Regional Convergence under Declining Population: The Case of Japan

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Abstract

Using regional data in Japan, we examine how the population growth affected regional convergence in Japan where population decline became conspicuous in several regions. The basic equation in the analysis allows two distinct features which previous studies rarely explored. First we allow that the coefficient of initial per capita output may change when growth rate of population is lower than a threshold value. Second we allow that growth rate of population has a non-linear effect on growth rate of per capita output. Our estimation results confirm the convergence hypothesis in Japan. However, we find that the declined speed of convergence was more conspicuous in the regions that had negative population growth. We also find that decline in population growth, which was irrelevant for per capita income growth before 1995, came to have harmful impacts on per capita income growth after 1995. We discuss that this happened because in societies with declining population, economies of agglomeration had disappeared in poorer regions more seriously than in richer regions.

JEL code: O47, O11, O18, R11

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1. Introduction

In neoclassical economic growth theory, per capita incomes in poorer economies tend to grow at faster rates than those in richer economies. In particular, if economies are similar with respect to preferences and technology, all economies should eventually converge in terms of per capita income. In the literature, a number of studies confirmed the convergence hypothesis not only across countries but also across regions (see Barro and Sala-i-Martin [1991] and Chapter 11 in Barro and Sala-i-Martin [2004]). In particular, using similar approaches, not a few studies found significant regional convergence in Japan (see Barro and Sala-i-Martin [1992], Kawagoe [1999], Shioji [2001a], Tsutsumi et al. [2012], Seya et al. [2012], and Shibamoto et al. [2016]). However, their analyses were based on the sample period when Japan experienced positive population growth. Thus it is far from clear whether the results are still robust when the population growth rate turns negative. Japan experienced dramatic population growth for a half century after the World War II. Its total population, which was 72 million in 1945, increased to 127 million in 2000. However, the population started to decline in 2008 and is expected to be 106 million in 2045. The population decline is more conspicuous in rural areas than in urban areas. Therefore, it is important to see whether convergence still occurs in the regions where population started to show a sharp decline.

Using regional data in Japan, the following analysis tests whether regional convergence still exists when population growth took large negative value in several regions. The regional data in Japan is an ideal data because population growth is highly heterogeneous across the regions. As shown in Figure 1, Japan consists of 47 prefectures. These prefectures are usually classified into eight regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu. Among the eight regions, Kanto region where Tokyo is located is most populated. Its share of total population was 33.8% in 2015. Chubu and Kinki are also populated regions. The share of total population was 16.9% for Chubu and 17.7% for Kinki in 2015. In contrast, Hokkaido, Tohoku, Chugoku, and Shikoku are less populated regions. The share of total population was only 4.2% for Hokkaido, 7.1% for Tohoku, 5.9% for Chugoku, and 3.0% for Shikoku in 2015.

These regions are heterogeneous not only in the level of population but also in the growth rate of population. . Figure 2 depicts how population in each region changed from 1975 to 2015 and is expected to change from 2020 to 2030. To normalize population size, it set the value in 1975 to be 100. Since Kanto is highly populated, we divided it into North Kanto and South

Kanto in the figure. In rural areas (that is, Hokkaido, Tohoku, Shikoku, and Chugoku), population started to decline in the late 1980s and the declining speed is expected to be accelerated during the next decade. In contrast, in South Kanto where Tokyo Metropolitan Area is located, population is expected to grow until the early 2020s and remain high during the next decade. Even in the other urban areas (that is, North Kano, Chubu, and Kinki), population had grown until around 2010 and is expected to remain high until around 2020. The contrasting rates of population growth between rural and urban areas allow us to test how the different population growth affects the degree of regional convergence.

The basic equation we estimate in the following analysis is similar to an equation that has been widely estimated in previous studies such as Mankiw, Romer, and Weil (1992). However, it allows two distinct features which previous studies rarely explored. First we allow that the coefficient of initial per capita output may change when growth rate of population is lower than a threshold value. Second we allow that growth rate of population can have both positive and negative effects on the growth rate of per capita output. Our estimation results confirm the convergence hypothesis in Japan when we allow regional heterogeneity. However, we find that the speed of convergence declined more conspicuously in the regions that had negative population growth. We also find that the decline in population growth, which was less relevant for per capita income growth before 1995, came to have harmful impacts on per capita income growth after 1995. We discuss that this happened because in societies with declining population, economies of agglomeration had diminished in poorer regions more seriously than in richer regions.

2. Model

In neoclassical growth models, it is well known that that per capita growth rate is inversely related to the starting level of output or income per person. In particular, to the extent that economies are similar with respect to preferences and technology, there is a force that promotes convergence in levels of per capita product and income. However, the argument is based on the assumption that there are constant returns to scale in production. In discussing regional convergence, the assumption is restrictive because the economies may benefit from agglomeration which will save the costs from concentrating output in particular areas. To explore how economies of agglomeration affect the degree of regional convergence, this section examine how the result changes when there are increasing-returns to scale in production. Increasing returns to scale are the simplest form that captures economies of agglomeration.

In the analysis, we assume the following Cobb-Douglas production function:

(1) $Y = K^{\alpha}(AN)^{1-\alpha}\bar{Y}^{\beta}$

where Y is output, K is capital input, A is labor-augmenting technology, N is labor input (or population), and $\bar{Y}$ are average output in the economy.

The production function follows Romer (1986) in the sense that average output in the economy $\bar{Y}$ has positive externality to the output. We assume that $\alpha > 0$, $\beta \geq 0$, and $0 < \alpha+\beta < 1$. Since $Y = \bar{Y}$, the aggregate production function in the economy is written as

(2) $Y = K^{\alpha/(1-\beta)}(AN)^{(1-\alpha)/(1-\beta)}$.

When $\beta > 0$, there are increasing-returns to scale in the aggregate production function. However, because $0 < \alpha+\beta < 1$, the degree of increasing-returns to scale is not too large.

For analytical simplicity, we assume constant gross savings rate. Then, the fundamental equation of the Solow growth model is

(3) $dK/dt = sY - \delta K$,

where s is saving rate and δ is depreciation rate.

Define per capita output in period t by $\hat{y}_t \equiv Y_t/N_t$. Denote population growth rate by n and technological growth rate by g. Then, as derived in Appendix, we can approximately obtain the following equation:

(4) $ln\ \hat{y}_t - ln\ \hat{y}_0 = -\phi(n) \ln\ \hat{y}_0 + \varphi(n)\phi(n) + (z-1)(n+g)\,t$,

where $z \equiv (1-\alpha)/(1-\alpha-\beta) > 1$, $\phi(n) \equiv [1 - \exp[-\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t]]$, and $\varphi(n) \equiv \{\alpha/(1-\alpha-\beta)\}[ln\ s - ln\{z(n+g)+\delta\}]$.

Equation (4) is our key equation which the following estimations will be based on. When z = 1 (or β = 0), this equation degenerates into the standard equation that was widely estimated in previous studies. However, it holds that $z > 1$ (or $\beta > 0$) when there are increasing-returns to scale in the aggregate production function. Since $\phi(n) > 0$ when $\alpha+\beta < 1$, equation (4) still indicates that per capita growth rate is inversely related to the starting level of per capita output even if $z > 1$. However, when $z > 1$, our fundamental equation becomes different from the standard equation in two respects.

First z (or β) affects the speed of convergence, that is, $\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t$]. Specifically, the speed of convergence is increasing in β when $n+g > 0$ but is decreasing in β when $n+g < 0$. This implies that economies of agglomeration may increase regional convergence when population grows but may decrease regional convergence when population declines substantially.

Second a decline in population growth may reduce the growth rate of per capita output when $z > 1$ (or $\beta > 0$). The effect arises because the right-hand side of equation (4) includes the term $(z-1)(n+g)\ t$. In previous studies which assumed that z =1 and that $\phi(n)$ is constant, the growth rate of per capita output was decreasing in n because $\varphi(n)$ is decreasing in n. But when there are economies of agglomeration, it is likely that the effect of $(z-1)(n+g)\ t$ dominates the effect of $\varphi(n)\phi(n)$. In such an environment, a decline of population growth may reduce the growth rate of per capita output.

3. Empirical Framework

In the last section, we derived equation (4) that describes the determinants of growth rate of per capita output when there are increasing returns to scale. The following section tests the validity of this equation. The basic equation we estimate in the following analysis is

$$(5) \quad (ln\ \hat{y}_{i,t} - ln\ \hat{y}_{i,0})/t = constant + (a + b \cdot pdummy)\ ln\ \hat{y}_{i,0} + c \cdot n_i + \Sigma_j\, d_j \cdot Dummy_j,$$

where *pdummy* is a dummy variable which takes one when growth rate of population is lower than a threshold value and zero otherwise. n is population growth rate. $Dummy_j$ is a regional dummy for region j = Hokkaido & Tohoku, Kanto, Chubu, Kinki, and Chugoku & Shikoku.

Equation (5) is a simplified version of equation (4). It is also similar to an equation that has been widely estimated in previous studies such as Mankiw, Romer, and Weil (1992). The coefficient of logged initial per capita income $ln\ \hat{y}_0$, whose expected sign is negative, captures the speed of convergence. If we denote the speed of convergence by β, it holds that $a \cdot t$ = 1–exp(-βt). We can thus derive the estimated speed of convergence as $\hat{\beta} = -ln(1\text{-}\hat{a} \cdot t)/t$, where $\hat{a}$ is the estimated value of a.

However, our basic equation allows two distinct features which previous studies rarely explored. First we allow that the coefficient of initial per capita output depends on a dummy variable which takes one when growth rate of population is lower than a threshold value. We allow the coefficient dummy because the speed of convergence $\{(1\text{-}\alpha\text{-}\beta)/(1\text{-}\beta)\}\{z(n+g)+\delta\}t$ is increasing in n. Most previous studies neglected this feature because a change in $\exp[-\{(1\text{-}\alpha\text{-}\beta)/(1\text{-}\beta)\}\{z(n+g)+\delta\}t]$ is negligible under reasonable parameters when n is significantly positive. However, when n is negative, it may not be appropriate to assume that the speed of convergence is constant over time.[1] In the following analysis, we set the threshold value for *pdummy* to be zero.

Second we allow that the growth rate of population can have both positive and negative effects on the growth rate of per capita output. In traditional neoclassical growth models, the growth rate of per capita output increases as population growth decreases because per capita capital stock increases when population declines. However, when there are increasing returns to scale in production, the growth rate of per capita output may decline as population growth decreases because economies of agglomeration diminish. Thus the total effects of population decline depend on which effect is larger.

In the following analysis, we estimate equation (5) by regional data in Japan. We use two types of regional data in Japan. One is prefecture-level data. The other is municipality-level data in each region. The sample period is from 1976 to 2015. We split the sample before and after 1995. We split the sample because in most of the prefectures, population grew from 1976 to 1995 but declined from 1995 to 2015. Figure 3 depicts the rate of population growth in 47 prefectures from 1975 to 1995 and from 1995 to 2015. From 1975 to 1995, average of

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[1] For example, suppose that $\alpha = 0.3$, $\beta = 0$, $g = 0.02$, $\delta = 0.2$, and $t = 20$. Then if n increases by 0.1% points from 2%, $\exp[-\{1-(\alpha+\beta)\}\{z(n+g)+\delta\}t]$ changes from 0.0347 to 0.0343 which is negligible. However, if n decreases by 0.1% points from -5%, $\exp[-\{1-(\alpha+\beta)\}\{z(n+g)+\delta\}t]$ changes from 0.0926 to 0.0939 which may not be negligible.

population growth rates in 47 prefectures was 10.6% for the twenty years. The population growth rate exceeded 10% in 17 prefectures. It was only in two prefectures where the population growth rate was negative. Even in the two prefectures (that is, Akita and Nagasaki), the decline in population was very modest from 1975 to 1995. In contrast, from 1995 to 2015, average of population growth rates in 47 prefectures was -3.0% for the twenty years. It was only in three prefectures (that is, Tokyo, Kanagawa, and Okinawa) where the population growth rate exceeded 10%. The population growth rate was lower than -10% in eight prefectures. This implies that there was dramatic structural change in Japan's regional population growth around the mid-1990s.

4. Empirical Results I: Evidence from prefecture-level data

This section reports the estimation results based on the prefecture-level data. The data on income and population are from the Economic and Social Research Institute (ESRI), Cabinet Office, "Annual Report on Prefectural Accounts" (various issues). We use per capita prefectural-level income for $\hat{y}_t$. Since the data was nominal, it was deflated by prefectural-level output deflator. The sample size of 47 is not necessarily large to test the speed of convergence. But since most of the previous studies used the prefecture-level data to test the convergence in Japan, the results are comparable to most of the previous studies. Following previous studies, we include control variables to check robustness of our estimation results. The control variables are five regional dummies, aging ratio, and population density.

Tables 1 and 2 summarize the estimation results for 1976-1995 and 1996-2015 respectively. In both of the subsample periods, the coefficient of logged initial per capita income was negative. This confirms the convergence hypothesis across prefectures in Japan. In particular, when we include regional dummies, the estimated value of a ($\equiv \hat{a}$) was almost stable over time; from -0.017 to -0.030 in the first subsample period and from -0.013 to -0.016 in the second subsample period. Since the estimated value of $\beta \equiv \hat{\beta} = -ln(1\text{-}\hat{a} \cdot t)/t$, this implies that the estimated speed of convergence $\hat{\beta}$ was from 0.021 to 0.044 in the first subsample period and from 0.014 to 0.019 in the second subsample period. Although $\hat{\beta}$ in the first subsample period is larger than that in the first-subsample period, $\hat{\beta}$ in each subsample period is almost consistent with that in previous studies.[2]

More importantly, the coefficient dummy, *pdummy*, which was not significant in the first subsample period, became significantly positive in the second subsample period. This implies that while the speed of convergence was almost independent of population growth before 1995, it became slower in the prefectures that had negative population growth after 1995. In other words, the declined speed of regional convergence after 1995 was more conspicuous in the prefectures that had negative population growth.

The coefficient of n was not significant in the first subsample period when we include regional dummies. This was true with and without control variables. In contrast, the coefficient of n became significantly positive in the second subsample period either when we included no control variable or when we included the dependency ratio as a control variable. This implies that population growth, which was less relevant for per capita income growth before 1995, came to have positive impacts on per capita income growth after 1995. The result in the second subsample period is consistent with the view that because of economies of agglomeration, population decline became harmful for per capita economic growth.

5. Empirical Results II: Evidence from municipality-level data

In the last section, we reported the estimation results based on the prefecture-level data. This section reports the estimation results based on the municipality-level data. There are 1747 municipalities in Japan. We classify them into six regions (that is, Hokkaido & Tohoku, Kanto, Chubu, Kinki, Chugoku & Shikoku, and Kyushu) and estimate equation (5) by using municipality-level data in each region. The data on income and population are from Ministry of Internal Affairs and Communications. We use taxable income per tax payer for $\hat{y}_t$. Since the data was nominal, it was deflated by prefectural-level output deflator. The size of the population movement is more conspicuous across municipalities than across prefectures. We thus estimated the equation by using instrumental variables.

Tables 5 and 6 summarize the estimation results without control variables for 1986-2015 and 1996-2015 respectively. The coefficient of logged initial income per capita was always significantly negative and stable throughout the two subsample periods in all regions. In

[2] For example, Table 11.5 in Barro and Sala-i-Martin (2004) showed that $\hat{\beta}$ was 0.019 for 1970-75, 0.006 for 1975-80, 0.010 for 1980-85, and 0.019 for 1985-90.

particular, its absolute value tended to be larger than that in the prefecture-level data. This indicates that the speed of convergence tends to be faster across municipalities in the region than across prefectures in Japan.

A noteworthy result is that the coefficient dummy, *pdummy,* was never significantly positive in the first subsample period but significantly positive in Hokkaido & Tohoku, Chubu, Chugoku & Shikoku, and Kyushu regions in the second subsample period. This implies that there was a substantial structural change in the speed of convergence across the municipals. The coefficient dummy, *pdummy,* was always negative and significantly negative in Hokkaido & Tohoku and Chubu in the first subsample period. This indicates that the speed of convergence in the first subsample period was faster in the municipals that had negative population growth. In contrast, the coefficient dummy, *pdummy,* became significantly positive except in Kanto and Kinki regions in the second subsample period. This suggests that except in metropolitan regions, the speed of convergence became slower in the municipals that had negative population growth in the second subsample period.

A contrasting feature between the first and second subsample periods is also observed for the coefficient of n. The coefficient of n was not only insignificant in all regions but also negative except in Kanto region in the first subsample period. This implies that population decline had no negative impact on per capita income growth in the first subsample period. In contrast, the coefficient of n was significantly positive in all regions in the second subsample period. This implies that population decline had negative impacts on per capita income growth in the second subsample period because there were economies of agglomeration in municipal levels.

6. Concluding Remarks

Japan's population is both declining and rapidly aging, and the situation will only grow more serious in the future. However, it is important to note that depopulation and the aging of society is not occurring at the same speed and manner everywhere across the country. In particular, the population decrease and the depth of aging is more serious in the countryside than in urban areas. Using regional data in Japan, this paper examined how the population decline affected regional convergence in Japan where population growth took large negative value in several regions.

The basic equation in the analysis allowed two distinct features which previous studies rarely explored. First we allowed that the coefficient of initial per capita output may change when the growth rate of population is lower than a threshold value. Second we allowed that the growth rate of population could have both positive and negative effects on the growth rate of per capita output. Our estimation results confirmed the convergence hypothesis in Japan. However, we found that the speed of convergence declined conspicuously in the regions that had negative population growth. We also found that decline in population growth, which was irrelevant for per capita income growth before 1995, came to have harmful impacts on per capita income growth after 1995. We discussed that this happened because in societies with declining population, economies of agglomeration had disappeared in poorer regions more seriously than in richer regions.

One of the reasons for why Japan had such a large demographic disparity is population flight from rural regions to urban areas stemming from the general preference of young people to live in big cities, particularly in the Tokyo metropolitan area. Although the size of the population movement has fluctuated over the years, the greater Tokyo area has consistently attracted the younger generations by providing opportunities for higher education and better-paying jobs. The metropolitan areas around Osaka and Nagoya have also been major destinations for people moving out of rural areas, but their power to attract the population inflow has weakened in recent decades. In the current version, we could not take into account regional migration in Japan explicitly. But incorporating regional migration in our analysis is an important research agenda in our revised version.

Appendix. Derivation of Equation (4) in Section 4

The purpose of this mathematical Appendix is to derive our fundamental equation (4) in section 2. Define $y \equiv Y/(AN)^z$ and $k \equiv K/(AN)^z$, where $z \equiv (1-\alpha)/\{1-(\alpha+\beta)\} > 1$. Then equation (2) leads to

(A1) $y = k^{\alpha/(1-\beta)}$.

It is worthwhile to note that y and k are different from output and capital per unit of effective labor unless $\beta = 0$.

Using y and k, we can rewrite the fundamental equation of the Solow growth model as

(A2) $dk/dt = s\, k^{\alpha/(1-\beta)} - \{z(n+g)+\delta\}\, k,$

where n is population growth rate and g is technological growth rate.

Define $v \equiv k^{(1-\alpha-\beta)/(1-\beta)}$. Then we can transform equation (A2) to

(A3) $\frac{1-\beta}{1-\alpha-\beta}\; dv/dt + \{z(n+g)+\delta\}\; v = s.$

The solution of this first-order linear differential equation in v is

(A4) $v_t = v^* + (v_0 - v^*) \exp[-\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t].$

where $v^* \equiv \frac{s}{z(n+g)+\delta}$ is the steady sate of v.

Since $ln\, y_t - ln\, y_0 = \frac{\alpha}{1-\alpha-\beta}(ln\, v_t - ln\, v_0)$, equation (A4) leads to

(A5) $ln\, y_t - ln\, y_0 = \frac{\alpha}{1-\alpha-\beta}(ln\, v^* - ln\, v_0)\, [1 - \exp[-\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t]],$

$= (ln\, y^* - ln\, y_0)[1 - \exp[-\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t]],$

where y^* is the steady state of y. Since $v^* = y^{*\frac{1-\alpha-\beta}{\alpha}}$, it holds

(A6) $ln\, y^* = \frac{\alpha}{1-\alpha-\beta}\; [\, ln\, s - ln\{z(n+g)+\delta\}]$

Define per capita output by $\hat{y} \equiv Y/N$. Then, since $ln\; \hat{y}_t - ln\; \hat{y}_0 \approx ln\, y_t - ln\, y_0 + (z-1)(n+g)t$, we obtain

(A7) $ln\; \hat{y}_t - ln\; \hat{y}_0 = (ln\, y^* - ln\, y_0)[1 - \exp[-\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t]] + (z-1)(n+g)t,$

$$= -\phi(n)\ln\ \hat{y}_0 + \varphi(n)\phi(n) + (z-1)(n+g)t + (z-1)\phi(n)\ln(N_0+A_0),$$

where $\phi(n) \equiv [1 - \exp[-\{(1-\alpha-\beta)/(1-\beta)\}\{z(n+g)+\delta\}t]]$ and $\varphi(n) \equiv \frac{\alpha}{1-\alpha-\beta}\ [\ln s - \ln\{z(n+g)+\delta\}]$.

However, as Basu (1996) or Basu and Fernald (1997) showed, the degree of increasing-returns to scale is, if any, small. Since $0 < \phi(n) < 1$, this implies that $(z-1)\phi(n)$ is second-order in magnitude and that the contribution of $(z-1)\phi(n)\ln(N_0+A_0)$ is negligible in (A7). Therefore (A7) is approximately written as our fundamental equation (4) in section 2.

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Figure 1. Map of Japan: 47 Prefectures and 8 Regions

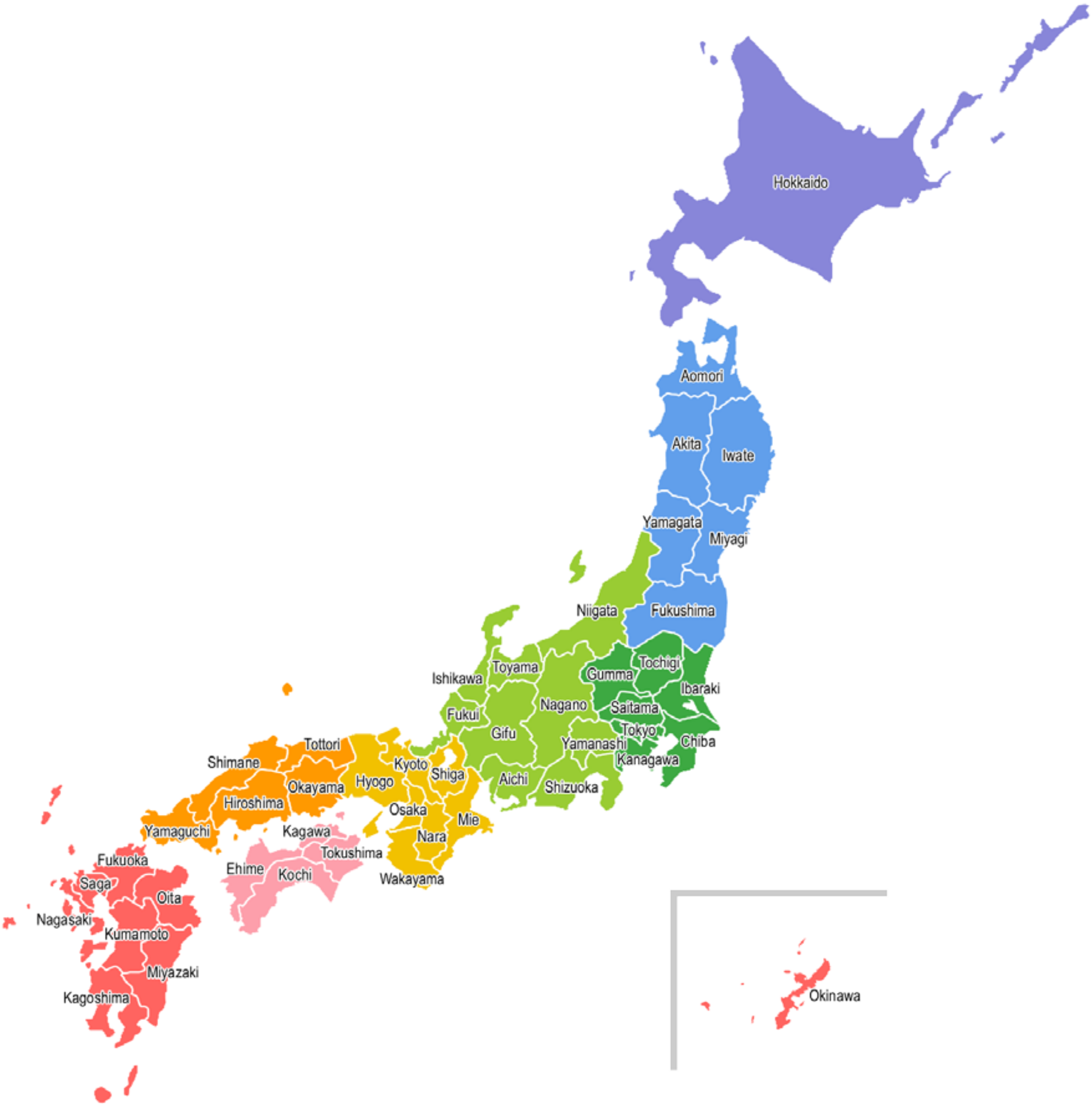

Figure 2.

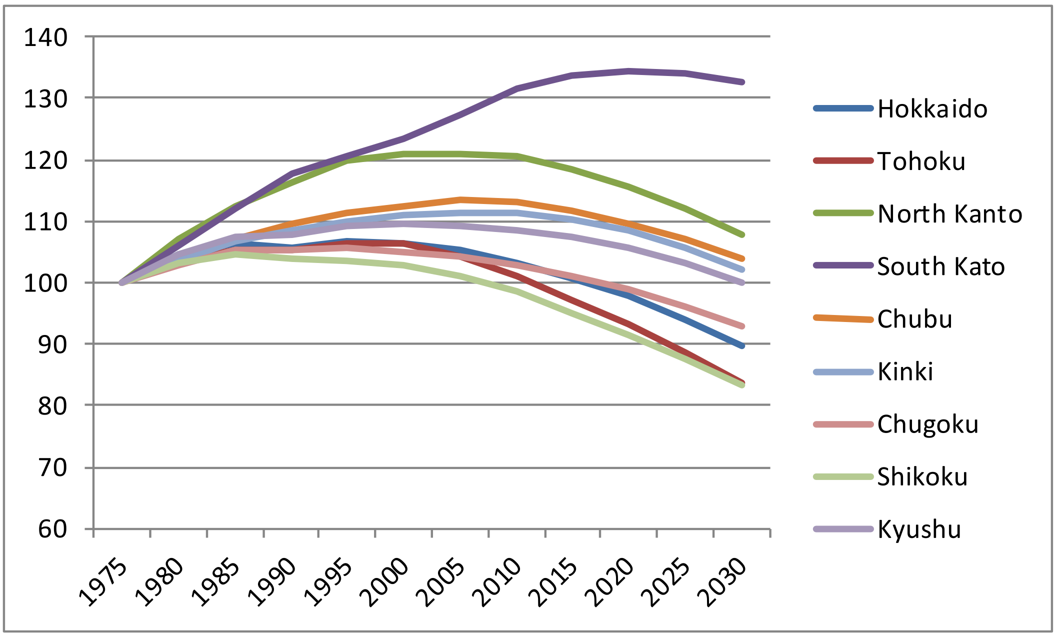

Figure 3.

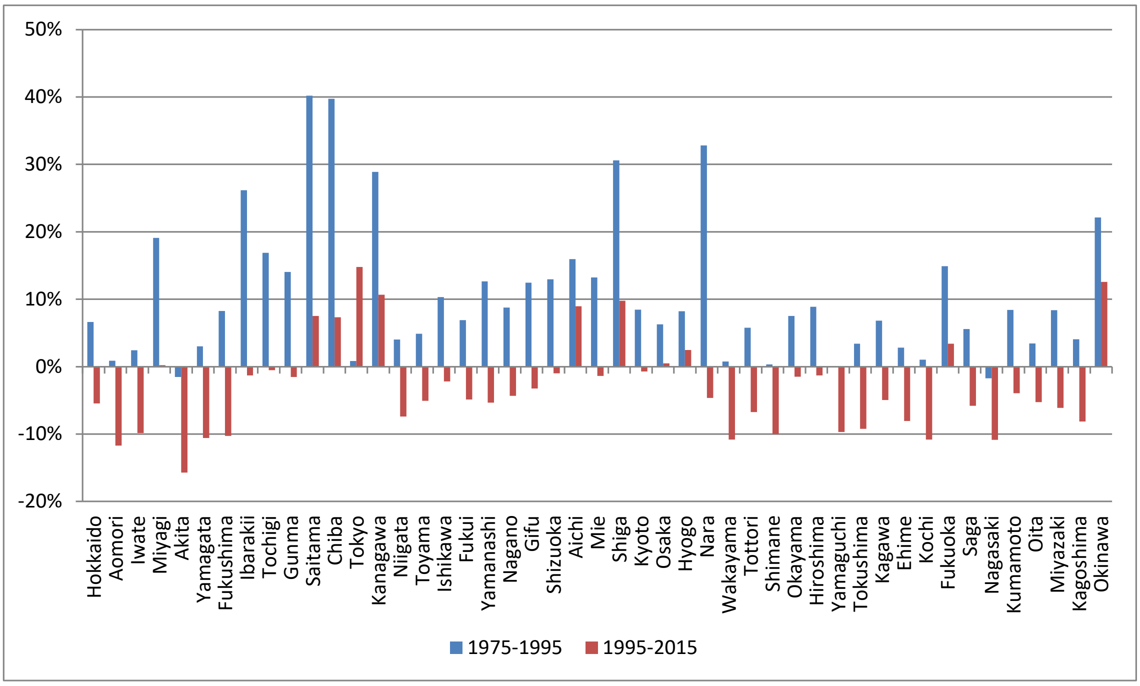

Table 1: Prefecture-level data from 1976 to 1995

	(1)	(2)	(3)	(4)	(5)
$ln\hat{y}_0$	-0.005	-0.017^{**}	-0.019^{**}	-0.030^{***}	-0.030^{***}
	(0.006)	(0.007)	(0.009)	(0.010)	(0.010)
$pdummy * ln\hat{y}_0$	0.001	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
n	0.429^{***}	0.213	0.156	0.265	0.315
	(0.158)	(0.183)	(0.228)	(0.181)	(0.240)
Ratio of Old to Young			-0.042		0.034
			(0.099)		(0.105)
Population Density				0.018^{*}	0.019^{*}
				(0.010)	(0.011)
Hokkaido&Tohoku		0.002	0.002	0.004	0.004
		(0.002)	(0.002)	(0.002)	(0.003)
Kanto		0.008^{**}	0.008^{**}	0.008^{***}	0.008^{***}
		(0.003)	(0.003)	(0.003)	(0.003)
Chubu		0.007^{***}	0.007^{***}	0.009^{***}	0.009^{***}
		(0.002)	(0.002)	(0.002)	(0.002)
Kinki		0.004	0.004	0.005^{*}	0.005^{*}
		(0.003)	(0.003)	(0.003)	(0.003)
Chugoku&Shikoku		0.003	0.004	0.005^{**}	0.005^{*}
		(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.039^{**}	0.069^{***}	0.078^{***}	0.104^{***}	0.100^{***}
	(0.016)	(0.019)	(0.029)	(0.027)	(0.031)
Observations	47	47	47	47	47

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 2: Prefecture-level data from 1996 to 2015

	(1)	(2)	(3)	(4)	(5)
$ln\hat{y}_0$	-0.012^{***}	-0.013^{**}	-0.012^{**}	-0.016^{**}	-0.014^{**}
	(0.004)	(0.005)	(0.005)	(0.008)	(0.007)
$pdummy * ln\hat{y}_0$	0.002^{***}	0.001^{*}	0.001^{*}	0.002^{*}	0.001^{*}
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
n	0.606^{**}	0.440	1.178^{***}	0.475	1.214^{***}
	(0.284)	(0.315)	(0.343)	(0.327)	(0.353)
Ratio of Old to Young			0.199^{***}		0.199^{***}
			(0.056)		(0.056)
Population Density				0.005	0.005
				(0.010)	(0.009)
Hokkaido&Tohoku		0.002	0.004^{*}	0.002	0.004^{*}
		(0.002)	(0.002)	(0.002)	(0.002)
Kanto		0.003	0.005^{*}	0.003	0.005^{*}
		(0.003)	(0.002)	(0.003)	(0.002)
Chubu		0.002	0.002	0.003	0.003
		(0.002)	(0.002)	(0.003)	(0.002)
Kinki		−0.002	0.000	−0.002	0.000
		(0.002)	(0.002)	(0.003)	(0.002)
Chugoku&Shikoku		−0.000	−0.002	−0.000	−0.001
		(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.039^{***}	0.044^{**}	0.020	0.051^{**}	0.027
	(0.014)	(0.017)	(0.016)	(0.022)	(0.021)
Observations	47	47	47	47	47

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 3: Prefecture-level data from 1976 to 1995, Using past population growth and birth rates as instrument

	(1)	(2)	(3)	(4)	(5)
$ln\hat{y}_0$	-0.014^{**}	-0.021^{***}	-0.033^{***}	-0.030^{***}	-0.038^{***}
	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)
$pdummy * ln\hat{y}_0$	-0.001	0.000	-0.002	-0.000	-0.002
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
n	0.384^{**}	0.041	-0.093	0.204	0.079
	(0.165)	(0.198)	(0.233)	(0.175)	(0.238)
Ratio of Old to Young			-0.196^{**}		-0.124
			(0.097)		(0.099)
Population Density				0.017^{***}	0.016^{**}
				(0.005)	(0.007)
Hokkaido&Tohoku		0.002	0.002	0.003^{**}	0.003
		(0.002)	(0.002)	(0.001)	(0.002)
Kanto		0.009^{***}	0.008^{***}	0.009^{***}	0.008^{***}
		(0.002)	(0.002)	(0.002)	(0.002)
Chubu		0.006^{***}	0.007^{***}	0.008^{***}	0.008^{***}
		(0.001)	(0.001)	(0.001)	(0.002)
Kinki		0.005	0.003	0.004	0.003
		(0.003)	(0.003)	(0.003)	(0.003)
Chugoku&Shikoku		0.002	0.005^{**}	0.003^{**}	0.005^{**}
		(0.002)	(0.002)	(0.001)	(0.002)
Constant	0.064^{***}	0.081^{***}	0.126^{***}	0.105^{***}	0.134^{***}
	(0.018)	(0.017)	(0.022)	(0.018)	(0.022)
Observations	46	46	46	46	46

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 4: Prefecture-level data from 1996 to 2015, Using past population growth and birth rates as instrument

	(1)	(2)	(3)	(4)	(5)
$ln\hat{y}_0$	-0.019^{***}	-0.008	-0.010^{**}	-0.031^{*}	-0.021^{**}
	(0.007)	(0.008)	(0.005)	(0.018)	(0.009)
$pdummy * ln\hat{y}_0$	0.003^{***}	0.004^{***}	0.002^{*}	0.009^{**}	0.004^{*}
	(0.001)	(0.001)	(0.001)	(0.005)	(0.002)
n	1.277^{***}	0.939^{*}	1.298^{***}	2.229	1.801^{***}
	(0.312)	(0.537)	(0.306)	(1.477)	(0.584)
Ratio of Old to Young			0.180^{***}		0.163^{**}
			(0.053)		(0.068)
Population Density				0.050	0.020
				(0.031)	(0.015)
Hokkaido&Tohoku		0.002	0.004^{***}	0.004	0.004^{**}
		(0.002)	(0.001)	(0.004)	(0.002)
Kanto		0.000	0.004^{**}	0.001	0.004
		(0.002)	(0.002)	(0.005)	(0.003)
Chubu		-0.001	0.001	0.000	0.002
		(0.003)	(0.002)	(0.004)	(0.003)
Kinki		-0.002	0.000	0.001	0.002
		(0.002)	(0.002)	(0.006)	(0.003)
Chugoku&Shikoku		-0.003	-0.003^{**}	-0.002	-0.002
		(0.002)	(0.001)	(0.003)	(0.002)
Constant	0.061^{***}	0.022	0.016	0.080	0.044^{*}
	(0.023)	(0.025)	(0.014)	(0.049)	(0.025)
Observations	46	46	46	46	46

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 5: Municipality-level data from 1986 to 2005, Using past population growth and birth rate as instrument

	(1) Hokkaido&Tohoku	(2) Kanto	(3) Chubu	(4) Kinki	(5) Chugoku&Shikoku	(6) Kyushu
$ln\hat{y}_0$	-0.0335***	-0.0217***	-0.0122***	-0.0265***	-0.0278***	-0.0150***
	(0.0038)	(0.0044)	(0.0027)	(0.0037)	(0.0030)	(0.0019)
$pdummy * ln\hat{y}_0$	-0.0047**	-0.0022	-0.0015**	-0.0022	-0.0006	-0.0009
	(0.0023)	(0.0014)	(0.0007)	(0.0023)	(0.0008)	(0.0014)
n	-0.2671	0.0103	-0.1154	-0.0460	-0.0552	-0.0825
	(0.2299)	(0.1058)	(0.0789)	(0.1672)	(0.1205)	(0.2026)
Ratio of Old to Young	0.0452**	0.0323*	0.0084	0.0157	-0.0014	-0.0080
	(0.0214)	(0.0178)	(0.0079)	(0.0283)	(0.0052)	(0.0068)
Population Density	-0.4444	0.5957***	0.4020	0.2406	0.8146*	-0.1010
	(1.2715)	(0.1065)	(0.2694)	(0.3079)	(0.4198)	(0.3590)
Constant	0.1190***	0.0797***	0.0548***	0.0994***	0.1022***	0.0626***
	(0.0146)	(0.0161)	(0.0087)	(0.0133)	(0.0099)	(0.0062)
Observations	222	283	269	159	150	181

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 6: Municipality-level data from 1996 to 2015, Using past population growth and birth rate as instrument

	(1) Hokkaido&Tohoku	(2) Kanto	(3) Chubu	(4) Kinki	(5) Chugoku&Shikoku	(6) Kyushu
$ln\hat{y}_0$	-0.0462***	-0.0252***	-0.0390***	-0.0270***	-0.0265***	-0.0286***
	(0.0031)	(0.0050)	(0.0069)	(0.0038)	(0.0049)	(0.0041)
$pdummy * ln\hat{y}_0$	0.0019**	0.0008	0.0043*	-0.0001	0.0032***	0.0026**
	(0.0010)	(0.0017)	(0.0024)	(0.0022)	(0.0012)	(0.0011)
n	0.3151**	0.7074***	0.6299***	0.4415***	0.6488***	0.4070**
	(0.1267)	(0.2477)	(0.2358)	(0.1683)	(0.1870)	(0.1853)
Ratio of Old to Young	-0.0376***	0.0286**	-0.0454**	0.0090	-0.0173**	-0.0209**
	(0.0083)	(0.0128)	(0.0214)	(0.0329)	(0.0078)	(0.0084)
Population Density	1.1482	0.6171***	-0.1666	0.4343**	1.3021***	-0.0961
	(0.8632)	(0.1135)	(0.4911)	(0.1902)	(0.4412)	(0.3705)
Constant	0.1575***	0.0767***	0.1394***	0.0873***	0.0894***	0.0960***
	(0.0112)	(0.0182)	(0.0260)	(0.0149)	(0.0167)	(0.0140)
Observations	197	278	259	156	143	172

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$