

Endogenous Migration and the Macroeconomic Impact of Foreign Workers in Japan^{*}

Sagiri Kitao[†]

Nozomi Takeda[‡]

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Abstract

This paper develops a multi-region overlapping generations model with endogenous migration to quantify the macroeconomic and fiscal effects of foreign workers in aging Japan. Migration decisions are modeled explicitly, driven by cross-country differences in wages, demographics, and fiscal systems across Japan and sending countries. The calibrated model replicates the sharp rise in Japan's foreign workforce over the past decade and projects that their share will peak in the 2040s before declining as demographic and wage trends in source countries evolve. Foreign workers modestly mitigate the decline in labor supply and output and ease fiscal pressures, though their contribution remains partial. The findings highlight the importance of incorporating endogenous migration in assessing long-run fiscal sustainability in aging economies.

Keywords: Foreign workers, migration decisions, demographic aging, fiscal sustainability, Japanese economy

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[†]National Graduate Institute for Policy Studies (GRIPS), Research Institute of Economy, Trade and Industry (RIETI), and Centre for Applied Macroeconomic Analysis (CAMA). Email: sagiri.kitao@gmail.com

[‡]University of Minnesota, Email: nozomitakeda.econ@gmail.com

1 Introduction

Most developed countries face rapidly aging populations, shrinking workforces, and rising fiscal burdens from public pension and healthcare systems. The demographic headwinds threaten long-run economic growth and the sustainability of the social insurance programs. In response, many governments have turned to the inflow of foreign workers as a potential solution to augment labor supply and strengthen public finances.

Japan is no exception. The country has witnessed a sharp increase in the number of foreign workers in recent years. A central question is whether Japan can continue to attract foreign workers at a scale sufficient to mitigate the adverse macroeconomic and fiscal consequences of demographic aging. Equally important is to understand how the inflow of foreign workers will affect not only the aggregate economy, but also the wage structure of Japanese workers, income inequality, and the welfare of different generations.

While an extensive literature has examined the role of foreign labor in advanced economies using structural models, most existing studies treat migration flows as exogenous, determined by past trends or policy choices in the host country. Obviously, however, migration decisions are endogenous: workers in foreign countries weigh potential earnings and fiscal policies at both origin and destination countries, and various mobility costs. Abstracting from this self-selection risks overstating or mischaracterizing the inflow of foreign workers and their macroeconomic contribution. Our paper aims to fill this gap by studying the inflow of foreign workers into Japan in a structural model with the demographic transition that incorporates migration decisions of foreign workers.

We develop a multi-region overlapping generations (OLG) model in which prospective foreign workers decide whether to migrate to Japan or remain in their home country. The model captures heterogeneity of foreigners in skills, wealth, and preferences for migration, along with cross-country differences in wages, productivity growth, demographic transitions, and fiscal policies. We assume that migration is temporary rather than permanent, reflecting the prevalence of “guest worker” arrangements in Japan. Decisions are also affected by moving costs, agglomeration effects, and the probability of return. We calibrate the model to the data of Japan and to key source countries including Vietnam, China, and the Philippines, using microdata on wages, assets, and population projections of these countries.

Our model replicates the recent rise in the number of foreign workers in Japan, which almost monotonically increased from less than 0.5 million workers in 2008 to 2.3 million in 2024. Extrapolating the model in its time horizon, our quantitative analysis demonstrates that the share of foreign workers in the adult population would peak at about 6–7 percent in the 2040s before declining as demographic transitions in source countries unfold and different wage growth rates shifts the relative wages and attractiveness of migrating to Japan. The composition of migrants initially shifts toward more high-skill workers, but

low-skill inflows dominate over the long run. We show how foreign workers mitigate the decline in aggregate labor supply and output. In their absence, aggregate output would be lower by 2–3 percentage points by mid-century, and tax burdens would be higher by 1–2 percentage points in terms of average consumption. Finally, we show that fiscal pressures remain severe even with the inflow of foreign workers, as the growing costs of pensions and health care outpace their contributions. Alternative scenarios underscore the importance of conditions in origin countries. Slower wage growth abroad could significantly boost inflows of foreign workers to Japan, while higher fertility or faster skill convergence alters the size and composition of migrants in the long run.

Our findings highlight both the promise and the limitations of relying on foreign workers to deal with demographic and fiscal challenges. Endogenizing migration decisions reveals that the inflow of foreign labor is sensitive to relative economic growth and policy developments in Japan and abroad, and that the mitigating role of foreign workers is necessarily partial. A comprehensive response to Japan’s demographic crisis will therefore require not only migration policy but also domestic reforms in productivity, labor supply, and fiscal systems.

Our study is related to a few lines of literature focused on the roles of foreign workers. The first strand of research studies the macroeconomic and fiscal consequences of immigration, typically treating migrant inflows as exogenous or policy-driven.¹ Quantitative OLG models highlight the fiscal implications of immigration for aging societies. [Storesletten \(2000\)](#) shows that young, high-skill immigrants can substantially improve U.S. fiscal sustainability, while [Fehr et al. \(2004\)](#) and [Attanasio et al. \(2007\)](#) emphasize that immigration only partially offsets the effects of demographic transition. More recent analyses, such as [Busch et al. \(2020\)](#), study Europe’s refugee inflows and highlight significant distributional and fiscal impacts. Studies focused on the Japanese economy by [İmrohoroglu et al. \(2016\)](#) and [Kitao and Yamada \(2021\)](#) show that immigration alleviates labor force decline and fiscal strain, though it cannot by itself restore fiscal balance. [Shimasawa and Oguro \(2010\)](#) show that a substantial increase in working-age immigration would alleviate the need for major fiscal reforms and reduce pension burden.²

A second line of research emphasizes endogenous migration decisions and the global efficiency gains from labor mobility. Klein and Ventura ([2007](#), [2009](#)) demonstrate in multi-region models that relaxing migration barriers leads to large welfare improvements, while [Kennan \(2013\)](#) calculates that “open borders” would generate gains comparable to a global growth miracle. [Dustmann and Preston \(2019\)](#) review the literature and stress both the aggregate surplus from mobility and the importance of distributional consequences.

¹[Borjas \(1999\)](#) provides a comprehensive survey of the economic analysis of immigration.

²[Okamoto \(2021\)](#) builds an overlapping generations model calibrated to the Japanese economy to investigate optimal immigration policy, focusing on welfare aspects of immigration policy.

[Dustmann and Frattini \(2014\)](#) empirically finds that immigrants arriving at UK between 1995 and 2011 contributed more in taxes than they received in benefits, generating strong positive fiscal effects.

These studies typically focus on long-run global efficiency, whereas our paper highlights the fiscal sustainability of a specific receiving country under demographic aging. We also focus on the roles of guest workers rather than permanent migration, reflecting the current context of Japanese policy.

Finally, a large empirical literature examines the labor market effects of immigration, with mixed conclusions. [Borjas \(2003\)](#) finds significant wage losses for competing native workers, while other studies emphasize small aggregate impacts ([Peri 2016](#); [Dustmann et al. 2016](#)). [Monras \(2020\)](#) shows that wage effects differ across cohorts, and [Alesina and Tabellini \(2024\)](#) provide a survey of empirical findings and also document how misperceptions about immigrants' characteristics shape political responses. Our contribution differs by combining these perspectives in a calibrated OLG model with endogenous migration decisions, applied to Japan's demographic and fiscal context.

2 Model

This section provides our quantitative model. Time is discrete denoted by $t = 1, 2, \dots$. The economy consists of two regions, Japan and a group of other countries. For simplicity, we call the latter as a foreign country, denote the regions as $x \in \{J, F\}$, representing Japan and a foreign country, respectively.

2.1 Demographics

The economy in each country is populated by individuals of age $j = \{1, 2, \dots, J\}$, each endowed with the skill level of $s \in \{L, H\}$, low and high skill. Individuals face mortality risks and $\phi_{x,j+1,t+1}$ denotes the conditional survival probability that an individual born in country x aged j survives until next period until age $j + 1$ at time $t + 1$. $\phi_{x,1,t} = 1$ and $\phi_{x,J+1,t} = 0$ for all t by assumption. $\Phi_{x,j+1,t+j}$ denotes the unconditional probability that an individual born in country x at time t survives until age $j + 1$ at time $t + j$. We assume that assets of the deceased individuals are distributed as a lump-sum accidental bequest, denoted as b to all surviving individuals.

The growth rate of a new cohort in country x is denoted as $n_{x,t}$. We assume that individuals retire from the labor force at the retirement age j_x^R .

The measure of age- j individuals of nationality x residing in Japan at time t is denoted as $\mu_{x,s,j,t}$. Note that this measure may include individuals born in the foreign country.

2.2 Preferences

An individual born in Japan at time t derives utility from consumption $c_{j,t+j-1}$ at each age j and his objective function is given as

$$U_J = \sum_{j=1}^J \beta^{j-1} \Phi_{J,j,t+j-1} u(c_{j,t+j-1}).$$

Individuals in the foreign country differ from each other by the disutility from living and working abroad, denoted as γ_i , where i represents an individual's fixed preference type. Foreign individuals draw this disutility from distribution F_γ upon entry to the market and it is fixed throughout their life-cycle. Foreign individuals incur the disutility in every period that he works abroad. The life-time utility of a foreign individual born at time t is given as

$$U_F = E_t \sum_{j=1}^J \beta^{j-1} \Phi_{F,j,t+j-1} \{u(c_{j,t+j-1} \mid \zeta_t) - \gamma_i I_j\}$$

where I_j denotes an indicator that takes a value of 1 if the individual resides abroad at age j , and 0 otherwise. The expectation is over the probability of returning to the foreign country if and after they move to Japan. ζ_t is an agglomeration utility term computed from the stock of foreign workers in Japan at time t and enters utility multiplicatively with consumption. More details of the functional form representing the agglomeration effect and parametrization are explained in Section 3.2.

2.3 Endowment

Individuals enter the economy with zero asset in both countries. Working-age individuals are endowed with efficiency units in each period, which they supply to the labor market inelastically. The efficiency units depend on the skill level and age of an individual, as well as the individual's origin and where he currently works.

$h_{x,s,j}$ represents efficiency units of an individual working in Japan, of origin x , skill s and age j . $\tilde{h}_{F,s,j}$ denotes efficiency units of a foreign individual of skill s and age j , working in the foreign country. We assume that the skill levels are time invariant.

2.4 Migration Decision of Foreigners

We assume that foreign individuals decide whether to migrate to Japan or stay in their own country upon entry to the economy at age $j = 1$ in the model. If a foreigner chooses to migrate, there is a one-time resource cost of moving, denoted as m_t . Foreigners are heterogeneous in their preference for migration and their types are denoted as i , which determines disutility of migrating, γ_i .

We assume that the probability of returning to his home country is λ every period, and therefore a foreign individual migrating to Japan stays in Japan for $1/\lambda$ years on average.³

2.5 Factor Markets and Production

We consider production in the home country and endogenously determine factor prices. For the foreign country, we assume that factor prices are exogenously given.⁴

In the home country, output is produced, using low and high-skill labor supplied by workers residing in the home country, as well as physical capital, according to the CRS production function:

$$Y_t = F(K_t, L_t, H_t) = Z_t K_t^\alpha (L_t^\varphi + A_t H_t^\varphi)^{\frac{1-\alpha}{\varphi}}$$

where Z_t denotes total factor productivity and A_t represents skill-biased technology level. L_t and H_t denote low and high-skill labor at time t , respectively. Capital depreciates at rate $\delta \in [0, 1]$.

The wage rates and rental rate of capital are given as the marginal product of labor and capital, respectively.

$$w_{J,L,t} = F_{L_t} = Y_t \frac{(1-\alpha)L_t^{\varphi-1}}{L_t^\varphi + A_t H_t^\varphi} \quad (1)$$

$$w_{J,H,t} = F_{H_t} = Y_t \frac{(1-\alpha)A_t H_t^{\varphi-1}}{L_t^\varphi + A_t H_t^\varphi} \quad (2)$$

$$r_{J,t}^k = F_{K_t} = \alpha \frac{Y_t}{K_t} - \delta \quad (3)$$

Wages in the foreign country are denoted as $w_{F,L,t}$ and $w_{F,H,t}$ for low and high-skill workers, respectively, and $r_{F,t}^k$ represents the rental rate of capital.

In country x , individuals supply labor and capital in competitive markets, taking the factor prices as given. Workers in country x with skill s receives the market wage $w_{x,s,t}$ per efficiency unit. They receive rental rate of capital $r_{x,t}$ on their savings in country x .⁵

2.6 Government

Japanese Government: The government in Japan imposes tax on consumption at rate $\tau_{J,t}^c$, labor income at $\tau_{J,t}^l$, return from private capital at $\tau_{J,t}^k$, and return from the

³We also assume that all foreign workers return to their country by the time they reach the retirement age in Japan.

⁴This assumption is partly based on the fact that the share of workers in the foreign country that choose to migrate to Japan is very small and production and factor prices are hardly affected by their migration decisions. However, we consider alternative assumptions about the wage paths in the foreign country, which may be driven by factors not considered in our model.

⁵We assume foreigners send their unconsumed assets to their own country, which are accumulated and earn the interest rate in the foreign country, $r_{F,t}$.

government bond at τ_t^b . The Japanese government issues one-period debt B_{t+1} and pays interest rate denoted as r_t^b in each period.

Tax revenues and proceeds from the government debt are used to finance government spending, which includes government consumption G_t , payment for the interest and repayment of the debt $(1 + r_t^b)B_t$, pension benefits to retirees, expenditures on medical insurance and long-term care insurance. Public pension benefit of a retiree aged j of skill s at time t is denoted as $p_{J,s,j,t}$, which depends on past earnings, defined as

$$p_{J,s,j,t} = \kappa_{J,t} \frac{\bar{y}_{J,s,j,t}}{j_J^R},$$

where $\bar{y}_{J,s,j,t}$ denotes the average past earnings of an individual aged j with skill s in Japan.

$$\bar{y}_{J,s,j,t} = \begin{cases} h_{J,s,j} w_{J,s,t} & \text{if } j = 1 \\ h_{J,s,j} w_{J,s,t} + \bar{y}_{J,s,j,t} & \text{if } 1 < j < j_J^R \\ \bar{y}_{J,s,j-1,t-1} & \text{if } j \geq j_J^R \end{cases}$$

The public pension is positive for individuals of age $j \geq j_J^R$ and zero otherwise.

$m_{j,t}$ and $lt_{j,t}$ denote payment for health and long-term care insurance, respectively, each individual of age j at time t paid by the government. We assume that the government provides the same social insurance benefits to foreign individuals.⁶

We assume that the Japanese government imposes the lump-sum tax $\tau_{J,t}^{ls}$ on each individual, and this tax is adjusted to satisfy the government budget constraint in each period, which is given as

$$B_{t+1} + T_t = G_t + P_t + M_t + LT_t + (1 + r_{b,t})B_t \quad (4)$$

where T_t , P_t , M_t , and LT_t denote total tax revenues, total pension payment, medical expenditures and long-term care spendings, respectively, and they are defined as follows.

$$\begin{aligned} T_t &= \tau_{J,t}^c \sum_{x,s,j} c_{x,s,j,t} \mu_{x,s,j,t} + (\tau_{J,t}^b \omega_t^b r_t^b + \tau_{J,t}^k \omega_t^k r_{J,t}^k) \sum_{s,j} a_{J,s,j,t} \mu_{J,s,j,t} \\ &\quad + \tau_{J,t}^l \sum_{x,s,j} h_{x,s,j} \mu_{x,s,j,t} + \tau_{J,t}^{ls} \sum_{x,s,j} \mu_{x,s,j,t} \\ P_t &= \sum_{s,j \geq j_J^R} p_{J,s,j,t} \mu_{J,s,j,t} \\ M_t &= \sum_{x,s,j} m_{j,t} \mu_{x,s,j,t} \\ LT_t &= \sum_{x,s,j} lt_{j,t} \mu_{x,s,j,t}, \end{aligned}$$

⁶We assume foreign workers return to their home country by the time they reach the pension eligibility age and therefore they do not receive public pension benefits in Japan.

where $c_{x,s,j,t}$ and $a_{x,s,j,t}$ denote the consumption and asset of an individual of origin x , skill s , and age j at time t , respectively. ω_t^k and ω_t^b represent the share of individuals' assets allocated to private capital and government bond, respectively at time t . Note that $\omega_t^k + \omega_t^b = 1$.

We denote by $R_{J,t} = 1 + (1 - \tau_t^b)\omega_{b,t}r_{b,t} + (1 - \tau_{J,t}^k)(1 - \omega_{b,t})r_{J,k,t}$ the gross after-tax interest rate on savings of Japanese individuals.

Foreign Government: The government in the foreign country also imposes tax on consumption, labor income and return from savings, and make social security payment to retirees, similarly defined as in Japan with replacement rate $\kappa_{F,t}$. We do not consider the budget constraint of the foreign country in our model and abstract from the government debt. The gross after-tax interest rate on savings of foreigners is denoted as $R_{F,t} = 1 + (1 - \tau_{F,t}^k)r_{F,k,t}$.

2.7 Individuals' Problem

In this section, we present the problems of the Japanese and foreign individuals.

2.7.1 Japanese Individuals' Problem

The state vector of a Japanese individual includes age j , skill s and asset a . For simplicity, time subscripts are omitted. a' denotes asset in the next period. The value function of a Japanese individual is given as follows.

$$V(j, s, a) = \max_{c, a'} \{u(c) + \beta \phi_{J,j+1} V(j+1, s, a')\}$$

subject to

$$(1 + \tau_J^c)c + a' = R_J a + (1 - \tau_J^l)w_{J,s}h_{J,s,j} - \tau_J^{ls} + p_{J,s,j \geq j_J^R} + b$$

2.7.2 Foreign Individuals' Problem

We now define the problem of foreigners, including their migration decision. We assume that foreign individuals make a decision at age $j = 1$ in the model, when the state vector includes skill s , asset a and preference type i , besides age. Each foreigner makes a draw of preference type before entering the economy and it determines the individual's per-period utility cost γ_i of working in Japan.

The value of foreigners who decide to migrate to Japan is denoted as $X(j, s, a, i)$, and the value of staying in the foreign country is denoted as $W(j, s, a)$. Note that since we assume that foreigners migrate to Japan at most once, the preference type is irrelevant once they decide to stay in the home country and the state i does not enter the value. We abstract from bequest transfers of foreigners.

Value of Stayers: The value function of individuals residing in the foreign country is given as follows. This value function applies to those who chose not to migrate to Japan and to those who migrated to Japan and have already returned to their home country.

$$W(j, s, a) = \max_{c, a'} \{u(c) + \beta \phi_{F, j+1} W(j+1, s, a')\}$$

subject to

$$(1 + \tau_F^c)c + a' = R_F a + (1 - \tau_F^l)w_{F, s} h_{F, s, j} + p_{F, s, j \geq j_F^R}$$

Value of Migrants: The value function of individuals who have migrated to and currently reside in Japan is given as follows.

$$X(j, s, a, i) = \max_{c, a'} \{u(c | \zeta_t) - \gamma_i + \beta \phi_{F, j+1} [(1 - \lambda)X(j+1, s, a', i | \zeta_{t+1}) + \lambda W(j+1, s, a')]\}$$

subject to

$$(1 + \tau_J^c)c + a' = R_F a + (1 - \tau_J^l)w_{F, s} h_{F, s, j} - m I_{j=1}$$

$I_{j=1}$ is an indicator that takes a value of 1 if the individual is aged 1 and just migrated, incurring one-time resource cost of moving, m , and 0 otherwise. As explained in section 2.4, foreign workers stay in Japan for the duration of $1/\lambda$ years on average, where λ represents the probability that they return to their home country in the next period.

Migration Decision: Upon entry to the market, there is heterogeneity in the asset holdings of foreigners. We assume that at $j = 1$ they draw initial asset holdings $\hat{a}$ from the distribution $\mathcal{G}$.

$$\hat{a} \sim \mathcal{G} \quad \text{at } j = 1$$

Migration is feasible at $j = 1$ if and only if assets cover the one-time moving cost m .

$$\text{migration feasible at } j = 1 \iff \hat{a} \geq m$$

Given this feasibility condition, the pre-migration value is

$$\widetilde{W}(1, s, \hat{a}, i) = \begin{cases} \max\{W(1, s, \hat{a}), X(1, s, \hat{a}, i)\}, & \text{if } \hat{a} \geq m, \\ W(1, s, \hat{a}), & \text{if } \hat{a} < m. \end{cases}$$

2.8 Equilibrium

We define the equilibrium conditions for the Japanese economy. Given the sequence of demographic parameters $\{\phi_{J, j, t}, n_{J, t}, \mu_{J, s, j, t}\}$, government policy parameters, interest rate on the government debt $\{r_t^b\}$, and asset allocation rules $\{\omega_t^k, \omega_t^b\}$, a competitive equilibrium is given by the sequence of consumption and asset choices $\{c_{x, s, j, t}, a_{x, s, j, t}\}$ for individuals of origin x , skill s , and age j at time t , factor prices $\{r_{x, t}^k, w_{x, s, t}\}$, lump-sum tax rates $\{\tau_{J, t}^{ls}\}$, and lump-sum bequest transfer $\{b_t\}$ that satisfy the following conditions.

1. Japanese and foreign individuals solve the optimization problems described in section 2.7.
2. Factor prices are determined competitively, as in equations (1), (2) and (3).
3. The markets for capital, government bond, and low and high-skill labor clear.

$$\begin{aligned}
K_t &= \omega_t^k \sum_{s,j} a_{J,s,j,t} \mu_{J,s,j,t} \\
B_t &= \omega_t^b \sum_{s,j} a_{J,s,j,t} \mu_{J,s,j,t} \\
L_t &= \sum_{x,j} h_{x,L,j} \mu_{x,L,j,t} \\
H_t &= \sum_{x,j} h_{x,H,j} \mu_{x,H,j,t}
\end{aligned}$$

Note that total savings of the Japanese individuals equal the sum of the aggregate capital stock and the government bonds.

$$A_t = \sum_{s,j} a_{J,s,j,t} \mu_{J,s,j,t} = K_t + B_t$$

4. The goods market clears.

$$C_t + K_{t+1} + G_t + M_t + LT_t + F_t = Y_t + (1 - \delta)K_t$$

where C_t denotes aggregate consumption and F_t represents part of foreign individuals' earnings sent to their home country as remittances.

5. The lump-sum tax $\tau_{J,t}^{ls}$ satisfies the government budget constraint (4).
6. The bequest transfer b_t equals the assets left by deceased individuals per survivor.

$$b_t = \frac{\sum_{s,j} a_t (1 - \phi_{J,j,t}) \mu_{J,s,j,t-1}}{\sum_{s,j} \mu_{J,s,j,t}}$$

where a_t is the saving of Japanese individuals in each state at time $t - 1$.

3 Calibration

We parameterize the model in two steps. A subset of parameters is directly pinned to data, while the remaining parameters are chosen so that the model matches selected data moments in equilibrium. The data moments are drawn from the Basic Survey on Wage Structure (BSWS), the Summary of Notification of Foreign Workers' Employment Status

(FWES), and estimates from the National Institute of Population and Social Security Research (IPSS).

For foreign workers' origin countries, we focus on Vietnam, China, and the Philippines, which are the three largest nationalities among foreign workers in Japan as of 2024. We weight country-specific data according to their 2024 shares among all foreign workers in Japan.⁷ For labor market data, we use the China Family Panel Studies (CFPS) for China; the Vietnam Labour Force Survey (VLFS) for Vietnam, and the Philippines Family Income and Expenditure Survey (PFIES) for the Philippines.

We calibrate the initial economy to approximate the Japanese economy in 2010 and simulate the transition dynamics from 2010 to 2400, when the economy is in the final steady state.

3.1 Demographics

Individuals enter the economy at age $j = 1$, which corresponds to 25 years old. Individuals live up to a maximum age $J = 75$, 99 years old. The survival rates $\phi_{J,j,t}$ for Japanese individuals are obtained from the Life Table provided by IPSS.

For the skill distribution of the Japanese, we use the Basic School Survey data to compute the share of the 4-year college enrollment for each cohort to initialize the skill distribution by age in 2010. The college enrollment rate in 2023 is 58% according to the Basic School Survey and we assume that the share of high-skill entrants will converge to 60% by the mid-2030s.

We use data of the FWES for the number of foreign workers in the past in approximating the transition from 2010 to 2024. For the pool of potential foreigners who would consider migrating to Japan in the past and in the future, we use demographic projections of the United Nations (UN) and the data for Vietnam, China, and the Philippines, the three countries with the largest shares of foreign workers in Japan.

According to the FWES, foreign workers from Vietnam and the Philippines constituted only a negligible share of all foreign workers in 2010, although by 2024, both countries account for top shares. Accordingly, for these two countries we set the initial value in 2010 to zero and assume a linear increase from 2010 to 2024 up to each country's target level. Specifically, for Vietnam the potential number increases linearly until it reaches the level of the country's 23–27-year-old population; for the Philippines, the level of Filipino potential workers in 2024 is computed based on their 2024 share among foreign workers in Japan, and the path from 2010 to 2024 is derived assuming a linear path to that level.

For China, which held the largest share of foreign workers in Japan in 2010, we back-cast to 2010 using the 2024 ratio to Vietnam together with UN population growth rates.

⁷According to FWES, in 2024 Vietnamese accounted for 24.8%, Chinese (including Macau) 17.8%, and Filipinos 10.7% of all foreign workers in Japan.

From 2025 onward, we extrapolate using each country’s UN population growth rates. The sum across countries of these calibrated per-period population measures is taken to be the potential number of individuals abroad who may migrate to Japan.

The survival rates of foreign workers $\phi_{F,j,t}$ are computed as the weighted average of the values for the three countries based on the projections of the United Nations.

3.2 Preferences

Risk aversion parameter σ is set to 2.0. The subjective discount factor for Japanese β_J is set to 1.021 so that capital to output ratio is 3.0 as in 2010. That of foreign nationals are set to $\beta_F = 0.95$.

We assume that the psychic cost of foreign workers residing in Japan, γ , is uniformly distributed over $[0, \bar{\gamma}_s]$, which may depend on the skill level s . The upper bound $\bar{\gamma}_s$ is calibrated to match, in the initial steady state, the number of foreign workers relative to the Japanese workers for each skill. The values are 0.44% and 0.23% for high skill and low skill workers, respectively.⁸

Foreigners derive an agglomeration utility from living in Japan and we assume that it increases in the stock of foreign workers in Japan. Normalizing the agglomeration utility in the initial steady state to 1, the functional form is

$$\zeta_t = \left(\frac{\sum_s \sum_j \mu_{F,s,j,t}}{\sum_s \sum_j \mu_{F,s,j,1}} \right)^\xi.$$

The parameter ξ is calibrated to match the growth in the number of foreign workers from 2010 to 2024, as presented in Section 4. The return probability λ is set to 16.74%, chosen so that the five-year retention rate is 40% as reported by [OECD \(2024b\)](#).

3.3 Endowment

Japanese workers’ earnings are given by $y_{s,j,t} = h_{J,s,j} w_{J,s,t}$, where $h_{J,s,j}$ denotes age and skill specific human capital and $w_{J,s,t}$ is the corresponding market wage in Japan. We normalize $h_{J,L,1} = h_{J,H,1} = 1$ and choose $h_{J,s,j}$ for $j \geq 2$ to match the age–skill wage profiles in the Basic Survey on Wage Structure (BSWS). Note that we assume that at $j = 1$ the skill premium is entirely captured by differences in market wages.

Foreign workers face the same market wage schedule in Japan as native workers but possess different human capital $h_{F,s,j}$. Given the market wage $w_{J,s,t}$ and observed wages for foreign workers in Japan, we obtain their implied human capital levels so that the model–implied wages replicate the empirical wage profiles.⁹ Figure 1 plots age-specific

⁸We set the lower bound of the distribution to 0, i.e., there is no psychic benefit of coming to Japan.

⁹See [Appendix A](#) for more details of the wage computation.

wages for high- and low-skill workers in Japan, separately for foreign and Japanese workers. For low-skill workers, the wage gap between Japanese and foreign workers is large and highly persistent. For high-skill workers, the gap is relatively small, and wage growth is similar up to around age 50. We calibrate $h_{F,s,j}$ to match these wage profiles.

Wages $w_{F,s}$ and human capital $\tilde{h}_{F,s,j}$ in the foreign country are constructed as follows. We assume that the market wage in the foreign country is exogenous and set $\tilde{h}_{F,s,j}$ so that the model-implied wage schedule by age and skill matches a weighted average of country-specific wage data across the three source countries using the 2024 nationality shares of foreign workers in Japan (China, Vietnam, and the Philippines). Foreign-country wage levels are normalized by Japan's low skill wage at age 25.¹⁰ We assume exogenous wages in the foreign country grow at 4% per year based on International Labour Organization (ILO) in the past. We consider alternative growth of their wages in the future in Section 4.

Foreign workers hold assets upon entering the economy. At $j = 1$, each worker draws initial asset holdings $\hat{a}$ from a distribution $\mathcal{G}$ estimated from the CFPS based on asset holdings at age 25. There is a moving cost m to migrate to Japan and only individuals who can cover this cost at age 25, i.e., those with $\hat{a} \geq m$, can make a migration decision. During the transition, we assume that the mean of initial asset holdings rises at the same rate as wage growth.¹¹

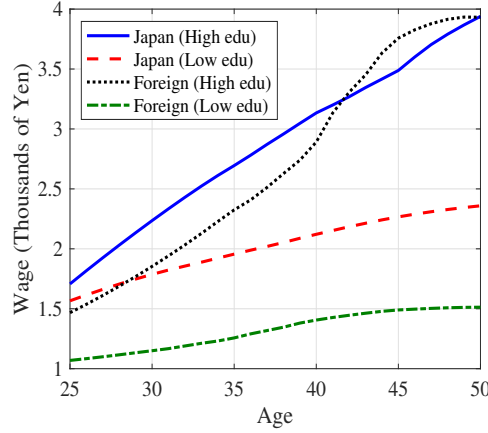


Figure 1: Hourly Wage in Japan

¹⁰Exchange rates are taken from the World Bank and expressed with the U.S. dollar (USD) as the base currency as of 2020. We use: USD/JPY = 106.77, USD/VDN = 23,208.37, USD/RMB = 6.90, USD/PHP = 49.62

¹¹In computing initial asset holdings, we restrict the sample to those co-residing with family at age 25, reflecting evidence from the Foreign Workers Employment Status Survey (FWES) that roughly 50% obtain financial support from family to cover initial costs.

3.4 Technology

There are two technological parameters that determine the economy's level of productivity in the production function.

$$Y_t = F(K_t, L_t, H_t) = Z_t K_t^\alpha (L_t^\varphi + A_t H_t^\varphi)^{\frac{1-\alpha}{\varphi}}$$

First, Z_0 represents general technology, i.e., total factor productivity (TFP). We set $Z_0 = 0.862$ as normalization so that the low-skill wage at age 25 in the initial steady state is unity. Second, A_0 governs the high-skill wage premium. We set $A_0 = 0.849$ so that $w_{J,H,t}/w_{J,L,t}$ at age 25 in the initial steady state matches the observed skill premium.

The growth rates of Z_t and A_t are computed from the average observed increases in wages and the skill premium over 2010–2024. Over this period, the average growth rate of Z_t (denoted g_Z) is 0.59% per year, and the average growth rate of A_t (denoted g_A) is 0.90% per year. These growth rates are held constant at that level until 2040 and then gradually converge to 0% by 2100. Following [Kitao and Yamada \(2021\)](#), the capital share of output α is set to 0.4, and capital depreciates at a rate of 8.3%. We set $\varphi = 0.7$ following [Taniguchi and Yamada \(2021\)](#).

3.5 Government

Public pension benefits are paid from $j^R = 41$ (age 65) onward. The pension replacement rate κ is set to 0.45 so as to match the ratio of total public pension expenditure to GDP in 2010. Government expenditures for health insurance benefits and long-term care insurance are computed from data published by the Ministry of Health, Labour and Welfare. The insurance coverage rate for health insurance varies by age group, ranging from 70% to 90%, and the government coverage rate for long-term care is 90%. Because we assume different growth rates for TFP and SBTC along the transition, we accordingly assume that per-household government expenditure on medical and long-term care grows at the rate of average wage growth.¹²

The consumption tax rate τ_c , the labor income tax rate τ_l , the capital income tax rate τ_k , and the tax rate on the government bond τ_b are 10%, 25%, 35%, and 20%, respectively, and these rates are assumed to be constant over the transition. The lump-sum tax is imposed on all individuals residing in Japan so that the government budget constraint (4) holds. The path of the lump-sum tax is presented in Section 4.

Government expenditure G_t is chosen so that, excluding public pension spending, the sum of G_t , health insurance, and long-term care insurance equals 20% of GDP in 2010. Government debt is set to 146% of GDP, corresponding to the 2010 ratio of government debt (financial assets basis) to GDP. The interest rate on government debt is 1.0%.

¹²This assumption is consistent with the idea that, as economy-wide wages rise, remuneration for workers in the medical and long-term care sectors and other costs for providing services rise as well.

Following the Japanese case, the foreign government collects taxes and pays public pensions from the retirement age onward. We assume the tax rates are held constant and we abstract from the government budget in the foreign country and the foreign government's period-by-period budget need not balance. Based on [OECD \(2024a\)](#), we set the pension replacement rate of the foreign country to 47 percent and the pension eligibility age to 58. Drawing on [OECD \(2024c\)](#), we set the consumption (VAT) rate in the foreign economy at 10 percent, while both the labor income tax rate and the tax rate on interest income are set to zero.

Table 1: Parameters of the Model

Parameter	Description	Value/Source
<i>Demographics</i>		
J	Maximum age	76 (age 100)
j^R	Retirement age	41 (age 65)
$\phi_{J,j,t}$	Survival probability (Japanese)	Life Table (IPSS)
$\phi_{F,j,t}$	Survival probability (foreign workers)	Life Table (IPSS)
<i>Endowment</i>		
$h_{J,s,t}$	Human capital (Japanese)	See text
$h_{F,s,t}$	Human capital (foreign workers)	See text
$\tilde{h}_{F,s,t}$	Human capital (foreign country)	See text
$\mathcal{G}$	Asset distribution of foreign workers ($j = 1$)	See text
λ	Return probability of foreign workers	16.74
<i>Preference</i>		
σ	Risk aversion parameter	2.0
β_J	Subjective discount factor (Japan)	1.021
β_F	Subjective discount factor (Foreign)	0.950
$\bar{\gamma}_L, \bar{\gamma}_H$	Psychic cost of migration (by skill)	35.64, 40.69
ξ	Agglomeration parameter	2.940
<i>Production</i>		
Z_0	Neutral technology	0.801
A_0	High skill productivity	0.849
g_Z	Growth rate of Z	0.59%
g_A	Growth rate of A	0.90%
α	Capital share of output	0.40
φ	EOS b/w low and high-skill labor	0.7
δ	Depreciation rate of capital	0.083
<i>Government (Japan)</i>		
j_R	Pension retirement age	41 (age 65)
κ	Public pension replacement rate	0.45
τ_l	Labor income tax rate	0.18
τ_k	Capital income tax rate	0.35
τ_c	Consumption tax rate	0.1
τ_b	Bond income tax rate	0.2

4 Numerical Results

4.1 Baseline Economy

In this section, we describe the characteristics of the baseline economy during the transition, based on the model and calibration presented in the previous sections. In presenting simulation results, we focus on the period 2010-2100, although the transition dynamics are computed over a much longer horizon, until 2400, to ensure smooth convergence.

Figure 2 shows the number of foreign workers in the model, along with the corresponding data for the period between 2010 and 2024. The number of foreign workers has increased significantly over the past 15 years, both in the model and in the data. As discussed in Section 3, the profile aligns with data partly because we calibrate preference parameters to approximate the initial number of foreign workers and agglomeration effects associated with the rise in the number of foreign workers over the past 15 years.

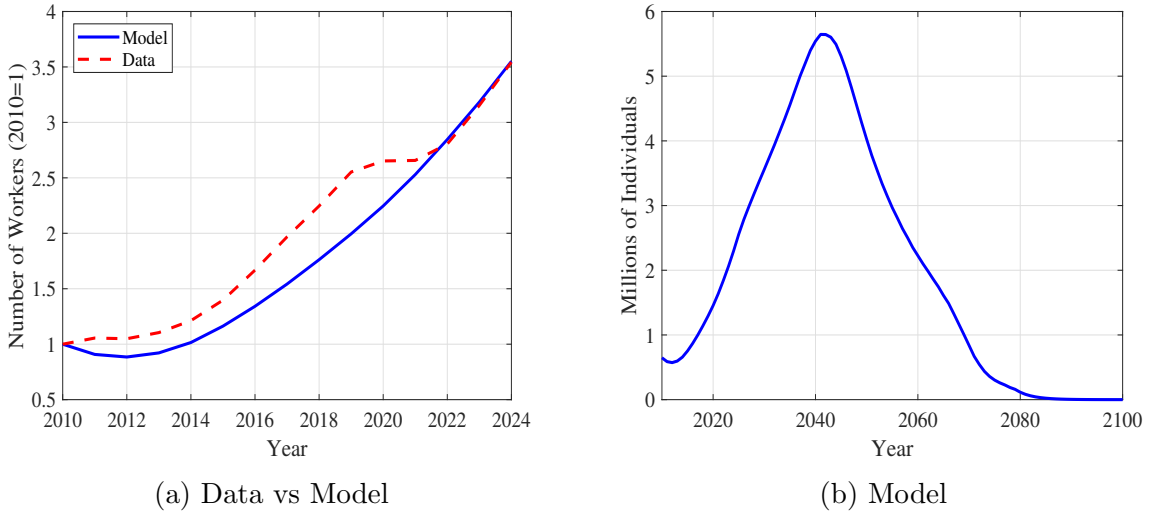


Figure 2: Foreign Workers in Japan

Extending the model beyond 2024, our simulation suggests that the number of foreign workers will continue to increase in the near term. This trend, however, begins to reverse in the early 2040s, after which Japan experiences a steady decline in foreign workers. In our baseline simulation, the number of foreign workers falls to nearly zero by 2080 and does not recover thereafter. This outcome stands in stark contrast to the projections of the IPSS, for example, which under its baseline scenario, expects the number of foreign residents to continue rising for a longer period, extrapolating the trend observed in recent years. Our model instead indicates that the inflow of foreign workers will soon begin to decline, driven by factors such as divergent wage growth paths and population dynamics.

As shown in Figure 3, the Japanese population is projected to decline monotonically throughout the century, and the share of foreign workers in the Japanese population aged

25 and above will rise from around 2% in 2025 to the peak of 6.7% in the early 2040s, before it starts to decline sharply.

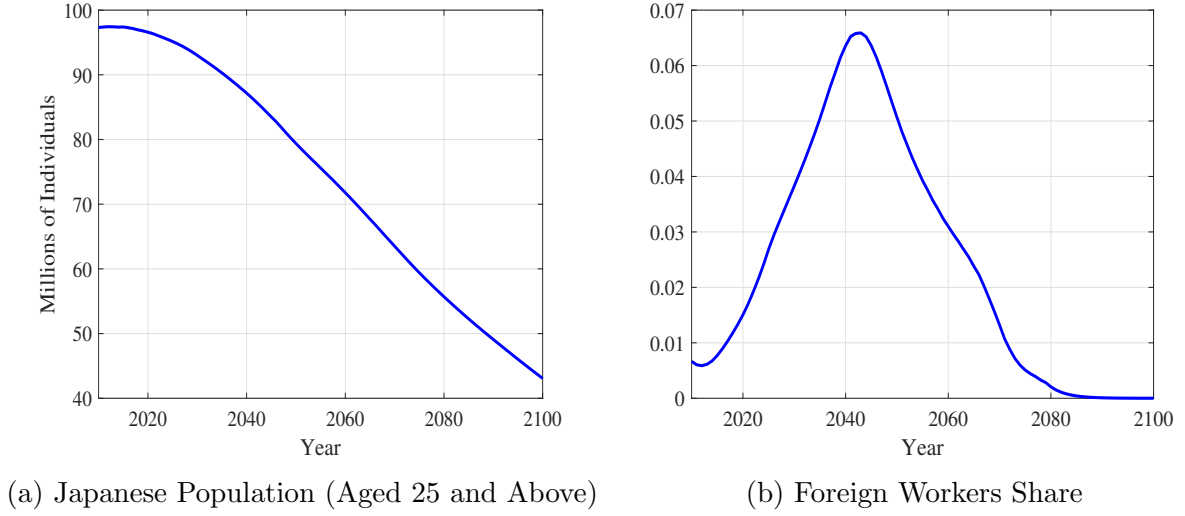


Figure 3: Japanese Population and Foreign Workers

Note: The Japanese population is based on the IPSS projections of the Japanese aged 25 and above.

The composition of foreign workers by their skill level is shown in Figure 4. The share of high-skill foreign workers in 2010 is about one third, which is in line with the data. Thereafter, the share rises to almost 50% by the mid-2020s, but declines thereafter, since the number of low-skill foreign workers continue to rise until the early 2040s while the number of high-skill workers starts to decline earlier.

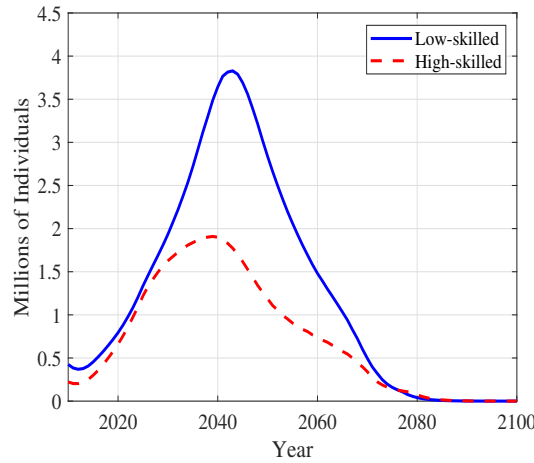


Figure 4: Foreign Workers in Japan: By Skill

As the capital stock becomes relatively less scarce than labor supply initially, the interest rate will rise from about 5% in 2010 to 7% in 2040 and decline thereafter as shown in Figure 5, because the labor falls faster than the aggregate capital. As the labor supply falls due to demographic aging, the wage rate monotonically rises for an extended period.

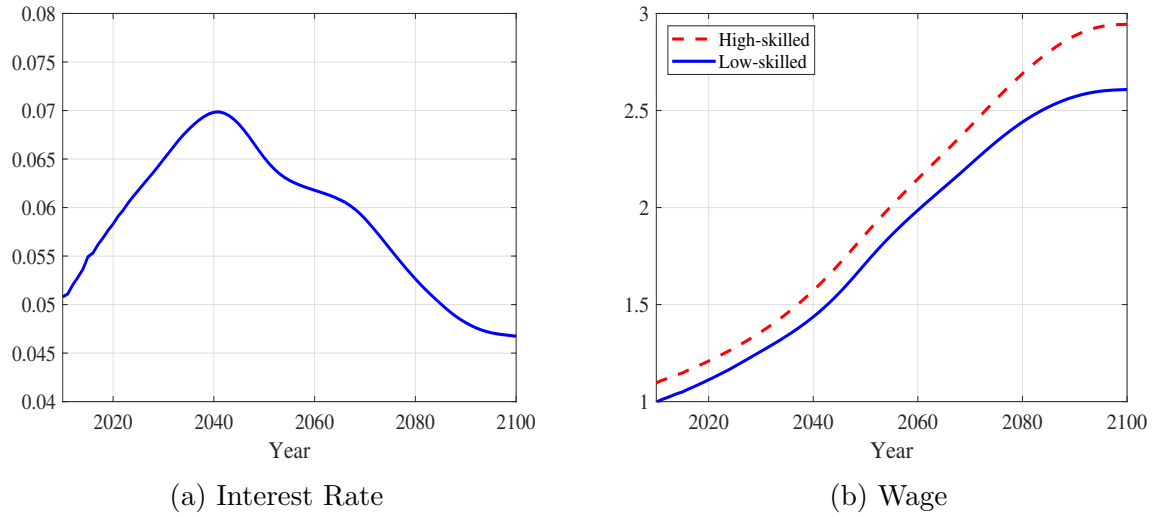


Figure 5: Factor Prices

Figure 6 shows the path of lump-sum tax that is required to balance the government budget each year. The tax is expressed in terms of per-capita consumption of the same year. The tax burden continues to rise throughout the century and reach 0.1 by the early 2050s and 0.2 in 2090. The peak magnitude of the tax burden is similar to that of other studies ([Kitao 2015](#), [Braun and Joines 2015](#)), although the shape of the time path differs from them. This is due to different assumptions along the transition. We assume that the expenditures for medical and long-term care services grow at the same rate as the average earnings. Also, our productivity process is based on more recent data observed between 2010 and 2024.

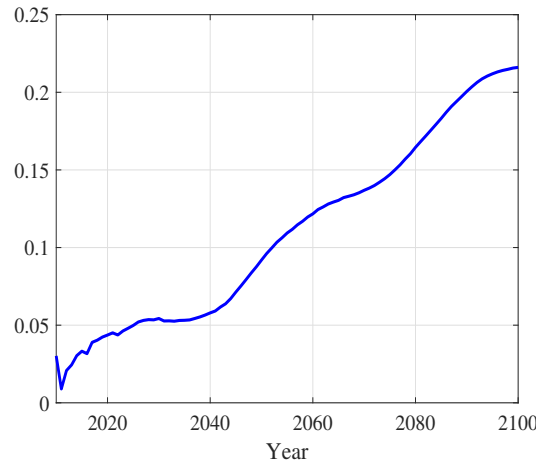


Figure 6: Lump-sum Tax

Note: Lump-sum tax expressed as a share of per-capita consumption.

4.2 Effects of Foreign Workers

In this section, we simulate the baseline model under an extreme assumption that there is no foreign worker in Japan so that we can highlight the roles of foreign workers in Japan. As shown in Table 2, aggregate labor supply of low and high-skill workers would be as much as 7% and 3.5% below the baseline model, respectively. Aggregate output would be about 2.5% lower in the 2040s and 2050s. With lower labor supply, wages are higher, though the effects are relatively small. The rise in the tax burden, expressed in terms of the lump-sum tax as a share of per-capita consumption, is about 2.2 percentage points in 2040 and falls to 1 percentage point by 2060, as the number of foreign workers declines in the baseline model and their effects diminish.

Table 2: Roles of Foreign Workers

	2025	2040	2050	2060
Low-skill Labor				
- Baseline	68.2	52.0	39.4	29.9
- No foreigner	66.9 (-2.0%)	48.3 (-7.0%)	36.6 (-7.2%)	28.4 (-5.0%)
High-skill Labor				
- Baseline	46.9	54.8	56.1	54.6
- No foreigner	45.6 (-2.6%)	52.9 (-3.5%)	55.0 (-2.1%)	53.9 (-1.4%)
Low-skill Wage				
- Baseline	1.00	1.22	1.45	1.68
- No foreigner	1.01 (+0.9%)	1.24 (+1.9%)	1.47 (+1.4%)	1.69 (+0.6%)
High-skill Wage				
- Baseline	1.00	1.23	1.46	1.68
- No foreigner	1.01 (+1.2%)	1.25 (+1.4%)	1.46 (+0.5%)	1.68 (-0.1%)
Aggregate Output				
- Baseline	1.00	1.14	1.23	1.26
- No foreigner	0.99 (-0.9%)	1.12 (-2.6%)	1.19 (-2.5%)	1.23 (-1.9%)
Lump-sum Tax (% of Cons.)				
- Baseline	4.98	5.79	9.20	12.17
- No foreigner	6.06 (+1.1ppt)	7.96 (+2.2ppt)	10.66 (+1.5ppt)	13.16 (+1.0ppt)

Note: The levels of wages and aggregate output are normalized by the level of output in the baseline model in 2025. The lump-sum tax is expressed as a share of per-capita consumption.

Welfare Effects: We now examine how the welfare of the Japanese population would be affected if there was no foreign worker in Japan. Specifically, we calculate the amount of compensation individuals would need in the baseline economy to be as well off as

they would be in an economy without foreign workers. Welfare is evaluated in terms of consumption equivalent variation, defined as the percentage change in consumption that must occur in every state of the economy for the remainder of an individual's life. A positive value indicates that individuals are better off in the economy without foreigners, meaning they would need to be compensated with additional consumption in the baseline economy. A negative value indicates that individuals are better off in the baseline economy and they are willing to pay to remain in the baseline economy.

The left panel of Figure 7 shows the welfare effects by age in 2010 for individuals of the two skill levels. All individuals experience a welfare loss, as indicated by the negative consumption equivalence. Quantitatively, the loss is larger for low-skill than for high-skill individuals across all ages, with the largest welfare declines observed among individuals in their late 50s and 60s.

In our model, household welfare depends on three macroeconomic variables in equilibrium and households' responses to them: wages, interest rates, and the lump-sum tax implied by the government budget. As discussed above, the economy without foreign workers is characterized by higher wages, lower interest rates, and a higher lump-sum tax relative to the baseline economy.

The right panel of Figure 7 decomposes the welfare effects by introducing the three factors that influence welfare: wages, interest rates, and taxes, one by one in the economy without foreign workers. The wage difference generates positive welfare effects for individuals of working age.¹³ The lump-sum tax is higher in the economy without foreign workers and generates negative welfare effects across all ages, with a larger impact on younger individuals who must pay higher taxes for more years. The effect of the lump-sum tax rises for the oldest individuals, whose savings have already become quite small, amplifying the income effect and leading to greater welfare losses. The interest rate is lower in the economy without foreign workers, as the capital-labor ratio increases with fewer workers, causing welfare losses that peak around the age of peak wealth before retirement, when individuals face lower returns on their accumulated savings. Taken together, these patterns account for the overall negative welfare effects and the variation in total effects across individuals of different ages and skill levels.

¹³Note that the wage effect is not zero even for oldest individuals, because the rise in the real wage in the economy without foreign workers also affects the level of social security benefits received by those who were already retired in the initial steady state.

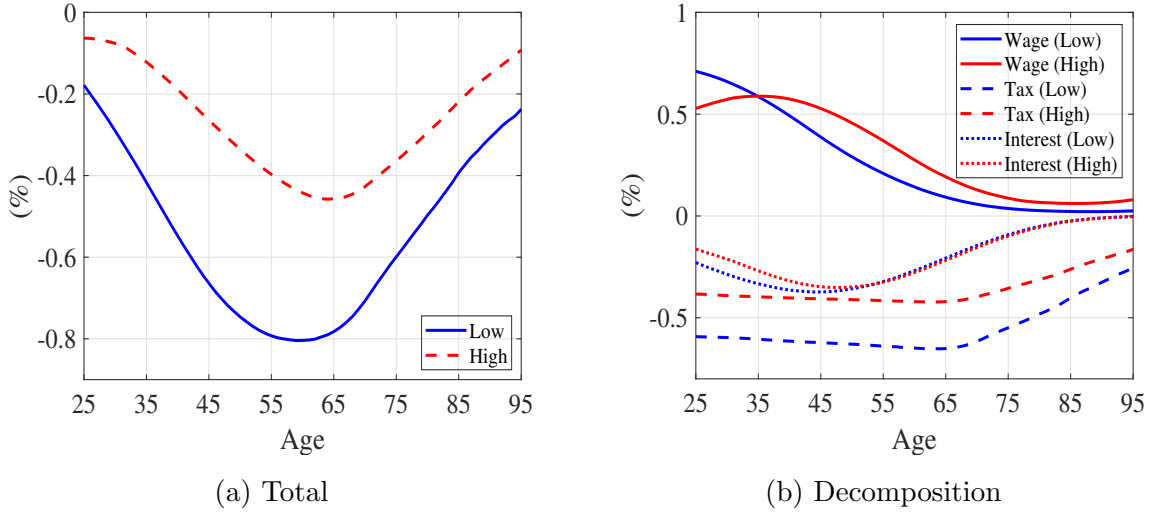


Figure 7: Welfare Effects of Japanese Household (In Consumption Equivalence, %)

The welfare effects of foreign workers on future generations can be computed in a similar manner. For each cohort entering the economy at age 25, we calculate the percentage change in lifetime consumption that would make an individual indifferent between the baseline economy and the economy without foreign workers.

The results are reported in Table 3 for cohorts entering in 2025, 2040, 2050, and 2060. The total welfare effects are negative in all years, but the breakdown by skill level reveals positive effects for low-skill individuals and larger negative effects for the high-skill individuals.

As shown in Figure 4, most of the foreign worker inflows in the coming decades are concentrated among low-skill workers.

As a result, the effective supply of low-skill labor increases, and general-equilibrium wage compression becomes more pronounced. Low-skilled entrants therefore experience a larger negative impact on their lifetime wages due to the inflow of foreign workers. Fiscal relief from a lower lump-sum tax or higher interest rates does not fully offset the adverse wage effects. High-skill individuals face a milder wage impact and benefit more from higher returns on savings in the baseline economy. This difference explains the diverging welfare effects between the two skill groups.

Table 3: Welfare Effects of Cohorts in Transition (In Consumption Equivalence, %)

	2025	2040	2050	2060
Low-skill	0.03%	0.11%	0.03%	0.04%
High-skill	-0.10%	-0.14%	-0.12%	-0.10%
Total	-0.033%	-0.018%	-0.045%	-0.065%

4.3 Alternative Scenarios

In this section, we explore alternative assumptions regarding key factors during the transition that influence the migration decisions of foreign workers and assess the sensitivity of our quantitative results to these assumptions.

4.3.1 Wage Differentials

In this section, we investigate the sensitivity of our results to alternative scenarios regarding the relative wages of the foreign country vs Japan.

Alternative Wage Growth in the Foreign Country: In the baseline model, we assumed that the current wage growth rate of 4% will continue in the foreign country. We now consider two scenarios of the wage growth rate, at 3% and 5%, respectively. The productivity growth and implied wage growth in Japan remain unchanged and coming to Japan becomes more (or less) attractive relative to the baseline case.

As shown in Figure 8, with low wage growth of 3% in the foreign country, Japanese wages are relatively more attractive to foreign workers and the number of foreign workers will reach 7 million by the early 2040s. With higher wage growth, the number of foreign workers will start to decline more quickly than in the baseline and will reach zero by the 2070s.

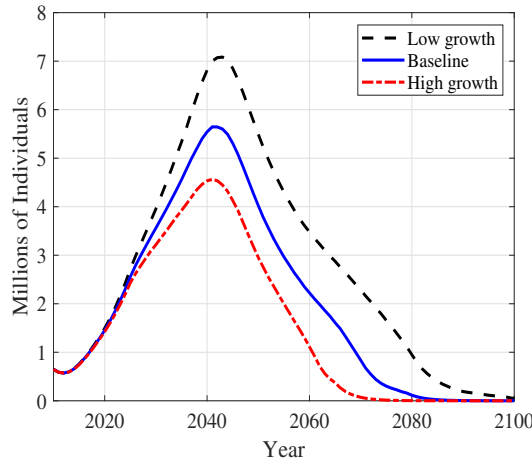


Figure 8: Foreign Workers in Japan: Alternative Wage Growth in the Foreign Country

The effects of the alternative scenarios on the future path of aggregate output and the tax burden are presented in Table 4. Given the relatively small share of foreign workers in the baseline economy, aggregate output is not significantly affected, although it is slightly higher under the scenario with lower wage growth and a larger number of foreign workers. The tax burden associated with the demographic transition is also somewhat alleviated, as more foreign workers contribute taxes to the Japanese government.

Table 4: Alternative Wage Growth in the Foreign Country

	2025	2040	2050	2060
Aggregate Output				
- Low Wage Growth	1.00	1.15	1.23	1.27
- Baseline	1.00	1.14	1.23	1.26
- High Wage Growth	1.00	1.14	1.22	1.25
Lump-sum Tax (% of Cons.)				
- Low Wage Growth	4.90	5.23	8.59	11.55
- Baseline	4.98	5.79	9.20	12.17
- High Wage Growth	5.05	6.21	9.59	12.69

Note: The level of aggregate output is normalized by the level of output in the baseline model in 2025.

4.3.2 Population Growth in the Foreign Country

In the baseline model, we use the median demographic projections of the U.N. for the calibration of potential foreign workers. However, there is considerable uncertainty about the demographic transition. Especially, the trend of fertility rates in origin countries is critical for the availability of potential workers coming to Japan. Therefore we consider two alternative scenarios about fertility rates in the foreign country, using low and high fertility projections of the U.N.

As shown in Figure 9, when fertility rates are higher and population of the foreign country grows faster, the number of foreign workers choosing to migrate to Japan would rise. This change, however, will start to manifest only after the 2050s, when additional new-born individuals now will start working. Therefore, uncertainty about fertility rates and future population growth will affect the long-run projections of the inflow of foreign workers to Japan, but it will not have large quantitative impact on the projections over the next two to three decades.

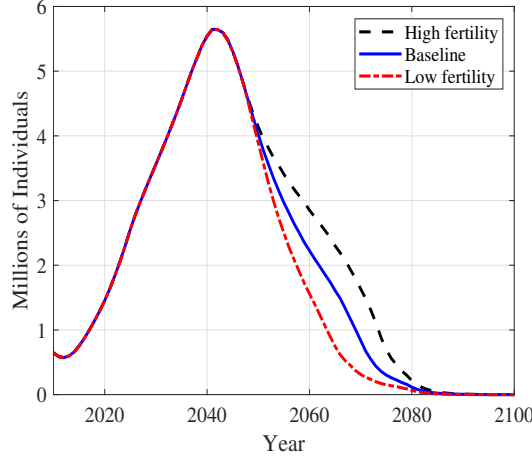


Figure 9: Foreign Workers in Japan: Alternative Population Growth in the Foreign Country

4.3.3 Educational Attainment in the Foreign Country

Lastly, we consider alternative scenarios about the educational attainment in the foreign country. In the baseline computation, we assume that the ratio of high-skill workers will rise and reach 60% over the next 70 years. We simulate the model assuming that the convergence occurs sooner in 40 years. This will affect not only the number of foreign workers coming to Japan but also the composition of them.

Figure 10 shows the number of foreign workers in total and by skill level. Compared to the baseline, as shown in Figure 4, the number as well as the share of high-skill foreign workers is higher. There are fewer low-skill workers staying in Japan after the peak in the early 2040s than in the baseline model. The total number of foreign workers would remain smaller.

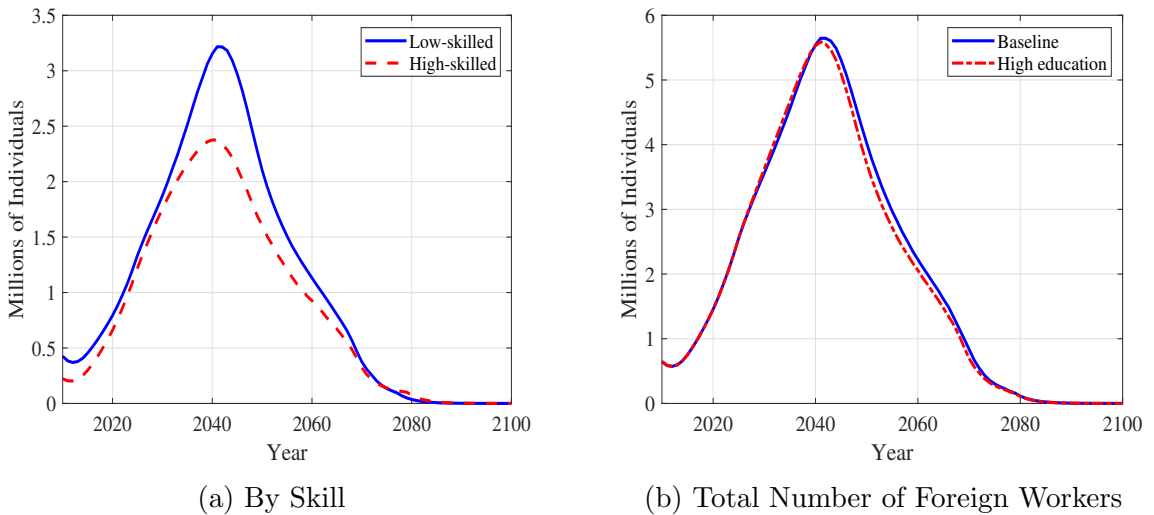


Figure 10: Foreign Workers in Japan: Alternative Educational Attainment in the Foreign Country

5 Conclusion

This paper has developed a multi-region overlapping generations model with endogenous migration to analyze the role of foreign workers in Japan’s aging economy. By endogenizing migration decisions, the framework highlights how differences in wages, demographics, and fiscal systems between Japan and major sending countries shape the inflow of workers, their skill composition, and ultimately Japan’s macroeconomic and fiscal trajectory and people’s welfare. The results show that foreign workers mitigate the decline in aggregate labor supply and output, alleviate the rise in fiscal burdens, and modestly affect wage dynamics, though their impact depends crucially on the evolution of productivity and demographic trends, both in Japan and abroad.

At the same time, the analysis underscores the limits of relying on foreign labor alone to counterbalance demographic headwinds. Even under favorable assumptions, the inflow of workers peaks and declines as sending countries undergo their own demographic transitions and wage growth. Our study suggests that fiscal sustainability in Japan requires a broader strategy that combines immigration policy with reforms to the fiscal system and labor markets. Moreover, our study highlights the importance of incorporating endogenous migration into quantitative models of aging economies, rather than simply extrapolating past trends, since they elastically respond to shifts in the economic environment in the origin and destination countries.

Appendix A Wage and Human Capital

This appendix describes how we compute wages per efficiency unit and efficiency units by skill and age. Using labor market data for Japan, Vietnam, China, and the Philippines, we construct hourly wages in Japan for Japanese workers $y_{J,s,j,t}$ and for foreign workers $y_{F,s,j,t}$, as well as hourly wages for foreign workers in the foreign country $\tilde{y}_{F,s,j,t}$. We set up the mapping from wages to efficiency as follows.¹⁴

Hourly wages are the product of wages per efficiency unit and efficiency units:

$$y_{J,s,j,t} = w_{J,s,t} h_{J,s,j}$$

$$y_{F,s,j,t} = w_{J,s,t} h_{F,s,j}$$

$$\tilde{y}_{F,s,j,t} = w_{F,s,t} \tilde{h}_{F,s,j}.$$

In Japan, Japanese and foreign workers with the same skill are perfect substitutes and are paid the same wage per efficiency unit $w_{J,s,t}$. Efficiency profiles $h_{J,s,j}$, $h_{F,s,j}$, and $\tilde{h}_{F,s,j}$ are time invariant. As normalization at t_0 , set $w_{J,L,t_0} = 1$ and $h_{J,L,1} = h_{J,H,1} = 1$, and impose $h_{F,s,1} = \tilde{h}_{F,s,1}$ for $s \in \{L, H\}$. Under this normalization, the productivity differential between low- and high-skill workers at age 1 is captured by differences in w across skills in Japan and the foreign country is captured by differences in w across countries.¹⁵

For low-skill workers, we use wages at t_0 . With $w_{J,L,t_0} = 1$ and $h_{J,L,1} = 1$, the Japanese efficiency age profile is obtained from ratios of wages across ages,

$$h_{J,L,j} = \frac{y_{J,L,j,t_0}}{y_{J,L,1,t_0}} \quad (j = 2, \dots, N_j).$$

For low-skill foreign workers in Japan,

$$h_{F,L,j} = \frac{y_{F,L,j,t_0}}{y_{J,L,1,t_0}} \quad (j = 1, \dots, N_j).$$

Using $h_{F,L,1} = \tilde{h}_{F,L,1}$ pins down the foreign-country wage per efficiency unit,

$$w_{F,L,t_0} = \frac{\tilde{y}_{F,L,1,t_0}}{y_{F,L,1,t_0}},$$

and the foreign-country efficiency profile is

$$\tilde{h}_{F,L,j} = \tilde{h}_{F,L,1} \frac{\tilde{y}_{F,L,j,t_0}}{\tilde{y}_{F,L,1,t_0}} \quad (j = 1, \dots, N_j).$$

For high-skill workers, the procedure is the same except for the wage rate. First set

$$w_{J,H,t_0} = \frac{y_{J,H,1,t_0}}{y_{J,L,1,t_0}},$$

¹⁴An alternative is $h_{F,s,j} = (1-\theta) \tilde{h}_{F,s,j}$ for some θ as in [Klein and Ventura \(2009\)](#). We do not take this route, since an age-invariant θ would overlook differences between age-specific wages of foreign workers in Japan and those in their home country.

¹⁵Note that wages in the foreign country is given exogenously.

normalize $h_{J,H,1} = 1$, and then recover

$$h_{J,H,j} = \frac{y_{J,H,j,t_0}}{y_{J,H,1,t_0}} \quad (j = 2, \dots, N_j),$$

$$h_{F,H,j} = \frac{y_{F,H,j,t_0}}{y_{J,H,1,t_0}} \quad (j = 1, \dots, N_j).$$

With $h_{F,H,1} = \tilde{h}_{F,H,1}$, the foreign-country wage per efficiency unit and efficiency profile are

$$w_{F,H,t_0} = \frac{\tilde{y}_{F,H,1,t_0}}{y_{F,H,1,t_0}} w_{J,H,t_0},$$

$$\tilde{h}_{F,H,j} = \tilde{h}_{F,H,1} \frac{\tilde{y}_{F,H,j,t_0}}{\tilde{y}_{F,H,1,t_0}} \quad (j = 1, \dots, N_j).$$

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