How much do mortality differentials affect an accuracy of a population projection? Evidence from a projection for Japanese municipalities.

Keita SUGA

National Institute Population and Social Security Research

Japanese society is the most advanced in terms of population aging in the world in 2010. The rate of population age 65 and above in 2010 is 23.0%, which is the highest among 233 countries/areas covered in the United Nation(2012)[1]. Moreover, the natural increase in Japan becomes a negative value first time in 2005, and the pace of the decrease has been accelerated after 2007. As a consequence, a population projection for Japan released in 2012[2] describes rapid population aging and decline in future as such we have never experienced in the human history.

The fundamentals underlying the future population decline focus on a relative increase in the gross death rate due to population aging, given a level of fertility and a scarce international migration in Japan. The standard cohort component method for population projection distinguishes the births and deaths from migrations for population change, and the extent that mortality assumptions influence the projection results will be expanded as population ages.

Japan is not the only country predicted for a future population decline. The median variant of United Nation(2012) forecasts one fourth of countries/areas will lose their population for 2035-40. The figures will increase in later periods: 54.5% for 2065-70 and 76.0% for 2095-2100. Especially, larger fractions of countries/areas in Asia and Europe are projected to suffer the population decline. Among 51 countries/areas in Asia, the fraction of population declining countries is 29.4% for 2045-50, 54.9% for 2060-65, 74.5% for 2075-80 and 82.4% for 2095-2100. The fractions are even higher in Europe: 54.2% for 2035-40, 60.0% for 2045-50, and 85.4% for 2095-2100. In those countries/areas, the role of mortality in the population projection is supposed to become crucial for an accuracy of the projection.

Among Japanese societies, the developments of population aging vary substantially. For 47 prefectures in Japan, the rate of age 65 and above is the highest at Akita-ken(29.6%) in 2010. It is lowest in Okinawa-ken(17.4%), resulting in the 12.2 points difference. The range in the rate of age 65 and above becomes wider at municipality level. Among 1,858 municipalities in Japan, 2010, the highest is 57.3% and the lowest is 9.2%, resulting in the 48.1 points difference. Moreover, there are 8 municipalities with the rate less than 14% while 11 municipalities the rate above 50%. Given these high levels of population aging and its variation, the natural increase in 38 prefectures (80.9%) has already been negative for 2005-10, and the natural increase of 72.9% municipalities has been negative for 2005-10.

---

[1] United Nation, 2012, *World Population Prospects: The 2012 Revision*, United Nations Pubns.: Washington.

[2] National Institute of Population and Social Security Research, Population Projections for Japan(January 2012). Available (as of November 2013) at http://www.ipss.go.jp/site-ad/index_english/esuikei/gh2401e.asp

We conduct a simulation study to evaluate the mortality effects on the accuracy of the population projection that utilizes the cohort component method. Specifically, to assess the forecast errors in death rates, we perform population projections with fixing death rates at past values but fertility and migration rates at current values for a period when population counts were known in population censuses. Then we compare the projected population with the end of period census population. The substantial variations in mortality among Japanese regions provide a source for the assessment of mortality effects enough to derive implications to future population projection for not only Japanese regions but also countries for which population aging and its consequence of population decline are anticipated.

Methodology

The cohort component method (Eq.[1]) for population projection extends the cohort's version of the fundamental equation of demography (Eq.[2]), which is an accounting equation and does not produce a statistical discrepancy if we apply the relationship to census counts, births & deaths and immigrations & emigrations between the censuses upon the accuracy in these statistics. This fact can be seen that we recover the relationship in Eq.[2] by taking the survival and net-migration rates observed for the period: ${}_5S^{CB}_{x,t-5\sim t} = 1 - {}_5D_{x-5,t-5\sim t} / P_{x-5,t-5}$ and ${}_5NMR^{CB}_{x,t} = \left({}_5I_{x-5,t-5\sim t} - {}_5O_{x-5,t-5\sim t}\right) / P_{x-5,t-5}$ (we call true cohort values hereafter).

$$P_{x,t} = P_{x-5,t-5} \cdot \left({}_5S^{CB}_{x,t-5\sim t} + {}_5NMR^{CB}_{x,t-5\sim t}\right) \qquad \text{Eq.[1]}$$

$$P_{x,t} = P_{x-5,t-5} - {}_5D_{x-5,t-5\sim t} + {}_5I_{x-5,t-5\sim t} - {}_5O_{x-5,t-5\sim t} \qquad \text{Eq.[2]}$$

where $P_{x,t}$ denotes census population of age x~x+4 in year t. $\left\{{}_5D_{x-5,t-5\sim t},\ {}_5I_{x-5,t-5\sim t} - {}_5O_{x-5,t-5\sim t}\right\}$ refers to the number of deaths and net-migrations of the cohort whose age is x~x+4 in year t that occurred between censuses of year t-5 and year t, respectively. $\left\{{}_5S^{CB}_{x,t-5\sim t},\ {}_5NMR^{CB}_{x,t-5\sim t}\right\}$ corresponds with some survival and net-migration rates of the cohort assumed for the period for year t-5~ t. Note that $P_{x-5,t-5}$ refers to the number of births between censuses in year t-5 and year t for the cohort of age 0-4 at the end of the period.

Results of population projection differ census counts ex-post solely due to inability to set the true fertility, survival and net-migration rates ex-ante in this framework.

In this presentation, we focus on the role of the survival rate and identify 4 potential sources that cause discrepancy in regional population projections: [1] measurement errors included in lifetable survival rates (compared to true cohort survival rates); [2] measurement errors in net-migration rates calculated with lifetable survival rates; [3] forecast errors for regional differentials in the survival rates; [4] forecast errors for net-migration rates. In practice, deaths by cohorts are not easily obtainable. Instead, period survival rates are often taken from an average, by age and sex, of survival rates of lifetables constructed for the beginning and the end of the year in the period(Smith 2001)[3]. The period survival rates based on two lifetables in general deviate from the true cohort survival rates. This differences cause the 1st type discrepancy even for the period when the true births and net-migrations are available. Additionally, the differences cause errors in the estimation of survival population in the calculation of net-migrations which in turn result in the 2nd type discrepancy.

To assess the size of 4 types of discrepancies, we conduct population projections by distorting one component each time separately with keeping other components at true values. For the 1st type discrepancy, we take lifetable survival rates for 2000-05 to project population toward 2005 based on census population in 2000 with keeping the number births and net-migrants at the true values. Similarly, for the 2nd type discrepancy, we take net-migrations estimated by using lifetable survival rates for 2000-05. For the 3rd type discrepancy, we assume the cohort survival rates of 2000-05 in the projection toward 2010 based on 2005 census population with keeping the number of births and net-migrations at the true values in 2005-10. For the 4th discrepancy, we keep the cohort net-migration rates observed in 2000-05 fixed in the projection toward 2010 based on 2005 census population. The projections are conducted for 1,799 municipalities in Japan.

Results

Table 1 summarizes the distributions of projection errors for 4 types of discrepancies. The percentage projection errors are defined by the projected population (age-sex total of a region) minus the census counterpart per one hundred census population. It is evident that discrepancies of type 1~3 are negligible for most of regions; the projection errors are in the range of -0.6~0.6% in 90% of regions; the maximum/minimum of projection errors of type 3 are 3.1% and -4.3%, respectively. The projection errors are relatively larger in regions with smaller size of population(Figure 1), which seems to be caused by instability in measuring rates in a small size of population. Still, it is remarkable that changes in survival rates by 5 years at most produce projection errors less than 5% even for municipalities with less than 1,000 inhabitants. Contrary, projection errors due to temporal changes in net-migration rates could be significant. Although projection errors of type 4 are in the range of -3.1~5.6% for 90% of regions, the errors caused by changes in net-migration rates by 5 years could be nearly 10% in regions even with population more than 500,000.

Discussions

There are positive correlations between the total size of population and the rate of population age 65 and over among Japanese municipalities. The smaller the population size, the more advanced in population aging. Results for simple regression analysis for projection errors of type 3 on the log of population size and the rate of

[3] Smith, Stanley, 2001, *State and Local Population Projections: Methodology and Analysis*, Springer: New York.

population age 65 and over show that the errors are associated more with smaller population size. Given the regional variation in population aging in Japan, we conclude that population aging does not lead the stronger mortality effect on the accuracy of population projections if the projections are made for a moderate size of population.

One drawback in this approach might be a contamination in the survival rates potentially caused by migrations. If the survival rates of immigrants differ from those of residents, the assumption for the type 4 discrepancy in which migration conditions are kept at the level in the previous period would require to set different survival rates to immigrants than observed in the projection period so that the survival rates for the projection period are necessarily modified. The discussion will be provided in the presentation.

Table 1. The distribution of the percentage projection errors by the type of the discrepancy.

	Type 1: Measurement errors in survival rates due to lifetable survival rates	Type 2: Measurement errors in net-migration rates due to lifetable survival rates	Type 3: Forecast errors in cohort survival rates	Type 4: Forecast errors in net-migration rates
5%	-0.6	-0.6	-0.5	-3.1
25%	-0.1	-0.2	-0.1	-0.1
median of projection errors	0.0	0.0	0.0	1.1
75%	0.2	0.1	0.2	2.6
95%	0.6	0.6	0.7	5.6

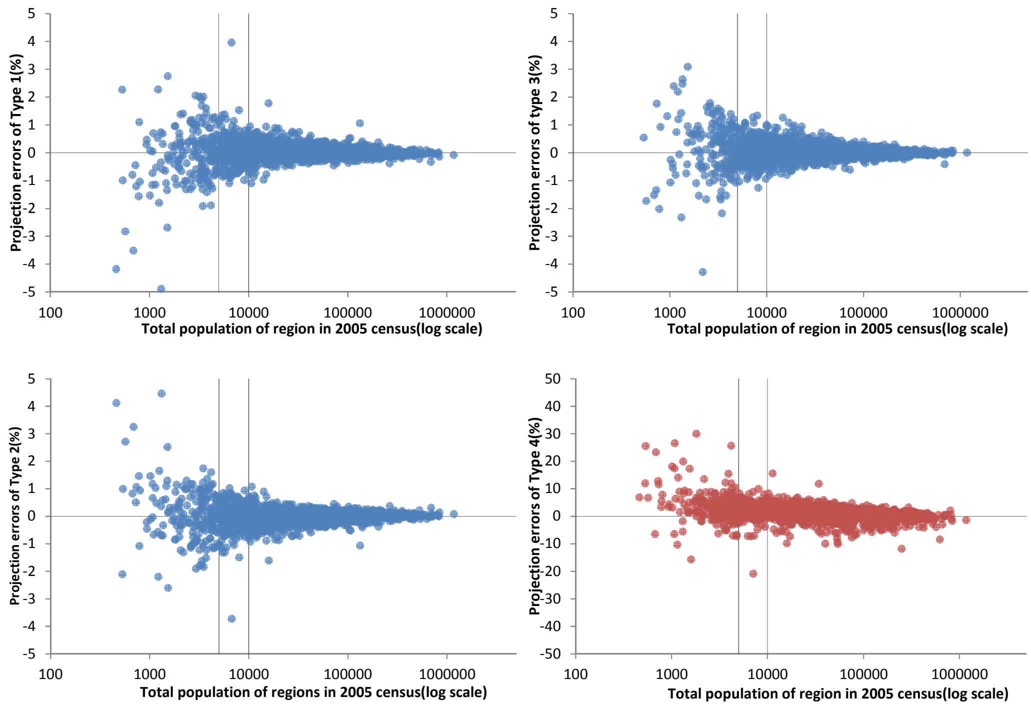

Figure 1. Percentage projection errors by the size of total population of the regions.