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Aging, Interregional Income Inequality, and Industrial Structure:
An empirical analysis based on the R-JIP Database and the R-LTES Database

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Aging, Interregional Income Inequality, and Industrial Structure: An empirical analysis based on the R-JIP Database and the R-LTES Database*

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Abstract

By merging two newly created databases for the analysis of prefecture-level productivity—the R-JIP Database 2013 and the R-LTES Database 2013—with other regional statistics, we examine how and why "aged prefectures" differ from other prefectures. Our main findings can be summarized as follows:

1. The high aged population ratio of some prefectures such as Akita and Shimane is due to a large out-migration experienced during Japan's high-speed growth era from 1955 to 1970.

2. Aged prefectures tend to have lower labor productivity. At the same time, we find that population aging does not systematically reduce local total factor productivity (TFP) levels. We therefore argue that, rather than population aging reducing TFP levels, the causality runs in the opposite direction. Most prefectures with a high aged population ratio today had a low TFP level 30–40 years ago; as low TFP levels mean lower wage rates, such prefectures experienced an out-migration of the young. Given that TFP differences across prefectures are stable over time (prefectures with a low relative TFP level maintain this condition), we observe a negative correlation between current TFP levels and current aged population ratios. This implies that there is no need for concern about Japan's average labor productivity declining in the future as a result of population aging.

3. Aged prefectures tend to have large net imports of goods and services. Their large net imports are mainly the result of large negative government savings. Active government capital formation in aged prefectures also contributes to some extent to their net imports. Since large transfers in the form of receipts of public pensions and medical care from less aged prefectures to more aged ones are not sustainable, it seems that residents in prefectures that are less aged now should expect a post-retirement life that will be much less prosperous than what residents in Akita and Shimane enjoy today.

Keywords: Aged population ratio, Migration, Regional inequality, Total Factor Productivity, Income transfer, R-JIP Database, R-LTES Database

JEL classification: D24, J11, N35, N95, R11, R23

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1. Introduction

Japan's population is aging rapidly. The share of those aged 65 and over in the total population in 2011 stood at 23.3%, the highest in the world, and the speed of population aging in Japan is much faster than in the advanced European countries and the United States (Statistical Research and Training Institute 2012). However, population aging in Japan is proceeding at an uneven pace across regions. In some prefectures, such as Akita and Shimane, population aging as measured by the ratio of those aged 65 and over is about 15 years ahead of Japan as a whole and 25 years ahead of the Tokyo Metropolitan Area. The economic situation in these prefectures likely is a precursor of things to come in Japan as a whole. To formulate appropriate land and macroeconomic policies, which have been put in place to deal with aging in Japan as a whole, it is important to understand the aging process in prefectures that are particularly advanced along this course.

In this paper, we examine how and why "aged prefectures" differ from other prefectures by merging two newly created databases for the analysis of prefecture-level productivity, the Regional-Level Japan Industrial Productivity Database 2013 (R-JIP 2013) and the Regional-Level Long Term Economic Statistics Database 2013 (R-LTES 2013),[1] with other regional statistics, such as the *Population Projections by Region (March 2012): 2011 to 2060* by the National Institute of Population and Social Security (IPSS), various issues of the *Population Census* by the Ministry of Internal Affairs and Communications (MIC), and various issues of the *Annual Report of Prefectural Accounts* by the Cabinet Office.[2]

The structure of the paper is as follows. In the next section, we examine intertemporal changes in the regional concentration of the aged population and the relationship between aging and regional economic performance indicators such as per capita income, labor productivity, and net exports of goods and services. We try to extract some stylized facts on these issues from long-term prefectural data. We will show that per capita income and labor productivity in aged prefectures are substantially lower than in other prefectures. We will also show that aged prefectures are net importers of goods and services. In Section 3, we then examine why in some prefectures, the population share of the old is so high and how the regional concentration of the aged population

[1] The R-JIP is compiled by the Research Institute of Economy, Trade and Industry and Hitotsubashi University. The R-JIP 2012 contains sectoral and macro-level data for each prefecture for the analysis of total factor productivity (TFP) for the period 1970–2008. The R-JIP 2012 (in Japanese) is available at <http://www.rieti.go.jp/jp/database/R-JIP2012/index.html>. The R-JIP 2013 contains macro-level data for each prefecture for TFP analysis for the period of 1955-2009 and each prefecture's sectoral-level data for TFP analysis for the period 1970–2009. For detail on the R-JIP Database, see Tokui et al. (2013). The R-LTES is compiled by Hitotsubashi University. The R-LTES 2013 contains sectoral data for each prefecture for the analysis of industrial structures and labor productivity for the period 1874–2009. For details on the part of the R-LTES Database for the prewar period, see Bassino et al. (2010).

[2] Data reported in the *Annual Report of Prefectural Accounts* by the Cabinet Office (in Japanese) are available at <http://www.esri.cao.go.jp/jp/sna/data/data_list/kenmin/files/files_kenmin.html.>

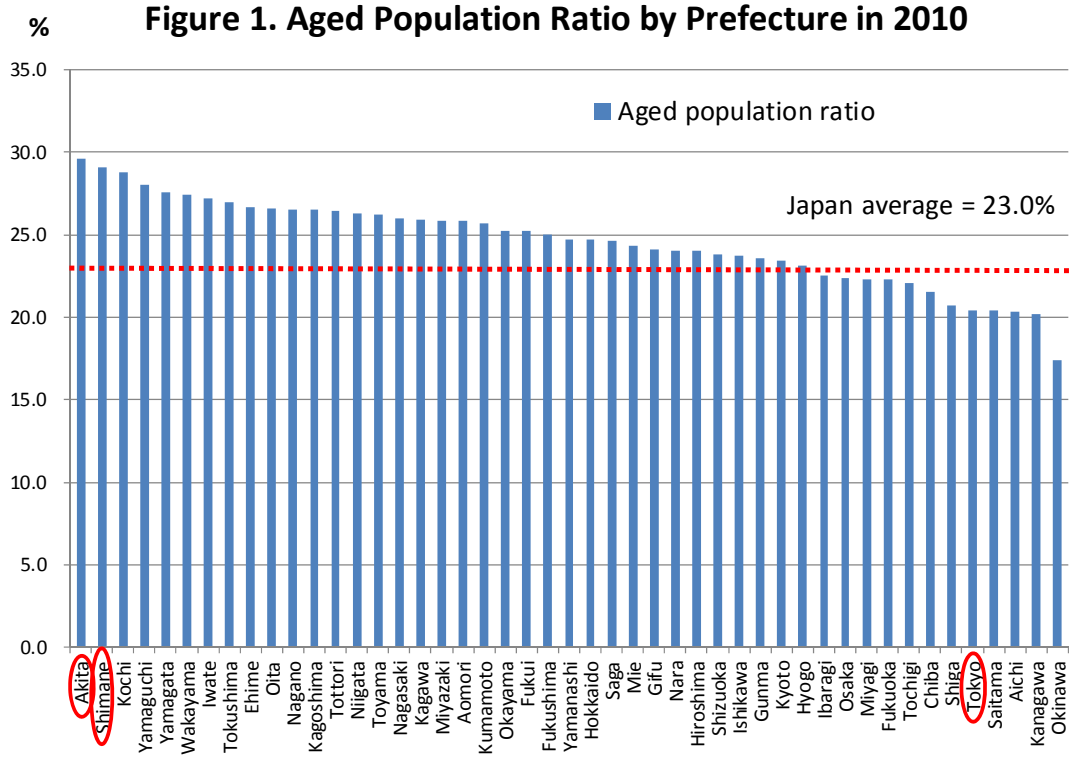
changed over time in Japan. Next, in Section 4, we examine why per capita income and labor productivity in aged prefectures are lower than in other prefectures. Further, in Section 5, we examine why aged prefectures are net importers of goods and services and whether the industrial structures of aged prefectures differ from those of other prefectures. Section 6 concludes the paper.

2. How Are Aged Prefectures Different from Other Prefectures?

In this section, we examine intertemporal changes in the regional concentration of the aged population. We also examine the relationship between aging and regional economic performance indicators such as per capita income, labor productivity, and net exports of goods and services.

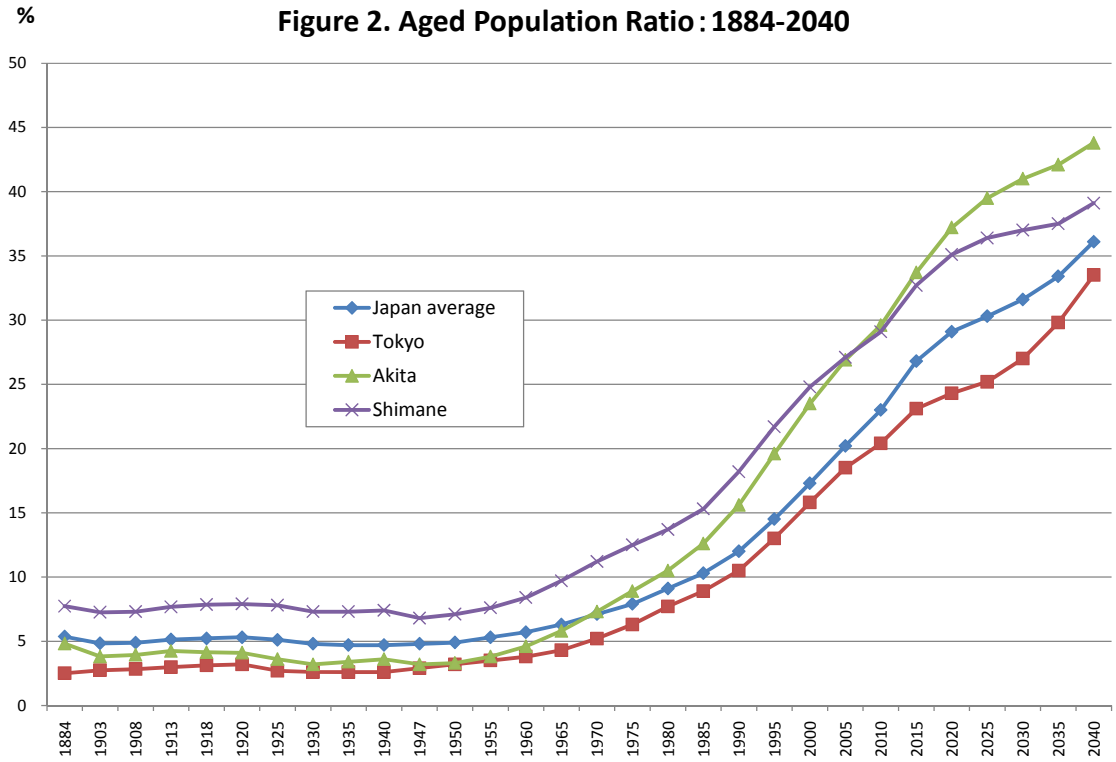
Figure 1 compares ratio of the aged population (those aged 65 and over) in 2010 across prefectures. Akita has the highest aged population ratio at 29.6%, which is 7 percentage points higher than the national average and 9 percentage points higher than that of Tokyo. The prefecture with the lowest aged population ratio is Okinawa, probably because of its high birth rate. Except for Okinawa, all the 12 prefectures that have a lower aged population share than the national average are either metropolitan areas, such as Tokyo, Osaka, Kanagawa, Aichi, Fukuoka, and Miyagi, suburbs of metropolises, such as Saitama, Chiba, and Shiga, or industrial districts around Tokyo, such as Ibaragi and Tochigi.

Figure 1. Aged Population Ratio by Prefecture in 2010



Source: *Population Census 2010*, Statistics Bureau, MIC.

Figure 2 shows how the aged population ratios of Akita, Shimane, Tokyo, and for Japan as a whole have changed over time and how they are expected to change in future. The population projections were conducted by IPSS. As already mentioned, Akita and Shimane are about 15 years ahead of Japan as a whole and about 25 years ahead of the Tokyo Metropolitan Area in terms of their aged population ratios.



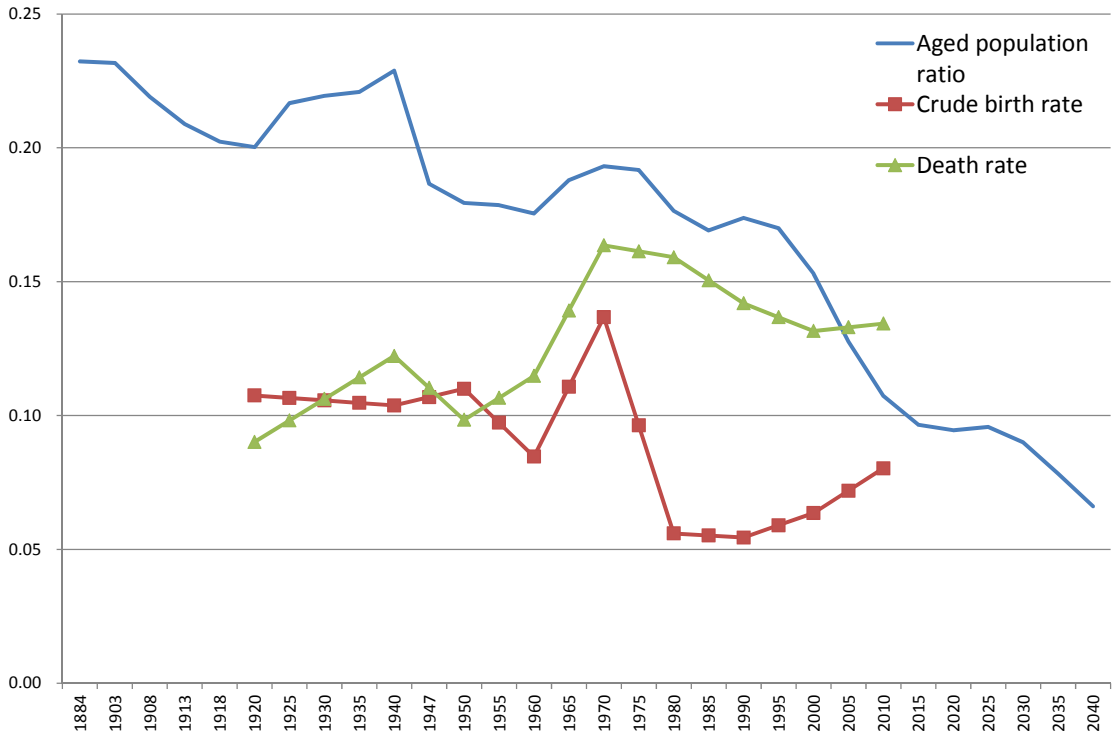
Sources: Data from 1884 to 1918 were estimated on the basis of the permanent domicile population. Data from 1920 to 2010 are based on the Population Census (various years), Statistics Bureau, MIC. Data from 2015 are projections by the National Institute of Population and Social Security.

Figure 2 also shows that from a historical perspective, Akita and Shimane are quite different from Japan as a whole. Shimane's aged population ratio has been more than double that of Tokyo and more than 40 percent above the national average throughout the entire period from 1884 to 2010. On the other hand, Akita's high aged population ratio is a more recent phenomenon. Until 1965, the ratio for Akita was below the national average, but it subsequently rapidly pulled ahead of the national average. In the next section, we will examine why the population ratio is so high in some prefectures such as Akita and Shimane.

Another interesting point which Figure 2 shows is that the difference in the aged population ratios across prefectures is projected to decline in the future. In fact, when we measure the difference

in the aged population ratios across prefectures using the coefficient of variation, we find that this difference show a long-term downward trend (Figure 3). Why has the difference in the aged population ratio across prefectures been on a declining trend and is projected to decline further in the future? This is an issue we will also examine in Section 3.

Figure 3. Coefficient of Variation over Time



Sources: See Figure 2.

Next, let us examine the relationship between aging and regional economic performance, such as per capita income, labor productivity, and net exports of goods and services.

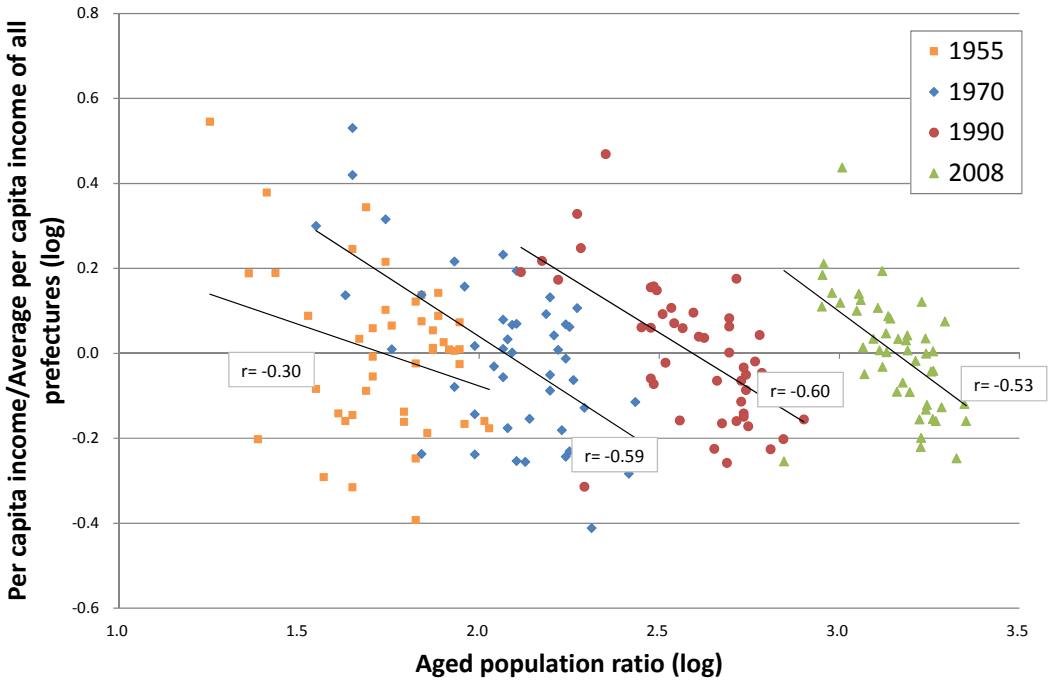
Figure 4 shows the correlation between the aged population ratio (in logarithm) and per capita income (logarithm of per capita income/average per capita income of all prefectures) for 1955, 1970, 1990, and 2008. In this figure, *r* denotes the correlation coefficient. The correlation is negative and statistically significant (at the 5% level) for all four benchmark years. Per capita income can be decomposed in the following two ways:

$$\text{Per capita income} = (\text{GDP per worker}) \times (\text{number of workers}) / (\text{total population}) + (\text{net receipts of factor income from other prefectures and abroad}) / (\text{total population})$$

$$= (\text{GDP per hour}) \times (\text{man-hour input}) / (\text{total population}) +$$

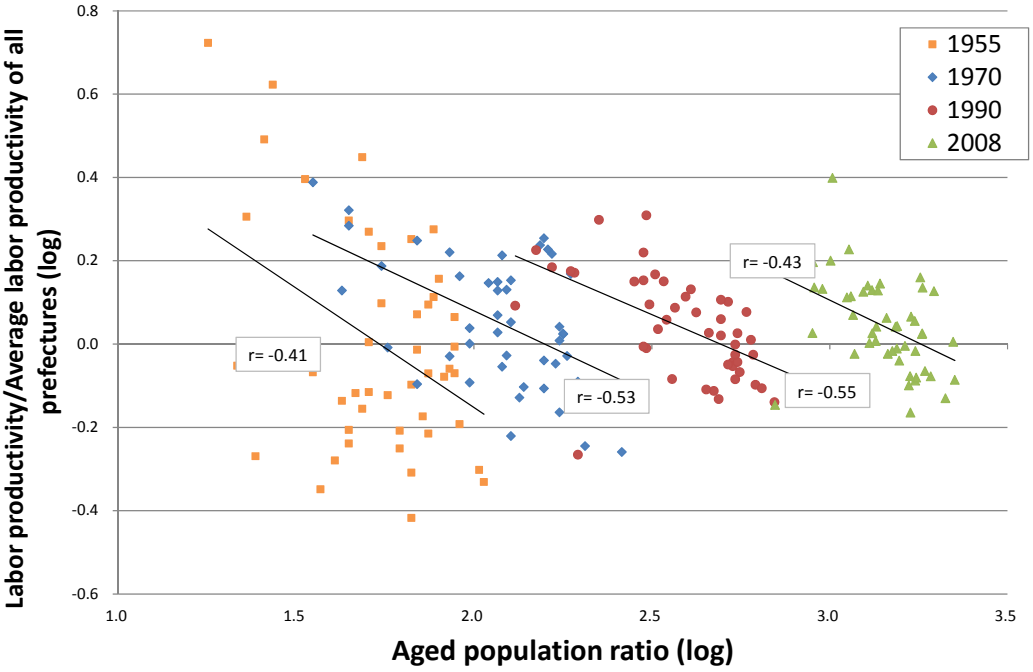
(net receipts of factor income from other prefectures and abroad) / (total population)

Figure 4. Aging and Per Capita Income



Sources: R-JIP Database 2013 and *Population Census*, Statistics Bureau, MIC.

Figure 5. Aging and Labor Productivity



Sources: See Figure 4.

Notes: Labor productivity in 1955 is measured in terms of nominal value added per worker. Labor productivity in 1970, 1990 and 2008 is measured in terms of nominal value added per hour.

The negative correlations observed in Figure 4 are likely partly due to the fact that aged prefectures tend to have lower workers/total population and man-hour input/total population ratios. But it is important to note that, as Figure 5 shows, the correlation between the aged population ratio and labor productivity is also negative in all the benchmark years.[3,4]

If population aging causes labor productivity decline, this has grave implications for aging societies. It is well known that population aging goes hand in hand with a lower percentage of workers in the total population and a reduction in per capita income. But the impact of population aging on labor productivity has not been well analyzed yet. In Section 4, we examine this issue in more detail.

According to the life-cycle model of household consumption over time, an increase of the aged population will reduce private savings. An increase of the aged population will also reduce government tax income by reducing per capita income. On the other hand, an increase of the aged population will have a negative impact on private fixed capital formation because of the slow or negative growth of the workforce.[5] If the negative impact of aging on prefectural saving is larger than the negative impact of aging on prefectural investment, aging prefectures will have a negative saving-investment balance and become net importers of goods and services.[6]

Figure 6 shows the cross-prefectural relationship between aging and the percentage of net exports of goods and services in total gross prefectural expenditure for benchmark years. The correlation is positive and statistically significant (at the 5% level) for all the benchmark years except 1955. The figure also shows that some aged prefectures have a very high net import ratio. In Section 5, we examine what factors are responsible for the large net imports of goods and service, a low private (or government) saving rate or a high private (or government) investment.

Prefectures with a negative saving-investment balance can meet supply shortage by importing goods and services. However, they cannot meet through imports any supply shortage of non-tradable

[3] As explained in the notes for Figure 5, labor productivity in 1955 is measured in terms of nominal value added per worker, while labor productivity in 1970, 1990, and 2008 is measured in terms of nominal value added per hour.

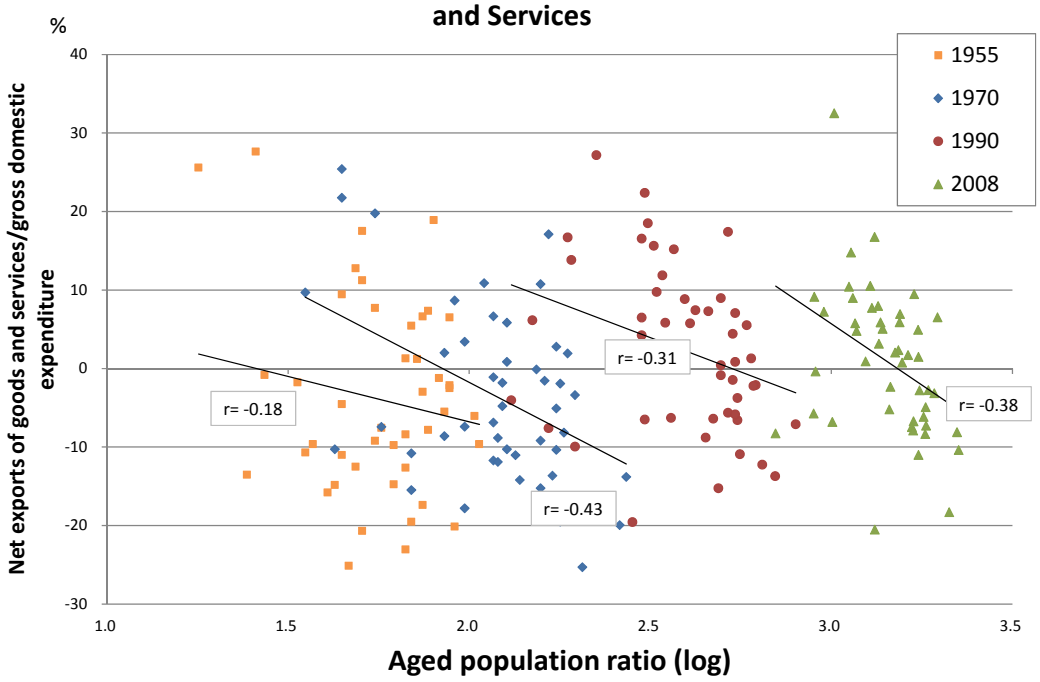
[4] If many workers of one prefecture commute to other prefectures and if we measure labor input on a resident basis, we will underestimate this prefecture's labor productivity. Therefore, we use labor input data on a workplace basis. A detailed discussion of this issue is available in Tokui et al. (2013).

[5] If interregional capital flows are limited, a decline in saving in a prefecture might reduce that prefecture's investment. However, since there are no barriers to interregional capital flows within Japan and such capital flows are likely very active, we think that the effect of population aging on prefectural saving is unlikely to have a large impact on prefectural investment.

[6] These issues have been discussed mainly at the national level. See Onitsuka (1974) and Auerbach and Kotlikoff (1990).

goods and services. As open economy macroeconomics tells us, countries or regions with negative a saving-investment balance (net importers of goods and services) therefore need to allocate more resources to the production of non-tradable goods and services. We would therefore expect a decline of tradable sectors, such as manufacturing and the primary sector, in aging prefectures. We will also examine this issue in greater detail in Section 5.

Figure 6. Relationship Between Aging and Net Exports of Goods and Services



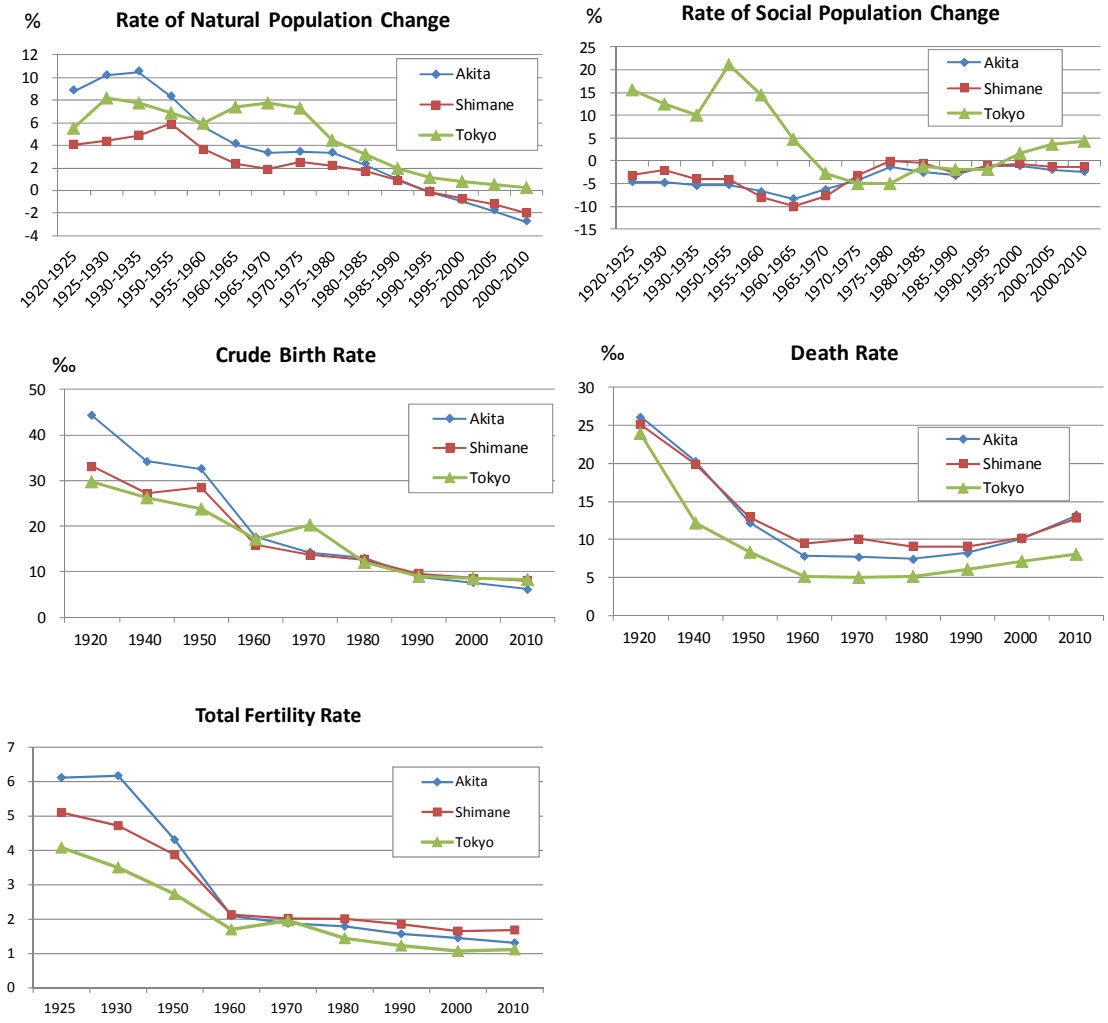
Sources: R-JIP Database 2013 and *Population Census*, Statistics Bureau, MIC.

3. Why is the Aged Population Ratio of some Prefectures so High?

In this section, we examine why the aged population ratio of some prefectures such as Akita and Shimane is so high. We also examine why the difference in the aged population ratio across prefectures has been on a declining trend and is projected to decline further in future.

Figure 7 compares various population statistics for Akita and Shimane with those of Tokyo: the rates of natural and social population change, the crude birth rate, the death rate, and the total fertility rate. The figure shows that there were substantial differences in rate of social population change across the three prefectures from 1920 to 1970. Shimane and Akita experienced large out-migration during this period, and the out-migration rate was particularly high during Japan's high growth era from 1955 to 1970.

Figure 7. Comparison of Population Change Statistics across Akita, Shimane and Tokyo: 1920–2010



Source: *Population Census* (various issues), Statistics Bureau, MIC. Data of the total fertility rate were provided by Professor Noriko Tsuya of Keio University.

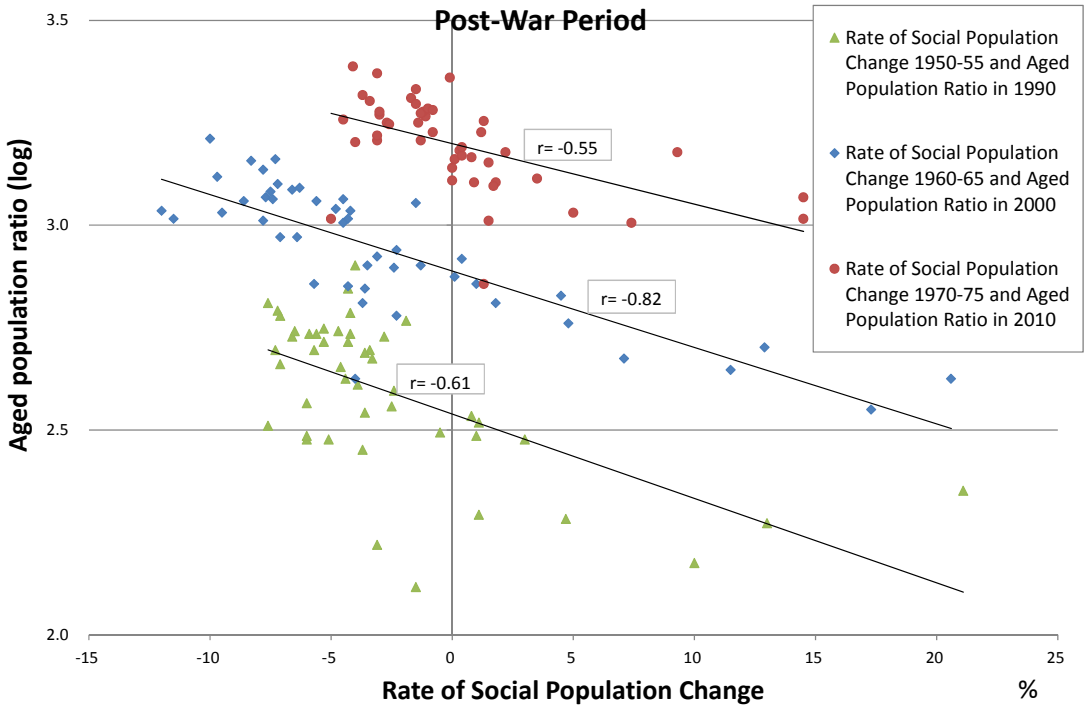
On the other hand, Tokyo experienced extremely rapid in-migration until the 1960s. It is interesting to note that the in-migration rate of Tokyo was already high before the Second World War. Population inflows to Tokyo gradually declined in the 1960s and even turned negative during the 1970s and 1980s, probably because of congestion phenomena, such as high land prices, air pollution, etc., and regulations on the startup of new factories and university campuses to stop overconcentration. People who wanted to work or study in the Tokyo area started to choose living in adjacent prefectures such as Chiba, Saitama, and Kanagawa.

We should point out that Figure 7 does not help to explain why Shimane's aged population ratio was so high even in the pre-war period (Figure 2). One possible explanation is that Shimane's

out-migration started much earlier than that of Akita, but to confirm this we need more long-term data than that shown in Figure 7.[7]

People are particularly likely to migrate in their teens or twenties. Therefore, out-migration will reduce the working age population and the crude birth rate, and will increase the aged population ratio for the following 30-40 years. Figures 8 and 9 show the correlation between the rate of social population change over each 5 year interval and the aged population ratio 40 years later by prefecture for both the post-war and the pre-war period. We find a negative and statistically significant correlation (at the 5% level) between in-migration and the aged population ratio 40 years later for all periods analyzed.

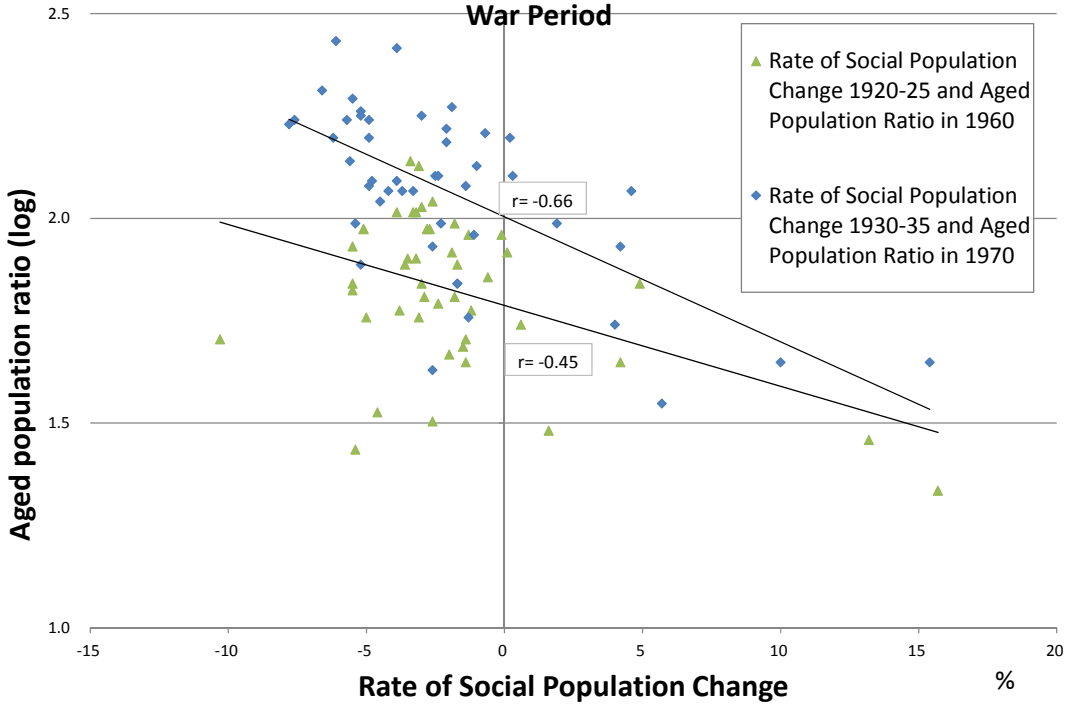
Figure 8. Migration and Aged Population Ratio 40 Years Later: Post-War Period



[7] Figure 7 also shows that Akita and Shimane have experienced large negative rates of natural population change in recent years. The rate of natural population change is equal to the crude birth rate minus the death rate. Figure 7 indicates that Akita and Shimane have considerably higher death rates than Tokyo, likely because they have older populations. Moreover, although Akita and Shimane have higher total fertility rates than Tokyo – i.e., women of childbearing age in the two rural prefectures tend to have more children than those in Tokyo –, the crude birth rates in the three prefectures are very similar, likely because there are relatively fewer women of childbearing age in the two rural prefectures due to their aged populations. This means that population aging reproduces itself through the decline in the crude birth rate and that, as a consequence, the rate of natural population decline will continue to be faster in prefectures with an older population.

Source: *Population Census* (various issues), Statistics Bureau, MIC.

Figure 9. Migration and Aged Population Ratio 40 Years Later: Pre-War Period

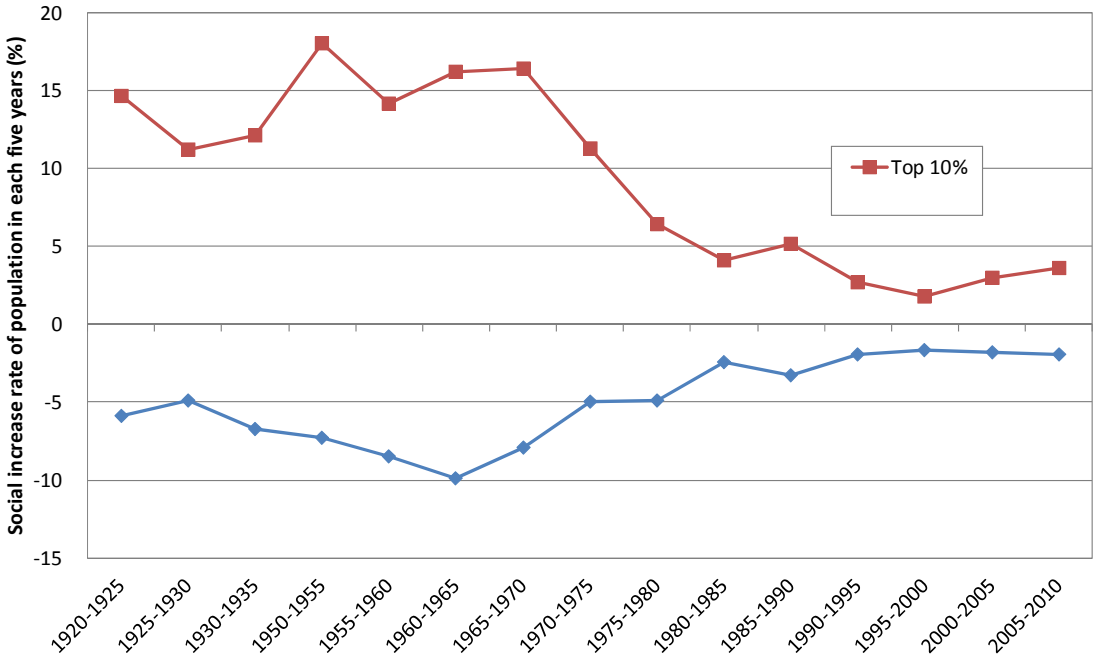


Source: See Figure 8.

Next, we examine the slowdown of migration within Japan. Figure 10 shows the rate of social population change in the top 10% and bottom 10% in-migration prefectures in terms of cumulative population. We find that migration as measured by the rate of social population change was highest in the high growth era from 1955 to the early 1970s and declined markedly thereafter.

Table 1 shows that for a long time, people in Japan, like people in other countries, migrated from low income to high income regions. Like Figure 7, this table shows that migration was most pronounced during the high growth era, i.e., in 1955 and 1970 in our table. However, migration, as measured by the rate of social population change in high and low income prefectures, has slowed in recent decades. There was more active migration in 1925-30 than in 1990 and 2008. This fact is related to our second question, namely, why differences in the aged population ratio across prefectures has been declining and is projected to decline further in the future.

Figure 10. Rate of Social Population Change in the Top 10% and Bottom 10% In-migration Prefectures in Terms of Cumulative Population



Source: *Population Census* (various issues), Statistics Bureau, MIC.

Table 1. Rate of Social Population Change in High and Low Income Prefectures: 1925–2008 (%, Annual Rate)

	1925–30	1955	1970	1990	2008
Rate of social population change in low per capita income prefectures (bottom 20% prefectures in terms of cumulative population)	−0.6	−0.7	−1.3	−0.4	−0.4
Rate of social population change in high per capita income prefectures (top 20% prefectures in terms of cumulative population)	1.6	1.7	0.0	−0.4	0.4

	1925–30	1955	1970	1990	2008
Rate of social population change in low per capita income prefectures (bottom 10% prefectures in terms of cumulative population)	−0.6	−0.7	−1.7	−0.5	−0.4
Rate of social population change in high per capita income prefectures (top 10% prefectures in terms of cumulative population)	2.2	2.3	−0.9	−0.4	0.6

Sources: *Population Census*, and *Annual Report on Internal Migration in Japan Derived from the Basic Resident Registration*, Statistics Bureau, MIC; R-LTES 2013; *Annual Report of Prefectural Accounts*, Cabinet Office.

Notes: The selection of the top and bottom prefectures in 1925 is based on the per capita gross prefectural product (GPP). The rate of social population change for 1925-1930 is the annual average rate of change for that period.

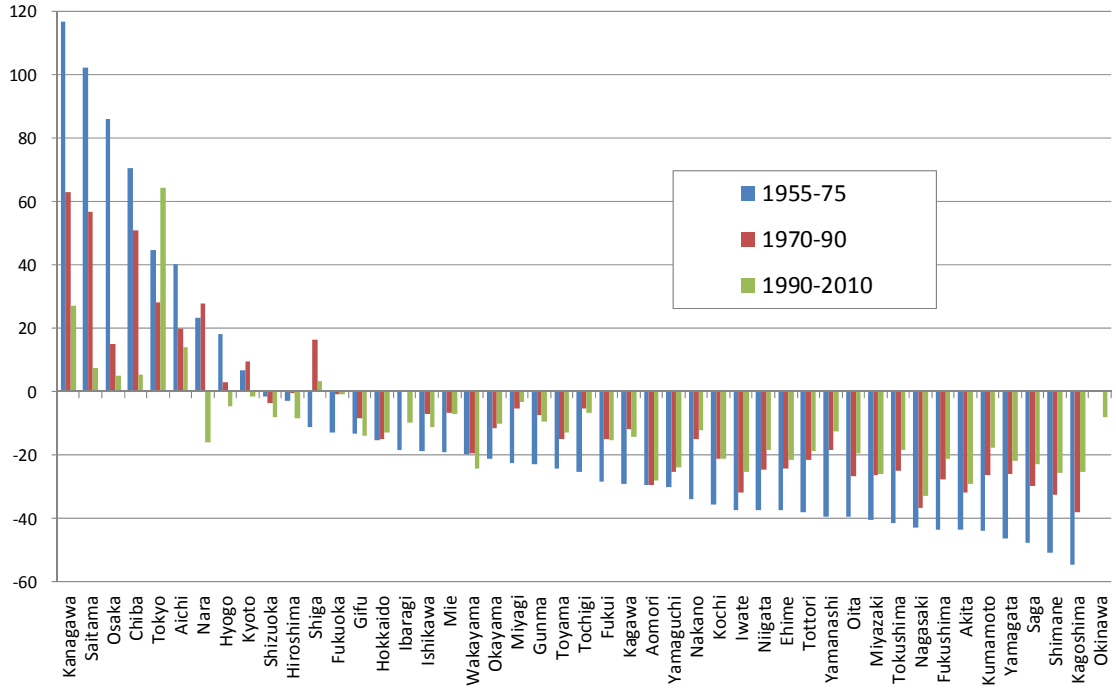
We can point out two causes of this slowdown of migration from low income to high income prefectures. First, as the aging of the population proceeds, the percentage of the population at an age when individuals are most likely to migrate, that is, the population in their teens and twenties in the total population, declines. Second, income disparities across prefectures, which are the main engine of migration, have gradually declined.

In order to confirm that not only the first factor but also the second factor has been responsible for the slowdown of migration in recent years, we measured the net migration rate of each cohort from when they are aged 10–14 to when they are aged 30–34 for each prefecture. For example, to derive the 20-year net migration rate of the cohort that was aged 10–14 in 1955, we used the following equation:

Net in-migration rate of prefecture *i* from 1955 to 1975 =
{(Population of 30–34 year olds in prefecture *i* in 1975) –
(Population of 10–14 year olds in prefecture *i* in 1975) × (National average survival rate of this cohort from 1955 to 1975)}/ (Population of 10–14 year olds in prefecture *i* in 1975)

Figure 11 shows our result. Prefectures are ordered in terms of their net in-migration rate from 1955 to 1975. The figure shows that young generations migrated from low income prefectures to high income prefectures. We find that migration of younger generations as measured by the net migration rates of cohorts from when they are aged 10–14 to when they are aged 30–34 declined substantially. As already explained, one likely explanation is that as income and wage disparities decreased over time younger generations in low income prefectures had less incentive to move to high income prefectures. Another likely explanation is that the decline of the birth rate created many one-child families and children of such families tended to stay with their parents. This change may have contributed to reducing out-migration from low income regions. However, more research is needed to determine what the main reasons for the decline of the migration rate among younger generations are.

Figure 11. Net Migration Rate of Each Cohort in the 20 Years from Age 10–14 to Age 30–34 by Prefecture



Sources: *Population Census* (various issues), Statistics Bureau, MIC.

Table 2 shows the correlation coefficients between the log of labor productivity relative to the national average and the net in-migration rate of each cohort in the 20 years from age 10–14 to age 30–34. We find that the correlation between labor productivity and subsequent migration is quite high.

Table 2. Correlation Coefficient Between the Log of Labor Productivity Relative to the National Average and the Net In-Migration Rate of Each Cohort in the 20 Years from Age 10-14 to Age 30-34

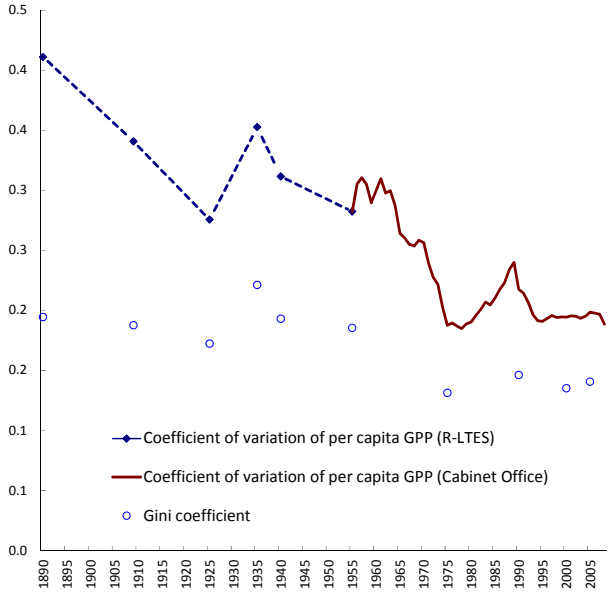
	1955-1975	1970-1990	1990-2008
Correlation coefficient	0.628	0.750	0.710

Sources: R-JIP Database 2013 and *Population Census* (various issues), Statistics Bureau, MIC.
Note: Okinawa is not included in the calculation for 1955–75 and 1970–90.

Next, we examine how income disparities across prefectures, which are likely to have been the main engine of migration, have changed over time. Figure 12 shows that regional income disparities measured in terms of the coefficient of variation for per capita (nominal) gross prefectural product (GPP) has declined substantially.

As mentioned in footnote 5, as commuting across prefectures has increased in recent years, it is not appropriate to measure regional income disparities in terms of per capita GPP. In order to take account of this problem, Figure 13 compares the coefficients of variation of per capita prefectural income, GPP per worker on a working place basis, and GPP per hour on a working place basis, in addition to coefficient of variation of per capita GPP. Regional economic disparities measured in terms of the coefficient of variation become smaller when income data, which include factor income from other prefectures, are used in place of GPP data. Regional economic disparities measured in terms of the coefficient of variation show a sharp downward trend when we use data on a working place basis.

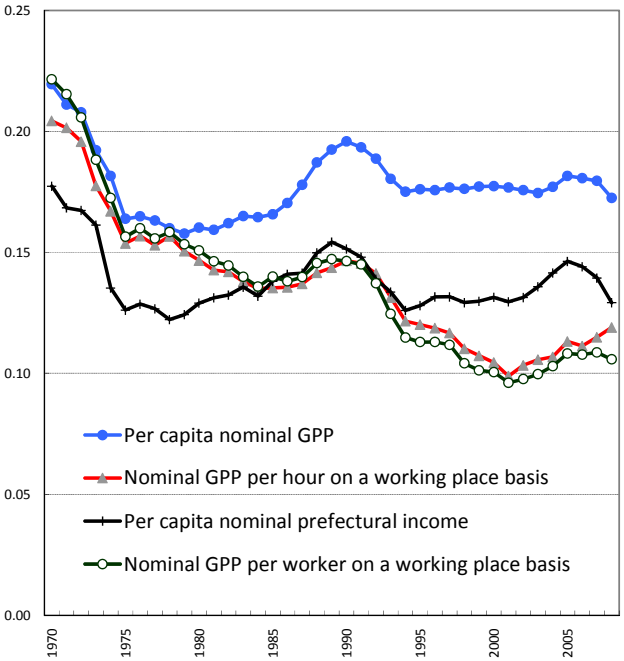
Figure 12. Regional Economic Disparities in Japan: 1890-2008



Sources: R-LTES 2013 and *Annual Report of Prefectural Accounts*, Cabinet Office.

Note: The Gini coefficient is calculated assuming that all residents in the same prefecture have the same income.

Figure 13. Regional Economic Disparities in Japan: 1970-2008



Sources: R-JIP Database 2013 and *Annual Report of Prefectural Accounts*, Cabinet Office.

4. Why Is Labor Productivity in Aged Prefectures Low?

In this section, we examine why labor productivity tends to be lower in aged prefectures. Following Caves et al. (1982), we decompose labor productivity differences across prefectures into differences in the TFP level, differences in capital intensity, and differences in labor quality:

$$\ln\left(\frac{v_i}{\bar{v}}\right) = RTFP_r + \frac{1}{2}\left(s_r^{\,K} + \bar{s}^{K}\right)\left\{\ln\left(\frac{Z_r}{\bar{Z}}\right) - \ln\left(\frac{H_r}{\bar{H}}\right)\right\} + \frac{1}{2}\left(s_r^{\,L} + \bar{s}^{L}\right)\ln\left(\frac{Q_r}{\bar{Q}}\right) \qquad (1)$$

where v_i, Z_i, H_i, Q_i, and $RTFP_i$ denote nominal value added per hour, capital service input, man-hour labor input, labor quality, and the relative TFP level of prefecture i. s_i^K and s_i^L denote the capital and labor cost shares in prefecture i. Variables with an upper bar denote the geometric mean of that variable across prefectures.

Using the above equation we can decompose the covariance between the log of the aged population ratio and the log of labor productivity relative to the national average into (1) the covariance between the log of the aged population ratio and the log of the relative TFP level (the first term on the right-hand side of the above equation), (2) the covariance between the log of the aged population ratio and the contribution of the relative capital-labor ratio to the labor productivity

gap (the second term on the right-hand side of the above equation), and (3) the covariance between the log of the aged population ratio and the contribution of relative labor quality to the labor productivity gap (the third term on the right-hand side of the above equation). Table 3 shows the result of this decomposition. We used the R-JIP Database 2013.

Table 3. Decomposition of the Covariance Between the Log of the Aged Population Ratio and the Log of Labor Productivity Relative to the National Average and Each Factor's Contribution (in Parentheses)

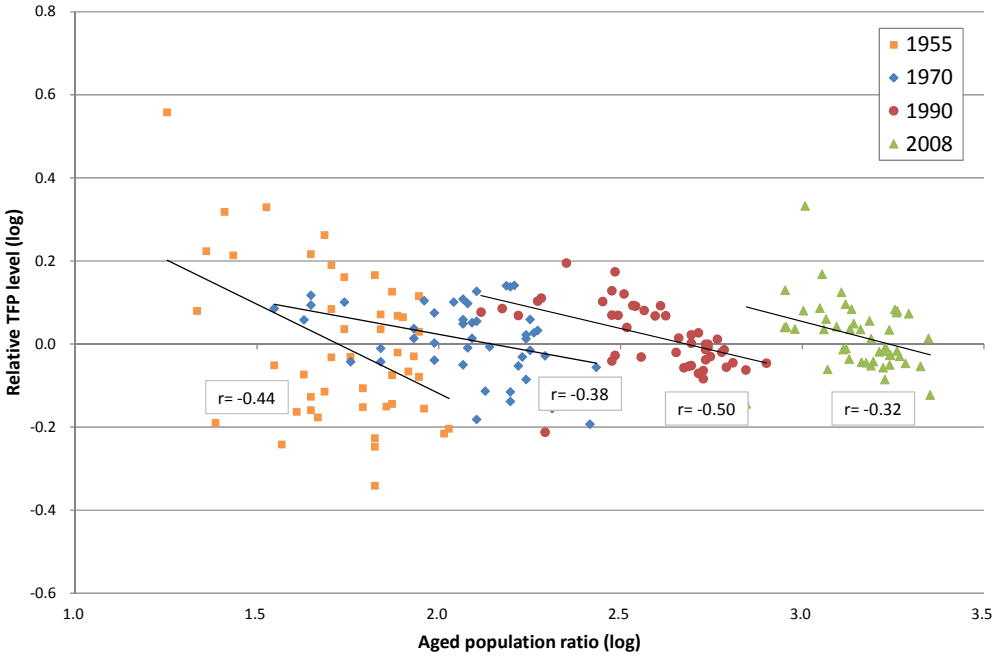
	1955	1970	1990	2008
Covariance between log of aged population ratio and log of labor productivity relative to national average	-0.020	-0.017	-0.012	-0.005
	(100.0)	(100.0)	(100.0)	(100.0)
Covariance between log of aged population ratio and log of relative TFP level	-0.015	-0.007	-0.007	-0.003
	(74.9)	(39.8)	(56.3)	(55.3)
Covariance between log of aged population ratio and contribution of relative capital-labor ratio to labor productivity gap	-0.003	-0.008	-0.003	-0.001
	(13.8)	(45.4)	(21.8)	(21.5)
Covariance between log of aged population ratio and contribution of relative labor quality to labor productivity gap	-0.002	-0.003	-0.003	-0.001
	(11.3)	(14.8)	(21.8)	(23.1)

Sources: R-JIP Database 2013 and *Population Census* (various issues), Statistics Bureau, MIC.

As Table 3 shows, the covariance between the log of the aged population ratio and all three factors underlying labor productivity differences – TFP, the capital-labor ratio, and labor quality – is always negative. Moreover, the correlation coefficients are all statistically significant at the 5% level except in two cases: the correlation with the capital-labor ratio in 1955 and 2008. We can thus say that all three factors contributed to the lower labor productivity in prefectures with a larger aged population ratio.

Among the three factors, TFP differences made the largest contribution in 1955, 1990, and 2008. In other words, labor productivity in aged prefectures is relatively low mainly because of their low TFP. Figure 14 shows the relationship between the relative TFP level and the aged population ratio.

Figure 14. Aged Population Ratio and TFP



Sources: R-JIP Database 2013 and *Population Census* (various issues), Statistics Bureau, MIC.

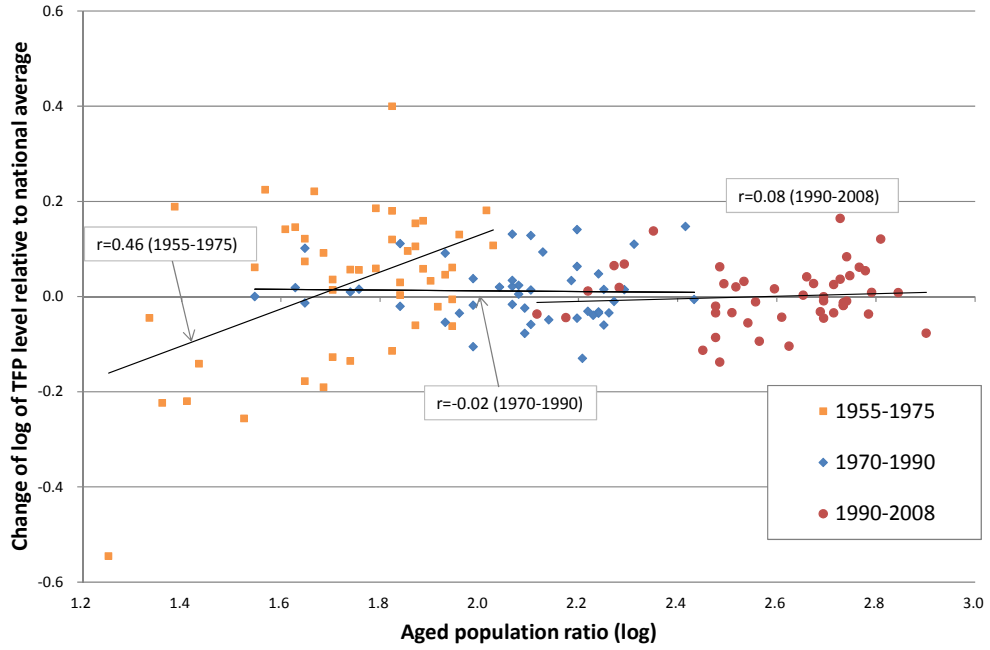
Table 3 suggests that in 1970, the contribution of capital-labor ratio differences was slightly larger than that of TFP differences. Compared with these two factors, the contribution of labor quality differences was relatively small. This is partly because of smaller differences in labor quality across prefectures (Tokui et al. 2013).

Next, we investigate why aged prefectures tend to have a lower TFP level. One possible explanation is that aging places a greater burden on local government and the local working age population through a decline in tax revenues and an increase in the need to provide care for the elderly, medical service, etc. Another explanation is that, as population aging proceeds, demand for care for the elderly and medical services expands and the production share of these sectors in the local economy increases. Since TFP growth in these sectors tends to be low, growth of these sectors may reduce macro-level TFP growth of aged prefectures. This is a kind of Baumol effect.

Figure 15 shows the relationship between the aged population ratio in 1955, 1970, and 1990 and TFP growth in the succeeding 20 years. The correlation is not statistically significant for 1970-90 and 1990-2008, but it is positive and significant for 1955-75. These results suggest that population aging does not reduce TFP growth.

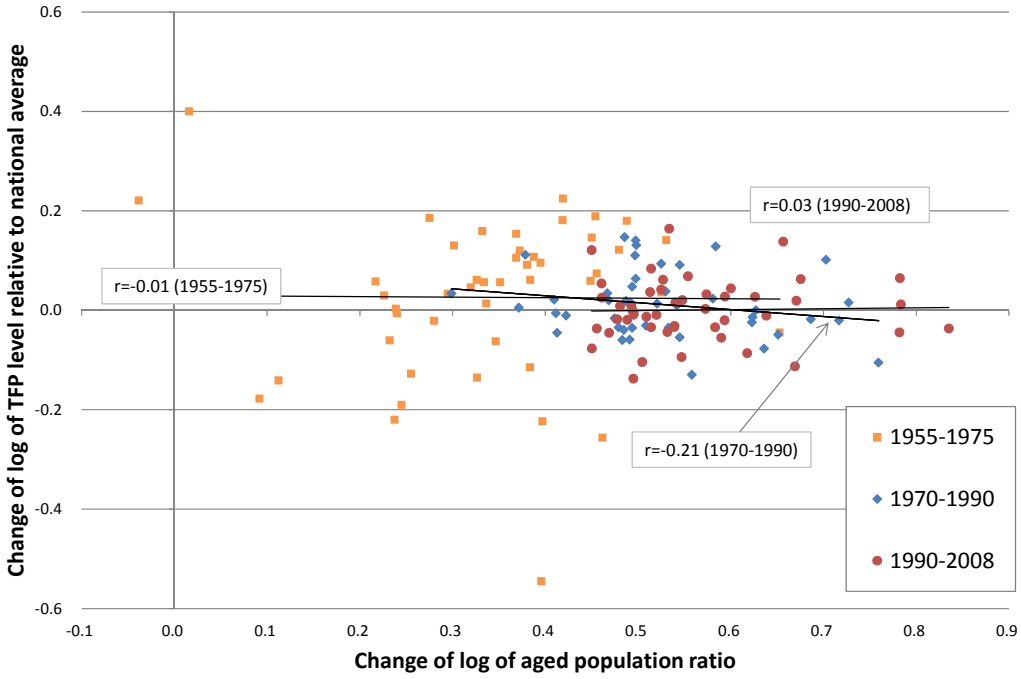
We also checked whether there is a statistically significant negative correlation between the change of the aged population ratio and the change of the TFP level in each period, i.e., 1955–75, 1970–90, and 1990–2008. However, as Figure 16 shows, we do not observe such a relationship.

Figure 15. Aged Population Ratio and TFP Growth



Sources: R-JIP Database 2013 and *Population Census* (various issues), Statistics Bureau MIC.

Figure 16. Change of Aged Population Ratio and TFP Growth



Sources: See Figure 15.

Employing a fixed effect model, we further estimated how the ratio of the aged population to the working age population affects the TFP level and TFP growth using prefectural level data for the period 1955-2008. The estimation results are reported in Table 4 and indicate that there is a statistically significant negative relationship between this ratio and the TFP level. However, in the case of TFP growth, we find a positive and statistically significant relationship. Therefore, although there is a negative correlation between aging and the TFP level, it seems that aging does not slow down TFP growth. These results are consistent with our findings from Figures 14 and 15.

Table 4. Relationships between Aging and the TFP Level/TFP Growth: Estimation Results Based on Fixed Effect Models, 1955-2008

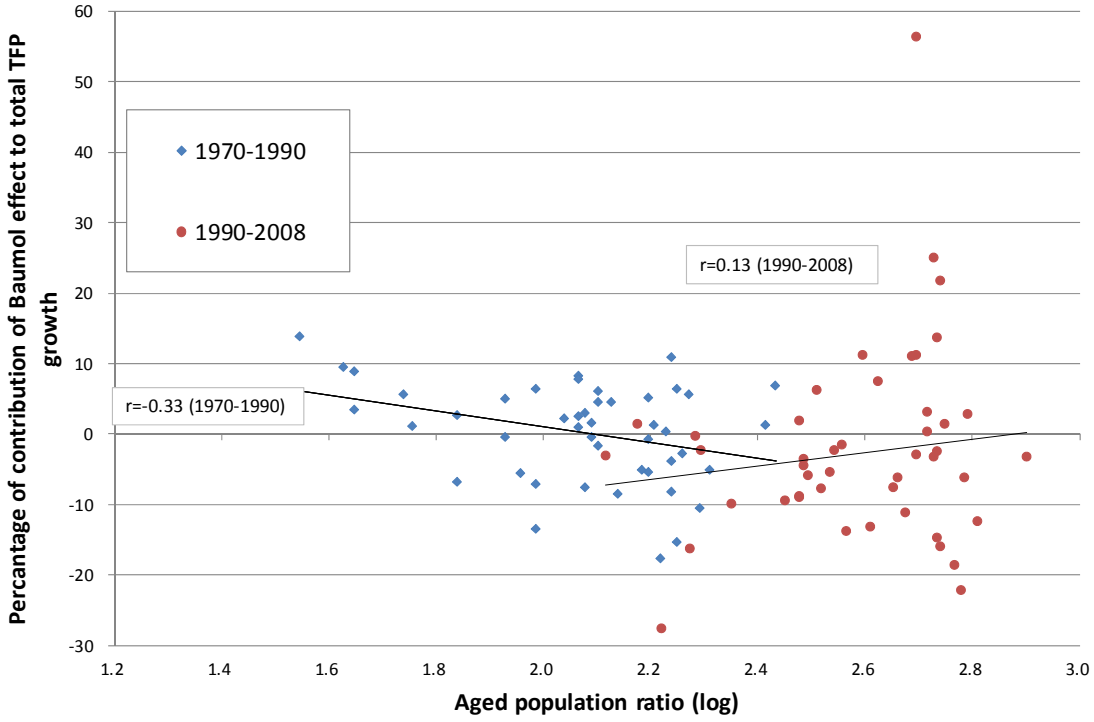
	Dependent variable	
	Log of TFP level	TFP growth
Log of (aged population/working age population	-0.138 **	0.018 ***
	(0.065)	(0.008)
Number of observations	184	138
Number of prefectures	46	46
Housman statistic	4.684	2.359
p-value	0.321	0.501
Adjusted R^2	0.042	0.120

Notes: In the case of the TFP level regression, we used data for 1955, 1970, 1990, and 2008. In the case of the TFP growth regression, we used data for 1955-1970, 1970-1990, and 1990-2008. Okinawa is not included in the regressions. Figures in parentheses are t-statistics. Year and prefecture dummies are included in each regression, but their coefficients are not reported. ** $p<0.05$ and *** $p<0.01$.

Figure 17 shows our result on the Baumol effect. Using sectoral TFP data, which are only available for 1970–2008 in the present R-JIP Database, we can decompose the macro-level TFP growth of each prefecture into the contribution of the expansion of sectors with high TFP growth and the contribution of TFP growth within each sector. We call the first term the Baumol effect. The vertical axis of Figure 17 measures the percentage of the Baumol effect in the total TFP growth of each prefecture for the periods 1970–1990 and 1990–2008. The horizontal axis shows the log of the aged population ratio in the starting year of each period, 1970 and 1990 respectively. In the case of the period 1970–1990, we find a statistically significant (at the 5% level) negative correlation between the aged population ratio in the starting year and the percentage of the Baumol effect in total TFP growth in the succeeding 20 years. However, even in the period 1970–1990, the Baumol effect accounts for less than 10% of the total TFP growth in most of prefectures.

To sum up our results on the effects of population aging on TFP growth, it seems that population aging does not systematically reduce local TFP levels.

Figure 17. Aged Population Ratio and Baumol Effect



Sources: R-JIP Database 2013 and *Population Census* (various issues), Statistics Bureau, MIC.

Let us consider the possibility that the causality is the reverse of what we have assumed so far. That is, if a lower TFP level means lower wage rates and out-migration of the younger generation, prefectures with a high aged population ratio may have suffered low TFP levels 30–40 years ago, so if TFP differences across prefectures are stable over time (prefectures with a low relative TFP level continue to have a low relative TFP level), we will observe a negative current correlation of the TFP level and the aged population ratio.

Table 5 shows the inter-temporal correlation coefficient of the relative TFP level. All the coefficients are statistically significant at the 5% level, indicating that TFP differences across prefectures are quite stable over time. Figure 4 shows the standard deviation of the relative TFP level (log) across prefectures. We find that from 1955 to 1970, TFP differences across prefectures declined substantially, but after that cross-regional differences did not change (Table 6).

Table 5. Intertemporal Correlation Coefficient of Relative TFP Level

	1955	1970	1990
1970	0.61		
1990	0.60	0.68	
2008	0.63	0.53	0.65

Source: R-JIP Database 2013.

Note: Okinawa is not included in the analysis.

Table 6. Standard Deviation of Relative TFP Level: 1955-2008

1955	1970	1990	2008
0.18	0.09	0.08	0.08

Source: R-JIP Database 2013.

Note: Okinawa is not included in the calculations for 1955 and 1970.

What factors are responsible for this persistence in TFP gaps across regions? Since firms carry out a lot of investment across regions and large firms have networks of affiliates throughout Japan, it seems to be difficult to explain this persistence as the result of slowness in technology diffusion. Instead, there must be other reasons and there are a number of possible explanations for the persistence in TFP gaps. One of these is agglomeration effects. High income regions enjoy positive agglomeration effects in certain industries or with regard to the population overall. And since firms and households are attracted by such positive effects, agglomeration does not disappear. Another possible explanation is locational advantages as a result of natural or policy factors. A prefecture with a good sea port may enjoy higher TFP for a long period.

Next, let us examine the theoretical relationship between differences in TFP across prefectures and differences in wage rates across prefectures.

We assume a constant returns to scale neoclassical production function with two production factors, capital and labor. Capital moves without friction across prefectures and the real rate of return on capital is always equalized across prefectures. On the other hand, we assume that it takes time for labor to move and workers' decision about where to live depends not only on wage rates but also other factors such as amenities, their personal history, the location of their parents, etc. Therefore, we assume that labor supply in each region is given at least in the short run and wage rate differences across prefectures continue to exist. All prefectures produce identical products and all markets are characterized by perfect competition. To simplify our analysis, we assume that labor quality is constant and does not differ across prefectures, although our main results would remain unchanged if we relaxed these assumptions regarding labor quality.

We assume the following neoclassical constant returns to scale production function:[8]

[8] We assume $f(k_i, A_i) \geq 0$, $\partial f(k_i, A_i)/\partial k_i > 0$, $\partial^2 f(k_i, A_i)/\partial k_i^2 < 0$, $\partial f(k_i, A_i)/\partial A_i > 0$ for any $k_i \geq 0$ and $A_i > 0$, and $\lim_{k_i \to +0} \partial f(k_i, A_i)/\partial k_i = +\infty$, and $\lim_{k_i \to +\infty} \partial f(k_i, A_i)/\partial k_i = 0$.

$$V_i = F(K_i, N_i, A_i) = N_i f(k_i, A_i), \tag{2}$$

where V_i, A_i, K_i, N_i, and k_i denote the real value added, the productivity index, the capital service input, the labor input, and the capital-labor ratio (K_i/N_i) of prefecture i.

Because of free capital movement, we have

$$\frac{\partial f(k_i, A_i)}{\partial k_i} = r, \tag{3}$$

where r denotes the rate of return on capital, which is identical across regions.

The real wage rate of prefecture i, w_i, is determined by the marginal productivity of labor in this prefecture:

$$w_i = f(k_i, A_i) - k_i \frac{\partial f(k_i, A_i)}{\partial k_i}. \tag{4}$$

To simplify our analysis, we introduce a small prefecture assumption, just like the small country assumption in international economics. We assume that prefecture i is so small that a change of the TFP level in this prefecture does not affect the national rate of return on capital, r. We assume that r is given and constant.

Under this assumption, we can regard equation (3) as an implicit faction, which shows how k_i is determined for a given value of A_i. Let us express this relationship by $k_i = k(A_i)$. By differentiating equation (3) with regard to A_i, we obtain

$$\frac{\partial^2 f(k_i, A_i)}{\partial {k_i}^2} \frac{dk_i(A_i)}{dA_i} + \frac{\partial^2 f(k_i, A_i)}{\partial A_i \partial k_i} = 0. \tag{5}$$

Using $k_i = k(A_i)$, equation (4) can be regarded as showing how changes in A_i affect the wage rate w_i:

$$w_i = f(k(A_i), A_i) - k(A_i) \frac{\partial f(k(A_i), A_i)}{\partial k_i}. \tag{6}$$

By differentiating equation (6) with regard to A_i and w_i and using equation (5), we obtain

$$\begin{aligned} dw_i &= \frac{\partial f\left(k\left(A_i\right), A_i\right)}{\partial k_i} \frac{dk\left(A_i\right)}{dA_i} dA_i + \frac{\partial f\left(k\left(A_i\right), A_i\right)}{\partial A_i} dA_i \\ &- \frac{\partial f\left(k\left(A_i\right), A_i\right)}{\partial k_i} \frac{dk\left(A_i\right)}{dA_i} dA_i - k_i \frac{\partial^2 f\left(k\left(A_i\right), A_i\right)}{\partial {k_i}^2} \frac{dk\left(A_i\right)}{dA_i} dA_i - k_i \frac{\partial^2 f\left(k\left(A_i\right), A_i\right)}{\partial A_i \partial k_i} dA_i \\ &= \frac{\partial f\left(k\left(A_i\right), A_i\right)}{\partial A_i} dA_i \end{aligned} \tag{7}$$

Keeping N_i and k_i constant and differentiating production function (2) with regard to V_i and A_i, we obtain the following relationship:

$$\frac{dV_i}{V_i} = \frac{N_i}{V_i} \frac{\partial f\left(k_i, A_i\right)}{\partial A_i} dA_i \tag{8}$$

The left-hand side of the above equation denotes percentage change of TFP, $d\ TFP_i / TFP_i$. Therefore, the above equation shows the relationship between a change in TFP and a change in the productivity index. From equations (7) and (8), we obtain the following relationship, which we have been looking for:

$$\frac{dw_i}{w_i} = \frac{V_i}{w_i N_i} \frac{dTFP_i}{TFP_i} \tag{9}$$

On the right-hand side, the coefficient, V_i/w_iN_i denotes the inverse of the cost share of labor, which is larger than 1. Therefore, equation (9) means that when TFP increases, the wage rate will increase more than proportionately under our assumption of a constant rate of return on capital.

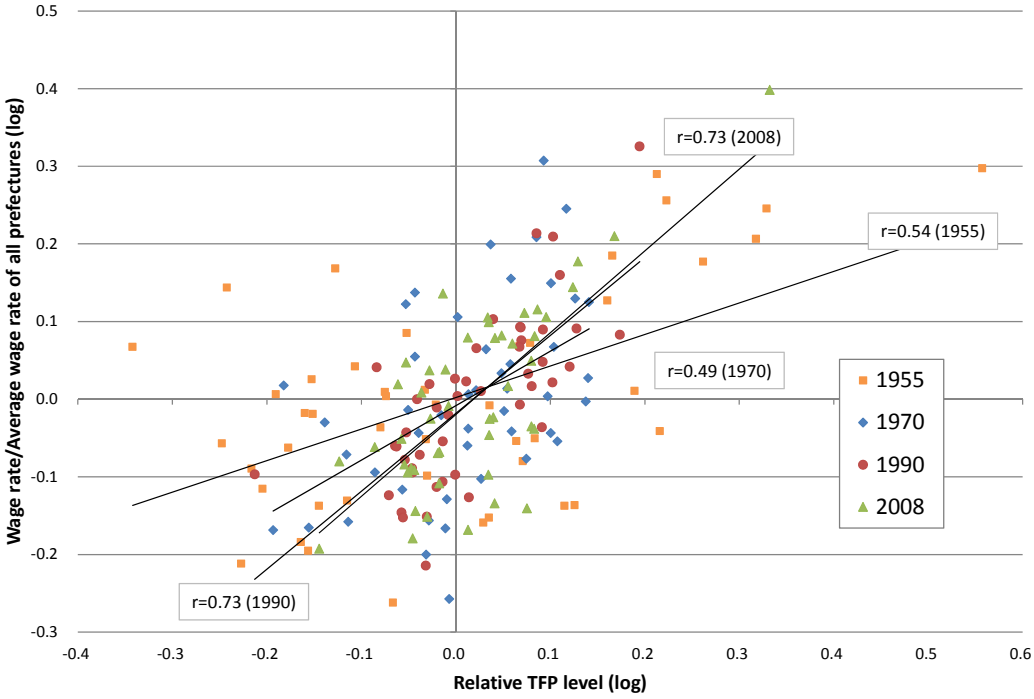
Will higher TFP bring a higher capital-labor ratio? The relationship of these two variables is given by equation (5). Under the assumptions we have made above, the relationship is ambiguous. However, we can show that if technology improvements are either Hicks neutral or Harrod neutral, one of which is assumed in most studies on economic growth, higher TFP will bring a higher capital-labor ratio.

What we have done above is a comparative static analysis of a small prefecture. But we can easily apply our results for the comparison of wage rates between two prefectures with different TFP levels, at least when the two prefectures are not very large.

Figure 18 shows the cross-prefectural relationship between relative TFP levels and wage rates. When we measure wage rates, differences in labor quality are not taken into account. Therefore, there is a risk that we may overestimate the wage rates of high income prefectures, since the labor quality of such prefectures tends to be high (Tokui et al., 2013).

The figure shows that there is a statistically significant (at the 5% level) positive correlation between TFP levels and wage rates. The slopes of the estimated fitted lines are less than one for 1955 and close to one for later years. Therefore, the slopes are smaller than equation (9) implies. However, taking account of the potentially large measurement errors in TFP, especially for 1955, we can probably say that the empirical results in Figure 18 are consistent with theory.

Figure 18. TFP and Wage Rate



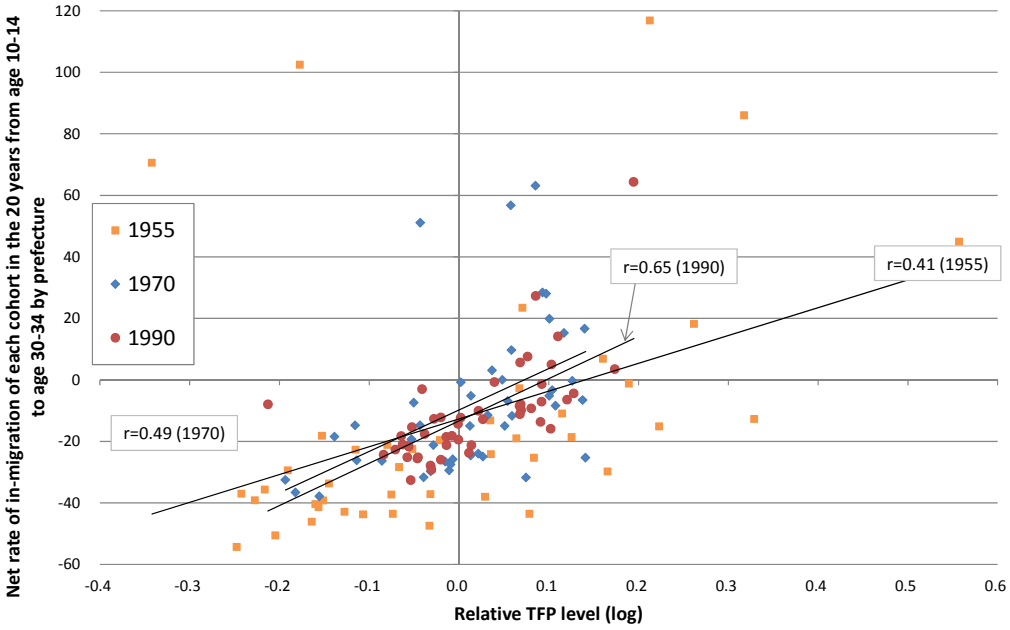
Sources: R-JIP Database 2013 and *Monthly Labour Survey* (*Prefectural Survey*), Ministry of Health, Labour and Welfare.

Did a lower TFP level cause the out-migration of younger generations? In Figure 19, we compare each prefecture's relative TFP level in 1955, 1970, and 1990 and the out-migration of younger generations in the periods 1955–75, 1970–90, and 1990–2010, respectively. In the same

way as in Figure 11, we measure migration of younger generations in terms of the net migration rates of a cohort from when they are aged 10–14 to when they are aged 30–34. Figure 19 shows that the correlation is positive and statistically significant (at the 5% level) in all three cases.

Let us summarize the results of this section. We found that population aging does not systematically reduce prefectural TFP levels. Instead, we found that it is more plausible that causality runs in the opposite direction. That is, a low TFP level means a low wage rate and out-migration of younger generations. Most prefectures that have a high aged population ratio today had a low TFP level 30–40 years ago. And since TFP differences across prefectures are stable over time (prefectures with a low relative TFP level continue to have a low relative TFP level), we observe a negative correlation between current TFP levels and current aged population ratios.

Figure 19. TFP and Net Migration Rate of Each Cohort in the 20 Years from Age 10-14 to Age 30-34 by Prefecture



Sources: R-JIP Database 2013 and *Population Census* (various issues), Statistics Bureau, MIC.

5. Aged Prefectures' Net Exports and Industrial Structure

As seen in Figure 6, aged prefectures tend to have large net imports of goods and services. In this section, we examine what factors are responsible for these large net imports of goods and services – a low private (or government) saving rate or a high private (or government) investment rate. As mentioned above, according to open economy macroeconomics, we would expect tradable sectors such as manufacturing and primary sector to decline in aging prefectures. We also examine this issue in this section.

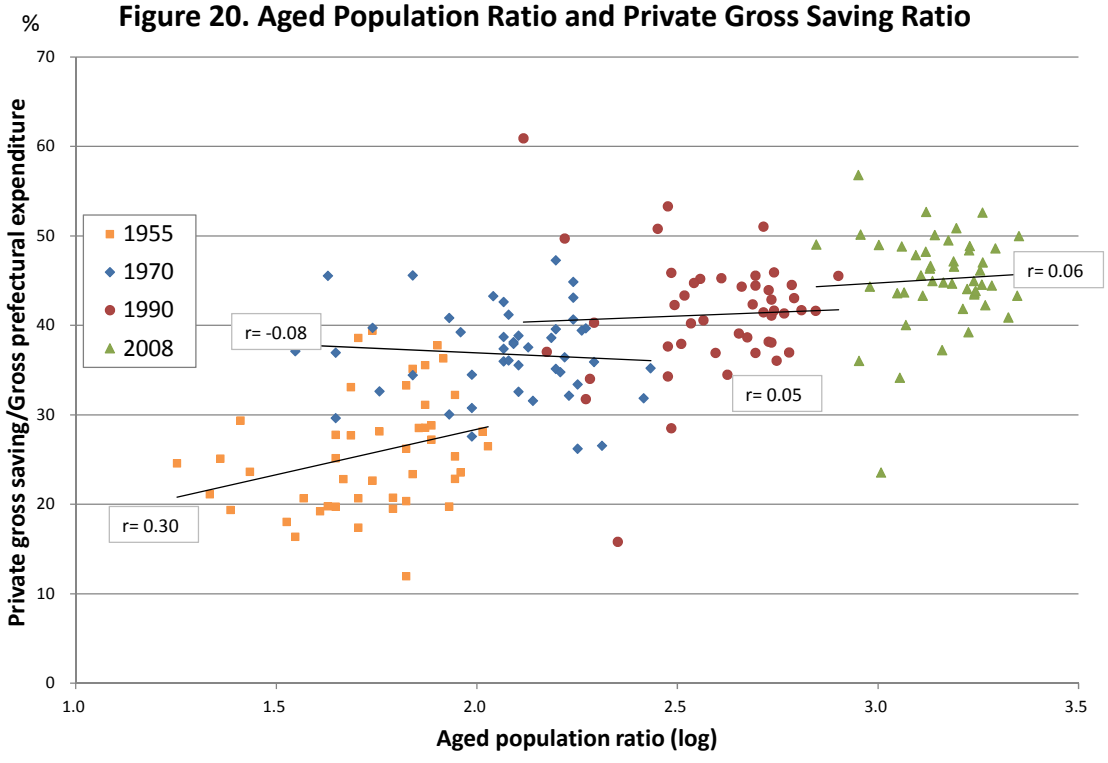
Figures 20, 21, 22 and 23 plot the log of the aged population ratio against the private gross saving/gross prefectural expenditure ratio, the private gross investment/gross prefectural expenditure ratio, the government gross saving/gross prefectural expenditure ratio, and the government gross investment/gross prefectural expenditure ratio, respectively, for the years 1955, 1970, 1990, and 2008.

As Figures 20 and 21 show, in the case of private sector saving and investment, there is little correlation with the aged population ratio.

On the other hand, Figure 22 shows, there is a statistically significant (at the 5% level) negative correlation between the aged population ratio and the government gross saving/gross prefectural expenditure ratio. Moreover, the negative slope has been getting steeper over time and some aged prefectures recorded remarkably large negative government saving ratios in 2008. The largest was that of Kochi (34.6%) and the second largest was that of Shimane (31.9%). Figure 23 shows there is also a statistically significant (at the 5% level) positive correlation between the aged population ratio and the government investment/gross prefectural expenditure ratio. It is difficult to understand why the central government concentrates investment in aged prefectures.

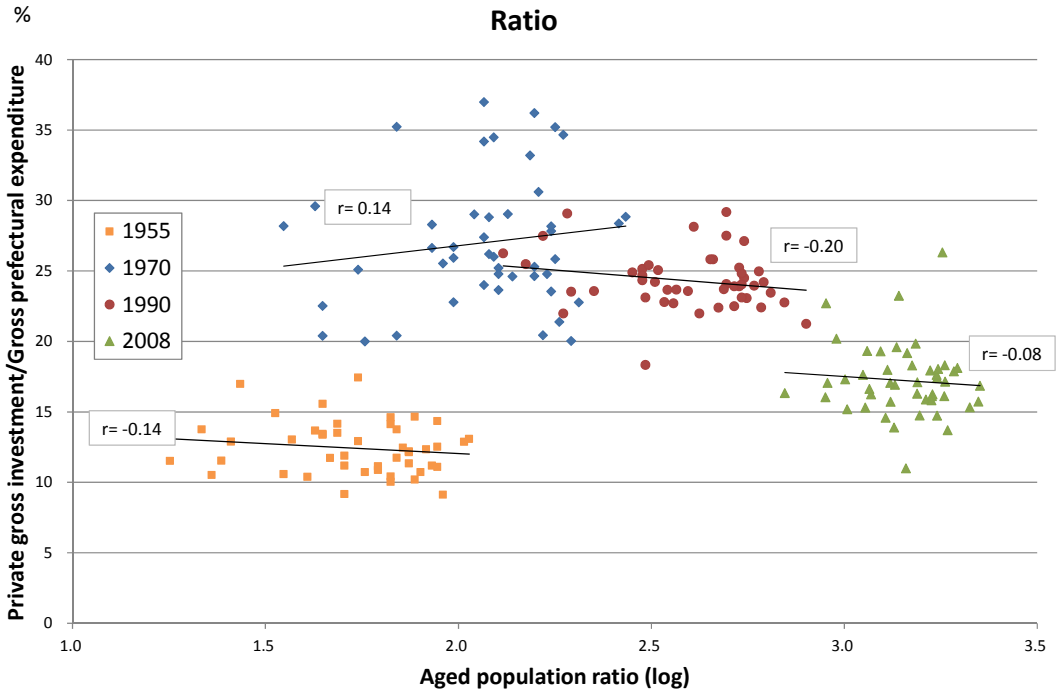
To sum up our analysis, the large net imports of aged prefectures, which we observed in Figure 6, are mainly the result of large negative government saving in those prefectures. Government's active capital formation in aging prefectures also made some contribution to the net imports of aging prefectures.

Figure 20. Aged Population Ratio and Private Gross Saving Ratio



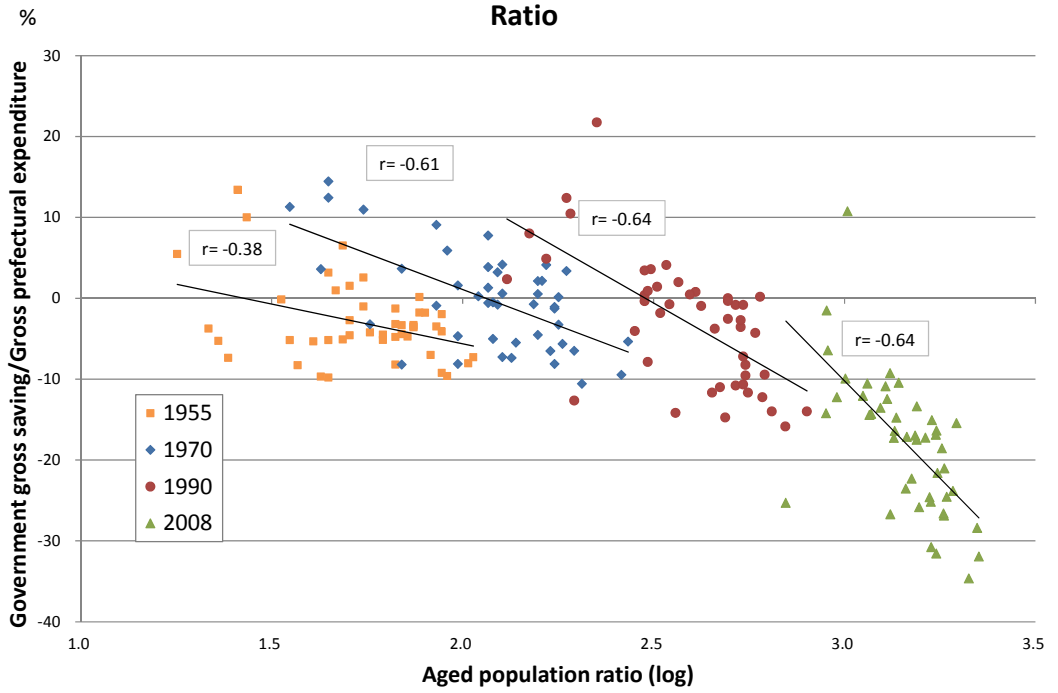
Sources: R-JIP Database 2013; Fukao and Yue (2000); *Population Census* (various issues), Statistics Bureau, MIC; *Prefectural Economic and Fiscal Model/Database*; and *Annual Report of Prefectural Accounts* (various issues), Cabinet Office.

Figure 21. Aged Population Ratio and Private Gross Investment Ratio



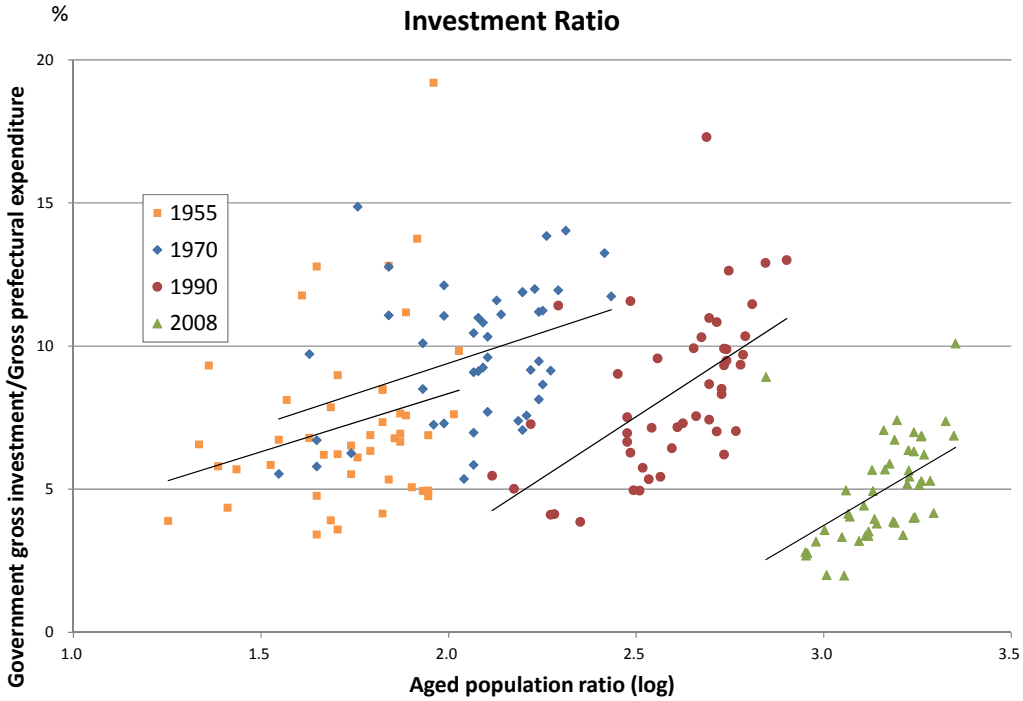
Sources: See Figure 20.

Figure 22. Aged Population Ratio and Government Gross Saving Ratio



Sources: See Figure 20.

Figure 23. Aged Population Ratio and Government Gross Investment Ratio



Sources: See Figure 20.

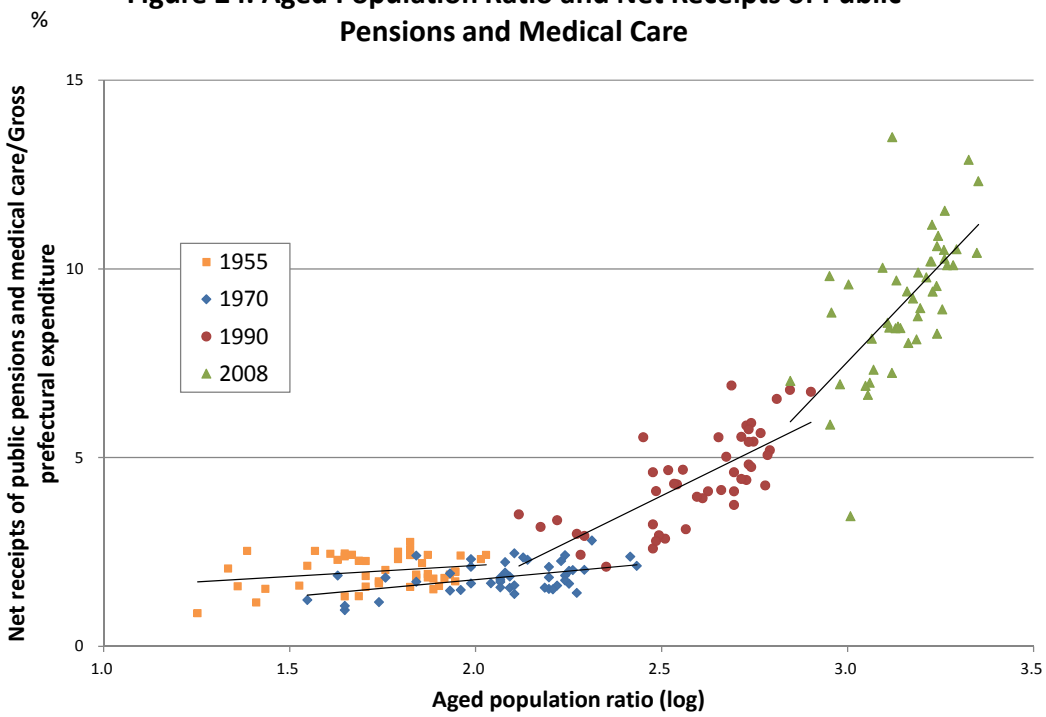
What factors are responsible for such large negative government saving in aged prefectures? Probably not surprisingly, it turns out the most important factor is net receipts of public pensions and medical care. As Figure 24 shows, for some aged prefectures, the ratio of net receipts to gross prefectural expenditure is around 12-13%. Another factor is the low ratio of tax payments to gross prefectural expenditure, as shown in Figure 25.

We should note that these large government transfers must contribute to raising the private saving ratio of aging prefectures. As we have seen in Figure 20, there is no negative correlation between the aged population ratio and private gross saving, which seems inconsistent with the life-cycle hypothesis on household consumption. However, the large government transfers likely raise the income and saving of the private sector in aged prefectures, and we can probably explain the inconsistency by this fact.

What lessons can we draw from these findings on prefectural I-S balances for the future of Japan as a whole? As Figure 2 showed, Japan's average aged population ratio will become similar to the current level of Akita and Shimane in 15 years. However, Japan as a whole will not be able to enjoy large net national imports and receipts of public pension and medical care, which Akita and Shimane now get. Since Japan's net foreign assets are equivalent to only 60% of its GDP, Japan

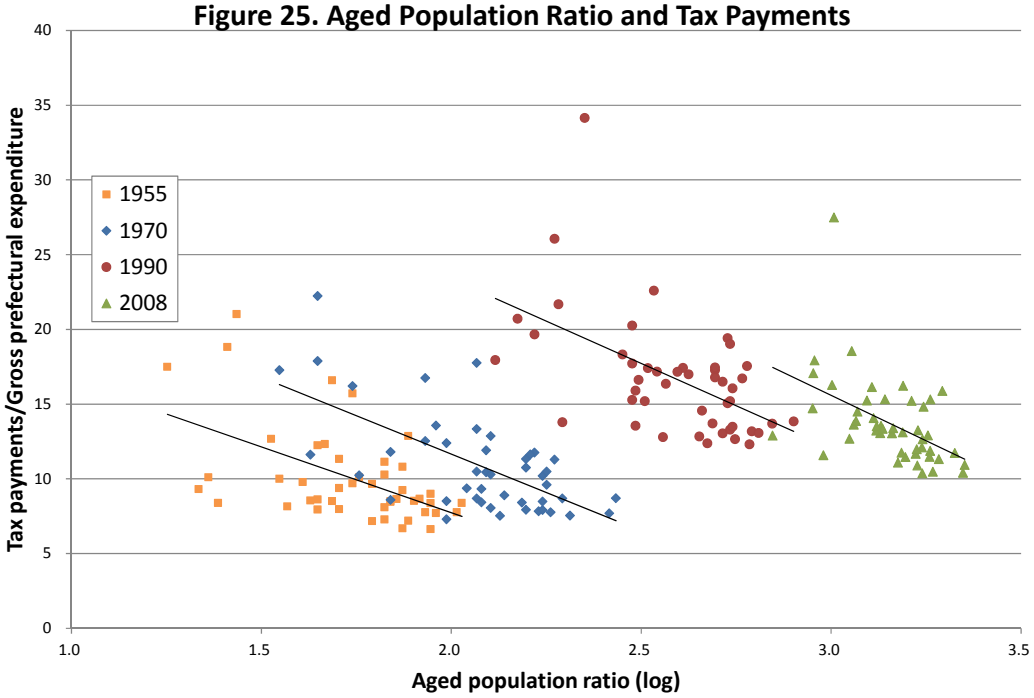
cannot maintain a 10% net import/GDP ratio for, say, 10 years. And of course Japan cannot expect huge income transfers from other countries similar to what aged prefectures now receive from Japan's other regions.

Figure 24. Aged Population Ratio and Net Receipts of Public Pensions and Medical Care



Source: See Figure 20.

Figure 25. Aged Population Ratio and Tax Payments



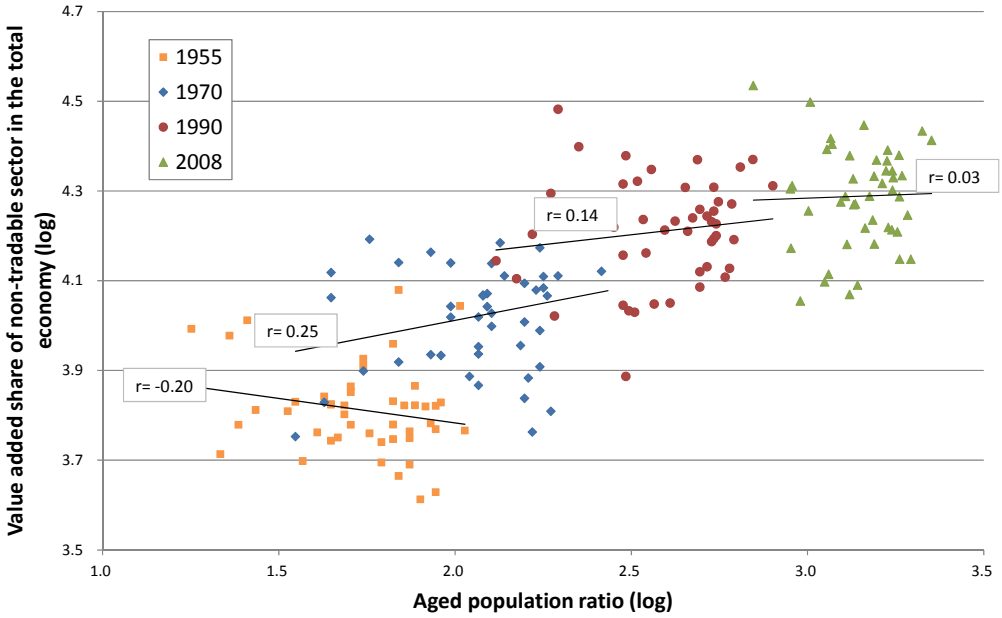
Source: See Figure 20.

It is true that less aged prefectures, such as Tokyo, have higher TFP, a higher capital-output ratio, and, as a result, higher labor productivity than aged prefectures. However, judging from the large transfers in the form of receipts of public pensions and medical care that aged prefectures receive, it seems that what is waiting for residents in prefecture that are less aged now is a post-retirement life that will be much less prosperous than what residents in Akita and Shimane enjoy today.

Next, let us examine whether the share of the non-tradable sector in the aged prefectures is smaller than that in other prefectures. Figure 26 shows the relationship between the aged population ratio and the value added share of the non-tradable sector. We find that there is no statistically significant relationship between the two variables – a result that contradicts standard open economy macroeconomics. Possible reasons for this finding include the following. First, our definition of the non-tradable sector includes some sectors whose activities are in fact tradable, such as wholesale, banking and insurance, transportation, communication and information services. Aged prefectures probably import a lot of such services. Second, aged prefectures tend to have a larger primary sector historically.

When we focus on a narrower definition of the service sector, which includes medical services and care of the elderly, we observe a statistically significant correlation between the aged population ratio and the value added share of this sector.

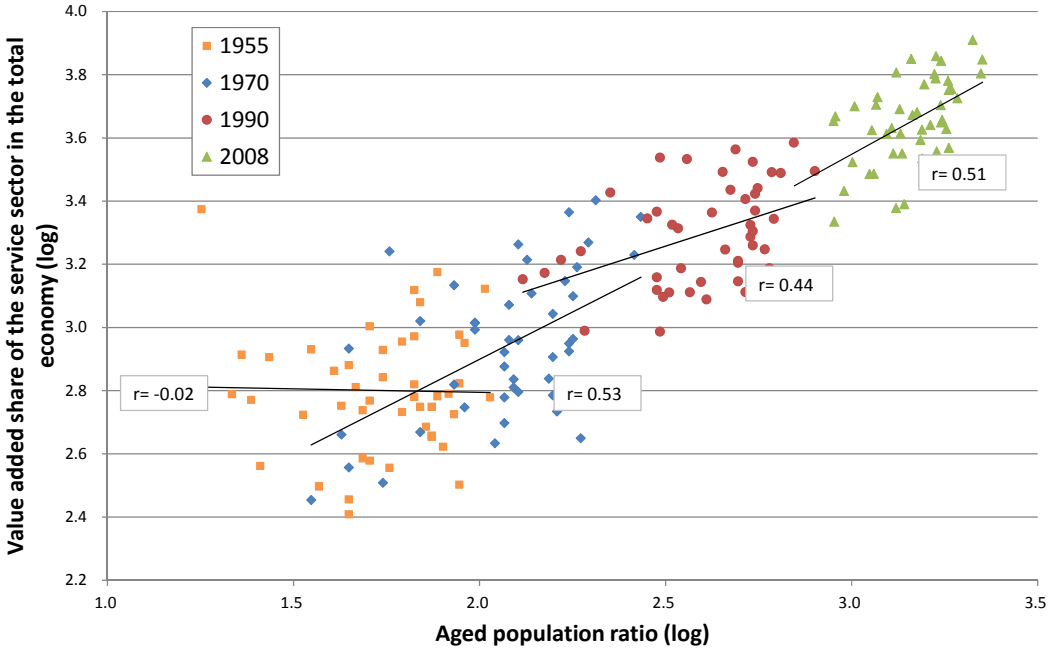
Figure 26. Aged Population Ratio and Value Added Share of the Non-Tradable Sector



Sources: See Figure 20.

Note: The non-tradable sector here includes all subsectors except manufacturing, agriculture, fishery, forestry, and mining.

Figure 27. Aged Population Ratio and Value Added Share of the Service Sector



Sources: See Figure 20.

Note: The service sector consists of private, non-profit, and government service activities.

6. Conclusions

In this paper, we examined how and why "aged prefectures" differ from other prefectures by merging two newly created databases for the analysis of prefecture-level productivity, the R-JIP Database 2013 and the R-LTES Database 2013, with other regional statistics, such as the *Population Projections by Region (March 2012): 2011 to 2060* by the IPSS, various issues of the *Population Census* of the Ministry of Internal Affairs and Communications, and various issues of the *Annual Report of Prefectural Accounts* by the Cabinet Office. Our main findings can be summarized as follows:

1. The aged population ratio of some prefectures such as Akita and Shimane is high because of large out-migration from these prefectures during Japan's high growth era from 1955 to 1970.
2. The differences in the aged population ratio across prefectures have followed a long-term downward trend and are projected to decline further in the future. People are particularly likely to migrate in their teens or twenties. Therefore, out-migration will reduce the working age population and the crude birth rate, and will increase the aged population ratio for the following 30-40 years. We find a negative and statistically significant correlation between in-migration and the aged population ratio 40 years later for all periods analyzed. We also find that migration as measured by the rate of social population change was highest in the high growth era from 1955 to the early 1970s and declined markedly thereafter. Migration was also relatively active in the pre-war period. Probably, the slowdown of migration from the 1970s contributed to reduce differences in the aged population ratio. We can point out two causes of this slowdown of migration from low income to high income prefectures. First, as population aging proceeds, the percentage of the population at an age at which individuals are most likely to migrate, that is, the population in their teens and twenties, declines. And second, income disparities across prefectures, which are the main engine of migration, have gradually declined.
3. Labor productivity in aged prefectures is relatively low mainly because of their low TFP.
4. Aged prefectures tend to have lower labor productivity. At the same time, we found that population aging does not systematically reduce local TFP levels. We therefore argued that, rather than population aging reducing TFP levels, the causality runs in the opposite direction. That is, low TFP levels mean lower wage rates and out-migration of the young. Most prefectures that have a high aged population ratio today had a low TFP level 30–40 years ago. And since TFP differences across prefectures are stable over time (prefectures with a low relative TFP level

continue to have a low relative TFP level), we observe a negative correlation between current TFP levels and current aged population ratios.

5. Aged prefectures tend to have large net imports of goods and services. The large net imports of aged prefectures are mainly the result of large negative government saving in those prefectures. Active government capital formation in aged prefectures also made some contribution to the net imports of such prefectures.
6. Since large transfers in the form of receipts of public pensions and medical care from less aged to more aged prefectures are not sustainable, it seems that what is waiting for residents in prefectures that are less aged now is a post-retirement life that will be much less prosperous than what residents in Akita and Shimane enjoy today.
6. There is no statistically significant relationship between the aged population ratio and the value added share of the non-tradable sector. However, when we focus on a narrower definition of the service sector, which includes medical services and care of the elderly, we observe a statistically significant correlation between the aged population ratio and the value added share of this sector.

To conclude this paper, let us consider what policy implications for Japan and other countries we can derive from the above findings.

First, the rapid aging of some prefectures, such as Akita and Shimae, was mainly caused by the out-migration of young workers to high-income prefectures several decades ago. Other things being equal, out-migration of workers from low income prefectures will raise the endowment of capital stock and land per capita and lead to an increase in the per capita income of such prefectures. From this perspective, migration, which in Japan was quite active during the interwar period and the high-speed growth era, was an important mechanism to reduce income inequality across regions. However, it is also important to note that active migration can result in aging and depopulation problems several decades later.

Second, aged prefectures tend to have lower labor productivity. The low labor productivity is mainly caused by low TFP levels. We find that the increase in the aged population ratio does not reduce labor productivity. Rather, causality runs the other way around: the reason that we observe a negative correlation between current TFP levels and current aged population ratios is that, in the past, workers migrated from prefectures with low TFP, and prefectures with a low relative TFP level in the past continue to have a low relative TFP level today. Therefore, it appears that we do not need to worry that Japan's average labor productivity will decline in the future as a result of population aging.

Third, aged prefectures have a very high ratio of net imports of goods and services to gross prefectural product, which corresponds to the trade deficit in goods and services relative to GDP in the case of countries. The ratio is about 10% or more for aged prefectures (Figure 6), and most of

their net imports are financed by income transfers from the central government. Akita and Shimane are 15 years ahead of Japan as a whole in terms of their aged population ratios. Does this mean that Japan will have a similarly high trade deficit relative to GDP in 15 years? The answer clear must be no. Japan's net foreign assets amount to only 60% of its GDP. Japan cannot expect huge income transfers from other countries and Japan's net factor income from abroad is not very large. Therefore, it is impossible for Japan to maintain a trade deficit in goods and services equivalent to 10% of GDP for very long (say, 10 years). Consequently, aged prefectures such as Akita and Shimane can hardly be considered as models from which we can derive lessons for Japan as a whole: fifteen years from now, when Japan's population as a whole will be as aged as the "oldest" prefectures today, Japan will not be able to rely on massive imports financed by income transfers.

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