Immigration Policy and Demographic Dynamics: Welfare Analysis of an Aging Japan [*]

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Abstract

This paper quantified the effects of immigration policies in an aging and depopulating Japan. Under a constant total number of immigrants, it focused on the optimal period for an immigration policy that maximized the per-capita utility. Simulation results, based on an extended lifecycle simulation model with endogenous fertility, showed that a longer period immigration policy increased the future population and enhanced long-run economic growth. Conversely, a shorter period immigration policy enhanced economic growth in earlier years but less so in the long run. This paper found that an optimal duration for an immigration policy, under the standard parameter settings for Japan, was nine years; this was derived by the reconcilement of merits and demerits between shorter period and longer period immigration policies.

Keywords: Immigration policy; aging population; welfare analysis; dynamic overlapping generations model; simulation analysis.

JEL classification: H30; C68

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1. Introduction

Japan's population is currently aging at an unprecedented speed for a developed nation, and the population is simultaneously decreasing, which has become one of Japan's most important problems. Figure 1 presents old-age dependency ratio projections (defined as a ratio of the population aged 65 or older against that of 20–64) for five advanced countries. The ratio will rise sharply and stay at an elevated level throughout the century. As the figure shows, the speed and magnitude of demographic aging in Japan are remarkable, even compared to other countries that face similar challenges. Thus, the projections of future fertility rates and survival probabilities in Japan indicate a severe reduction in both the total and working-age population. Regarding the problems associated with aging and depopulating societies, increases in childcare allowances are often discussed as one effective countermeasure. Another method for mitigating rapid population decreases in Japan is an enhanced immigration policy.

In reality, advanced countries such as the United States (US) and Germany have accepted many immigrants and have used the immigrant population to maintain the population level or to promote economic growth. As Imrohoroglu et al. (2017) pointed out, however, Japan has been historically insular concerning immigration and has followed insular policies for centuries, relying mainly on native-born workers for economic growth. The annual inflow of immigrants to Japan is currently low; according to data from the United Nations (2021), the stock of immigrants in Japan was only 1.97% of the total population (i.e., 126 million people) in 2019. Conversely, the stock of immigrants in the US was 15.40% of the total population (i.e., 328 million people) in 2019.

During our research, we used the lifecycle general equilibrium simulation model of overlapping generations, developed by Auerbach and Kotlikoff (1983a, 1983b) and similarly applied in Auerbach and Kotlikoff (1987), Seidman (1983), Auerbach et al. (1989), Altig et al. (2001), Homma et al. (1987), Ihori et al. (2006, 2011), Okamoto (2005, 2010, 2013), and so on. Okamoto (2020) extended the simulation model to introduce the number of children freely chosen by households, thus incorporating endogenous fertility and future demographic dynamics.

In 2014, the Japanese government stated that it would consider a guest worker program that would bring 200,000 foreign workers to Japan annually over 10 years, eventually accumulating a total of two million guest workers. To investigate the quantitative effects of an enhanced immigration policy, we extended the simulation model to freely set or choose the numbers and timings of immigrant inflow. Alternative immigration policies have different durations and annual numbers of immigrants. This paper analyzes the quantitative effects that increased immigration to Japan might have on the future population and per-capita household welfare. It specifically focuses on the optimal immigration policy duration, under a constant total number of immigrants (with equally distributed immigrants each year). Here it should be noted that this result is obtained under the current level of government childcare subsidies and under the assumption that the immigrants are completely identical to the Japanese natives.

Regarding government childcare subsidies, in 2014, the Japanese government set a target population of approximately 100 million in 50 years, whereas the population is projected by the National Institute of Population and Social Security Research (2017) to reach only 88 million in 2065. This was the first time in history that the government formally expressed a numerical target for the future population, revealing a sense of impending crisis. To realize the *desired fertility rate of 1.8* the government began devising countermeasures for the falling birth rate. When the subsidies increase, an optimal period for immigration policy may change. Therefore, we will examine the effects of alternative immigration policies in a situation where child allowances increase.

Although our baseline simulation results are obtained under the assumption that the immigrants have completely the same features as the native Japanese, immigrants to Japan tend to have higher fertility, a shorter life expectancy, and lower labor productivity than Japanese natives; these three characteristics of immigrants may change an optimal period for the immigration policy. Therefore, we will evaluate the effects of each atypical characteristic.

Our study also introduces an additional government institution, the Lump Sum Redistribution Authority (LSRA), as shown in Okamoto (2020). Alternative immigration policies generally improve the welfare of some generations but reduce the welfare of others. If combined with redistribution from winning to losing generations, such policies may offer the prospect of *Pareto improvements*. Without implementing intergenerational redistribution, however, potential efficiency gains or losses cannot be estimated. Therefore, like Auerbach and Kotlikoff (1987) and Nishiyama and Smetters (2005), we introduce LSRA as a hypothetical government institution. This distinguishes potential efficiency gains/losses from possible offsetting changes in the welfare of different generations. To isolate pure efficiency gains or losses, we consider simulation cases via LSRA transfers where alternative immigration policies are implemented. The introduction of LSRA transfers enables us to examine policy proposals from a long-term perspective, considering not only the welfare of current generations but of future generations as well, which will allow us to present concrete and useful policy proposals.

The remainder of this paper is organized as follows: Section 2 describes literature related to our study; Section 3 identifies the basic model applied in the simulation analysis; Section 4 explains the method and assumptions of simulation analysis; Section 5 evaluates the simulation findings and discusses policy implications; Section 6 summarizes and concludes.

2. Related Literature

This paper is contributing to the literature on immigration policy; the main literature related to our study is:

Auerbach and Oreopoulos (1999) reconsidered the fiscal impact of immigrants over time, using the technique of generational accounting, and obtained two conclusions. First, whether immigration contributes to (or helps) alleviate fiscal stress depends on the extent to which that stress will be shouldered by future generations. If the entire fiscal imbalance currently estimated for the US is placed on future generations, then the presence of new immigrants reduces the burden to natives. Second, the impact of immigration on fiscal balance is extremely small in relation to the overall size of an imbalance. Therefore, immigration should not be viewed as a major source of an existing imbalance nor as a potential solution to one.

Storesletten (2000) used a general equilibrium model with overlapping generations, calibrated to the US economy, and estimated the long-run fiscal impact of immigrants. Explicitly considering the differences between immigrants and natives, the study argued that a large immigration policy (about 1.6 million annual flow starting in 2000) of high- and medium-skilled immigrants could resolve fiscal problems. It found that the fiscal impact of immigration on the host country was positive, even when taking into account the ages and skill levels of immigrants.

Lee and Miller (2000) analyzed the fiscal impact of immigration and found that 100,000 more immigrants per year would initially raise taxes for nonimmigrants, later reducing them by amounts less than one percent of current tax levels. A higher rate of immigration would benefit OASDI (Old-Age, Survivors, and Disability Insurance), even though many immigrants might have lower education. As with other fiscal impacts, however, the effect was quite small. Their results also suggested that a policy of admitting only highly educated immigrants from young working ages could be highly beneficial fiscally, which was consistent with the findings of Auerbach and Oreopoulos (1999) and Storesletten (2000).

Storesletten (2003) used an accounting model for Sweden and calculated the net public gain of a new immigrant as the discounted value of future tax payments, minus transfers and additional government consumption. Consequently, the study found potential gains to be large, at approximately $20,000 per new immigrant.

Fehr, Jokisch, and Kotlikoff (2004) developed a three-region overlapping generations model for the US, Japan, and European Union, and analyzed whether immigration could mitigate the negative impacts of demographic transition on an economy. Their baseline experiment called for an annual flow of 54,000 immigrants (with the same amount of capital and children as their native-born counterparts), and an alternative of 108,000 only high-skilled immigrants. Their overall conclusion was that there were small welfare effects and that the impact would be "too little too late." In other words, immigration would not alter the major negative impacts of demographic transition, regardless of the immigrants' skill levels.

Our paper is contributing especially to the literature on immigration policy in Japan, as few previous studies analyzed the quantitative effects of immigration policy for Japan. Both Shimasawa and Oguro (2010) and Imrohoroglu et al. (2017) investigated using a lifecycle dynamic simulation model with overlapping generations, revealing that more immigrants or high-skilled guest workers would benefit the Japanese economy and that even more immigrants were needed to improve the fiscal balance of the government.

Shimasawa and Oguro (2010) used a 16-country/region overlapping generations model in which immigrants could not be distinguished from natives upon entry. Based on this assumption, like Fehr, Jokisch, and Kotlikoff (2004) and other studies, immigrants' labor productivity was the same as their native counterparts, and they were eligible for pensions and public health insurance. Their baseline immigration policy brought 150,000 immigrants annually, and the foreign-born population eventually reached 37% of the Japanese population by 2100. Despite this large immigrant population, the fiscal burden was hardly mitigated. The debt to GDP ratio by 2050 was 699%, while it was 719% under the baseline case without immigration. When the consumption tax rate was raised to 30% under this high immigration assumption, the gains were much larger, and the debt to GDP ratio also declined to 234% in 2050. Therefore, Shimasawa and Oguro (2010) concluded that immigration policy alone could not alleviate the fiscal burden.

Imrohoroglu et al. (2017) also developed a quantitative overlapping generations model and analyzed the impact of guest worker programs in Japan. Against a baseline general equilibrium transition where fiscal sustainability was attained by the consumption tax, the study computed alternative transitions with guest worker programs. Their results revealed that, with a relatively manageable increase in the consumption tax, these programs could mitigate Japan's fiscal imbalance problem; however, this was dependent on the size and skill distribution of guest workers.

Unlike the two studies above, we focus primarily on studying an optimal period for the immigration policy (with equally distributed immigrants each year) under a constant total of two million immigrants. Additionally, we consider the characteristics of immigrants that differ from Japanese natives, such as their higher fertility, their shorter life expectancy, or their lower labor productivity, and what effects these differences can have.

3. Theoretical Framework

We calibrate the simulation of the Japanese economy by applying population data from 2017, estimated by the National Institute of Population and Social Security Research. The model includes 106 overlapping generations, corresponding to ages 0–105 years old. Three types of agents are incorporated: households, firms, and the government. The following subsections describe the basic structures of households, firms, and the government, as well as the market equilibrium conditions.

3.1. Household behavior

The economy is populated by 106 overlapping generations that live with uncertainty, corresponding to ages 0–105. Each agent is assumed to consist of a neutral individual because our model does not distinguish by gender. Each agent enters the economy as a decision-making unit and starts to work at age 21 years, and lives to a maximum age of 105 years. Each household is assumed to consist of one adult and its children. The children aged 0–20 only consume, involving childrearing costs for their parent. Each household faces an age-dependent probability of death. Let $q^t_{j+1|j}$ be the conditional probability that a household born in year t lives from age j to $j+1$. Then the probability of a household born in year t, surviving until s can be expressed by

$$p^t_s = \prod_{j=21}^{s-1} q^t_{j+1|j} \,. \qquad (1)$$

The probability $q^t_{j+1|j}$ is calculated from data estimated by the National Institute of Population and Social Security Research (2017). Since the survival probability is different among agents with different birth year, agents born in different years have the different utility function.

Each agent who begins its economic life at age 21 chooses perfect-foresight consumption paths (C^t_s), leisure paths (l^t_s), and the number of born children (n^t_s) to maximize a time-separable utility function of the form:

$$U^t = \frac{1}{1-\frac{1}{\gamma}}\left[\alpha\sum_{s=21}^{40} p^t_s(1+\delta)^{-(s-21)}\left(n^t_s\right)^{1-\frac{1}{\gamma}} + (1-\alpha)\sum_{s=21}^{105} p^t_s(1+\delta)^{-(s-21)}\left\{\left(C^t_s\right)^{\phi}\left(l^t_s\right)^{1-\phi}\right\}^{1-\frac{1}{\gamma}}\right]. \qquad (2)$$

This utility function represents the lifetime utility of the agent born in year t. C^t_s, l^t_s, and n^t_s are respectively consumption, leisure, and the number of children to bear (only in the age 21–40) for an agent born in year t, of age s; α is the utility weight of the number of children relative to the consumption–leisure composite, γ is the intertemporal elasticity of substitution, δ is the adjustment coefficient for discounting the future, and ϕ is the consumption share parameter to leisure.

As shown in Okamoto (2020), fertility choice in the model is only based on the direct utility that households obtain from their offspring, neglecting the investment element of children. The demand for children as *investment goods* played an important role in traditional economies (and still does in developing countries), where transfers from the young to the old arise within the family. In modern advanced countries, however, a pay-as-you-go (PAYG) social security scheme makes the investment aspect of children socialized, as Groezen et al. (2003) pointed out. This creates the possibility for households to free-ride on the scheme by rearing fewer or no children, still being entitled to a full pension benefit. Therefore, we treat children as “consumption goods,” and a parent is assumed to obtain the utility from the number of children born at each age of 21–40.

Letting A_s^t be capital holdings for the agent born in year t, of age s, maximization of Equation (2) is subject to a lifetime budget constraint defined by the sequence:

$$A_{s+1}^t = \{1 + r_{t+s}(1-\tau^r)\} A_s^t + (1 - \tau^w - \tau_{t+s}^p) w_{t+s} e_s \{1 - l_s^t - tc_s^t(n_s^t)\} + a_s^t - or_s^t$$
$$+ b_s^t(\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE}) - (1 + \tau_{t+s}^c) C_s^t - (1 + \tau_{t+s}^c) \Phi_s^t, \qquad (3)$$

where r_t is the pretax return to savings, and w_t is the real wage at time t; τ^w, τ^r, and τ_t^c are the tax rates on labor income, capital income, and consumption, respectively. τ_t^p is the contribution rate to the public pension scheme at time t. All taxes and contributions are collected at the household level. $tc(n)$ is the time cost for childrearing. a is the bequest to be inherited, and or is the childrearing cost for orphans. There are no liquidity constraints, and thus the assets A_s can be negative. Terminal wealth must be zero. An individual's earnings ability e_s is an exogenous function of age.

The public pension program is assumed to be a PAYG scheme similar to the current Japanese system. The pension benefit is assumed to comprise an earnings-related pension:

$$b_s^t(\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE}) = \begin{cases} \theta H^t(\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE}) & (s \geq ST) \\ 0 & (s < ST) \end{cases}, \qquad (4)$$

where

$$H^t(\{1 - l_s^t - tc_s^t(n_s^t)\}_{s=21}^{RE}) = \frac{1}{RE - 20} \sum_{s=21}^{RE} w_{t+s} e_s (1 - l_s^t - tc_s^t(n_u^t)). \qquad (5)$$

The age at which a household born in year t starts to receive the public pension benefit is ST, the average annual labor income for the calculation of pension benefit for each agent is $H^t(\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE})$, and the weight coefficient of the part proportional to H^t is θ. The symbol $b_s^t(\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE})$ signifies that the amount of public pension benefit is a function of the age profile of labor supply, $\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE}$.

A parent is assumed to bear children with the upper limit of 40 years old, and expend for them until they become independent of their parent, namely, during the period when children are 0–20 years old. Regarding the childrearing costs, the model takes account of both monetary and time costs. The children aged below 21 years old do not conduct an economic activity independently, and childrearing costs for their parent arise until they become independent of their parent. The financial cost for rearing the children, for the parent born in year t and s years old, is represented by

$$\Phi_s^t = \begin{cases} \sum_{k=21}^{s} \xi^t (1-\rho_{t+s}) n_k^t & (s = 21, 22, \cdots, 40) \\ \sum_{k=s-20}^{40} \xi^t (1-\rho_{t+s}) n_k^t & (s = 41, 42, \cdots, 60) \end{cases}, \quad (6)$$

$$\Phi_s^t = 0 \quad (s = 61, 62, \cdots, 105), \quad (7)$$

$$\xi^t = \beta NW^t, \quad (8)$$

where ξ^t is the childrearing cost for the parent born in year t, ρ is the rate of government subsidy (including child allowances) to childrearing costs, and β is the ratio of childrearing costs to the net lifetime income, NW^t, of the parent born in year t.

The number of children affects the available time endowment for a parent, because of the time required for childrearing. The time cost for rearing the children for the parent born in year t, of age s, is represented by

$$tc_s^t = \mu n_s^t, \quad (9)$$

where μ is the parameter that shows the relation between the number of children and the time required for childrearing, which is assumed to be proportional to the number of born children.

The model contains accidental bequests that result from uncertainty over length of life. The bequests, which comprise assets previously held by deceased households, are distributed equally among all surviving households at time t. When BQ_t is the sum of bequests inherited by households at time t, the bequest to be inherited by each household is defined by

$$a_s^t = \frac{(1-\tau^h) BQ_{t+s}}{E_{t+s}}, \quad (10)$$

where

$$BQ_t = \sum_{s=21}^{105} (N_s^{t-s-1} - N_{s+1}^{t-s-1}) A_{s+1}^{t-s-1}, \quad (11)$$

τ^h is the tax rate on inheritances of bequests. The amount of inheritances received is linked to the age profile of assets for each household. E_t is the number of the households conducting an economic activity independently, aged 21 and older. The number of the generation born in year t, of age s, is represented by

$$N_s^t = p_s^t N_0^t, \quad (12)$$

Total childrearing cost of the orphans, who are inevitably generated as a consequence of parents' uncertainty over length of life, is distributed equally among all surviving households at time t. When OR_t is the sum of childrearing costs incurred by households with age s years at time t, the childrearing cost for orphans for each household is defined by

$$or_s^t = \frac{OR_{t+s}}{E_{t+s}}, \tag{13}$$

where

$$OR_t = \sum_{s=21}^{60} (N_{s-1}^{t-s} - N_s^{t-s}) \Phi_s^{t-s}. \tag{14}$$

Therefore, the net amount of bequests is represented as $a - or$. When we consider the utility maximization problem over time for each agent, besides the flow budget constraint represented by Equation (3), the following constraint is imposed:

$$\begin{cases} 0 \le l_s^t \le 1 - tc_s^t(n_s^t) & (21 \le s \le RE) \\ l_s^t = 1 & (RE + 1 \le s \le 105) \end{cases}. \tag{15}$$

This is a constraint that labor supply is nonnegative, and that each household inevitably retires after passing the compulsory retirement age, RE.

Let us consider the case where each agent maximizes expected lifetime utility under two constraints. Each individual maximizes Equation (2) subject to Equations (3) and (15) (see Appendix A for further details). From the utility maximization problem, the equation expressing the evolution of the number of children over time for each individual is characterized by

$$W_s^t = \left(\frac{p_{s-1}^t}{p_s^t} \right) \left[\frac{1+\delta}{1 + r_{t+s}(1-\tau^r)} \right] W_{s-1}^t, \tag{16}$$

$$W_s^t = \frac{\alpha k^{1-\frac{1}{\gamma}} (n_s^t)^{-\frac{1}{\gamma}}}{(1+\tau_{t+s}^c) \sum_{g=0}^{20} \Omega_{s,g}^t \xi^t (1-\rho_{t+s})}, \tag{17}$$

where $\Omega_{s,0}^t = 1$ for $g = 0$, $\Omega_{s,g}^t = \left(\prod_{k=1}^{g} \{1 + r_{t+s-1+k}(1-\tau^r)\} \right)^{-1}$ for $g = 1, 2, \cdots, 20$.

Similarly, that for the consumption–leisure composite is represented by

$$V_s^t = \left(\frac{p_{s-1}^t}{p_s^t} \right) \left[\frac{1+\delta}{1+r_{t+s}(1-\tau^r)} \right] V_{s-1}^t, \tag{18}$$

$$V_s^t = \frac{(1-\alpha)\left\{ (C_s^t)^{\phi} (l_s^t)^{1-\phi} \right\}^{-\frac{1}{\gamma}} \phi (C_s^t)^{\phi-1} (l_s^t)^{1-\phi}}{1+\tau_t^c}. \tag{19}$$

3.2 Firm behavior

The model has a single production sector that is assumed to behave competitively using capital and labor, subject to a constant-returns-to-scale production function. Capital is homogeneous and depreciating, while labor differs only in efficiency. All forms of labor are perfectly substitutable. Households with different ages, however, supply different amounts of some standard measure per unit of labor input.

The aggregate production technology is the standard Cobb-Douglas form:

$$Y_t = K_t^{\varepsilon} L_t^{1-\varepsilon}, \tag{20}$$

where Y_t is aggregate output (national income), K_t is aggregate capital, L_t is aggregate labor supply measured by the efficiency units, and ε is capital's share in production. Using the property subject to a constant-returns-to-scale production function, we can obtain the following equation:

$$Y_t = (r_t + \delta^k) K_t + w_t L_t, \tag{21}$$

where δ^k is the depreciation rate.

3.3 Government behavior

As shown in Okamoto (2020), at each time t, the government collects tax revenues and issues debt (D_{t+1}) that it uses to finance government purchases of goods and services (G_t) and interest payments on the inherited stock of debt (D_t). The government sector consists of a narrow government sector and a pension sector, and a portion of revenues is transferred to the public pension sector. Pension account expenditure is financed by both contributions and a transfer from the general account.

The budget constraint of the narrower government sector at time t is given by

$$D_{t+1} = (1+r_t) D_t + G_t - T_t, \tag{22}$$

where G_t is total government spending on goods and services, T_t is total tax revenue from labor income, capital income, consumption and inheritances, and D_t is the net government debt at the beginning of year t . D_t is gross public debt minus the accumulated pension fund because the model abstracts the public pension fund, which is represented as a ratio to national income:

$$D_t = dY_t , \tag{23}$$

where d is the ratio of net public debt to national income.

The public pension system is assumed to be a simple PAYG style and consists of earnings-related pension. The budget constraint of pension sector at time t is represented by

$$R_t = (1-\pi)B_t , \tag{24}$$

where R_t is total revenue from contributions to the pension program, B_t is total spending on the pension benefit to generations of age ST and above, and π is the ratio of the part financed by the tax transfer from the general account.

The total government spending on goods and service is defined by

$$G_t = gY_t + \pi B_t + GS_t , \tag{25}$$

where G_t includes transfers to the public pension sector (πB_t) and the government subsidies to childrearing (GS_t). The government spending except for the transfers and the subsidies is gY_t , which is assumed to be represented as a constant ratio (g) of national income. The spending is assumed to either generate no utility to households or enter household utility functions in a separable fashion.

The total amount of government subsidy (including child allowances) to the childrearing cost in year t is GS_t :

$$GS_t = \rho_t \sum_{s=21}^{60} (RC_{s,t}^a + RC_{s,t}^b) , \tag{26}$$

$$\begin{cases} RC_{s,t}^a = \sum_{k=21}^{s} N_k^{t-s} \xi^{t-s} n_k^{t-s} & (s = 21, 22, \cdots, 40) \\ RC_{s,t}^b = \sum_{k=s-20}^{40} N_k^{t-s} \xi^{t-s} n_k^{t-s} & (s = 41, 42, \cdots, 60) \end{cases} , \tag{27}$$

where RC_t^a and RC_t^b are costs for childrearing when the parent's age is 21–60 years old. Once the parent become 61 years old, the cost does not exist because all children are independent. N_s^t is the number of the generation with age s years born in year t .

The total spending on the pension benefit to generations of age ST and above is represented by

$$B_t = \sum_{s=ST}^{105} N_s^{t-s} b_s^{t-s} . \tag{28}$$

The total revenue from pension contributions and the total tax revenue are represented by

$$R_t = \tau^p w_t L_t , \tag{29}$$

$$T_t = \tau^w w_t L_t + \tau^r r_t AS_t + \tau_t^c AC_t + \tau^h BQ_t . \tag{30}$$

Aggregate assets supplied by households, AS_t, and aggregate consumption, AC_t, are given by

$$AS_t = \sum_{s=21}^{105} N_s^{t-s} A_s^{t-s} , \tag{31}$$

$$AC_t = \sum_{s=21}^{105} N_s^{t-s} C_s^{t-s} + \sum_{s=21}^{60} (RC_{s,t}^a + RC_{s,t}^b) , \tag{32}$$

where aggregate consumption consists of adult's consumption (at age 21–105 years old) and children's consumption or cost (at age 0–20 years old).

Total population (i.e., the population aged 0–105), the population aged 21–105 (i.e., independents financially), and the population aged 65–105 (i.e., retirees) in year t are respectively represented by

$$Z_t = \sum_{k=0}^{105} \sum_{i=21}^{40} N_i^{t-k-i} p_k^{t-k} n_i^{t-k-i} , \tag{33}$$

$$E_t = \sum_{k=21}^{105} \sum_{i=21}^{40} N_i^{t-k-i} p_k^{t-k} n_i^{t-k-i} , \tag{34}$$

$$O_t = \sum_{k=65}^{105} \sum_{i=21}^{40} N_i^{t-k-i} p_k^{t-k} n_i^{t-k-i} . \tag{35}$$

The aging rate (i.e., the old-age dependency ratio), the ratio of the population aged 65 and over to the total population, is given by O_t / Z_t.

3.4. Market Equilibrium

Finally, equilibrium conditions for the capital, labor, and goods markets are described below:

3.4.1. Equilibrium condition for the capital market

Because aggregate assets supplied by households equal the sum of real capital and net government debt,

$$AS_t = K_t + D_t . \tag{36}$$

3.4.2. Equilibrium condition for the labor market

Measured in efficiency units, because aggregate labor demand by firms equals aggregate labor supply by households,

$$L_t = \sum_{s=21}^{RE} N_s^{t-s} e_s \{1 - l_s^{t-s} - tc_s^t(n_s^t)\}. \quad (37)$$

3.4.3. Equilibrium condition for the goods market

Because aggregate production equals the sum of private consumption, private investment, and government expenditure,

$$Y_t = AC_t + \{K_{t+1} - (1-\delta^k)K_t\} + gY_t. \quad (38)$$

An iterative program is performed to obtain the equilibrium values of the above equations.

4. Simulation Analysis

4.1. Method

The simulation model presented in the previous section is solved, given the assumption that households fundamentally have perfect foresight and correctly anticipate interest, wages, the tax and contribution rates, and other factors. If the tax and social security systems and other elements are determined, then the model can be solved using the Gauss–Seidel method [see Auerbach and Kotlikoff (1987) and Heer and Maußner (2005) for the computation process].

Our study assumes the transitional economy of Japan from the initial steady state in 2015 to the final steady state in 2300. Alternative scenarios on the immigration policy are assumed to be announced at the end of 2015. For simplicity, 2015 is set as the starting year, and we simulate the demography and the economy in the following years. For the generations that were alive in 2015 and have survived in 2016, their formation of future expectations is needed to pay attention to. In 2016, these generations realized that their previous expectations no longer apply and thus again maximize their remaining lifetime utility given perfect foresight. Based on the ex-post age profiles of the number of children to bear, consumption, and leisure for these generations, we calculated their lifetime utility at 21 years.

The LSRA first transfers to each household affected by alternative immigration policies just enough resources (possibly a negative amount) to return its expected remaining lifetime utility back to its pre-change level in the benchmark simulation. For each household that is alive when the policy is announced at the end of 2015, at its age in 2016, the LSRA makes a lump-sum transfer, to return its expected remaining lifetime utility back to its pre-change utility level. For each household that enters the economy after a change (from 2016 onward), at its age of 21 years, it makes a lump-sum transfer, to return its expected entire lifetime utility back to its pre-change level.

Note that the net present value of these transfers in 2016 across living and future households will generally not sum to 0. Thus, the LSRA makes an additional lump-sum transfer to each household so that the net present value across all transfers is 0. To illustrate, we assume that these additional transfers are uniform across all future generations. If the transfer is positive, then the change has produced extra resources after the expected remaining lifetime utility of each household has been restored to its pre-change level. In this case, we can interpret that the change has created efficiency gains, i.e., *Pareto improvements*. Conversely, if the transfer is negative, then the change has generated efficiency losses. Thus, the total net present value of all lump-sum transfers to current and future generations sums to 0 in 2016, satisfying the LSRA budget constraint (see Appendix B in Nishiyama and Smetters (2005) for further details).

4.2. Simulation cases

This study considers scenarios with different immigration policies in Japan, as well as additional cases in which LSRA transfers are introduced in alternative immigration policy cases. The following simulation cases are investigated:

4.2.1. Baseline simulation

The benchmark case simulates the standard transition of the Japanese economy from 2015 to 2300, in which no immigration policy is assumed in order to isolate the effect of alternative immigration policies.

4.2.2. Immigration policy proposals

In 2014, the Japanese government mentioned an immigration policy that brought 0.2 million immigrants annually for 10 years, for a total of two million immigrants. With a constant total of two million immigrants, we considered the four immigration policy proposals with different durations. Table 1 shows alternative scenarios with different periods, namely 1, 10, 20, and 30 years, respectively. All policy proposals started in 2016 but ended in different years, which meant different durations. In each immigration policy case, immigrants were equally distributed each year. We assumed that immigrants could not be distinguished from natives upon entry and were completely identical to the Japanese natives. Therefore, the labor productivity was the same as the native counterparts, and the immigrants were also eligible for pensions.

4.2.3. Cases with LSRA transfers

We regarded the period in which the individual welfare gain was maximized as an optimal duration for the immigrant policy. To distinguish potential efficiency gains/losses from possibly offsetting changes in the welfare of different generations, we introduced the LSRA into the alternative simulation scenarios with different immigration policies. The LSRA transfers produced a leveled and common welfare gain/loss for each household.

4.2.4. Immigration policy with increased government child subsidies

In 2014 the Japanese government set a target population of approximately 100 million in 50 years and, as such, may increase the subsidy to childcare allowances. Therefore, we evaluated alternative immigration policies with increased government child subsidies. First, we briefly examined the effects of increases in the ratio of government subsidies to the overall cost of childrearing, assuming the ratio in the baseline simulation to be 10% ($\rho = 0.1$). From 2016 onward, the ratio ρ was increased from 0.1 to 0.2, 0.3, 0.4, and 0.5, respectively, for each case. In a situation where the subsidies were increased, an optimal duration for the immigration policy was investigated. When the ratio ρ was increased, a leveled welfare gain for each household was calculated using the LSRA method, and an optimal duration for the immigration policy was derived.

Additionally, we considered the combination of increased government childcare subsidies and immigration policy. We assessed the effects of an immigration policy that brought all immigrants at one time in 2016, in a situation where the subsidies rate to the childrearing cost was 0.5 ($\rho = 0.5$).

4.2.5. Immigrants with characteristics that differ from Japanese natives

In the above simulation, the immigrants were assumed to be completely identical to the Japanese natives and could not be distinguished from natives upon entry. In reality, however, the immigrants were likely to have higher fertility rates, shorter life expectancies, and/or lower labor productivity. Therefore, we additionally considered an immigrant policy case and evaluated an optimal duration for the immigrant policy with consideration to each of these three characteristics.

4.2.6. Delayed immigration policy reforms

Furthermore, we also considered scenarios in which the immigration policy bringing all immigrants at one time was implemented; in the baseline simulation, the immigration policy was conducted in 2016, but we considered additional cases in which it was postponed and implemented in 2026 and 2036, respectively.

4.3. Specification of the parameters

We chose realistic parameter values for the Japanese economy based on the literature (Nishiyama and Smetters, 2005; Oguro et al., 2011; Imrohoroglu et al., 2017; Kitao and Mikoshiba, 2020). Table 2 displays the parameter values assigned in the baseline simulation, and the data source used in the calibration. Parameter values were chosen such that the calculated values of the model's endogenous variables approached the actual data values. Table 3 presents the endogenous variables in the 2015 initial steady state. Because the simulation results depend on the model setting and the given parameters, we must be careful about the effects of any parameter changes.

4.3.1. Demography

The old-age dependency ratio, defined as a ratio of the population aged 65 or older against that of 20–64, will rise sharply and stay at an elevated level throughout the century. Figure 1 illustrates projections, based on data from the Organization for Economic Co-operation and Development (OECD; 2017), of the dependency ratio in Japan and several other countries. It demonstrates that the speed and magnitude of demographic aging in Japan are remarkable, even when compared to other countries facing similar challenges.

Next, we describe how we assigned parameter values for childrearing since our simulation model incorporated endogenous fertility. The Cabinet Office (2010) indicated the average annual childrearing costs for a first-born child to annual income for each age. Based on this survey, we assigned the parameter value of β (i.e., the ratio of childrearing costs to parental net lifetime income) such that the ratio of the annual net childrearing costs to annual labor income for the individual was, on average, close to 21.4%. Thus, β was assigned 0.036275.

The OECD (2017) presented public spending on family benefits in cash, services, and tax measures as a percentage of GDP in 2013. For Japan, public spending ratios on family benefits in cash, services, and tax measures to GDP were 0.80%, 0.46%, and 0.23%, respectively.[1] We assigned the value of parameter ρ (government childcare subsidies divided by childrearing cost) to 0.1 in the model, as in Oguro et al. (2011). Consequently, the ratio of total government subsidies to national income was 1.39% in the initial steady state.

Our model incorporated not only the monetary costs of childrearing but also the time costs. Increases in the number of children diminish the parent's available time, because of the time required for childrearing; more children to bear, more time required for childrearing. The parameter determining this relation, μ, was assigned under the simple assumption that one child required 1 h per day for childrearing.[2]

4.3.2. Immigrants

All first-generation immigrants were assumed to enter Japan at age 21[3]and permanently live in Japan. In the baseline simulation, we assumed that the immigrants were identical to the Japanese natives. As the data in Table 4 shows, however, immigrants to Japan were likely to have different characteristics in the three previously discussed respects. We consider these characteristics in additional simulation cases: the first feature is the higher fertility rates of immigrants. Table 4 displays that the (weighted) average total fertility rate was 1.80, which was much higher than that of the Japanese natives (i.e., 1.45 in 2015). The parameter value of preference to children in the utility for the first-generation immigrants was assigned in the additional scenario to produce the target of

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[1] In Japan, the ratio of total family benefits to GDP is only 1.49%, whereas it is, on average, 2.43% for the 33 OECD member countries. Thus, the level of governmental support for childrearing is considerably lower in Japan than in the OECD.

[2] It is difficult to calibrate the value of parameter, μ, which determines the time cost for childrearing in the model. In the 2015 initial steady state, an average number of children to which a parent gives birth at the age 21–40 is 0.0364 per year. We assume that the parent's available time endowment is 16 h per day and that the childrearing time cost for one child is 1 h per day.

[3] According to the data on age distribution for immigration excess number (Figure 3-5-4) in the National Institute of Population and Social Security Research (2017), the age range of immigrants to Japan was roughly 15 to 35, and most immigrants were around age 21 for both males and females. This data showed our assumption that all immigrants entered Japan at age 21 was plausible.

the total fertility rate, namely 1.80, in the 2015 initial steady state.

The second feature is the shorter life expectancy of immigrants. The (weighted) average life expectancy was shorter by approximately 8 years than that of the Japanese natives. As Table 4 shows, it was only 75.81 years for the immigrants, as compared to 83.84 years for the Japanese natives. In the additional scenario, the survival probability for the first-generation immigrants was reduced by a ratio of 75.81/83.84. In Imrohoroglu et al. (2017), the life expectancy of guest workers was assumed to be 70, which was shorter than that in our study. This was primarily because their study used the life expectancy of male workers while our study used an average of males and females.

The third feature is the lower labor productivity of immigrants. In Imrohoroglu et al. (2017), the labor productivity of immigrants was assumed to be half of the native Japanese counterparts for low-skilled workers and the same for high-skilled workers. Because we did not distinguish the two types of workers, we assumed that the first-generation immigrants were 0.75 times as productive as their native Japanese counterparts. Thus, in the additional scenario, the labor endowments of the immigrants were reduced by a ratio of 0.75.

In each additional simulation case, one of the different characteristics for the immigrants was introduced. To reflect the gradual assimilation process of immigrants, the second-generation immigrants (children of the first-generation immigrants) were assumed to take a middle position between the first-generation immigrants and the Japanese natives. Therefore, regarding the three parameters on the preference to children in the utility function (α), survival probabilities (vp_s), and labor productivity (xe_s), the second-generation immigrants had an average parameter value between the first-generation immigrants and the Japanese natives, as shown in Table 6.[4]

4.3.3. Age profile of labor efficiency

The age profile of earning ability was estimated using data from the Basic Survey on Wage Structure (Chingin Sensasu) by the Ministry of Health, Labour and Welfare for the period (2008–2017). For workers, including both males and females, the labor efficiency profile was constructed

[4] Here, we assumed that immigrants to Japan, especially the first-generation immigrants, had the three characteristics: higher fertility, shorter life expectancies, and lower labor productivity; however, in reality, these characteristics may be weakened in the Japanese living environment and culture.

from Japanese data on employment, wages, and monthly work hours.

To estimate the age profile of earnings ability, e_s, the following equation was constructed:

$$Q_t = a_0 + a_1 A_t + a_2 A_t, \tag{39}$$

where Q is the average monthly cash earnings and A is the average age, for both male and female workers. Because bonuses account for a large part of earnings in Japan, Q includes bonuses.

4.3.4. Taxes and expenditures

Tax rates on labor income, capital income, and inheritances were fixed at the current levels (6.5%, 40%, and 10%, respectively) during the entire period. Tax rates on consumption were endogenously determined to satisfy Equations (25) and (30). General government expenditures, except for transfers to the public pension sector (πB_t) and government subsidies to childrearing (GS_t), were proportional to national income (Y_t) as indicated in Equation (25). The ratio of general expenditure to national income, g, was assigned 0.1 such that the endogenous tax rate on consumption was realistic and plausible in the 2015 initial steady state (i.e., 12.16%). The ratio held constant at 0.1 during the entire period.

4.3.5. The public pension system

The public pension program was assumed to be a simple PAYG system similar to the current Japanese system. The benefit was assumed to comprise an earnings-related pension, although Japan's actual public pension system is two-tiered: a basic flat pension and an amount proportional to the average annual labor income for each household. General tax revenue finances half of the flat part, whereas contributions to the pension system fund both the remaining half and the entire proportional part. We assigned the ratio (π) of the part financed by the tax transfer from the general account in Equation (24) as 0.25, taken from Oguro and Takahata (2013). The replacement ratio (θ) for public pension benefits in Equation (4) was equal to 40%, following Braun et al. (2009).

The age at which households start to receive public pension benefits (ST) is constant during the entire period. The compulsory retirement age (RE) is the starting age of public pension benefits (ST) minus 1. Thus, after households retire at the end of the year in which they reach compulsory retirement, they immediately start to receive pension benefits from the beginning of the next year.

4.3.6. Government deficits

To make our simulation feasible, net government debt (D_t) was assumed to be proportional to national income. The value of parameter d, which is the ratio of net public debt to national income as given in Equation (23), was assigned based on data from the Cabinet Office (2017). After 2015, Japan's national income is expected to decrease as the population declines. Therefore, the assumption that net government debt was proportional to national income during the entire period implied that the government would successfully reduce future deficits.

4.3.7. Share parameter on consumption in utility

The value of the consumption share parameter, ϕ, in the utility function was assigned based on Altig et al. (2001). Consequently, in the 2015 initial steady state, an individual devoted, on average, approximately 58% of the available time endowment (of 16 h per day) to labor during their working years (ages 21–64 years).

4.3.8. Technological progress

The technological progress of private production is significant because it greatly influences economic growth. Thus, careful attention should be paid to our assumptions. Technological progress was assumed to be 0 in the simulation, reflecting Japan's experience during the past two or three decades (see Ihori et al., 2006).

5. Simulation Results

The overall results obtained by our simulation analysis revealed that more immigrants generate more preferable outcomes and more productive immigrants bring about more favorable results, as shown in Shimasawa and Oguro (2010) and Imrohoroglu et al. (2017). As the previous studies have suggested, our results showed that a greater number of immigrants enhanced per-capita welfare, indicating that the policy generates favorable economic outcomes. Under the assumption that immigrants are completely identical to the Japanese natives, the optimal duration for an immigration policy leading to a maximization of per-capita welfare was nine years, given a constant total number of immigrants (with equally distributed immigrants each year).

Our simulation results also found that immigration policies with longer terms produced higher economic growth in the long run; however, during the early years, less favorable economic outcomes were identified because of fewer initial annual immigrants. Conversely, if all immigrants entered immediately in a concentrated period, there would be positive outcomes in the early years but less favorable outcomes in the long run. This was because the utility-maximizing behavior of individuals was badly disturbed due to substantial adjustment costs accompanied by sudden and large changes in this immigration policy. The optimal immigration policy duration of nine years, as mentioned, was derived by reconciling merits and demerits between shorter period and longer period immigration policies.

5.1. Baseline simulation

In the baseline scenario, to isolate the effects of immigration policies, no immigration policy was assumed. Figure 2 illustrates the transition of the total population for the benchmark case ($\rho = 0.1$) and the reform cases in which government childcare subsidies were increased ($\rho = 0.2, 0.3, 0.4, 0.5$). As the subsidies were increased, the future population was progressively enhanced.

5.2. Immigration policy proposals

First, we described the simulation results for four experiments on immigration policy, with 1, 10, 20, and 30-year durations, respectively. Figure 3 shows the percent changes in the total population for the four experiments from the benchmark scenario. In the long run, the immigration policy with a 30-year duration created the largest total population, while that with only 1-year duration created the smallest total population. By contrast, for approximately the first 50 years after policy implementation, the immigration policy introducing all immigrants at one time in 2016 brought about the largest total population. Figure 4 illustrates the percent changes in national income for the four experiments from the benchmark case. For approximately the first 50 years, the 1-year immigration policy attained the highest national income, reflecting the transition of total population. In the long run, conversely, the 30-year immigration policy ultimately achieved the highest national income. Figures 5 and 6 present the percent changes in capital stock and labor supply, respectively, for the four experiments.

From the long-term perspective, the 30-year period immigration policy was desirable, as shown in Figure 4. In the long run, the immigration policy attained a 6.5 percent increase from the baseline simulation for total population, capital stock, labor supply, and national income. Conversely, from the short-term perspective, the 1-year-period immigration policy was preferable. Although the 1-year immigration policy temporarily provided a large shock to the economy because of many immigrants at one time, it created the most favorable outcomes on national income for the first 44 years of 2016–2059. From 2060 onward, however, it declined to the worst performance, mainly because the first-generation immigrants would simultaneously retire in 2060.

Therefore, from the short-term perspective, the immigration policy that immediately brought all immigrants at one time in 2016 was desirable. Conversely, from the long-term perspective, the immigration policy that gradually brought fewer annual immigrants for a long period was desirable because this policy generated a larger future population.

Regarding the four scenarios on immigration policy, Figures 5 and 6 illustrate the percent changes in capital stock and labor supply, respectively, from the benchmark case. During approximately the first 50 years, the immigration policy with a 1-year duration attained the highest levels of capital stock and labor supply.[5] Conversely, in the long run, the 30-year immigration policy achieved the highest level at 6.5 percent, reflecting the total population.

Concerning the four scenarios on immigration policy, Figures 7 and 8 show the percent changes in interest rates and wage rates, respectively, from the benchmark scenario. For approximately the first 40 years, the immigration policy that brought all immigrants in 2016 sharply reduced the wage rates because of sudden increases of immigrant workers, rapidly raising the interest rates. This 1-year immigration policy dramatically changed the factor prices and thus the economy. Conversely, the immigration policy proposal with a longer duration, such as 20–30 years, did not disturb the factor prices so sharply.

Regarding the four scenarios on immigration policy, Figures 9 and 10 illustrate the percent changes in consumption tax rates and contribution rates, respectively, from the benchmark case. As Figure 9 shows, these immigration policy proposals fundamentally reduced the tax rates on consumption (roughly speaking, during the period from around 2035 to around 2100) because of the

[5] In the case of the immigration policy that brought all immigrants at one time, just after the reform, the capital stock slightly decreased in a few years. One of possible reasons for this was the assumption that the net government debt was proportional to the national income each year, and thus that a rapid increase of the debt, caused by a sharp increase in national income, decreased the capital stock (see Equation (36)).

promoted economic growth. Because the policies increased workers who were levied on contributions and decreased the dependency ratio between retirees and workers, these immigration policies sharply reduced the contribution rates, as Figure 10 shows.

Figure 11 illustrates the welfare change rates for each generation concerning the above four immigration scenarios. Broadly speaking, throughout the alternative cases, the generations born until around 2050 were made substantially better off, while the generations born from around 2060 to around 2150 are made slightly worse off. Initially, new immigrant workers greatly benefited the Japanese natives; however, after the immigrants retired and pension benefits began, it made the natives slightly worse off for a while.

5.3. Cases with LSRA transfers

The simulation results of cases with LSRA transfers showed that the nine-year immigration policy was desirable from the viewpoint of per-capita welfare. As Table 5 presents, the leveled welfare gain for each individual was approximately 0.854 million yen (approximately 7,000 U.S. dollars in 2015), which is a considerable amount.[6] In terms of efficiency, it is preferable to implement the nine-year-period immigration policy with approximately 0.222 million immigrants annually. One may expect that an immigration policy that immediately brings all immigrants at one time creates favorable outcomes not only in the short term but also in the long term because many immigrants in earlier years lead to more children and more descendants, resulting in a larger total population and more favorable results in the long run. However, this expectation can be wrong and several elements should be considered.

We assumed the initial steady state in 2015. The generations alive in 2015 and into 2016 realized in 2016 that their previous expectations were wrong and again maximized their remaining lifetime utility. The immigration policy that immediately brought all immigrants at one time may severely disturb their utility-maximizing behavior and badly hurt welfare due to sharp, rapid, and unexpected changes and fluctuations. Because there was a large gap between the ex-ante

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[6] The GDP of Japan in 2015 was estimated to be 516.79 trillion yen by the Cabinet Office (2017), and the labor force aged 20–64 years was 57.79 million in 2015, according to data from the Ministry of Internal Affairs and Communications (2017). We calculated the income per worker using these data and also derived the value for national GDP in 2015 in our model, yielding a conversion rate between actual amounts of yen and values in the model. Consequently, in 2015, unity in the model corresponded to 5.1614 million yen.

expectation in the 2015 initial steady state and the ex-post expectation in 2016, the generations could not fully maximize their lifetime utility. This entails large adjustment costs, which may also bring about fewer children to bear.

Also, in the case of immigration policy that immediately brought all immigrants at one time, 44 years later the immigrants would all simultaneously retire because we assumed that they all entered and started to work at age 21 and retired at age 64. All first-generation immigrants retired at one time in 2060, which also gave a substantial negative shock to the economy. The wage rate sharply decreased in 2016, when many immigrants simultaneously enter Japan, and then suddenly jumped in 2060 when they all retired at the same time. This depends mainly on our simple assumption that all immigrants enter Japan at age 21, which may be slightly unrealistic. Conversely, the immigration policy that gradually brought immigrants over a long period could disturb the economy less because of the gradual and smooth changes and fluctuations.

Figures 3 and 4 illustrate that the 30-year immigration policy achieved the highest total population and the highest economic growth in the long run. A reason for this could be that the Japanese population will continue to rapidly decrease, and immigrants in later years take a larger share in the total population. In later years, immigrants would be more valuable and more beneficial to the economy. The above results depend on the fertility rate for the immigrants. If we assume higher fertility for the immigrants, the policy that immediately brought all immigrants at one time could create more favorable results.

In 2014, the Japanese government mentioned an immigration plan to allow 0.2 million immigrants annually for 10 years (a total of two million immigrants). We found that this immigration policy period was very close to the period suggested as an optimal duration in our simulation analysis (nine years), which was robust despite the total number of immigrants (for the total, one to three million immigrants). Note that this result was obtained under the current level of government child subsidies ($\rho = 0.1$) and under the assumption that the immigrants were identical to the Japanese natives with completely identical characteristics. In reality, in 2014 the government declared a concrete numerical goal on the future population. Specific countermeasures for the declining birth rates may be introduced, and government childcare allowances may be actively promoted.

5.4. Immigration policy with increased government child subsidies

Table 5 displays that increases in government childcare allowances reduced the optimal period for immigration policy. Under the current child subsidies (ρ = 0.1) an optimal period for immigration policy was nine years, but six years for ρ = 0.3 and only one year for ρ = 0.5. When the Japanese government increases the subsidies, it would be desirable to simultaneously implement an immigration plan that brings a greater number of immigrants in earlier years. An increase in childcare allowances would promote economic growth in the long run, but just after the increase, there would be a decrease in national income for several years. This is because it takes roughly 20 years for the children, who were newly born due to increases in child subsidies, to become adults and contribute to society.

Therefore, this negative effect could be compensated for by allowing more immigration in earlier years. For example, when ρ is equal to 0.5, the 1-year period for immigration is desirable because it can compensate for the large negative effects of high consumption tax rates, induced by the policy of increases in childcare allowances. There are two ways for maintaining the future population, namely, immigration policy and child allowances, but the two policies have substantially different effects on the economy. The combination of these two policies is desirable because the immigration policy can successfully compensate for the drawbacks of the government child subsidies policy.

Regarding the increased government child subsidies policy (ρ = 0.5), the immigration policy that brought all immigrants at one time in 2016, and their combination cases, Figures 12, 13, and 14 show the changes in national income, capital stock, and labor supply, respectively, from the levels of the benchmark case. Figure 14 illustrates that increases in the child subsidies (ρ = 0.5) decrease the labor supply, mainly because of childrearing time cost, until 2041, after which, the labor supply begins to increase. Consequently, as Figure 12 shows, increases in child allowances reduce the national income until 2022, increasing thereafter. This revealed that a large increase in government child subsidies would be detrimental to the economy during the first several years, thereafter the increase would have a substantial positive effect. As Figure 12 suggests, the immigration policy that brought two million immigrants at one time in 2016 could successfully cover this potential issue with increased childcare subsidies. The policy of increased childcare subsidies alone decreased national income until 2022, whereas the combination policy of the increased subsidies and this immigration plan reduced national income only until 2017.

5.5. Immigrants with characteristics that differ from Japanese natives

The above results were obtained under the assumption that the immigrants had three characteristics in common with the Japanese natives: the preference for children, life expectancies, and labor productivity. However, according to the data in Table 4, which shows details of immigrants to Japan, immigrants were likely to have a stronger preference for children, a shorter life expectancy, and lower labor productivity. The differences in characteristics between the immigrants and the natives brought about different outcomes and thus different optimal duration for the immigration policy. Table 6 presents the parameter values that determined these characteristics for the immigrants, and Table 7 shows that each difference shortens an optimal period for the immigration policy.

First, when a higher fertility characteristic for the immigrants was considered, an optimal duration for the immigration policy became shorter by four years, from nine years to five years (indicated in Table 7). The per-capita welfare obtained through LSRA transfers enhanced from ¥854,000 to ¥986,000, which signified welfare improvement for the Japanese natives. This was because immigrants with higher fertility contributed more to the future population, which had a positive effect on the economy, especially under a PAYG social security system, reducing contribution rates by more young workers.

Second, when shorter life expectancies for the immigrants were considered, the Japanese natives' welfare was improved. This was because the immigrants were more likely to die earlier, taking less public pension benefits than their Japanese counterparts from the government, thereby improving the pension finance. Thus, shorter life expectancies in immigrants generated more favorable outcomes for the Japanese natives. The optimal duration became shorter by two years, from nine years to seven years, as shown in Table 7. The per-capita welfare increased from ¥854,000 to ¥878,000, which meant welfare improvement for the Japanese natives.

Third, when lower productivity characteristics for the immigrants were considered, the

Japanese natives' welfare deteriorated. This was because the impact reduced national income. The optimal duration became shorter by two years, from nine years to seven years, as displayed in Table 7. The per-capita welfare decreased from ¥854,000 to ¥648,000, which signified welfare deterioration for the Japanese natives. This was caused by less labor supply, measured by efficiency units, because labor productivity for the immigrant workers was lower than that in the benchmark scenario.

On the whole, as the government child subsidies increased, or if each of the three characteristics for immigrants (higher fertility, shorter life expectancy, and lower labor productivity) was introduced, the optimal duration for the immigration policy was reduced. If the immigrants were assumed to have higher fertility or a shorter life expectancy, it would benefit the Japanese economy. This was primarily because higher fertility led to a larger future population, which was beneficial to the Japanese natives, especially under a PAYG social security system. A shorter life expectancy meant that the immigrants received fewer pension benefits, resulting in improved pension finance. Conversely, the immigrants' lower labor productivity had a negative influence on the Japanese natives, and made them worse off, damaging economic growth.

Finally, Table 4 shows that the population share of immigrants from the Philippines to Japan is fairly high (10.2%). Filipinos have a high fertility rate (TFR 2.944) and a considerably shorter-than-average life expectancy (68.4 years). Based on the above analysis, it may be beneficial to the Japanese natives to positively increase Filipinos as immigrants to Japan, due to their high fertility rates and short life expectancies.

5.6. Delayed implementation of immigration policy proposals

In the baseline simulation, the immigration policy that brought all immigrants at one time was conducted in 2016. We considered additional cases in which this was conducted in 2026 and 2036, respectively. Although we assumed to immediately start implementing immigration policy proposals, in reality, the implementation will be likely postponed. To analyze the effects of delayed implementation, we simulated the additional cases in 2026 and 2036.

Table 8 reveals that a delay in immigration policy implementation decreased the per-capita welfare through LSRA transfers. As the starting year of the immigration policy was postponed from 2016 to 2026 and 2036, the per-capita welfare gained by the immigration policy decreased from ¥842,000 to ¥777,000 and ¥714,00, respectively. This was mainly because a lower ratio of young workers to retirees will potentially damage the economy and deteriorate individual welfare, especially under a PAYG social security system. Since more immigrants increased this ratio, the immigration policy proposal recommended in this study should be executed as early as possible.

5.7. Sensitivity analysis for the time preference

Furthermore, to examine the effect on an optimal duration for the immigration policy, we conducted a sensitivity analysis for the adjustment coefficient for discounting the future. Table 9 shows that, as the adjustment coefficient for discounting the future, δ, was larger, an optimal duration for the immigration policy grew shorter. The optimal period for the standard value ($\delta = 0.0001$) was nine years. As the value (δ) increased to 0.001, 0.05, and 0.01, it reduced the optimal duration to eight years, four years, and one year, respectively. Thus, if we assumed a higher time preference for individuals, an optimal period for the immigration policy was shorter. This was because, when individuals discounted more the future in their utility function and the present was more important, they preferred more immigrants in earlier years.

6. Conclusions

This study examined the quantitative effects of immigration policies on the future demography and individual welfare in an aging and depopulating Japan. Using an extended lifecycle general equilibrium model with endogenous fertility, it quantified the effects of alternative immigration policy proposals during the period from 2015 to 2300. We focused especially on the optimal duration for the immigration policy under a constant total number of immigrants. Additionally, to evaluate the pure efficiency gains or losses of these policy proposals, we introduced an additional government institution (LSRA) and calculated the per-capita welfare.

Our analysis revealed four main findings:

1. As several previous studies suggested, our simulation results revealed that more immigrants enhanced the per-capita welfare of future generations, increasing the future population. The optimal duration for the immigration policy, in which the per-capita welfare of individuals was

maximized, was nine years under a constant total number of immigrants (with equally distributed immigrants each year). The result had robustness for a total of one to three million immigrants. It should be noted that this result was obtained under the current level of government child subsidies and under the assumption that immigrants had identical characteristics with the Japanese natives.

2. In terms of economic growth in the long run, a longer duration for the immigration policy was desirable. An immigration policy with a longer period ultimately generated a larger total population and higher national income; however, in the early years, just after the immigration policy started, the policy could not bring about favorable outcomes due to fewer annual immigrants. Conversely, the immigration policy that immediately brought all immigrants at one time led to substantially improved performance in the early years, but less so over the long term. Also, this 1-year immigration policy badly disturbed the utility maximization behavior for individuals for sudden and large changes on the economy. Therefore, the above optimal duration of nine years for the immigration policy was led by the reconciling of these two effects working in different directions.
3. As the government childcare subsidies increased, an optimal period for the immigration policy was reduced. If the Japanese government simultaneously implemented these policies (childcare subsidies increases and the immigration proposal), more immigrants were desirable in earlier years. This was because an increase in childcare allowances promoted economic growth in the long run, but, for the years just after the increase, there was a decrease in national income due to the added childrearing costs spanning approximately 20 years. More immigrants in earlier years could successfully compensate for this negative effect on the economy.
4. Immigrants to Japan are likely to have higher fertility, shorter life expectancies, and lower labor productivity than Japanese natives. The introduction of each of these three characteristics for immigrants shortens the optimal duration for an immigration policy. The per-capita welfare gains for the Japanese natives increased when the immigrants had higher fertility or shorter life expectancies. This was because higher fertility contributed more to the future population, which benefited the natives, especially under a PAYG social security system. Additionally, because a shorter life expectancy meant fewer pension benefits received by the immigrants,

improvements were seen in pension finance. Conversely, when the immigrants had lower labor productivity, the welfare gains decreased through damage to the economy.

Appendix A: The Utility Maximization Problem

The utility maximization problem over time for each individual in Section 2 is regarded as the maximization of U^t in Equation (2) subject to Equations (3) and (15). Let the Lagrange function be

$$L^t = U^t + \sum_{s=21}^{105} \lambda_s^t \Big[-A_{s+1}^t + \{1 + r_{t+s}(1-\tau^r)\} A_s^t + [1 - \tau^w - \tau_{t+s}^p] w_{t+s} e_s \{1 - l_s^t - tc_s^t(n_s^t)\} + a_s^t - or_s^t$$

$$+ b_s^t(\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE}) - (1 + \tau_{t+s}^c) C_s^t - (1 + \tau_{t+s}^c)\Phi_s \Big] + \sum_{s=21}^{RE} \eta_s^t \{1 - l_s^t - tc_s^t(n_s^t)\}, \quad \text{(A1)}$$

where λ_s^t and η_s^t represent the Lagrange multiplier for Equations (3) and (15), respectively.

The first-order conditions on the number of children n_s^t, consumption C_s^t, leisure l_s^t, and assets A_{s+1}^t for $s = 21, 22, \ldots, 105$ can be expressed by

$$p_s^t \alpha (1+\delta)^{-(s-21)} (n_s^t)^{-\frac{1}{\gamma}} = \lambda_s^t \left\{ \mu [1 - \tau^w - \tau_{t+s}^p] w_{t+s} e_s + (1 + \tau_t^c) \sum_{g=0}^{20} \Omega_{s,g}^t \xi^t (1 - \rho_{t+s}) \right\}$$

$$+ \mu \sum_{k=ST}^{105} \lambda_k^t \frac{\theta w_{t+s} e_s}{RE - 20} + \mu \eta_s^t, \quad \text{(A2)}$$

where $\Omega_{s,0}^t = 1$ for $g = 0$, $\Omega_{s,g}^t = \left(\prod_{k=1}^{g} \{1 + r_{t+s-1+k}(1-\tau^r)\} \right)^{-1}$ for $g = 1, 2, \cdots, 20$,

$$p_s^t (1-\alpha)(1+\delta)^{-(s-21)} \left\{ (C_s^t)^\phi (l_s^t)^{1-\phi} \right\}^{-\frac{1}{\gamma}} \phi (C_s^t)^{\phi-1} (l_s^t)^{1-\phi} = \lambda_s^t (1 + \tau_{t+s}^c), \quad \text{(A3)}$$

$$p_s^t (1-\alpha)(1+\delta)^{-(s-21)} \left\{ (C_s^t)^\phi (l_s^t)^{1-\phi} \right\}^{-\frac{1}{\gamma}} (1-\phi)(C_s^t)^\phi (l_s^t)^{-\phi}$$

$$= \lambda_s^t \left\{ (1 - \tau^w - \tau_{t+s}^p) w_{t+s} e_s \right\} + \sum_{k=ST}^{105} \lambda_k^t \frac{\theta w_{t+s} e_s}{RE - 20} + \eta_s^t \qquad (s \le RE), \quad \text{(A4)}$$

$$\lambda_s^t = \{1 + r_{t+s}(1-\tau^r)\} \lambda_{s+1}^t, \quad \text{(A5)}$$

$$\eta_s^t \{1 - l_s^t - tc_s^t(n_s^t)\} = 0 \qquad (s \le RE), \quad \text{(A6)}$$

$$1 - l_s^t = 0 \qquad (s > RE), \quad \text{(A7)}$$

$$\eta_s^t \ge 0. \quad \text{(A8)}$$

The combination of Equations (A2) and (A5) produces Equations (16) and (17). If the initial value, n_{21}^t, is given, the initial value, W_{21}^t, can be derived from Equation (17). If the value, W_{21}^t, is specified, the value of each age, W_s^t, can be derived from Equation (16), which generates the value of each age, n_s^t. If the value, n_s^t, is specified, the childrearing cost for lifetime is calculated, which gives the lifetime budget constraint represented by Equation (A10).

The combination of Equations (A3) and (A5) produces Equations (18) and (19). If the initial value, V_{21}^t, is specified, the value of each age, V_s^t, can be derived from Equation (18). If V_s^t is specified, the values of consumption, C_s^t, and leisure, l_s^t, at each age are obtained in the method that follows.

For s = 21, 22, …, *RE*, the combination of Equations (A3) and (A4) yields the following expression:

$$C_s^t = \left[\frac{\phi \left\{ (1-\tau^w - \tau_{t+s}^p) w_{t+s} e_s + \sum_{k=ST}^{105} \frac{\lambda_k^t}{\lambda_s^t} \frac{\theta w_{t+s} e_s}{RE-20} + \frac{\eta_s^t}{\lambda_s^t} \right\}}{(1-\phi)(1+\tau_{t+s}^c)} \right] l_s^t . \tag{A9}$$

If the value of l_s^t is given under $\eta_s^t = 0$, the value of C_s^t can be obtained using a numerical method, and then the value of V_s^t can be derived from Equation (19). The value of l_s^t is chosen so that the value of V_s^t obtained in the simulation is the closest to that calculated by evolution from V_{21}^t through Equation (18). If the value of l_s^t chosen is unity or higher, the value of C_s^t is obtained from Equation (19) under $l_s^t = 1$. If it is less than unity, the value of C_s^t is derived from Equation (A9).

For s = *RE*+1, *RE*+2, …, 105, the condition of l_s^t=1 leads to the following equation:

$$V_s^t = \frac{(1-\alpha)\phi (C_s^t)^{-\frac{\phi}{\gamma}+\phi-1}}{1+\tau_{t+s}^c} . \tag{19}$$

The value of C_s^t is chosen to satisfy this equation.

From Equation (3) and the terminal condition $A_{21}^t = A_{106}^t$=0, the lifetime budget constraint for an individual (=NW^t) is derived:

$$\sum_{s=21}^{RE} \Psi_s^t [1-\tau^w - \tau_{t+s}^p] w_{t+s} e_s \{1 - l_s^t - tc_s^t(n_s^t)\} + \sum_{s=ST}^{105} \Psi_s^t b_s^t (\{1 - l_u^t - tc_u^t(n_u^t)\}_{u=21}^{RE}) + \sum_{s=21}^{105} \Psi_s^t (a_s^t - or_s^t)$$
$$= \sum_{s=21}^{105} \Psi_s^t (1+\tau_{t+s}^c) C_s^t + \sum_{s=21}^{40} \sum_{k=21}^{s} \Psi_s^t (1+\tau_{t+s}^c) \xi^t (1-\rho_{t+s}) n_k^t + \sum_{s=41}^{60} \sum_{k=s-20}^{40} \Psi_s^t (1+\tau_{t+s}^c) \xi^t (1-\rho_{t+s}) n_k^t \tag{A10}$$

where $\Psi_{21}^{t} = 1$ for $s = 21$, $\Psi_{s}^{t} = \left(\prod_{u=22}^{s} \{1 + r_{t+u}(1 - \tau^{r})\} \right)^{-1}$ for $s = 22, 23, \ldots, 105$.

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Table 1 Alternative simulation scenarios on the immigration policy

Duration (years)	Annual immigrants (thousands)
1 (2016)	2,000
10 (2016–2025)	200
20 (2016–2035)	100
30 (2016–2045)	66.66667

Note: Each scenario has a total of two million immigrants.

Table 2 Exogenous variables for the benchmark simulation

Parameter description	Parameter value	Data source
Share parameter for consumption	$\phi = 0.5$	Nishiyama and Smetters (2005): $\phi = 0.47$
Weight parameter of the number of children to the consumption–leisure composite in utility	$\alpha = 0.25$	
Rate of time preference	$\delta = 0.0001$	Oguro et al. (2011): $\delta = 0.01$
Intertemporal substitution elasticity	$\gamma = 0.5$	Imrohoroglu et al. (2017)
Ratio of government subsidies to childrearing costs	$\rho = 0.1$	Oguro et al. (2011): $\rho = 0.1$
Ratio of childrearing costs to net lifetime income	$\beta = 0.036275$	
Time cost for childrearing	$\mu = 1.7234$	
Capital share in production	$\varepsilon = 0.3794$	Imrohoroglu et al. (2017)
Depreciation rate	$\delta^k = 0.0821$	Imrohoroglu et al. (2017)
Tax rate on labor income	$\tau^w = 0.065$	Kato (1998): $\tau^w = 0.065$
Tax rate on capital income	$\tau^r = 0.4$	Hayashi and Prescott (2002): $\tau^r = 0.48$; Imrohoroglu et al. (2017): $\tau^r = 0.35$
Tax rate on inheritance	$\tau^h = 0.1$	Kato (1998)
Ratio of government expenditures to national income	$g = 0.1$	
Ratio of the part financed by tax transfer to total pension benefit	$\pi = 0.25$	Oguro and Takahata (2013)
Replacement ratio for public pension benefits	$\theta = 0.4$	Braun et al. (2009)
Ratio of net public debt to national income	$d = 1.3$	Imrohoroglu et al. (2017)
Compulsory retirement age	$RE = 64$	
Starting age for receiving public pension benefits	$ST = 65$	
Ratio of people aged 21 and above to the total population	$E / Z = 0.81721$	
Dependency ratio (i.e., aging rate)	$O / Z = 0.26647$	

Table 3 Endogenous variables in the 2015 initial steady state

Parameter description	Parameter value
Interest rate, r	0.07240
Wage rate, w	1.07480
Tax rate on consumption, τ^c	0.12157
Contribution rate, τ^p	0.14224
Capital–income ratio, K/Y	2.45559
Total fertility rate (TFR)	1.45001
Ratio of net childrearing costs to annual labor income	0.21180
Ratio of government childcare subsidies to national income, GS/Y	0.01388

Table 4 Origin countries for immigrants to Japan

	Country	TFR	Life expectancy	Share (%)
1	China	1.569	75.986	29.189
2	Korea, Rep.	1.239	82.156	19.015
3	Philippines	2.944	68.407	10.226
4	Vietnam	1.96	75.778	8.393
5	Brazil	1.778	74.676	7.593
6	Nepal	2.167	69.973	2.832
7	United states	1.843	78.741	2.254
8	Rep. of China (Taiwan)	1.12	80.2	2.215
9	Peru	2.427	74.781	2.004
10	Thailand	1.497	74.601	2.000
11	Indonesia	2.437	69.072	1.798
12	Korea, Dem. People's Rep.	1.968	70.338	1.362
13	India	2.395	68.349	1.203
14	Myanmar	2.177	66.042	0.746
15	Sri Lanka	2.062	74.953	0.728
16	United Kingdom	1.81	81.605	0.691
17	Pakistan	3.55	66.377	0.577
18	Bangladesh	2.144	72.001	0.519
19	France	2.01	82.671	0.488
20	Australia	1.833	82.451	0.436
21	Canada	1.6	82.138	0.421
22	Malaysia	1.931	74.875	0.381
23	Cambodia	2.595	68.656	0.351
24	Russian Federation	1.75	70.909	0.349
25	Mongolia	2.638	69.821	0.320
26	Germany	1.5	81.09	0.284
27	Bolivia	2.923	68.74	0.233
28	Turkey	2.052	75.426	0.195
29	Iran, Islamic Rep.	1.685	75.591	0.168
30	Italy	1.37	83.49	0.160
	(Weighted average)	1.803	75.811	97.131

Notes: This is stock data for immigrants in 2016. Japan in 2015: TFR 1.45, Life expectancy 83.844 years.

Table 5 Optimal duration for alternative immigration policies under different levels of government child subsidies

Government child subsidies ratio (ρ)	Optimal period (years)	Welfare gains in yen (thousand)
0.1	9	853.63
0.2	8	2,674.63
0.3	6	4,635.12
0.4	4	6,738.37
0.5	1	9,002.72

Note: The ratio of government subsidy to the total childrearing cost is 0.1 in the benchmark case.

Table 6 Parameter values atypical to immigrants to Japan

	First-generation	Second-generation	Japanese natives
α	0.0729	0.058765	0.04463
ν	0.904186	0.952093	1
x	0.75	0.875	1

α : Preference parameter to children in the utility function
ν : Weight parameter on survival probabilities (νp_s)
x : Weight parameter on labor efficiency (xe_s)

Table 7 Welfare gains for the immigration policy in which immigrants have one of three features different from Japanese natives

	α	ν	x	Optimal period (years)	Welfare gains in yen (thousand)
Benchmark	0.04463	1	1	9	853.63
Higher fertility	**0.0729**	1	1	5	985.52
Lower life expectancies	0.04463	**0.90418**	1	7	877.81
Lower labor productivity	0.04463	1	**0.75**	7	647.57

Note: Parameters (α , ν , x) are described in Table 6, which also presents the parameter values for the second-generation immigrants.

Table 8　Welfare gains for the immigration policy with different timings of implementation

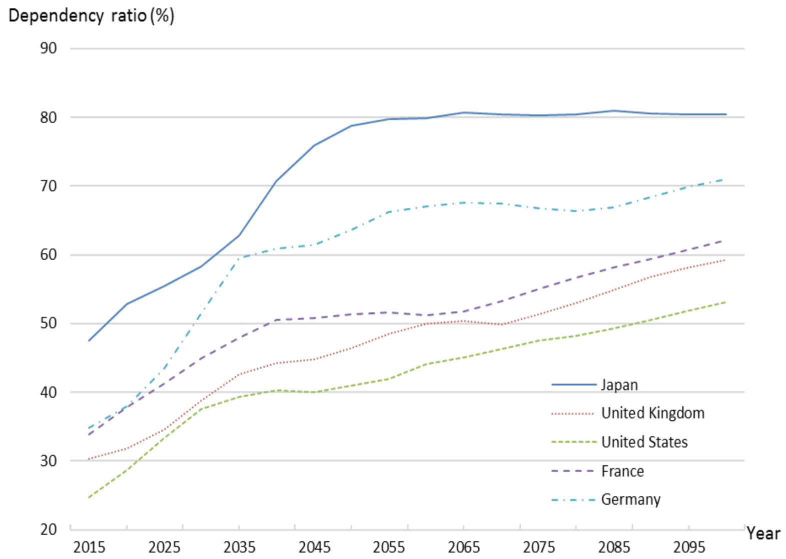
Year of implementation	Welfare gains in yen (thousand)
2016	842.07
2026	776.99
2036	714.07

Note: The results for the simulation case immediately bringing two million immigrants at one time.

Table 9　Welfare gains for the immigration policy under different rates of time preference

δ	α	ν	x	Optimal period (years)	Welfare gains in yen (thousand)
0.0001	0.04463	1	1	9	853.63
0.001	0.04463	1	1	8	824.32
0.005	0.04463	1	1	4	706.73
0.01	0.04463	1	1	1	589.53

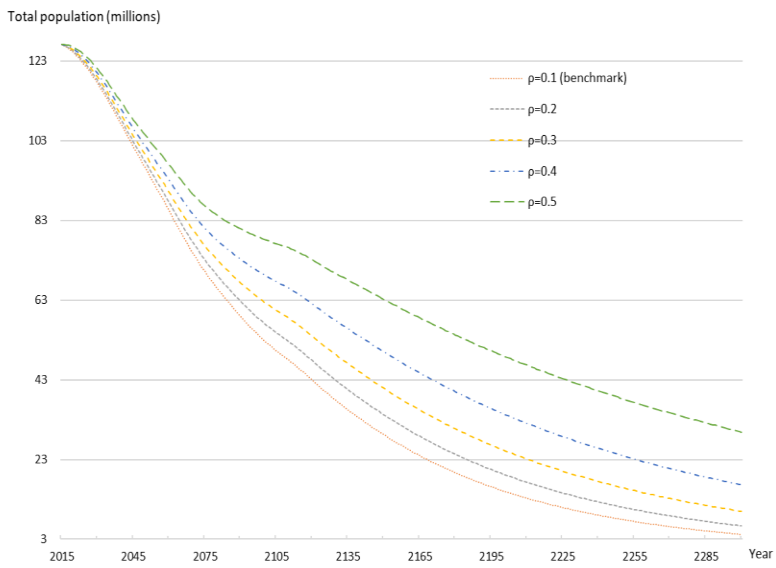
δ : Adjustment coefficient for discounting the future in the utility function
α : Parameter that represents the preference to children in the utility function
ν : Weight parameter on survival probabilities (νp_s)
x : Weight parameter on labor efficiency (xe_s)



Source: OECD (2017)

Note: The dependency ratio denotes the ratio of the people aged 65 or over against that aged 20–64.

Figure 1 Old-age dependency ratio projections for five advanced countries



Notes: The ratio of government childcare subsidies (ρ) is 0.1 in the benchmark case. The ratio is increased to 0.2, 0.3, 0.4, and 0.5 for the alternative cases.

Figure 2 Transition of total population for the benchmark and four cases of increases in government childcare subsidies

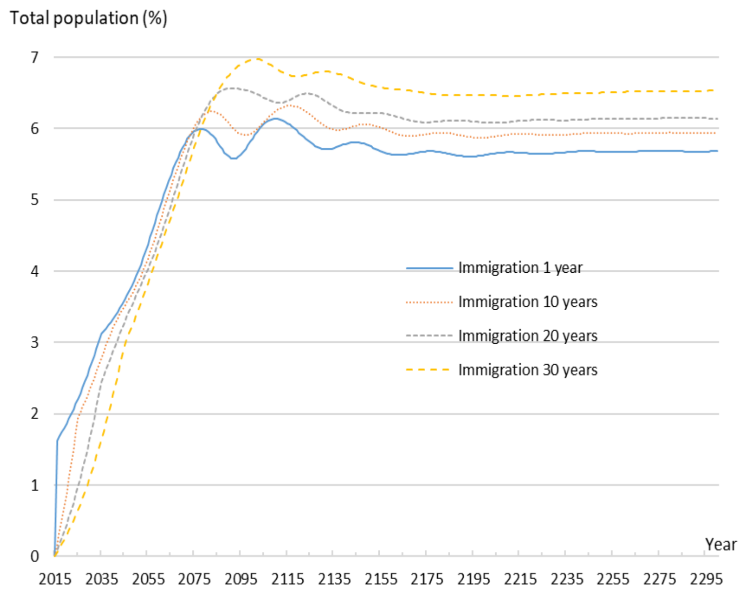


Figure 3 Changes in total population from the benchmark for four immigration policy scenarios

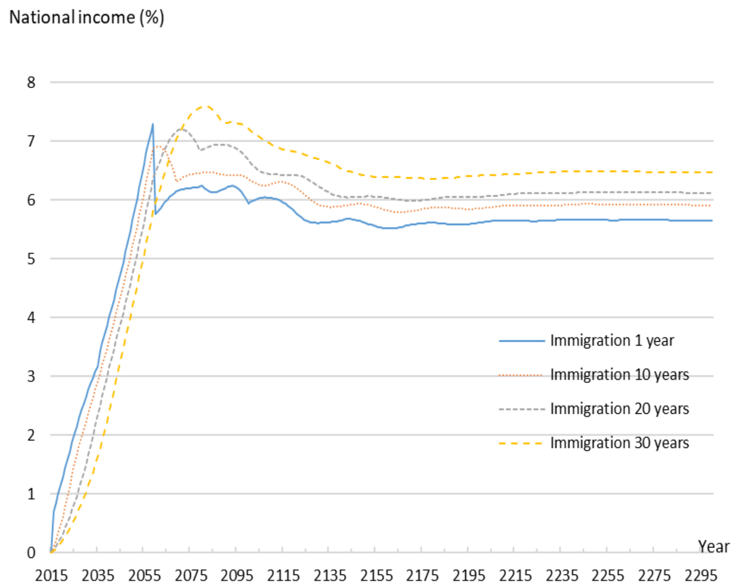


Figure 4 Changes in national income from the benchmark for four immigration policy scenarios

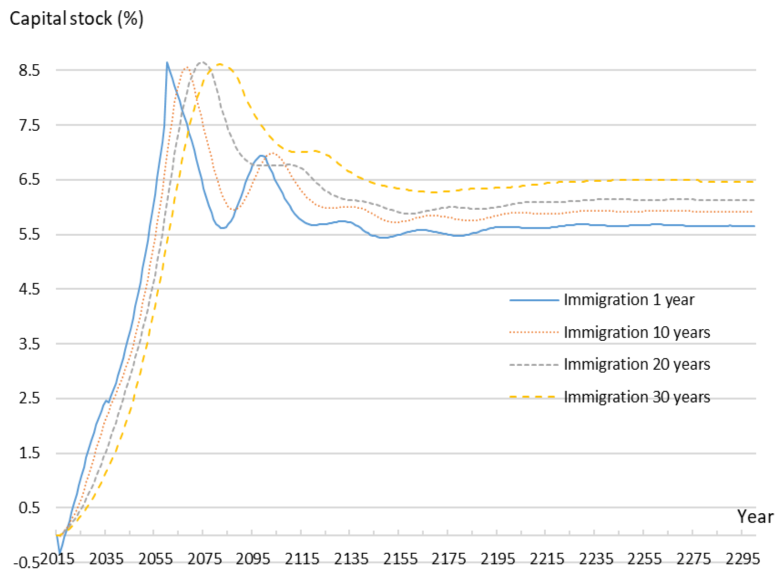


Figure 5 Changes in capital stock from the benchmark for four immigration policy scenarios

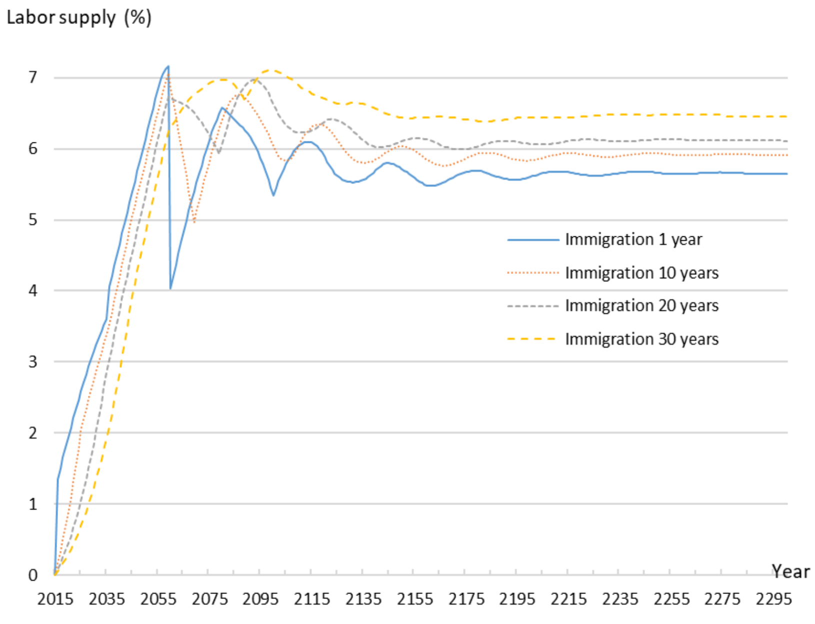


Figure 6 Changes in labor supply from the benchmark for four immigration policy scenarios

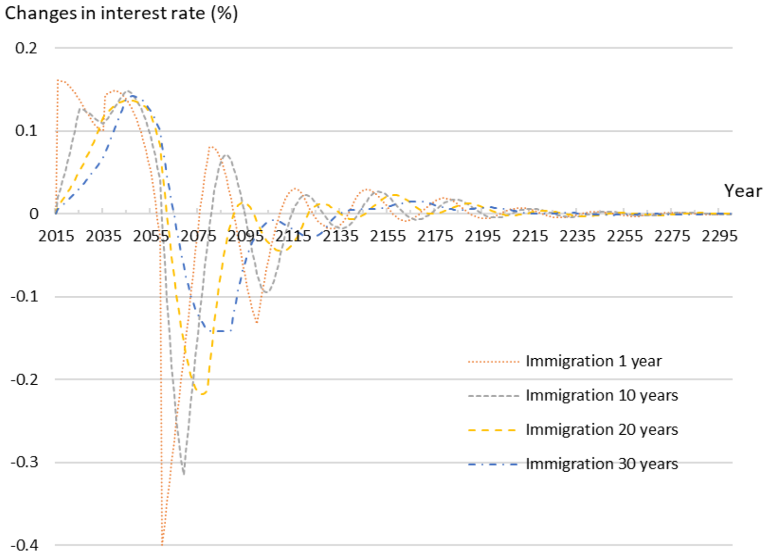


Figure 7 Percentage-point changes in interest rates from the benchmark for four immigration policy scenarios

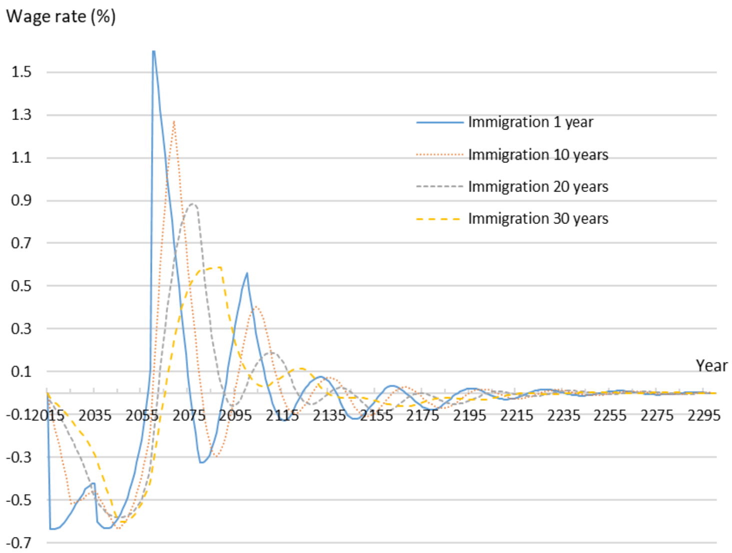


Figure 8 Changes in wage rates from the benchmark for four immigration policy scenarios

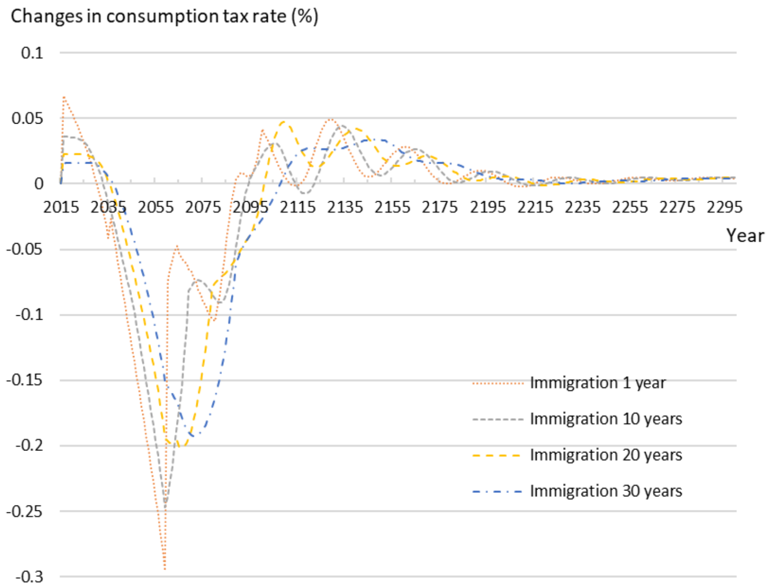


Figure 9 Percentage-point changes in consumption tax rates from the benchmark for four immigration policy scenarios

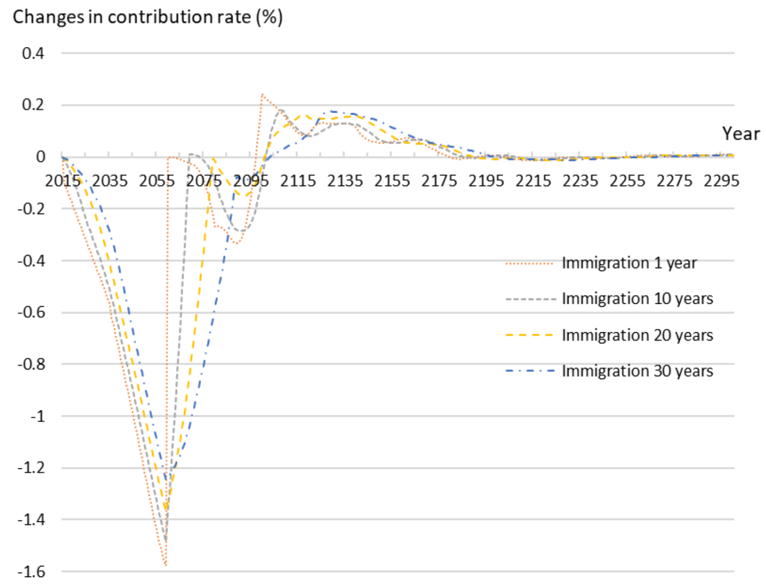


Figure 10 Percentage-point changes in contribution rates from the benchmark for four immigration policy scenarios

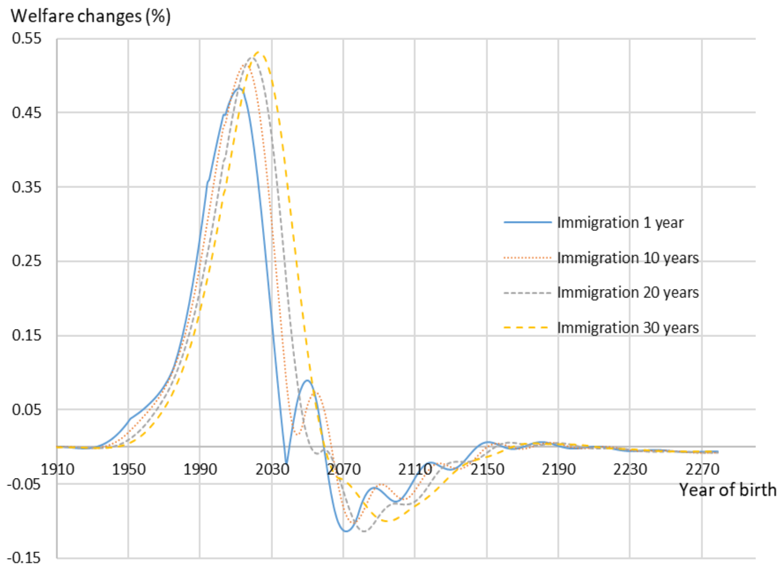


Figure 11 Welfare changes of each generation from the benchmark for four immigration policy scenarios

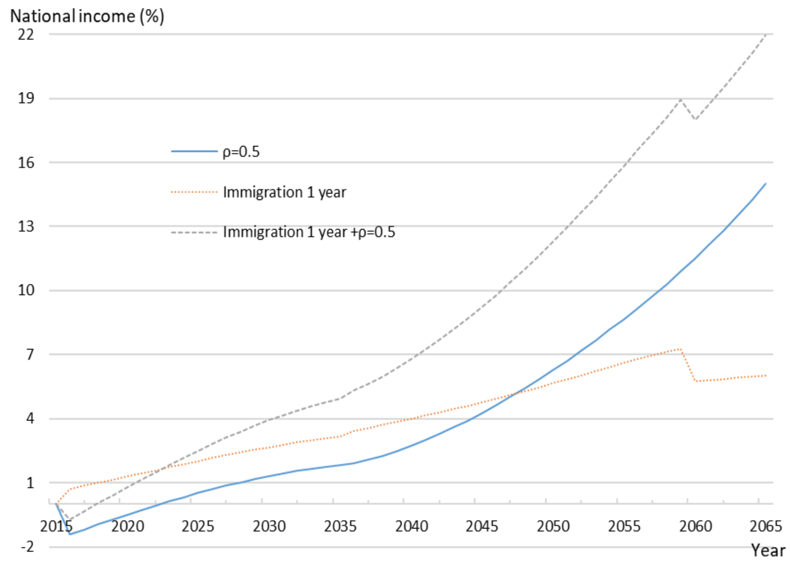


Figure 12 Changes in national income from the benchmark for immigration policy, government child subsidy, and their combination

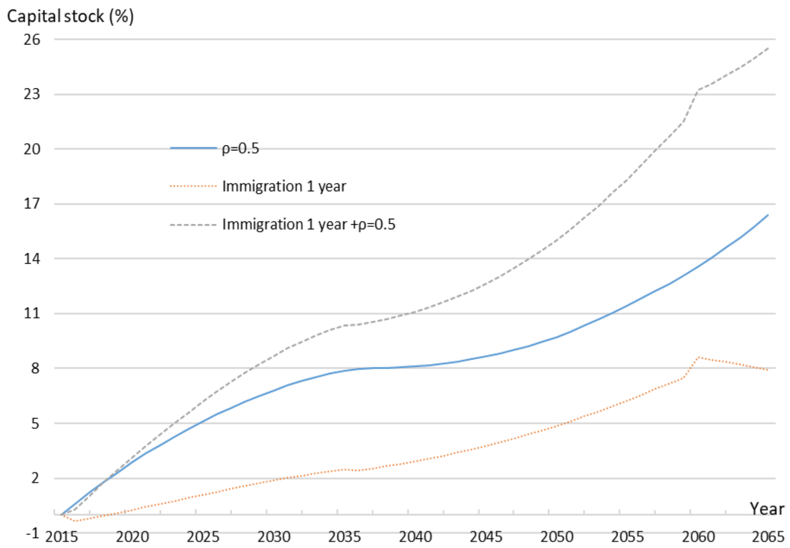


Figure 13 Changes in capital stock from the benchmark for immigration policy, government child subsidy, and their combination

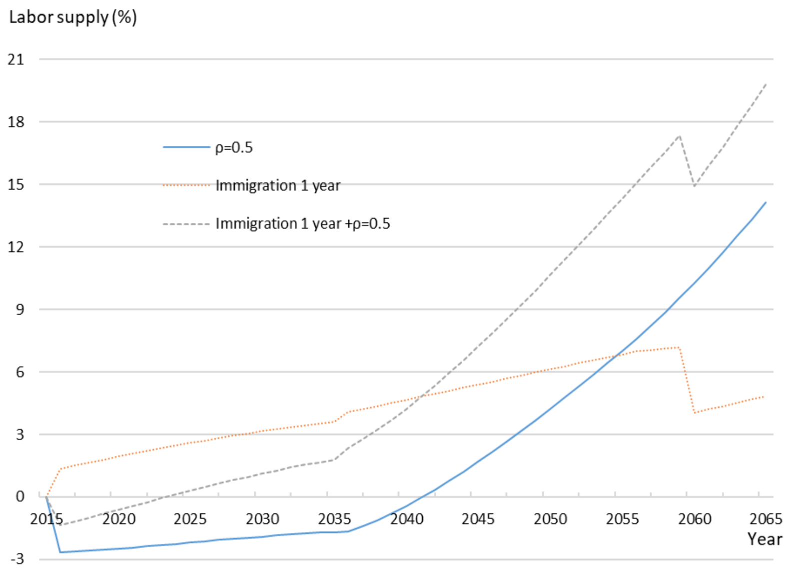


Figure 14 Changes in labor supply from the benchmark for immigration policy, government child subsidy, and their combination