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The Effects of Admitting Immigrants: A Look at Japan's School and Pension Systems

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Abstract

This paper investigates the effects of admitting immigrants to Japan on the welfare of native Japanese residents. The paper considers the imperfect substitutability between native and immigrant laborers in line with the pension and education systems. It is argued that immigration may have indirect negative effects, for example, imposing the additional burden of educating immigrant children who require additional support to master the Japanese culture, customs, and language. This research uses numerical data analysis of Japan. The findings indicate that admitting immigrants, even when they are not perfectly complementary, might increase the wage level and the utility of the natives. There are also direct implications on the type of pension system that is available for natives and immigrants. This study recommends that the defined replacement rate pension system is preferable for natives when there is a relatively substitutable relationship between natives and immigrants.

Keywords: Immigrants, Burden of schooling, Pension, Substitutability, Complementarity.

JEL Codes: J61, H52, H55.

1. Introduction

The number of international migrants has gradually increased over the past two decades. However, as it is well known, the coronavirus disease 2019 (COVID-19) pandemic drastically changed the global atmosphere and reduced the number of international migrants. The United Nations (UN) SESA (2020) estimates that before the disruptions to migration caused by the COVID-19 pandemic, the number of persons living outside of their country of origin reached 281 million in 2020. Almost 3 years have passed since the COVID-19 pandemic. Countries throughout the world, including Japan, have begun to accept the COVID-19 reality and have started reopening their doors. Japan is one of the strictest countries in terms of its attitude toward international immigration.[1] After opening their doors, the number of international immigrants to Japan will increase drastically. It is therefore time for an in-depth investigation of the effects of admitting immigrants after a period during which international immigration has been restricted.

This paper investigates the effects of admitting immigrants on the welfare of native Japanese residents considering imperfect substitutability between native and immigrant laborers in an economy in which there is a pay-as-you-go (PAYG) pension system and an educational system that must carry the additional burden of teaching immigrant children.

According to a textbook analysis, admitting immigrants elementarily decreases the wage level of natives because natives and immigrants are assumed to be perfectly substitutable. Studies like Borjas (2003) and Borjas and Katz (2007) estimated that immigrants decrease the wages of natives. According to a summary on the effects of admitting immigrants on native wage rates in the United States over the last 50 years edited by Powell (2015), immigration has a small but relatively negative effect on native wages. Ottaviano and Peri (2008, 2012), in attempting to reconcile the most divergent results in the literature that examines immigration's effect on negative wages, showed that immigration reduced the wages of natives without a high school degree by only 0.7% in the short run but increased their wages by 0.6%–1.7% in the long run.

[1] *The Japan Times* (2022) reported that the government of Japan is considering increasing the daily cap on overseas arrivals to 10,000 from the current cap of 7,000 starting in April of 2022.

The most important assumption in Ottaviano and Peri (2008, 2012), which yields the most divergent results, is that immigrant laborers are imperfectly substitutable with native laborers in the same educational cell. These studies imply that the assumption that natives and immigrants are perfectly substitutable for each other is too strong to describe the real-world economy. However, Dustmann et al. (2016) showed that there is a possibility of misclassification, even if immigrants and natives are assumed imperfectly substitutable, because immigrants tend to be "downgraded" upon arrival to natives in the same education cell, that is, to natives who have the same education and experience as the immigrants (the skill-cell approach).[2] This study also found that downgrading is likely to lead to an overstatement of the negative (relative) wage response of natives, especially when using the skill-cell approach, but it will also lead to an understatement of the (total) wage response of natives using a structural approach. In sum, Dustmann et al. (2016) advocated that researchers exploit the variations in overall immigration shocks to identify the total labor market effects of immigration. These studies imply that it is necessarily to consider the imperfect substitutability between natives and immigrants, but it may be misleading to assume that there is imperfect substitutability in the same education cell.

This paper adapts a production function in which there is imperfect substitutability only between the total labor supply of the natives and immigrants, a technique that is used in Guerreiro, Rebelo, and Teles (2020) and Llull (2020).[3] While this production function does not address all of the problems to be considered, it at least considers the imperfectly sustainable relationship between natives and immigrants.

All of the immigrants do not necessarily return to their home country or another country after some time; some of them stay and have children in the host country. Raising and teaching immigrant

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[2] Friedberg (2000) and Mattoo, Neagu, and Özden (2008) also indicate that the immigrants face the relatively lower returns to education and experience due to downgrading. On the other hand, it is also worthy that Sharpe and Bollinger (2020) propose the method of stratifying the labor market by occupation rather than education and experience.

[3] Guerreiro, Rebelo, and Teles (2020) analyzed what immigrant policy is best for natives' welfare in an economy in which the government designs an optimal redistributive welfare system and supplies public goods. In this model, the substitutability between natives and immigrants plays an important role because the immigrants not only decrease but also increase the productivity of natives through the production function, which is quite different when the relationship between the natives and immigrants is perfectly substitutable. In Llull (2020), this production function is used to show why the results of Borjas (2003), Borjas and Katz (2007), and Ottaviano and Peri (2008, 2012) differed.

children imposes an additional burden on native residents because immigrant children are not familiar with the culture and language of the host country, so educators must provide them with additional cultural or linguistic educational support to help them live in the host country.

As Zinovyeva, Felgueroso, and Vazquez (2014) and Bernhofer and Tonin (forthcoming) showed, the children of immigrants and students learning in a language other than their mother tongue tend to perform significantly worse than natives or those learning in their mother tongue. Zinovyeva, Felgueroso, and Vazquez (2014) pointed out that the children of immigrants tend to perform worse using data from 2003, 2006, and 2009 from the Programme for International Student Assessment. Bernhofer and Tonin (forthcoming) pointed out that taking an exam in a second language leads to approximately a 9.5% loss in grade. These studies imply that education in a language other than the students' mother tongue is difficult and imposes an extra educational burden. From the point of reviewing the relationship between immigration or ethnic diversity and public good provision or redistribution, Speciale (2012) showed that an increase in the immigrant population had a small negative effect on public education expenditures in the presence of Tiebout-type migration, which is a kind of extra educational burden caused by admitting immigrants.[4] While Zinovyeva, Felgueroso, and Vazquez (2014) pointed out that immigrant children's performance improved with time spent in the host country, it is necessary for the host country's government to provide extra support (e.g.,., language assistants). This extra educational burden of hiring more educators as language assistants is treated explicitly.

Jinno and Yasuoka (2022) investigated this aspect of admitting immigrants with endogenous unemployment rates by assuming that immigrant children require a greater number of educators in the host country.[5] Jinno and Yasuoka (2022), however, did not consider a pension system in which the

[4] As Casarico and Devillanova (2003) and Mavisakalyan (2011) demonstrated, the effects of immigrants on private educational choices are important when human capital accumulation is considered. However, only the structural effects caused by the immigrants are considered in this paper for the sake of simplicity.

[5] Jinno and Yasuoka (2022) showed that immigration may improve the welfare of native residents when the additional number of educators required for immigrant children is sufficiently low, while the numerical example using values in Japan showed that admitting immigrants does not improve the welfare of Japanese natives because the positive effects of admitting immigrants do not overcome the negative effects. Keminitz (2003) examined the impact of immigration on a host country with welfare state arrangements that supported both the unemployed and the elderly under the assumption that immigrant and native labor is perfectly substitutable.

immigrants who entered the host economy as contributors to the pension would provide benefits to the native residents (Razin and Sadka, 1999). Thus, we would like to investigate the effects of admitting immigrants with a numerical analysis in Japan in an economy in which there is imperfect substitutability between immigrant and native laborers, there is an additional burden caused by providing education to immigrant children, and the pension system is considered.[6]

This paper compares the effects of admitting immigrants on the wages and utility of natives and immigrants using numerical analysis in Japan, which is one of the highest aging countries in which expenditures on social security, especially pensions, are expected to rise significantly. Thus, admitting immigrants could help improve the fiscal burden that future generations will have to bear. There are related studies such as Shimasawa and Oguro (2010), Imrohoroğlu et al. (2017), and Okamoto (2021) that have analyzed the quantitative effects of admitting immigrants to Japan using an overlapping-generations simulation model. They showed that admitting immigrants improved the financial burden for future generations.[7] However, they did not consider the production relationship between the natives and immigrants—namely, if they were substitutes or complementary—a fact that this paper considers.

The remainder of this paper is organized as follows. Sections 2 and 3 present the model and a welfare analysis. Section 4 discusses the findings, and Section 5 concludes.

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[6] Casarico and Devillanova (2003) and Brunello, Lodigiani, and Rocco (2020) investigated how immigration affected the endogenous accumulation of human capital of natives. They showed that there were endogenously forced responses by natives to increase their accumulation of human capital. While the additional burden on natives imposed by educating immigrant children is considered in this paper, the endogenous responses of natives are not considered because the accumulation of human capital is not considered for the sake of computational simplicity. This point remains for future consideration.

[7] Shimasawa and Oguro (2010) investigated the effects of an immigration policy with an annual flow of 150,000 immigrants forever on the country's fiscal burden and showed that the debt-to-GDP ratio became slightly lower than the baseline scenario with no immigration. Imrohoroğlu et al. (2017) analyzed the effects of admitting guest workers on fiscal sustainability in which they were not eligible for public pensions. Imrohoroğlu et al. (2017) showed that guest worker programs could mitigate Japan's fiscal imbalance. Okamoto (2021) explored the effects of an immigration policy with endogenous fertility and different periods under a constant total number of immigrants and found the optimal duration for an immigration policy. Some other papers have examined the effects of admitting immigrants on public finances; this includes Lee and Miler (2000), Storesletten (2000), Auerbach and Oreopoulos (2000), and Collado and Valera (2004). These studies generally show that admitting medium- or high-skilled immigrants improves the fiscal burden on future natives. However, they assume perfect substitutability between natives and immigrants, who are classified as having the same education and experience.

2. The model

This model was developed by Jinno and Yasuoka (2021) considering imperfect substitutability between natives and immigrants and different pension systems under full employment.

We apply an overlapping-generations model in which the individuals live for three periods: childhood, working, and retirement. Children require educators. Natives in the working period are endowed with one unit of labor that is inelastically supplied to consumption or the education sector. Immigrants in the working period supply some of the endowed labor to the consumption sector. Natives and immigrants are not perfectly substitutable in the consumption sector. Individuals decide the amount of consumption, savings, and number of children, and subsequently retire in their old age by consuming all of the returns from savings and pension benefits.

The term *immigrant* refers only to those who are admitted as non-citizens during the initial period. However, for simplicity, we assume that the children of immigrants have the same productivity as natives due to the educational support provided by an additional number of educators. Thus, we treat them as natives in the next period.

2.1. Admitting immigrants in the working period

In each period, the λ_t is the rate of the native working people in period t as immigrant workers continuously enter the country without capital.

$$\boldsymbol{N_t^{IM} = \lambda_t N_t^N,} \tag{1}$$

where N_t^{IM} is the number of immigrants in period *t*, and N_t^N is the number of native working people in period *t*. The superscripts IM and N denote immigrants and native residents, respectively. Thus, the population of the t^{th} generation, including immigrants, becomes $N_t^T = N_t^N + N_t^{IM} = (1 + \lambda_t)N_t^N$. P is the relative productivity of immigrants compared to natives; we assume it to be less than 1.[8]

[8] Jinno and Yasuoka (2021), referring to the "Basic Survey on Wage Structure" by the Ministry of Health, Labour and Welfare (2021), found the relative productivity of immigrants to natives in Japan was 0.61, which is less than 1. Please see Jinno and Yasuoka (2021) for additional details.

2.2. Child-rearing and education

Children of the native population need a certain number of educators for child-rearing and education, h^N; however, the children of immigrants require additional educators. Thus, the number of educators that immigrants require, h^{IM}, is greater than h^N. The relationship between the number of educators per native or immigrant child is as follows:

$$\boldsymbol{h^N < h^{IM} = qh^N} \tag{2}$$

where $q > 1$. The total number of educators that native and immigrant children need in period t, H_t, becomes $H_t = h^N n_t^N + h^{IM} n_t^{IM}$, where n_t^N (n_t^{IM}) is the number of children per native (immigrant). Only natives are assumed to be employed because individuals must educate both immigrant and native children to learn the host country's language, culture, and so on. Using Equations (1) and (2), the number of educators may be calculated as follows:

$$\boldsymbol{H_t^N = (n_t^N + \lambda_t q \cdot n_t^{IM}) h^N N_t^N.} \tag{3}$$

With a greater number of educators, the children of immigrants will be able to fully exert their abilities, similar to natives, when they become adults.[9] For simplicity, immigrant children are natives in period $t + 1$. Thus, the transition of the generation's population, including immigrants, becomes as follows:

$$\boldsymbol{N_{t+1}^N = n_t^N N_t^N + n_t^{IM} N_t^{IM}} \tag{4}$$

which implies that the children of immigrants become perfectly assimilated in the host country. Using Equation (1), the transition of the generation's population from Equation (4) is as follows:

$$\boldsymbol{\frac{N_{t+1}^N}{N_t^N} = \bar{n}_t^N = (n_t^N + \lambda_t n_t^{IM})} \tag{4'}$$

where $\bar{n}_t^N$ is the average population growth rate of natives, which includes immigrant children because, in this paper, immigrant children are assumed educated so that their productivity become as

[9] This is a very strong assumption. The Organization for Economic Cooperation and Development's (2019) PISA results report that the scores of immigrant children are lower than those of the children of natives, even though they receive more support from educators than do native children in some host countries. Like in Jinno (2011, 2013), the additional burden of assimilation into the host country should be explicitly considered, which is beyond the consideration of this paper.

high as native ones when they are old. Thus, the growth rate in Equation (4') implies one from the point of view of productivity.

2.3. Firms in the consumption sector

The production function is $Y_t^T = (K_t^T)^{\delta}(L_t^T)^{(1-\delta)}$, where $\delta \in (0,1)$. Y_t, K_t, and L_t denote the output produced, capital, and labor, respectively. The variables with the superscript T represents the total number of variables (e.g. capital or labor). To consider the relationship between natives and immigrants as perhaps characterized as perfect substitution or imperfect substitution (complement), we use the following production function.[10] The total labor supply is as follows:

$$\begin{aligned} \boldsymbol{L_t^T = [\psi(L_t^N)^{\phi} + (1-\psi)(L_t^{IM})^{\phi}]^{\frac{1}{\phi}}, \quad if\ \phi \le 1, or\ \phi \neq 0 \text{ or}} \\ \boldsymbol{L_t^T = (L_t^N)^{\psi}(L_t^{IM})^{1-\psi}, \quad if\ \phi = 0,} \end{aligned} \tag{5}$$

where L_t^N (L_t^{IM}) is the labor force supplied by natives (immigrants). The relationship between natives and immigrants becomes perfectly substitutable when $\phi = 1$. The relationship between natives and immigrants becomes an imperfect substitute when $0 < \phi < 1$. The relationship between natives and immigrants becomes complementary when $\phi < 0$. After this, we assume that $\phi \neq 0$. $K_t^T = s_t^N N_t^N + s_t^{IM} N_t^{IM}$ where s_t^X $(X = N\ or\ IM)$ is the amount of savings per native or immigrant.

We assume that all capital at the end of each period depreciates in one period. According to profit maximization theory, we have the following:

$$\boldsymbol{(1 + r_t) = \delta(k_t^N)^{\delta-1}[\psi(\epsilon_t^N)^{\phi} + (1-\psi)(\lambda_t \mathbf{P})^{\phi}]^{\frac{1-\delta}{\phi}}} \tag{6-a}$$

$$\boldsymbol{w_t^N = (1-\delta)\psi(k_t^N)^{\delta}[\psi(\epsilon_t^N)^{\phi} + (1-\psi)(\lambda_t \mathbf{P})^{\phi}]^{\frac{1-\delta-\phi}{\phi}}(\epsilon_t^N)^{\phi-1}} \tag{6-b}$$

$$\boldsymbol{w_t^{IM} = (1-\delta)(1-\psi)(k_t^N)^{\delta}[\psi(\epsilon_t^N)^{\phi} + (1-\psi)(\lambda_t \mathbf{P})^{\phi}]^{\frac{1-\delta-\phi}{\phi}}(\lambda_t \mathbf{P})^{\phi-1}} \tag{6-c}$$

where $\epsilon_t^N = \frac{E_t^N}{N_t^N}$, and E_t^N is the number of natives employed in the consumption sector. ϵ_t^N is the ratio of native employees in the consumption sector, which can be calculated by using Equation (3) as follows:

[10] This formula for the production function was adapted from Llull (2020), who investigated the impact of immigration on productivity.

$$\boldsymbol{\epsilon_t^N = 1 - \left(n_t^N + \lambda_t q n_t^{IM}\right) h^N} \tag{7}$$

We obtain the following relationships by logarithmically differentiating Equations (6-b) and (6-c) to L_t^{IM} and L_t^N, respectively, as follows:

$$\boldsymbol{\frac{d\ln w_t^N}{d\ln L_t^{IM}} \gtreqless 0 \text{ and } \frac{d\ln w_t^{IM}}{d\ln L_t^N} \gtreqless 0 \quad \text{if } (1-\delta) \gtreqless \phi} \tag{8}$$

Thus, if $1-\delta \le \phi < 1$, the relationship between natives and immigrants is imperfectly substitutable, and an increase in the number of the immigrants (natives) decreases the wage rate of the natives (immigrants). Thus, if $0 < \phi < 1-\delta$, the relationship between natives and immigrants is imperfectly substitutable, and an increase in the number of immigrants (natives) increases the wage rate of the natives (immigrants). Thus, if $\phi < 0$, the relationship between natives and immigrants is complementary, and an increase in the number of immigrants (natives) increases the wage rate of the natives (immigrants).

Using Equations (6-b) and (6-c), we calculate the relative wage rate as follows:

$$\boldsymbol{\frac{w_t^{IM}}{w_t^N} = \Psi(\chi_t^E)^{1-\phi}} \tag{9}$$

where $\chi_t = \frac{\epsilon_t^N}{\lambda_t \mathrm{P}}$ and $\Psi = \frac{(1-\psi)}{\psi}$. The average income among natives and immigrants, $\overline{w}_t = \frac{w_t^N N_t^N + w_t^{IM} P N_t^{IM}}{N_t^N + N_t^{IM}}$, becomes

$$\boldsymbol{\overline{w}_t = \left(\frac{w_t^N + \lambda_t P w_t^{IM}}{1+\lambda_t}\right)} \tag{10}$$

by using Equation (1).

2.4. Education sector

The wages of educators are financed by the common educational expenses for natives and immigrants: z_t^E. Variables with a superscript of E are common variables for natives and immigrants. The budget constraint on educational expenses becomes $z_t^E(n_t^N N_t^N + n_t^{IM} N_t^{IM}) = w_t^{edu} H_t^N$, where w_t^{edu} is the wage rate of educators. Natives can be educators in the education sector as well as workers in the consumption sector. The wage rate of educators becomes the same as that of workers because natives move freely between the education and consumption sectors: $w_t^N = w_t^{edu}$.

Thus, by using Equations (1) and (2) and considering the arbitrage movement caused by the natives, education expenses becomes as follows:

$$\boldsymbol{z_t^E = \left(\frac{n_t^N + \lambda_t q n_t^{IM}}{n_t^N + \lambda_t n_t^{IM}}\right) w_t^N h^N.} \tag{11}$$

An increase in the value of q increases the education expenses. Thus, admitting immigrants whose children impose a relatively heavy burden increases education expenses.

2.5. The pension system

Three types of pension systems are considered in this paper.

2.5.1. A pension system with a defined contribution rate: The DC pension system

The fundamental type of pension is the defined contribution rate system. In this system, the pension premium is constant, and the funded pension premiums are equally divided among the old as a pension benefit. The average pension benefit is endogenously determined.

The budget constraint of this pension system is as follows:

$$\boldsymbol{pen_{t+1}^E N_t^N + pen_{t+1}^E N_t^{IM} = \theta^E w_{t+1}^N N_{t+1}^N + \theta^E w_{t+1}^{IM} P N_{t+1}^{IM}} \tag{12-a}$$

where pen_{t+1}^E is the common pension benefit for the old in the t + 1st period, and θ^E is the exogenously defined contribution rate.

By substituting Equations (1), (4'), and (9) into Equation (12-a), we obtain the endogenously determined pension benefit as follows:

$$\boldsymbol{pen_{t+1}^E = \left(\frac{1+\lambda_{t+1}}{1+\lambda_t}\right) \theta^E \bar{n}_t^N \bar{w}_{t+1}} \tag{13-a}$$

We have a replacement ratio in period t + 1: $v_{t+1} \equiv \frac{pen_{t+1}^E}{\bar{w}_{t+1}} = \left(\frac{1+\lambda_{t+1}}{1+\lambda_t}\right) \theta^E \bar{n}_t$ from Equation (13-a).

2.5.2. A pension system with a defined benefit: The DB pension system

In this system, the pension benefit is constant and thus the pension contribution is endogenously determined to finance the budget constraint of the pension system. The budget constraint of this pension system is as follows:

$$\boldsymbol{pen^E\ N_t^N + pen^E\ N_t^{IM} = \theta_{t+1}^E w_{t+1}^N N_{t+1}^N + \theta_{t+1}^E w_{t+1}^{IM} N_{t+1}^{IM}} \quad (12\text{-b})$$

By substituting Equations (1) and (4') into Equation (12-b), we obtain the endogenously determined pension contribution as follows:

$$\boldsymbol{\theta_{t+1}^E = \left(\frac{1+\lambda_t}{1+\lambda_{t+1}}\right)\frac{pen^E}{\overline{n}_t^N \overline{w}_{t+1}}} \quad (13\text{-b})$$

2.5.3. A pension system with a defined pension replacement rate: The DR pension system

In this system, the pension benefit is adjusted to be a certain rate of the average income of the working generation: $\overline{pen}_{t+1} = v\,\overline{w}_{t+1}$, where v is the replacement rate of income. The contribution rate is endogenously determined to finance the budget constraint. The budget constraint of this pension system is as follows:

$$\boldsymbol{pen_{t+1}^E N_t^N + pen_{t+1}^E N_t^{IM} = \theta_{t+1}^E w_{t+1}^N N_{t+1}^N + \theta_{t+1}^E w_{t+1}^{IM} \mathrm{P} N_{t+1}^{IM}} \quad (12\text{-c})$$

By substituting Equations (1), (4'), and $\overline{pen}_{t+1} = v^E\,\overline{w}_{t+1}$ into Equation (12-c), we obtain the endogenously determined pension contribution rate as follows:

$$\boldsymbol{\theta_{t+1}^E = \left(\frac{1+\lambda_t}{1+\lambda_{t+1}}\right)\frac{v^E}{\overline{n}_t^N}} \quad (13\text{-c})$$

2.6. Consumption utility

The utility of individuals is dependent on the amount of consumer goods that they consume when they are young and old and the number of children that they have. Their utility function is as follows:

$$\boldsymbol{U_t^X = \alpha \ln c_t^X + \beta \ln d_{t+1}^X + \gamma \ln n_t^X}, \quad (14)$$

where $\alpha + \beta + \gamma = 1$, and $X = N\ or\ IM$. The budget constraints when individuals are young and old are as follows:

$$\boldsymbol{c_t^X + z_t^E n_t^X + s_t^X = (1-\theta_t^E) In_t^X, \text{ and}} \quad (15)$$

$$\boldsymbol{d_{t+1}^X = (1+r_{t+1}) s_t^X + pen_{t+1}^E} \quad (16)$$

Where $X = N$ or IM, and $In_t^N = w_t^N$ and $In_t^{IM} = \mathrm{P}w_t^{IM}$.

Individuals choose the optimal savings and number of children during the working period to maximize their utility. Some calculations lead to the following optimal solutions:

$$s_t^{X^*} = \frac{\beta(1-\theta)In_t^X \cdot R_{t+1} - (1-\beta)pen_{t+1}^X}{R_{t+1}}, \tag{17}$$

$$n_t^{X^*} = \gamma \frac{(1-\theta)In_t^X \cdot R_{t+1} + pen_{t+1}^X}{z_t \cdot R_{t+1}}. \tag{18}$$

The accumulation of capital is $K_{t+1} = s_t^{N^*} N_t^N + s_t^{IM^*} N_t^{IM}$, where capital is perfectly depleted for one period. The capital per native $\left(k_{t+1}^N\right)$ is calculated as follows:

$$k_{t+1}^N = \frac{s_t^{N^*} + \lambda s_t^{IM^*}}{n_t^{N^*} + \lambda n_t^{IM^*}}. \tag{19}$$

3. Simulation analysis

We simulate the model in this section using Fortran. The key parameters are presented in Table 1.

Key parameter	Value	Key parameter	Value
α	0.5	h^N	0.102
β	0.4	q	1.5
γ	0.1	ψ	0.8
δ	0.337	θ	0.183
ρ	0.2		

Table 1. Key parameters.
Note: Dividing the labor costs by the total added value from "Statistics of corporations by industry (2018)" yields 0.663, which is the share of labor. Thus, δ becomes 0.337. Dividing the total number of faculty members by the total number of students in the "Statistical abstract of education (2020)" yields 0.102, which is h^N. The contribution rate of the welfare pension system in Japan is 0.183.

According to Equation (8) and the value of δ, which is calculated using the date in "Statistics of corporations by industry (2018)," we adopt the representative values of the relationship between natives and immigrants in Table 2.

Case	Relationship	Value of ϕ
(A)	perfectly substitutable decreasing the wage rate of natives	1.0
(B)	imperfectly substitutable decreasing the wage rate of natives	0.8

(C)	imperfectly substitutable increasing the wage rate of natives	0.65
(D)	imperfectly substitutable increasing the wage rate of natives	0.3
(E)	complementary increasing the wage rate of natives	-0.05

Table 2. The value of ϕ.
Note: The value of ϕ represents the relationship between natives and immigrants.

Under these key parameters, we simulate the effects of an increase in admitting immigrants from 2% to 3% in the third period.[11] We obtain the steady-state values in the case that $\phi = 0.8$, which are put together in Table 3.[12]

Endogenous variable	Value	Endogenous variable	Value	Endogenous variable	Value
k^*	0.067	n_*^N	0.898	u_*^N	−1.941
$1 + r^*$	1.586	n_*^{IM}	0.458	u_*^{IM}	−2.613
w_*^N	0.229	s_*^N	0.061	pen_*^E	0.038
$\mathrm{P} \cdot w_*^{IM}$	0.103	s_*^{IM}	0.019	v_*^E	0.166
χ^*	56.688	ϵ_*^N	0.907	z_*^E	0.023

Table 3. Endogenously calculated variables at the steady state of this model with $\phi = 0.8$.
Note: These endogenous variables change depending on the value of ϕ. These endogenous variables at the initial steady state are the same among the different pension systems when the value of ϕ is the same.[13] When the value of ϕ increases from 1.0 to 0.65, the endogenously calculated variables are reasonable because the wage rate of the natives is higher than that of the immigrants.

[11] There are 1,724 thousand immigrant workers in Japan is according to the "Foreign Employment Status" published by the Ministry of Health, Labour, and Welfare (2021) as of the end of October 2020. The number of workers in Japan is about 66.94 million, according to Ministry of Health, Labour, and Welfare's "Labor Force Survey" (2021) as of October 2020. Thus, the rate of immigrant workers is now about 2%. We use an initial rate of immigration of 2%. However, in the case that the relationship between natives and immigrants is complementary, the rate of immigration is too low to estimate the effects of admitting immigrants. Thus, we calculate the effects of admitting immigrants at a rate of 5% with an initial rate of immigration of 10%.

[12] The steady-state values are different according to the value of ϕ. However, these differences are not essential. We would like to describe only essential points of difference in this paper.

[13] When the value of ϕ is between 1.0 and 0.8, which satisfies the condition $(1 - \delta) < \phi$, an increase in the number of immigrants (natives) decreases the wage rate of the natives (immigrants). Conversely, when the value of ϕ is between 0.65 and −0.03, which satisfies the condition $(1 - \delta) > \phi$, an increase in the number of immigrants (natives) increases the wage rate of the natives (immigrants).

3.1 Comparisons

Now, we estimate the effects of admitting more immigrants when a general PAYG pension system is considered using Equations (13-a), (13-b), and (13-c). When this pension system is considered, admitting more immigrants implies an increase in the number of people in the working generation who bear the burden of pension benefits together. The results of the simulation of admitting more immigrants are presented in Table 4–6.

We estimate the effects of admitting more immigrants on the wages and utility of immigrants when the defined contribution rate PAYG pension system (the DC pension system) is considered. The effects are presented in Table 4-a and Table 4-b.

the DC pension system										
Natives										
	(A) ϕ =1.0		(B) ϕ =0.8		(C) ϕ =0.65		(D) ϕ =0.3		(E) ϕ =-0.03	
Total utility changes	-0.055%		-0.008%		0.083%		0.815%		3.031%	
	wage	utility	wage	utility	wage	utility	wage	utility	wage	utility
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.03%	0.00%	0.06%	0.00%	0.10%	0.00%	0.35%	0.00%	0.89%
3	-0.07%	-0.10%	-0.05%	-0.09%	0.03%	-0.07%	1.12%	0.25%	6.33%	1.41%
4	0.02%	0.01%	0.05%	0.02%	0.10%	0.03%	0.50%	0.14%	2.08%	0.49%
5	0.01%	0.00%	0.02%	0.01%	0.03%	0.01%	0.17%	0.05%	0.70%	0.17%
6	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.06%	0.02%	0.23%	0.06%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.08%	0.02%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.03%	0.01%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 4-a. The effects of admitting immigrants on the wages and utility of natives under the DC pension system.

the DC pension system										
Immigrants										
	(A) ϕ =1.0		(B) ϕ =0.8		(C) ϕ =0.65		(D) ϕ =0.3		(E) ϕ =-0.03	
Total utility changes	-0.101%		-2.435%		-5.558%		-23.45%		-120.61%	
	wage	utility	wage	utility	wage	utility	wage	utility	wage	utility
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.02%	0.00%	0.04%	0.00%	0.09%	0.00%	0.71%	0.00%	8.66%
3	-0.07%	-0.13%	-7.84%	-2.50%	-13.22%	-5.70%	-23.91%	-24.60%	-29.95%	-136.49%
4	0.02%	0.01%	0.05%	0.01%	0.10%	0.03%	0.50%	0.29%	2.08%	4.79%
5	0.01%	0.00%	0.02%	0.00%	0.03%	0.01%	0.17%	0.10%	0.70%	1.62%
6	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.06%	0.03%	0.23%	0.54%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.08%	0.18%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.03%	0.06%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%

Table 4-b. The effects of admitting immigrants on the wages and utility of immigrants under the DC pension system.

According to Table 4-a and Table 4-b, the effects of admitting more immigrants on the wages and utility of natives become negative (positive) when immigrants are relatively substitutable (complementary) with natives.

We focus on the cases of (B) $\phi = 0.8$ and (C) $\phi = 0.65$. These cases present the effects of admitting imperfectly substitutable immigrants under a reasonable steady-state economy.[14] While the total utility changes in Case (B) are negative, in Case (C), they are positive. Thus, the parameter condition of whether admitting immigrants increases the wages of natives or not is very important for natives when an economy admits immigrants under the DC pension system. Conversely, the total change in utility for the immigrants becomes negative no matter what the relationship between the natives and immigrants is under the DC pension system.

[14] In the case of (B), the relative income of the natives to the immigrants $\left(\frac{w^N}{\mathrm{P}\cdot w^{IM}}\right)$ is 2.23. The value of (C) is 1.22. In the cases of (D) and (E), it is less than one. The cases of (A) through (C) are reasonable. According to Jinno and Yasuoka (2022), the relative income in Japan is $1/0.61 \approx 1.64$. Thus, the results in (B) and (C) are relatively more reasonable in Japan.

We estimate the effects of admitting more immigrants on the wages and utility of immigrants when the defined benefits PAYG pension system (the DB pension system) is considered. The effects are presented in Table 5-a and Table 5-b.

Under the DB pension system, the basic results are the same as under the DC pension system. When the condition of the parameters satisfies $(1-\delta)<\phi$, the total utility changes become negative, while when $(1-\delta)>\phi$, the total utility changes become positive. The total utility changes for the immigrants become negative no matter what the relationship between natives and immigrants is under the DB pension system.

the DB pension system										
Natives										
	(A) ϕ=1.0		(B) ϕ=0.8		(C) ϕ=0.65		(D) ϕ=0.3		(E) ϕ=-0.03	
Total utility changes	-0.139%		-0.060%		0.073%		1.009%		3.558%	
	wage	utility	wage	utility	wage	utility	wage	utility	wage	utility
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.02%	0.00%	0.03%	0.00%	0.06%	-0.01%	0.19%	-0.03%	0.46%
3	-0.05%	0.00%	-0.02%	0.01%	0.08%	0.05%	1.32%	0.46%	6.99%	1.87%
4	-0.06%	-0.10%	-0.01%	-0.07%	0.06%	-0.03%	0.62%	0.20%	2.55%	0.70%
5	-0.04%	-0.03%	-0.02%	-0.02%	0.01%	-0.01%	0.24%	0.09%	1.00%	0.31%
6	-0.02%	-0.01%	-0.01%	-0.01%	0.00%	0.00%	0.10%	0.04%	0.40%	0.13%
7	-0.01%	0.00%	-0.01%	0.00%	0.00%	0.00%	0.04%	0.02%	0.17%	0.05%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.07%	0.02%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.03%	0.01%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%

Table 5-a. The effects of admitting immigrants on the wages and utility of natives under the DB pension system.

the DB pension system										
Immigrants										
	(A) ϕ =1.0		(B) ϕ =0.8		(C) ϕ =0.65		(D) ϕ =0.3		(E) ϕ =-0.03	
Total utility changes	-0.079%		-2.448%		-5.562%		-22.91%		-112.31%	
	wage	utility	wage	utility	wage	utility	wage	utility	wage	utility
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%
2	0.00%	0.00%	0.00%	0.02%	0.00%	0.05%	0.01%	0.52%	0.04%	6.88%
3	-0.05%	-0.01%	-7.82%	-2.39%	-13.18%	-5.58%	-23.79%	-24.17%	-29.61%	######
4	-0.06%	-0.05%	-0.01%	-0.05%	0.07%	-0.03%	0.61%	0.42%	2.49%	7.12%
5	-0.04%	-0.02%	-0.02%	-0.01%	0.01%	0.00%	0.23%	0.18%	0.96%	3.10%
6	-0.02%	-0.01%	-0.01%	-0.01%	0.00%	0.00%	0.09%	0.08%	0.39%	1.31%
7	-0.01%	0.00%	-0.01%	0.00%	0.00%	0.00%	0.04%	0.03%	0.16%	0.55%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.07%	0.23%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.03%	0.09%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.04%

Table 5-b. The effects of admitting immigrants on the wages and utility of immigrants under the DB pension system.

We estimate the effects of admitting more immigrants on the wages and utility of immigrants when the defined pension replacement rate PAYG pension system (the DR pension system) is considered. The effects are presented in Table 6-a and Table 6-b.

the DR pension system										
Natives										
	(A) ϕ =1.0		(B) ϕ =0.8		(C) ϕ =0.65		(D) ϕ =0.3		(E) ϕ =-0.03	
Total utility changes	-0.051%		0.004%		0.101%		0.847%		3.018%	
	wage	utility	wage	utility	wage	utility	wage	utility	wage	utility
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	-0.05%	0.00%	-0.02%	0.00%	0.03%	0.00%	0.28%	-0.03%	0.82%
3	0.02%	0.10%	0.04%	0.09%	0.12%	0.10%	1.21%	0.39%	6.99%	1.57%
4	-0.01%	-0.07%	0.02%	-0.05%	0.08%	-0.02%	0.50%	0.12%	2.55%	0.41%
5	-0.02%	-0.02%	0.00%	-0.01%	0.02%	-0.01%	0.16%	0.04%	1.00%	0.14%
6	-0.01%	-0.01%	0.00%	0.00%	0.00%	0.00%	0.05%	0.01%	0.40%	0.05%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.17%	0.02%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.07%	0.01%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%

Table 6-a. The effects of admitting immigrants on the wages and utility of natives under the DR pension system.

the DR pension system										
Immigrants										
	(A) ϕ =1.0		(B) ϕ =0.8		(C) ϕ =0.65		(D) ϕ =0.3		(E) ϕ =-0.03	
Total utility changes	-0.103%		-2.429%		-5.539%		-23.35%		-120.79%	
	wage	utility	wage	utility	wage	utility	wage	utility	wage	utility
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
2	0.00%	-0.09%	0.00%	-0.04%	0.00%	0.02%	0.00%	0.62%	0.04%	8.38%
3	0.02%	0.04%	-7.76%	-2.34%	-13.15%	-5.53%	-23.86%	-24.34%	-29.61%	-135.34%
4	-0.01%	-0.03%	0.02%	-0.03%	0.08%	-0.02%	0.51%	0.24%	2.49%	4.04%
5	-0.02%	-0.01%	0.00%	-0.01%	0.02%	0.00%	0.16%	0.08%	0.96%	1.40%
6	-0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.03%	0.39%	0.48%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.16%	0.16%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.07%	0.06%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.02%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%

Table 6-b. The effects of admitting immigrants on the wages and utility of immigrants under the DR pension system.

The results under the DR pension system are slightly different for natives than those under the DC and DB pension systems. The total utility changes for natives become positive, even in the case of (B) $\phi = 0.8$ under the DR pension system.

An increase in admitting immigrants directly decreases native and immigrant wages, which implies a decrease in the average income. A decrease in the average income decreases the pension benefit because of the mechanism in the DR pension system whereby it indirectly increases the amount of savings by the second generation who perfectly consider the decrease in pension benefits paid by the third generation. The direct and indirect effects of admitting immigrants on the wage of the third generation deny each other, and the indirect effects dominate in this numerical analysis. Thus, the wages of the third generation become higher. The utility of the third generation becomes much higher than the utility loss of the other generations. Thus, the total utility changes under the DR pension system become positive, even in Case (B). The values belonging to the third generation are presented as the difference from the steady-state value in Table 7.

	Natives	Immigrants
Wages	0.038%	-7.765%
Savings	0.279%	-13.208%
Children	-0.022%	-6.122%
Pension contribution rate	-0.892%	-0.892%
Consumption in the working period	0.219%	-5.895%
Consumption in the retired period	0.175%	-5.937%

Table 7. Endogenous variables belonging to the third generation.
Note: The values are represented as the difference from the values at the steady state.

According to Table 4 through Table 6, the more complementary immigrants that are admitted, the higher (lower) the level of welfare obtained by the natives (immigrants). Whenever the relationship between natives and immigrants is perfectly substitutable, the additional welfare that the natives would obtain becomes negative. While the DR pension system is preferable for natives when the relationship between natives and immigrants is relatively substitutable, the DB pension system is preferable for natives when the relationship between them is relatively complementary. In other words, the government should change the pension system depending on the character of the immigrants if possible. Ottaviano and Peri (2008, 2012) showed that if the relationship between natives and immigrants is imperfectly substitutable, either the DR or DB pension system is preferable when the government admits more immigrants according to our analysis.[15].

To consider the effects of the additional burden on the education system caused by admitting more immigrants, a comparison of the steady state from $q = 1.5$ to $q = 2.0$ when $\phi = 0.8$ is presented in Table 8.

	q=1.5	**q=1.75**	**q=2.00**
k^*	0.067	0.067	0.068

[15] According to the note 9, the cases of (B) or (C) are reasonable in Japan. Thus, the DR pension system is the most preferable for the natives in Japan.

		(0.38%)	(0.75%)
$1+r^*$	1.586	1.582	1.578
		(-0.25%)	(-0.50%)
e_*^N	0.907	0.907	0.907
		(0.00%)	(0.00%)
z_*^E	0.023	0.024	0.024
		(0.38%)	(0.75%)
u_*^N	-1.9411	-1.9412	-1.9413
		(-0.01%)	(-0.01%)
u_*^{IM}	-2.6135	-2.6136	-2.6137
		(-0.004%)	(-0.008%)

Table 8. The endogenously calculated variables at the steady state in this model with $\phi = 0.8$ and when q goes from $q = 1.5$ to q = 2.0. The values in parentheses represent the change from the values when $q = 1.5$.

According to Table 8, an increase in the value of q, which implies an increase in the educational burden of hiring extra educators, raises the capital-labor ratio and the education cost per child, with the labor–educator ratio remaining the same, and it decreases the utility of both natives and immigrants.

Basically, while accepting that the heavy burden of immigrants might well decrease the utility of natives, it might not decrease the utility of immigrants even if there was a relatively heavier education burden for natives, which represent a higher value of q. This numerical analysis shows that accepting immigrants that impose a heavier educational burden decreases the utility of the immigrants themselves at the steady state as well as that of natives because the burden of education is endogenously adjusted to the wages of educators. Thus, the heavy educational burden decreases the utility of immigrants through the endogenously increased educational costs.

3.2 Discussion

In this section, we focus on the mechanism whereby the defined replacement rate (DR) pension system is preferred when the relationship between natives and immigrants is relatively complementary (substitutable).

We will first review the features of each pension system. The pension contribution rate is defined as constant under the DC pension system. Basically, an increase in the labor force under the pension system raises pension benefits but does not have any effects on the disposable income as far as wages for the labor force generation do not change. If the wages of natives increase due to admitting more immigrants, disposable incomes as well as pension benefits become higher. However, even if the wages of natives become higher, the pension contribution transfers a certain portion of the rise in wages from the working generation to the retired generation as far as the pension contribution rate is defined, which implies that disposable incomes for the working generation do not increase as much as the rise in wages. Thus, under this pension system, an increase in the labor force tends to benefit the retired generation more than the working generation.

The pension contribution rate depends on the size of the labor force under the DB and DR pension systems. Basically, an increase in the labor force under the DB pension system decreases the pension contribution rate but does not have any effect on pension benefits. Thus, under this pension system, an increase in the labor force tends to benefit the working generation more than the retired generation.

Conversely, under the DR pension system, both pension benefits and contribution rates depend on the size of the labor force because the pension benefits and contribution rate may be changeable and constantly proportional to the change in wages of the working generation, even if the replacement ratio of benefits to wages of the working generation is constant. An increase in the complementary labor force may decrease the pension contribution rate, which increases the savings rate and the wages of the next generation of natives and immigrants. Thus, under this pension system, an increase in a relatively complementary labor force tends to benefit the working and future generations more than the retired generation.

An increase in the number of relatively more complementary immigrants raises the wage of natives in the period in which the immigrants are received. If the DB pension system is in effect, a rise in the wage of natives decreases the pension contribution rate, and the disposable

incomes of natives become higher, which increases the savings and improves the utility of subsequent generations. This is why the DB pension system is preferable when the admitted immigrants are relatively complementary.

As Collado and Valera (2004) pointed out, a greater number of immigrants will substantially alleviate the fiscal burden on future generations in highly aging countries.[16]. This paper also demonstrates that the productivity relationship between natives and immigrants and which pension system is enforced play a very important role when aging-population countries admit immigrants.

4. Conclusion

This paper investigates the effects of admitting immigrants on the welfare of native residents considering imperfect substitutability between native and immigrant laborers under an economy in which there is a PAYG pension system and an education system that suffers the additional burden imposed by teaching immigrant children. This paper's analysis shows that admitting immigrants, even if they are not perfectly complementary, might increase the wages and utility of the natives and that the kind of pension system that is desirable depends on the relationship between natives and immigrants.

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[16] As Kato (2022) analyzed the dynamic impact of future demographic changes on the Japanese economy with a particular focus on multisector production and overlapping generations, highly aging countries like Japan needs more workers in the social security sectors, which implies a high burden for the future generations.

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