the regressions in Table 9 using these values, and the estimated coefficient on the net migration rate turned out to be at most 0.239. Given that changes in E_t translates into changes in income growth at most by one-to-one, this means that, even under these extreme assumptions, the educational composition effect could go less than half way toward resolving the gap between theory and empirics.

Another possible source of underestimation is externalities from the quality of regional labor force. An increase in the share of educated workers might increase output not only through their own contribution to output but also by improving the general productivity of the region, through, for example, facilitating exchanges of ideas among the workers. This possibility was suggested by Lucas (1988) and was empirically supported by Rauch (1991). This means that, in equation (11'), A_t, the disembodied productivity of a region, depends positively on E_t, the educational composition. For example, $A_t = B_t \cdot E_t^{\omega}$, where $\omega > 0$, and B_t signifies other determinants of the productivity. I go to an extreme and assume that $\omega = 1$. This means that the elasticity of output with respect to the externality term is $1 - \alpha$, or about 0.58. In this case, the predicted effect of the educational composition on output is doubled. A 1 % increase in the net migration rate now increases output, through its educational composition effect, by at most 0.044 %, instead of 0.022 %. But this is still way too small to fill the gap between the theory and the empirics.

Hence, I conclude that the main conclusion of this section is quite robust to the possibility of underestimation.

6 Conclusion and Suggestions for Further Research

It was shown that there was a gap between the theoretical prediction on the effects of migration on regional growth and the regression results. I investigated the possibility that this gap was due to the "educational composition effect" of migration. It was shown that, although this effect was indeed working in the expected direction, its size was simply too small to account for the gap. Then what could account for the gap ? I suggest several directions for further research.

Unobserved Ability: Migration might favor the receiving regions not only in terms of observed ability such as education, but also in terms of unobserved ability. The results in this paper suggests that this effect should be really strong if it were to account for the gap between the theory and the empirics.

Age Distribution and Labor Force Participation Rate: As I showed in section 4, migration changes age distribution across regions. The role of this effect should be studied further. In section 5, I assumed, for simplicity, that everybody in the adult population worked. This is of course not very realistic. By reducing the share of older people, inflow of workers could increase the labor force participation rate of a region, and thus increase income per adult resident.

Externalities and Scale Effects: It is possible that the theory employed in this paper failed to take account of important benefits of migration on productivity. These effects are of central concern to today's growth theory. Inflow of labor might improve the productivity of regional labor force through faster learning by doing (Romer (1986)) or by facilitating further division of labor (Ethier (1982), Krugman (1991), Shioji (1995, chapter 2), etc.).

Better Instruments: It is also possible that the empirical approach that I used to estimate the quantity effect of migration in section 3, not the theory, was inadequate. I argued in footnote 11 in section 3 that migration could be positively correlated with growth through its response to technological changes within the period. That was why past population growth and migration rates were used as instruments in the regressions. There is a possibility that these were not very good instruments. Different types of instruments should be found to study the robustness of the regression results.

Capital Mobility: The presence of capital mobility could reduce the theoretically predicted quantity effect of migration which was discussed in section 3. To illustrate this point, assume that the production function was as in equation (1), that capital was perfectly mobile not only across regions but across countries in the world, and that the world interest rate was given by r^*. Then, it can be shown that $Y_t = \left[\frac{\alpha}{r^*+\delta}\right]^{\frac{\alpha}{1-\alpha}} \cdot A_t \cdot L_t$. Note that, this "reduced form production function" exhibits constant returns to labor. Hence, changes in L_t do not affect output per labor, which means zero quantity effect of migration. This could explain why I did not find significantly negative effect of migration in section 3. A problem with this approach is that the same model also implies convergence at the speed of 100 % (Barro and Sala-i-Martin (1995, chapter 3)), which is at odds with our observation. To counter this shortcoming, the slow convergence will have to be explained by introducing other models, such as those of technological diffusion (Nelson and Phelps (1966), and Barro and Sala-i-Martin (1995, chapter 8)).

Appendix: Data sources

Income: Prefectural Income, "Annual Report on Prefectural Accounts", various years, Economic Planning agency (EPA).

Consumption and GDP, before 1974: EPA (1991).

Consumption and GDP, after 1975: "Annual Report on Prefectural Accounts", various years, EPA.

Output data for the construction of the industrial variables: "Annual Report on Prefectural Accounts", EPA. The type of output measure varied across the years. For 1960, the data on "Domestic Production Income" was used. For 1970, "Net Domestic Product", and for 1980, "Gross Domestic Product" were used, respectively.

Population, 1960, 70,80 and 90: "Estimated Population", Management and Coordination Agency (MCA).

Adult population, labor force, educational attainment, age structure, and population before 1960: "The Population Census", MCA.

Prices: Regional Difference Index of Consumer Prices, MCA. Note: The data was available from 1956. Hence the values for 1955 was estimated using the values for 1956, by assuming that the rate of change between 1955 and 1956 was the same as that of the National CPI for the whole prefectures. The National CPI is also taken from MCA.

Migration: Net–migration, Migrants by prefectures, Statistics Bureau, MCA.

GOUNIV: School Basic Survey, Ministry of Education.

Wage data (for the construction of the "educational composition variable"): "Basic Survey of the Wage Structure" (monthly contractual earnings (total) of male workers for industries covered, and all sizes of enterprises).

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Table 1: Convergence Regressions – Estimated β

Sample size: 39,

Method: NLS (except for the "restricted" case, where 3SLS is used.)

Dependent variable: Average annual growth rate of (output measure)/(labor input measure)

Regressors: Log of the initial value of (output measure)/(labor input measure), initial shares of the primary and the secondary industries, and the constant

Only the estimated "β", the speed of convergence, is reported. The t statistics are in round parentheses. Adjusted R^2's are in the squared brackets.

Note 1: The t-statistics are based on the White's heteroscedasticity consistent std. errors.

Note 2: In the "restricted" case, β is restricted to be equal across the ten-year sub-periods, while the other parameters are allowed to be the same. R^2's are omitted to save space. The superscript "*" indicates that the Likelihood Ratio test does NOT reject the parameter constancy restriction at the 1% significance level.

A: Output Measure = Prefectural Income

	60-90	60-70	70-80	80-90	restricted
(i) National CPI Population	0.014 (2.20) [0.48]	0.014 (1.85) [0.15]	0.047 (3.06) [0.68]	–0.012 (–3.26) [0.06]	0.010 (1.77)
(ii) Regional CPI Population	0.019 (2.79) [0.52]	0.016 (1.95) [0.14]	0.055 (3.17) [0.67]	–0.008 (–1.69) [–0.003]	0.013 (2.36)
(iii) Regional CPI Adult Pop.	0.014 (2.09) [0.27]	0.019 (1.81) [0.06]	0.038 (2.55) [0.47]	–0.002 (–0.44) [–0.03]	0.011 (2.13)
(iv) Regional CPI Labor Force	0.036 (2.84) [0.60]	0.035 (2.66) [0.23]	0.053 (3.39) [0.54]	0.013 (2.54) [0.08]	0.027* (4.36)

B: Output Measure = GDP

	60-90	60-70	70-80	80-90	restricted
(i) National CPI Population	0.033 (3.76) [0.73]	0.027 (1.87) [0.16]	0.084 (3.67) [0.74]	−0.012 (−2.78) [0.07]	0.014 (2.29)
(ii) Regional CPI Population	0.025 (2.42) [0.56]	0.027 (2.11) [0.14]	0.105 (3.34) [0.73]	−0.009 (−1.77) [0.03]	0.017 (2.79)
(iii) Regional CPI Adult Pop.	0.024 (1.93) [0.39]	0.037 (1.97) [0.11]	0.089 (3.28) [0.58]	−0.004 (−0.97) [−0.008]	0.016 (2.60)
(iv) Regional CPI Labor Force	0.052 (2.09) [0.67]	0.051 (3.95) [0.28]	0.094 (3.95) [0.69]	0.010 (2.01) [0.04]	0.035 (4.97)

C: Output Measure = Consumption

	60-90	60-70	70-80	80-90	restricted
(i) National CPI Population	0.033 (3.76) [0.73]	0.064 (3.57) [0.47]	0.059 (6.87) [0.80]	0.002 (0.01) [−0.07]	0.049 (6.85)
(ii) Regional CPI Population	0.038 (3.46) [0.74]	0.070 (3.53) [0.44]	0.074 (6.94) [0.80]	0.008 (0.50) [−0.07]	0.061 (7.25)
(iii) Regional CPI Adult Pop.	0.034 (3.44) [0.62]	0.076 (4.31) [0.46]	0.079 (5.72) [0.66]	0.009 (0.69) [−0.06]	0.059 (6.99)
(iv) Regional CPI Labor Force	0.041 (3.83) [0.74]	0.080 (6.00) [0.53]	0.070 (6.05) [0.64]	0.023 (1.81) [0.02]	0.062 (8.90)

Table 2: Estimating the Contribution of Migration to Convergence, using the Solow-Swan Model

Sample size: 39

The "Income coefficient in Migration Regression" is estimated by regressing the net migration rate on the initial income per adult. The method is OLS, except in the "restricted" case where 3SLS is used. In the "restricted" case, the coefficient on the initial income is restricted to be the same across the three periods. Likelihood Ratio test rejects the parameter constancy restriction at the 1% significance level.

	60-90	60-70	70-80	80-90	restricted
$\lambda\cdot\psi$: Income coef. in Migration Regression	0.0225 (9.129) [0.622]	0.0457 (10.03) [0.720]	0.0144 (8.34) [0.386]	0.0130 (6.36) [0.368]	0.0197 (8.76)
$\psi \equiv \frac{1}{\beta}\cdot\frac{1-e^{-\beta T}}{T}$	0.813	0.913	0.830	1.01	0.946
λ: sensitivity of migration to income	0.0277	0.0501	0.0173	0.0129	0.0208
$\beta = \alpha\cdot\lambda + b$: Estimated Speed of Convergence	0.0143	0.0186	0.0384	−0.00192	0.0112
$\alpha\cdot\lambda$: Contribution of Migration	0.0116	0.0210	0.00727	0.00541	0.00875
b: Contribution of the rest	0.00268	−0.00248	0.0311	−0.00733	0.00245

Note: See the text for the definitions of the parameters. The value of α is set to 0.42, following Barro and Sala-i-Martin (1995).

Table 3: Estimating the Contribution of Migration to Convergence, using the Regression Approach

Sample size: 39,

Method: Instrumental Variables Approach (except for the "restricted" case, where 3SLS is used.)

Dependent variable: Average annual growth rate of Prefectural Income per adult

Regressors: Log of the initial Prefectural Income per adult, shares of the primary and the secondary industries, Net Migration Rate, and the constant

t statistics are in round parentheses.

Note 1: The t-statistics are based on the White's heteroscedasticity consistent std. errors.

Note 2: In the "restricted" case, β and the coefficient on the net migration rate are restricted to be equal across the ten-year sub-periods, while the other parameters are allowed to be the same. R^2's are omitted to save space.

	60-90	60-70	70-80	80-90	restricted
β	0.064 (1.21)	0.051 (1.95)	0.045 (2.61)	0.013 (1.45)	0.024 (3.16)
Net Migration Rate	0.647 (2.53)	0.520 (1.96)	0.751 (1.24)	1.058 (2.48)	0.628 (3.33)
Adjusted R^2	0.434	0.261	0.454	0.078	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

List of Instruments

1960-90:	Population growth rate: 1920-30, 1930-40, and 1940-50
1960-70:	The same as above
1970-80:	Population growth rate: 1920-30, 1930-40, 1940-50, and 1950-60
1980-90:	Population growth rate: 1920-30, 1930-40, 1940-50, and 1950-60 Net migration Rate: 1960-1969
Restricted:	The same as in "1960-90"

Table 4: Determinants of Educational Attainment

Sample size: 39

Method: OLS, except for the "restricted" case, where 3SLS is used.

t statistics, based on White's heteroscedasticity consistent std. errors, are in parentheses .

Note: In the "restricted" case, all the coefficients are restricted to be equal across the periods (constants are allowed to be different).

a: Universities

Dependent variable: UNIV-d

Period	60-90	60-70	70-80	80-90	restricted
UNIV-0	−0.017 (−10.68)	−0.016 (−3.692)	−0.027 (−12.65)	−0.019 (−7.423)	−0.018 (−8.890)
GOUNIV-0	0.005 (3.831)	0.004 (0.961)	0.016 (7.588)	0.009 (3.758)	0.008 (4.244)
OLD-0	0.018 (7.451)	0.024 (3.829)	0.011 (2.829)	0.010 (2.271)	0.014 (3.661)
MIGRATE	0.760 (10.13)	0.518 (2.949)	1.254 (8.553)	1.091 (7.200)	0.689 (6.247)
Adj. R^2	0.888	0.434	0.880	0.830	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

UNIV: the number of four-year university (and over) graduates as a share of adult population (age 15 and over, not at school), in logs.

GOUNIV: the number of students who seek higher education as a share of the total number of high school graduates, in logs.

OLD: the number of people over the age of 60 as a share of the total population over 15, not attending school, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

b: High Schools

Dependent variable: HIGH-d

Period	60-90	60-70	70-80	80-90	restricted
HIGH-0	–0.020 (–21.98)	–0.018 (–8.009)	–0.033 (–17.41)	–0.028 (–15.74)	–0.027 (–22.14)
OLD-0	–0.012 (–1.130)	–0.003 (–0.912)	–0.007 (–3.765)	0.003 (2.102)	0.0006 (0.298)
MIGRATE	0.114 (2.619)	0.145 (2.403)	0.222 (2.369)	0.247 (2.972)	0.266 (7.130)
Adj. R^2	0.939	0.651	0.897	0.899	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

HIGH: the number of two-year college or high school graduates as a share of adult population (age 15 and over, not at school) who did not graduate from a four-year university, in logs.

OLD: the number of people over the age of 60 as a share of the total population over 15, not attending school, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

Table 5: Determinants of School Enrollment

Sample size: 39

Method: OLS, except for the "restricted" case, where 3SLS is used.

t statistics, based on White's heteroscedasticity consistent std. errors, are in parentheses .

Note: In the "restricted" case, all the coefficients are restricted to be equal across the periods (constants are allowed to be different).

Dependent variable: ENROLL-d

Period	60-90	60-70	70-80	80-90	restricted
ENROLL-0	−0.394 (−11.26)	−0.661 (−4.912)	−0.481 (−3.602)	−0.334 (−4.004)	−0.704 (−8.013)
GOUNIV-0	0.009 (5.474)	0.140 (3.177)	0.024 (4.884)	0.013 (4.988)	0.018 (6.553)
YOUTH-0	0.019 (4.786)	0.118 (6.815)	0.065 (3.231)	0.054 (3.560)	0.096 (10.25)
MIGRATE	0.718 (7.522)	0.394 (2.365)	1.040 (3.515)	0.962 (4.844)	0.338 (2.542)
Adj. R^2	0.749	0.738	0.568	0.571	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

ENROLL: the number of population at school as a share of adult population (age 15 and over, not at school), in logs.

GOUNIV: the number of students who seek higher education as a share of the total number of high school graduates, in logs.

YOUTH: the number of people under the age of 15 as a share of the total population, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

Table 6: Determinants of the Share of Youths

Sample size: 39

Method: OLS, except for the "restricted" case, where 3SLS is used.

t statistics, based on White's heteroscedasticity consistent std. errors, are in parentheses .

Note: In the "restricted" case, all the coefficients are restricted to be equal across the periods (constants are allowed to be different).

Dependent variable: YOUTH-d

Period	60-90	60-70	70-80	80-90	restricted
YOUTH-0	−0.018 (−10.24)	−0.038 (−7.064)	−0.037 (−7.881)	−0.034 (−3.257)	−0.038 (−10.85)
OLDER-0	−0.029 (−3.302)	−0.210 (−11.61)	−0.063 (−6.020)	−0.226 (−7.248)	−0.112 (−11.11)
MIGRATE	0.061 (1.220)	0.087 (1.420)	0.501 (5.473)	−0.529 (−2.172)	0.153 (3.008)
Adj. R^2	0.823	0.914	0.909	0.685	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

YOUTH: the number of people under the age of 15 as a share of the total population, in logs.

OLDER: the number of people between age 5 and 15, as a share of population between 0 and 15, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

Table 7: Determinants of the Share of Younger Adults

Sample size: 39

Method: OLS, except for the "restricted" case, where 3SLS is used.

t statistics, based on White's heteroscedasticity consistent std. errors, are in parentheses .

Note: In the "restricted" case, all the coefficients are restricted to be equal across the periods (constants are allowed to be different).

Dependent variable: YA-d

Period	60-90	60-70	70-80	80-90	restricted
YA-0	−0.017 (−5.903)	−0.036 (−7.064)	−0.022 (−2.729)	−0.043 (−3.263)	−0.034 (−6.151)
UPPER-0	−0.027 (−2.990)	−0.072 (−3.615)	−0.053 (−3.753)	−0.018 (−0.425)	−0.054 (−7.983)
YOUTH-0	0.010 (3.292)	0.041 (3.823)	0.034 (3.190)	0.075 (3.493)	0.050 (8.279)
MIGRATE	0.605 (6.588)	0.745 (4.859)	0.306 (2.398)	1.884 (5.035)	0.728 (7.593)
Adj. R^2	0.657	0.560	0.837	0.604	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

YA: the number of people between the age 15 and 30, as a share of the total population over the age 15, in logs.

UPPER: the number of people between age 20 and 30, as a share of population between 15 and 30, in logs.

YOUTH: the number of people under the age of 15 as a share of the total population, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

Table 8: Determinants of the Share of Older People

Sample size: 39

Method: OLS, except for the "restricted" case, where 3SLS is used.

t statistics, based on White's heteroscedasticity consistent std. errors, are in parentheses .

Note: In the "restricted" case, all the coefficients are restricted to be equal across the periods (constants are allowed to be different).

Dependent variable: AGED-d

Period	60-90	60-70	70-80	80-90	restricted
AGED-0	−0.002 (−0.368)	0.035 (4.322)	0.034 (4.577)	0.004 (0.947)	0.016 (4.688)
YOUNGER-0	0.018 (2.892)	0.057 (6.531)	0.062 (6.819)	0.034 (4.955)	0.042 (11.55)
MIGRATE	−0.533 (−13.23)	−0.427 (−13.28)	−0.705 (−9.131)	−0.540 (−4.991)	−0.505 (−18.00)
Adj. R^2	0.857	0.847	0.818	0.741	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

AGED: the number of people over the age of 60 as a share of the total population over 30, in logs.

YOUNGER: the number of people between age 50 and 60, as a ratio to population over 60, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

Table 9: Determinants of the Educational Composition Variable

Sample size: 39

Method: OLS, except in the "restricted case, where 3SLS is used.

t statistics, based on White's heteroscedasticity consistent std. errors, are in parentheses .

Note: In the "restricted" case, all the coefficients are restricted to be equal across the periods (constants are allowed to be different).

Dependent variable: ln E-d

Period	60-90	60-70	70-80	80-90	restricted
ln E-0	0.015 (4.090)	0.032 (6.717)	0.014 (6.979)	6.47e-4 (0.312)	0.011 (4.916)
GOUNIV-0	0.94e-4 (4.296)	0.31e-4 (0.961)	1.78e-4 (6.404)	1.87e-4 (5.495)	1.40e-4 (4.799)
OLD-0	1.67e-4 (4.271)	0.55e-4 (1.231)	−0.46e-4 (−1.077)	0.64e-4 (0.783)	0.37e-4 (0.738)
MIGRATE	0.016 (12.29)	0.006 (3.994)	0.017 (8.303)	0.022 (9.447)	0.010 (8.866)
Adj. R^2	0.900	0.900	0.922	0.820	

Likelihood ratio test rejects the parameter constancy restriction at any conventional significance level.

Definitions:

ln E: Log of the "Educational Composition Variable", E_t, calculated from educational attainment. See the text for its construction.

GOUNIV: the number of students who seek higher education as a share of the total number of high school graduates, in logs.

OLD: the number of people over the age of 60 as a share of the total population over 15, not attending school, in logs.

MIGRATE: net migration rate (annual average)

Note: "-0" stands for the values in the initial year (in logs), while "-d" stands for the growth rates over the period (log differences, annual average).

Figure 1: Map of Japan

Prefectures

01 - Hokkaido	13 - Chiba	25 - Shiga	37 - Kagawa
02 - Aomori	14 - Tokyo	26 - Kyoto	38 - Ehime
03 - Iwate	15 - Kanagawa	27 - Osaka	39 - Kochi
04 - Miyagi	16 - Yamanashi	28 - Hyogo	40 - Fukuoka
05 - Akita	17 - Nagano	29 - Nara	41 - Saga
06 - Yamagata	18 - Shizuoka	30 - Wakayama	42 - Nagasaki
07 - Fukushima	19 - Toyama	31 - Tottori	43 - Kumamoto
08 - Niigata	20 - Ishikawa	32 - Shimane	44 - Oita
09 - Ibaraki	21 - Gifu	33 - Okayama	45 - Miyazaki
10 - Tochigi	22 - Aichi	34 - Hiroshima	46 - Kagoshima
11 - Gumma	23 - Mie	35 - Yamaguchi	47 - Okinawa
12 - Saitama	24 - Fukui	36 - Tokushima	

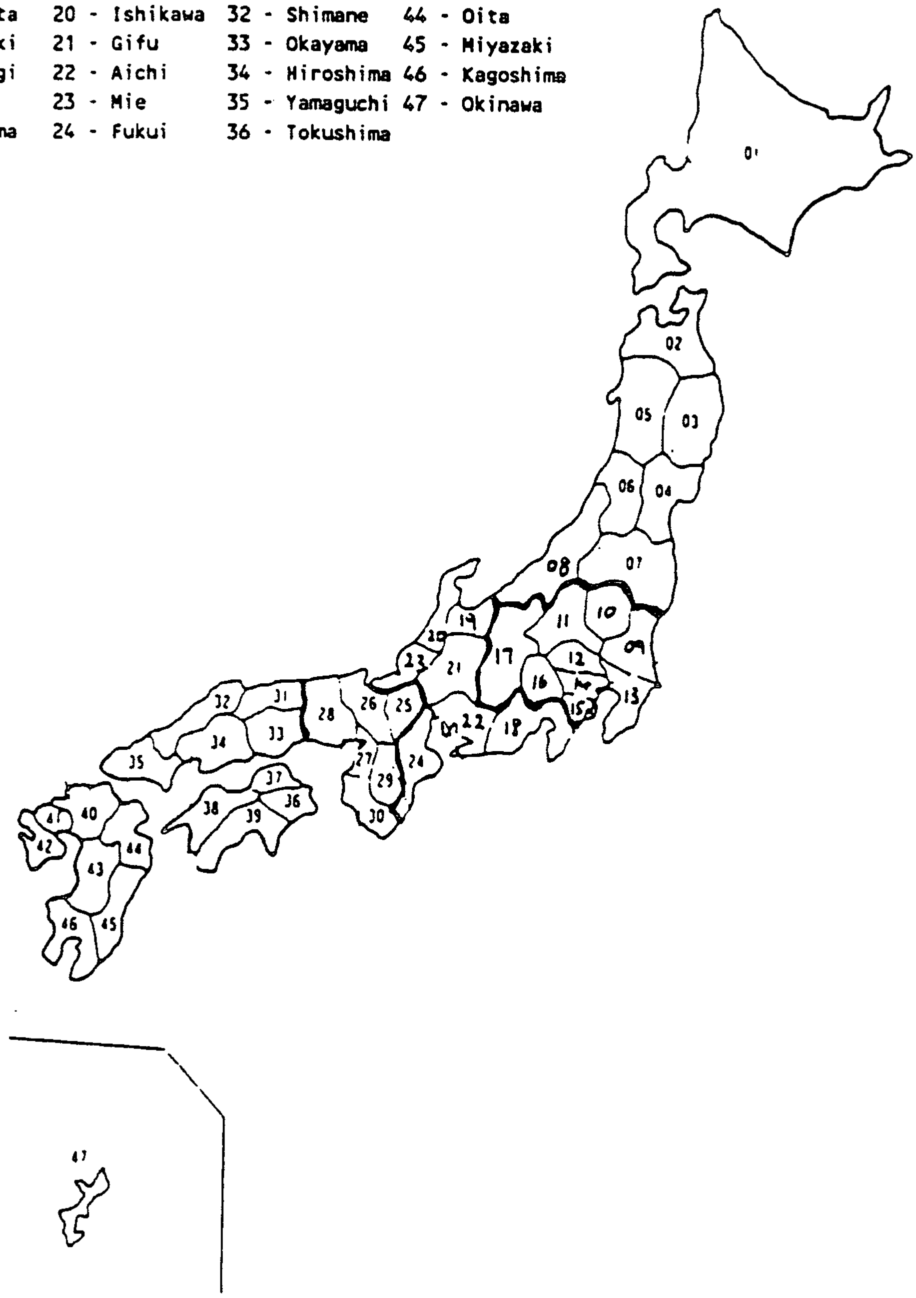


Figure 2 Sigma Convergence
Dispersion of GDP per Labor Force, Common Deflator v.s. Regional CPI

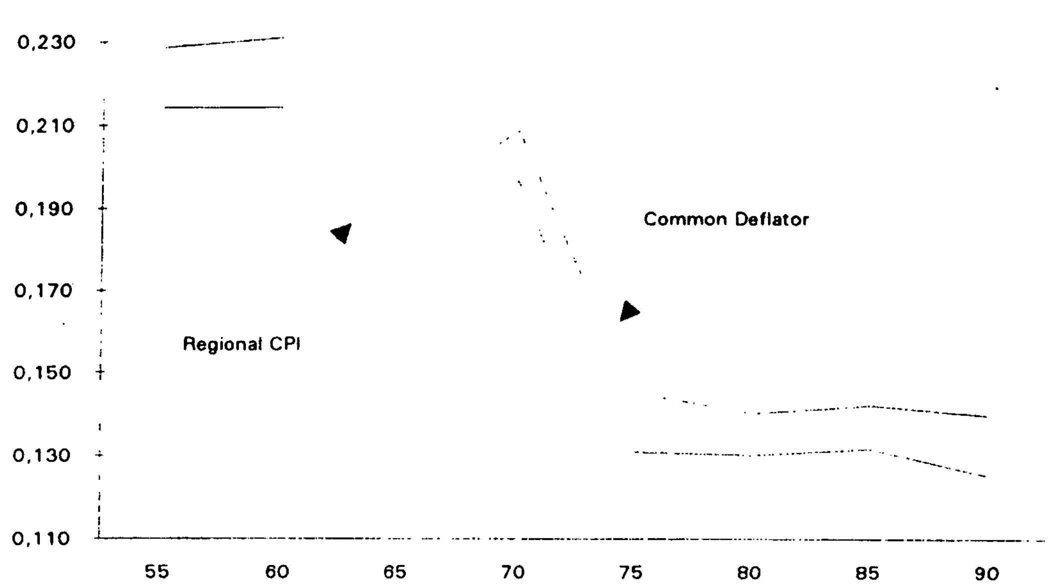
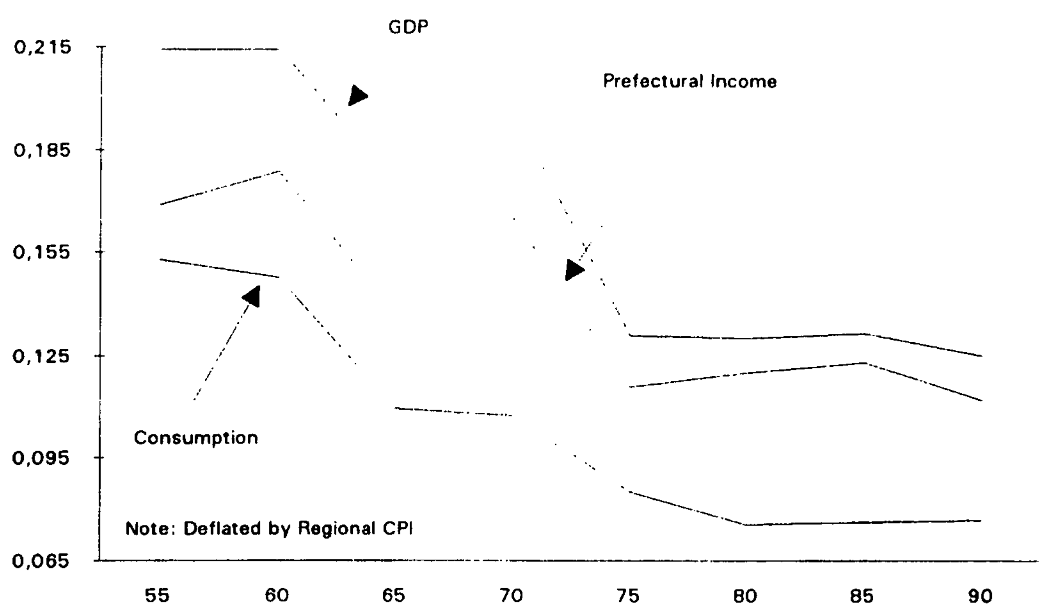
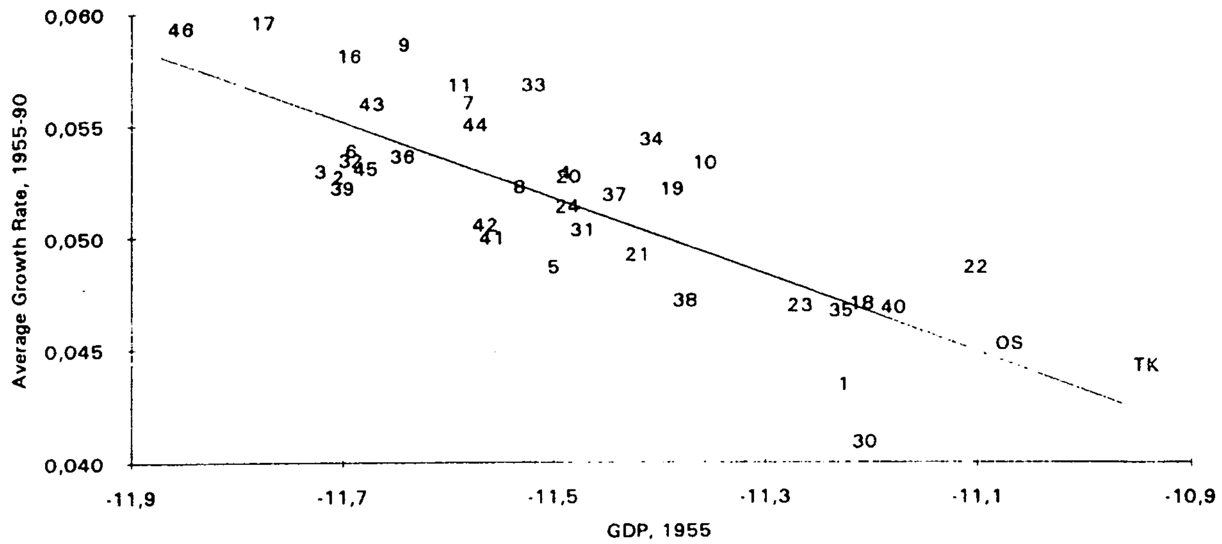


Figure 3 Sigma Convergence
Dispersion of Various Output Measures per Labor Force



Note: In the above figures, "dispersion" is defined as the standard deviation of the logs.

Figure 4 Beta Convergence
Log of GDP per Labor Force, deflated by the Regional CPI



Note1: The numbers for the prefectures correspond to those in Figure 1.
Note 2: "TK" is Greater Tokyo, and "OS" is Greater Osaka.
Note 3: The straight line is the regression line from OLS.

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