Should Germany Have Built a New Wall? Macroeconomic Lessons from the 2015-18 Refugee Wave*

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Abstract

We evaluate the macroeconomic and distributional effects of the recent wave of refugee immigration into Germany, increasing immigration from its long-run average of 200,000 per year to about one million both in 2015 and 2016. To do this we develop a quantitative overlapping generations model and calibrate it to replicate education, and productivity differentials between foreign born and native workers using German panel micro data from the German Socio-Economic Panel (SOEP). Workers of different skill types and of different migration background (natives and immigrants) are modelled as imperfect substitutes in aggregate production, giving rise to endogenous wage differentials. We then simulate the short- and long-run positive and normative effects of the refugee wave, with specific focus on the welfare impact from this wave on natives with low skills that directly compete with migrants in the German labour market. Our results indicate that this group suffers moderate welfare losses; the welfare gains of other parts of the native population are large enough, however, to compensate the low-skilled for these losses.

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1 Introduction

In the last few years, Europe has experienced a massive refugee wave from Africa and Asia (and Syria specifically) that has brought in an inflow of mostly young, mostly unskilled refugees, substantially increasing the flow in migration into Western Europe from other parts of the world. Germany has been the recipient of a large share of these refugees, creating political opposition to further in-migration. In 2015 and 2016 alone, ca. 2 million individuals immigrated into Germany, making it by far the largest recipient of migration in Europe.[1] This flow is large in absolute terms, relative to a native population in Germany of 82 million, and has created substantial political backlash and the rise of right-wing political parties. The flow is comparable to the flow of individuals migrating from East to West Germany after World War II, inducing the political regime in East Germany to build the German Wall in 1961. It is larger than the net inflow of ca. 1.8 million individuals from East Germany into West Germany from 1989 to 2006 after the wall came down in 1989, see Glorius (2010). This in-migration of young foreigners occurs against the backdrop of a secular massive ageing of the native German population, raising the possibility that reforms of the public pay-as-you-go pension system necessitated by population ageing could be postponed or moderated.

Motivated by these observations we evaluate the macroeconomic and welfare implications of the large wave of refugee inflows into the German economy in the short- and in the long run. Simply put, we ask whether it would have been in the economic interest of the local population to erect, figuratively speaking, a new wall to fence Germany off from the observed migration flow. The more nuanced question we answer is what are the economic characteristics of the group of native Germans that were most bound to gain, and those most bound to lose from such a large-scale refugee wave.

To answer this question we construct, calibrate and simulate a quantitative OLG model with time-varying demographic structure and neoclassical production that is subject to empirically realistic inflows of a low-skilled migrant population. To gain intuition we first construct a simple two-period version of the model as in Diamond (1965), and show analytically that these migrant inflows have four main impacts on welfare of natives. First, they raise overall labor supply in an otherwise ageing economy and thus lower the capital-labor ratio and wages, and increase rates of return, as long as the economy is closed. Second, the migration inflow changes the supply of low-skilled non-native workers, relative to that of their native brethren, and relative to high-skilled labor. If these workers are imperfect substitutes, then wages of skilled native workers rise (since skilled workers have become relatively scarcer). On the other hand, the impact on wages of unskilled native workers is

[1] The UK is a distant second among European countries, with ca. 600,000 immigrants in 2015.

ambiguous: unskilled workers are now more abundant, which lowers their wages. But to the extent that unskilled native and unskilled migrant workers are also imperfect substitutes, the native unskilled are now scarcer as well. The net effect on the relative wage of this group is then determined by the substitutability of skilled v/s unskilled labor relative to the substitutability between unskilled native and migrant labor. If this latter substitution elasticity is high relative to the former elasticity (as we estimate empirically), relative wages of native unskilled workers will fall. Third, since migrants are young, an increase in their inflow reduces the old-age dependency ratio and increases the relative return on the PAYGO social security system for native contributors. Finally, the inflow of low-skilled migrants leads to an increase of tax-financed administrative government expenditures which reduces welfare of the natives, ceteris paribus.

We then extend our analysis to a quantitative OLG economy with a national labor market in order to *quantify* the relative importance of these four channels. As in the simple model workers with differential skill levels and different migratory background are imperfect substitutes in production. We model the public social security system closely following the actual German system, and introduce a realistic demographic structure, including a demographic transition towards an ageing population. This demographic transition necessitates reforms of the social security system in the absence of migration inflows of young workers. Our main thought experiment consists of a sudden, unexpected inflow of refugees of the size and composition experienced in the years 2015 to 2018. We compute the transition induced by this refugee wave and contrast it with the scenario in which the refugee inflow does not occur, and thus the ageing of the population continues at pre-refugee speed. By comparing these scenarios we quantify the macroeconomic, distributional and welfare consequences for natives in different skill classes from this recent refugee wave.

In order to conduct our quantitative analysis we require as inputs aggregate migration flows, the skill composition of migrants, as well as micro estimates for wage profiles and assimilation speeds of migrants. To derive the latter two we turn to micro data from the German Socio-Economic Panel Study (SOEP). The structure of the SOEP allows us to measure wages of immigrants from different geographic origins over a long period of time (1984–2017). We use this information to estimate the elasticity of substitution between different groups of natives and immigrants, key ingredients in the aggregate production function for the quantitative analysis. Apart from the core samples of the SOEP we also use data from the IAB-SOEP Migration Sample (2013-2017), which oversamples immigrants from Arab and Islamic countries, the main source countries of the immigration wave from 2015-18 we study, as well as the IAB-BAMF-SOEP Refugee sample (2015-2017), which samples the refugee population that arrived in Germany in the years of interest. We use this information to characterize the incumbent migrant population and the incoming refugees.

Figure 1: Wages since Immigration

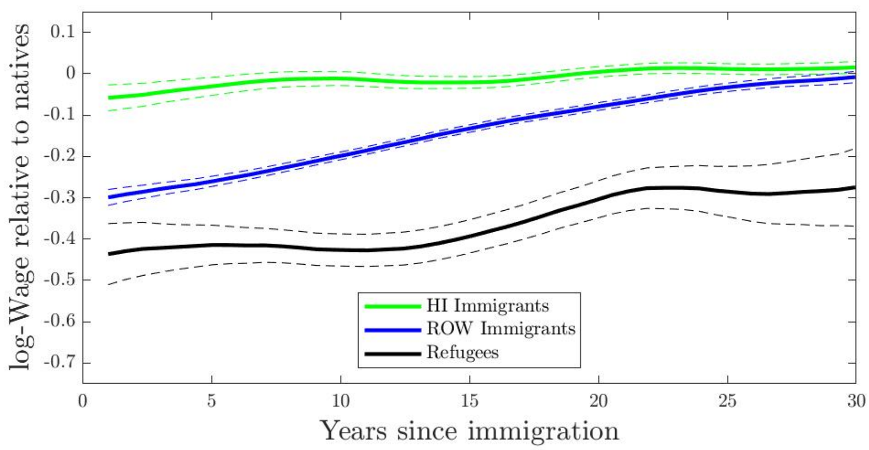


Figure 1 displays wages of migrants, relative to natives with the same level of education, age and family background, as a function of the time since arrival in Germany. It shows very sizeable initial wage discounts, in the order of 30% for economic immigrants from poor countries, and in excess of 40% for political asylum seekers, with very significant convergence towards native German wages over time, especially for the economic migrants, but at much slower speed for political refugees.[2] The availability of rich micro data on migrant labor market outcomes is an important benefit of analyzing the German experience in the context of world-wide immigration flows in the last five years. Equipped with these key empirical ingredients we simulate the macroeconomic and distributional impacts of the recent migration wave. We feed into our model the actual evolution of the domestic and migrant population (the high migration scenario), as well as two counterfactual scenarios in which we either fix migration flows to relatively low average levels (the baseline scenario) or only let *political refugees* in-migrate (the refugee migration scenario). We obtain three main quantitative findings. First, gross wages of unskilled natives deteriorate, on account of increased competition on the labor market from equally unskilled refugees. This effect is partially offset by lower effective contributions to social security; thus net wages of low skilled natives decrease throughout our entire projection period. Furthermore, taxes increase to finance administrative expenditures and transfers to low skilled refugees. Thus, low skilled individuals currently alive and born in the future experience welfare losses. Second, medium and high

[2]The much slower convergence among the asylum seekers might not be due to slow productivity convergence, but also reflect restricted access to the German labor market by this group stemming from administrative hurdles described in section 3. It could also stem from reduced incentives to accumulate Germany-specific human capital since political refugees face a much larger probability of return migration.

skilled natives experience significant welfare gains. Third, the aggregate gains, measured as consumption equivalent variation, are much larger than the aggregate losses. This suggests that a compensation of low skilled natives is possible.

Based on these results our answer to the question motivating this paper is that Germany should not have built a new wall once transitional dynamics and fiscal and general equilibrium consequences from the refugee wave in 2015-2018 are taken into account. This is true even from the perspective of the native low-skilled population, which is most severely subjected to the migrant competition on the German labor market, but only if this population group is compensated for their net wage losses using the gains of the rest of the German population.

2 Related Literature

Our work relates to four strands of the literature. First, we build on a large literature studying the effects of immigration on incomes and welfare of natives. An early influential paper is Borjas (1999) who shows that an influx of immigrants into a host country (the U.S. in his context) leads to redistribution among natives towards capital income and an overall net benefit to native households which Borjas calls the 'Immigration Surplus'. It emerges as long as capital and (immigrant) labor are not perfect substitutes in production. Ben-Gad (2004) extends the analysis to endogenous labor supply and capital accumulation and finds a smaller immigration surplus to the U.S. The same effect of an inflow of labor will be present in our analysis, and it dampens the long-run decline in the labor force due to the demographic transition of the native population. Motivated by the evidence in Borjas (2003) subsequent papers assume imperfect substitution among workers with different characteristics so that immigration lowers the wages of competing workers. Ben-Gad (2008) allows for heterogeneous skills and concludes the immigration surplus is maximized with skilled immigration due to complementarity between skilled labor and capital. In a study for Germany D'Amuri, Ottaviano, and Peri (2010) show that the pre-2010 inflow of immigrants leaves wages and employment levels of natives broadly unaffected; incumbent immigrants are adversely affected by the inflow of new migrants. Felbermayr, Geis-Thöne, and Kohler (2010) and Ottaviano and Peri (2012) largely confirm these conclusions. In our model we take these relative gross wage responses into account by allowing for a flexible substitution structure across skill and nationality groups in aggregate production. This approach is subject to the criticism by Dustmann, Schonberg, and Stuhler (2016) who argue that the underlying assumption that migrants can be sorted into conventional experience-, education- and nationality cells might be invalid, a concern we address through sensitivity analyses.[3]

Second, our paper is related to the literature on assimilation of migrants. Borjas (1985) emphasizes the problem of (positive) selection of immigrants who stay in a given country for estimates of assimilation speeds. More recently, the work by Weiss, Sauer, and Gotlibovski (2003) and Eckstein and Weiss (2004) emphasizes the adjustment of occupational choices and human capital formation for wage growth of immigrants to Israel. Dustmann and Preston (2012) point out an initial skill degradation among immigrants upon arrival into host countries and Lessem and Sanders (2019) find skill upgrading of immigrants over time, emphasizing the role played by language skill in this process.[4] Motivated by this evidence we capture assimilation in a reduced form way by allowing the conditional productivity of immigrants to increase with time since immigration, by estimating assimilation speeds of wage processes between different groups of immigrants, based on the data shown in Figure 1.

Third, regarding the fiscal effects of migration we follow Storesletten (2000), who analyzes the impact of immigration to the U.S. from 1960-1990 in a general equilibrium overlapping generation economy such as ours. The key finding is that only medium- and high-skilled immigration can ease the fiscal burden in the country, whereas low-skilled immigration cannot. In the context of the ageing population of Japan, Imrohoroglu, Kitao, and Yamada (2017) reach similar conclusions. Chojnicki, Docquier, and Ragot (2011) perform a retrospective analysis of the immigration wave of 1945-2000 to the U.S. and conclude that welfare gains could have been achieved for natives had the past immigration to the U.S. been dominantly high-skilled. Similarly, the findings of Guerreiro, Rebelo, and Teles (2019) suggest that free immigration is welfare-maximizing for natives if immigrants can be excluded from the social welfare system. Finally, using SOEP data Kirdar (2012) estimates the fiscal impact of immigration on Germany in the presence of an endogenous return migration choice.[5]

[3] Llull (2018) observes that imperfect substitutability across workers is an endogenous outcome of heterogenous education, labor supply and career choices of natives and incumbent immigrants to show that natives who are close competitors of immigrants are adversely affected. Similarly, Colas (2019) argues that natives and old immigrants respond to new immigrants by internally migrating to different labor markets, and Burstein, Hanson, Tian, and Vogel (2017) analyze how these adjustments vary across tradeable and non-tradeable sectors.

[4] Lagakos, Moll, Porzio, Qian, and Schoellman (2018) show that returns to experience accumulated in the birth country of a migrant before coming to the U.S. are positively correlated with birth-country GDP per capita. Heise and Porzio (2019) document that even 25 years after the German reunification, real wages in the East are still 26% lower than in the West.

[5] A related recent literature uses frictional labor market models and stresses positive effects on immigration on host economies through endogenous job creation, see e.g. Chassamboulli and Palivos (2014), Nanos and Schluter (2014), Moreno-Galbis and Tritah (2016), Battisti, Felbermayr, Peri, and Poutvaara (2018) and Iftikhar and Zaharieva (2019).

Finally, this paper contributes to studies on the impact of the most recent immigration wave into the European Union, and into Germany specifically. Kancs and Lecca (2018) analyze alternative refugee integration scenarios for the period 2016-2040 to show that full repayment of investment in refugees' integration is achieved in 9 to 19 years and that immigration has a positive growth effect on the German economy.[6] Scharfbillig and Weissler (2019) find no evidence that immigrants displace employment of natives but that employment of incumbent migrants is adversely affected. Their results suggest that natives and immigrants are imperfect substitutes in production despite having similar qualifications, whereas the degree of substitution between asylum seekers and other migrant residents of Germany is higher, which is a key ingredient in our quantitative model.[7]

3 Institutional Background

In this section we give a brief description of the historical and institutional background of the large migration inflow in 2015-16. The goal is not to provide a comprehensive review, but rather give the background for justifying key modelling assumptions in the quantitative model. More than 50% of the increase in migrants in 2015 and 2016 stems from political refugees originating in Syria. The Syrian civil war officially began on March 15, 2011. Political asylum seekers started arriving in numbers via land and sea in Europe in 2013, and in 2015 the crisis reached its peak when the EU received more than one million asylum applications from Syria alone. Germany was the main destination country for these refugees. Chancellor Angela Merkel announced in August 2015 a temporarily suspension of the EU Dublin regulations which required refugees to apply for asylum in the country to which they arrive first. In September 2015 Germany agreed to let refugees from Hungary enter Germany.

As the flow of new asylum seekers subsided in 2017, the focus of policy shifted towards the integration of these refugees into the German labour market. In August, 2016 the Prior Review policy that restricted the access of the immigrants to the labour markets was suspended until August of 2019. In June 2019 "The Alien Employment Promotion Act" was adopted to promote assistance with asylum procedures and integration into the labour market. Whereas officially recognized political refugees (those having been granted asylum) have unrestricted access to German job market and have the same rights as German citizens, asylum seekers cannot access the labour market during the first three months of their arrival in Germany. After this waiting period is over access to the labour market is granted with

[6]Related, Stähler (2017) studies the macroeconomic effects of (failed) integration.

[7]Further, Dehos (2017) finds a positive association between refugees' inflow during 2010-2015 and non-violent property crimes while Sola (2018) concludes that the refugee crisis of 2015 affected the concerns of the public regarding immigration in the short-run.

restrictions. In order to get a work permit the asylum seekers must have a job offer and the German job centers responsible for administering German labour market law check that neither an EU citizen and nor a non- EU citizen with a residence permit is displaced as a result of the hiring of the asylum seeker. All asylum seekers are barred from taking up self-employment for the entire duration of their asylum procedure. Overall, these restrictions negatively impact both employment opportunities of asylum seekers and the wages they can earn. As a consequence, wages and earnings of these individuals are initially low, as figure 1 in the introduction shows.

Finally, in order to assess the fiscal consequences of the recent migration wave, it is important to assess the extent to which migrants qualify for social assistance. Asylum Seekers are provided social and medical benefits in accordance with the Asylum-Seekers' Benefits Act. Benefits include food, housing, heating, healthcare, personal hygiene, assistance in sickness, pregnancy and birth as well as household durables and consumables. In October, 2015 the level of social benefits were raised and 'in kind' benefits were substituted by 'in cash' benefits. Furthermore asylum seekers are entitled to standard social benefits and full healthcare after receiving social benefits under Asylum Seekers' Benefits Act for 15 months. Thus, it is a fairly accurate approximation of reality to assume that asylum seekers are eligible for the same type of social assistance payments as natives, certainly after an initial period in which these benefits are moderately lower. For a refugee (i.e. a successful asylum applicant) the same statement applies.

Against this background, and motivated by the massive inflow of migrants into Germany in 2015-16 into a labour market characterized by an ageing workforce, we now develop first a simple model to study the qualitative impact of these developments, before quantifying them in a more realistic version that allows us to capture the institutional details of Germany in this period more accurately.

4 Simple Model

We now develop an OLG model with two-period lived households whose basic structure will also form the foundation for the quantitative model in the next section. The purpose of this simple model is to clarify the main trade-offs from the recent migration inflows. On one hand, the asylum seeking immigrants are on average young, and thus help to stabilize social security budgets. On the other hand, at least initially these migrants have low labor productivity in the German labor market and the migration system has to be administered which is costly.

Competitive firms operate a neo-classical technology that employs capital and three types of labor inputs. There are high-skilled (hi) native (na) workers and low skilled workers (lo) which might either also be natives or come from a per period inflow of foreigners (fo). These three different groups of workers are assumed to be imperfect substitutes in production. This structure permits us to display three main effects of an inflow of migrants on gross wages: First, it increases the relative scarcity of high skilled workers, which, in a model with imperfect substitutability, increases relative wages of the high skilled and reduces wages of low-skilled workers. Second, if low-skilled natives and low-skilled foreigners are imperfect substitutes, an increase in migration raises the relative wage of low-skilled natives. And finally, an inflow of workers increases the overall supply of labor which, in general equilibrium, decreases the overall wage level.

We assume that the economy is ageing, modelled through an exogenous population growth rate $\gamma^n < 1$ of the native population. In addition, in every period a number of young migrants enter the country, shifting the demographic composition of the population towards younger individuals. In retirement, households earn a social security income, which is related to past contributions in a Bismarckian pay-as-you-go (PAYGO) pension scheme. Pension payments in the PAYGO system are financed by levying the contribution rate τ on labor income of young workers. This structure gives rise to an additional effect of migration beyond the impact on wages of natives: it increases the population growth rate and thus the fraction of the young in the population, thereby raising, ceteris paribus, the implicit rate of return of the pension system.

4.1 Population

There are two-period lived households. We denote by $N_t(0)$ the size of the period t young population and by $N_t(1)$ the size of the old. We ignore mortality risk, thus $N_{t+1}(1) = N_t(0)$. The young population in each period t consists of native high skill workers, $N_t(0, hi, na)$, and low skill native- and foreign-born workers $N_t(0, lo) = N_t(0, lo, na) + N_t(0, lo, fo)$. There is a constant share ω of high skilled workers in the native population, thus $N_t(0, hi, na) = \omega N_t(0, na)$ and $N_t(0, lo, na) = (1 - \omega)N_t(0, na)$. The population grows at an exogenous rate γ_t and thus the young population in t is given by $N_t(0) = \gamma_t N_{t-1}(0)$.

The population growth rate γ_t is determined jointly by the fertility rate of the native population and the migration rate of individuals from abroad. Let γ_t^n denote the birth rate of the native population; we assume that once migrants enter the country, they possess the same fertility rate as native individuals. We further express the exogenous migration flows as a share of the population stock of the young population in the previous period,

$$N_t(0, lo, fo) = \mu_t N_{t-1}(0)$$

Combining these two assumptions yields

$$\begin{aligned} N_t(0) &= \gamma_t^n N_{t-1}(0) + N_t(0, lo, fo) \\ &= (\gamma_t^n + \mu_t) N_{t-1}(0) = \gamma_t N_{t-1}(0). \end{aligned}$$

Therefore the population growth rate $\gamma_t = \gamma_t^n + \mu_t$ is the sum of the fertility rate γ_t^n of individuals living in the country when young, and the migration rate μ_t; a positive immigration $\mu_t > 0$ then acts like an increase in the fertility rate of the economy.

4.2 Technology

Production takes place with a nested CES-Cobb-Douglas production function of form

$$Y_t = K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where

$$L_t = \left(L_t(lo)^{1-\frac{1}{\sigma_{lh}}} + L_t(hi)^{1-\frac{1}{\sigma_{lh}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}}. \tag{2}$$

and

$$L_t(lo) = \left(L_t(lo, na)^{1-\frac{1}{\sigma_{nf}}} + L_t(lo, fo)^{1-\frac{1}{\sigma_{nf}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \tag{3}$$

where σ_{lh} is the elasticity of substitution between skilled and unskilled labor, and σ_{nf} is the elasticity of substitution between low-skilled labor supplied by natives and migrants. Notice that $L_t(s, i)$ are efficiency weighted units of labor with productivity differences across types of workers described next. Finally, the depreciation rate of capital is denoted by $\delta = 1$.

4.3 Households

Households work one unit of time when young and have skill-specific ($s \in \{lo, hi\}$) labor productivity $\epsilon(s, i)$ that also depends on their migratory origin $i \in \{na, fo\}$. We normalize $\epsilon(hi, na) = 1$. The group-specific wage per unit of time is denoted by $w_t(s, i)$, on which individuals pay social security contributions at rate τ_t. When young they consume $c_t(0, s, i)$ and save $a_{t+1}(s, i)$. Assets earn a gross risk-free interest rate R_{t+1}. When old they receive an exogenous retirement income $b_{t+1}(s, i)$, identical across all workers within a group s, i, and consume $c_{t+1}(1, s, i)$. The budget constraints in the two periods of life for workers in group s, i, are thus given by

$$c_t(0, s, i) + a_{t+1}(s, i) = w_t(s, i)(1 - \tau_t) \tag{4a}$$

$$c_{t+1}(1, s, i) = a_{t+1}(s, i)R_{t+1} + b_{t+1}(s, i). \tag{4b}$$

Households born in period t of type (s, i) have logarithmic preferences over consumption, discount the future with factor β. Thus, their lifetime utility function $U_t(s, i)$ given by

$$U_t(s, i) = \ln(c_t(0, s, i)) + \beta \ln(c_{t+1}(1, s, i)). \tag{5}$$

4.4 Government

The government organizes a PAYG pension system. We assume that pensions of workers of group i are proportional to their wages when young, where the replacement rate ρ_t determines the size of the social security system, and is assumed to be constant across all groups:

$$b_t(s, i) = \rho_t \tau_{t-1} w_{t-1}(s, i). \tag{6}$$

Note that the pension system is organized as a Bismarckian system in which benefits are closely tied to past contributions, which is an accurate approximation of the actual German system.[8] Also note that ρ_t can be interpreted as the internal gross return of the pension system since we can rewrite equation (6) as

$$\rho_t = \frac{b_t(s, i)}{\tau_{t-1} w_{t-1}(s, i)}$$

In addition, the government has to finance the bureaucracy in charge of integrating migrants into Germany. We assume that per migrant a resource cost of $\tilde{\kappa}_t \tau_t w_t$ is required to administer the migration system. These resource costs constitute lost output rather than transfers, and for analytical convenience we express them as a share $\tilde{\kappa}_t$ of tax payments. The total cost for migrants then depends on the number of migrants, and is given by

$$\tilde{\kappa}_t \tau_t w_t N_t(0, lo, fo) = \kappa_t \tau_t w_t L_t$$

where $\kappa_t = \tilde{\kappa}_t \frac{N_t(0,lo,fo)}{L_t}$. Written in this way, the cost κ_t captures both the cost per migrant $\tilde{\kappa}_t$, a parameter of the model, and the effect of an increase in the number of migrants (as parameterized by μ_t), since the ratio $\frac{N_t(0,lo,fo)}{L_t}$ is strictly increasing in μ_t.

[8] The German legislation does not feature dependency on τ_{t-1}, but note that this is just a rescaling of the replacement rate because we could equivalently write $b_t(s, i) = \tilde{\rho}_t w_{t-1}(s, i)$

Finally, we assume that the budget of the government is balanced in every period, which requires that the sequence of payroll tax rates $\{\tau_t\}$ satisfies:

$$\tau_t \sum_{s\in\{hi,lo\}} \sum_{i\in\{na,fo\}} w_t(s,i)N_t(0,s,i) = \rho_t\tau_{t-1} \sum_{s\in\{hi,lo\}} \sum_{i\in\{na,fo\}} w_{t-1}(s,i)N_t(1,s,i) + \kappa_t\tau_t w_t L_t. \tag{7}$$

By assumption there are no high-skilled migrants in the model, and thus $N_t(0, hi, fo) = N_t(1, hi, fo) = 0$. Simply put, given labor income taxes $\{\tau_t\}$ and costs for administrating migration (as parameterized by κ_t), the social security replacement rate ρ_t adjusts to changes in the demographic composition of the population, to ensure government budget balance.[9]

4.5 Characterization of Equilibrium

We relegate a formal definition of the competitive equilibrium to appendix A. As is common in neoclassical growth models, the key variable describing the dynamics of the competitive equilibrium is the capital-labor ratio $k_t = \frac{K_t}{L_t}$. Starting from an arbitrary initial capital K_0 and for an exogenous sequence of skilled and unskilled labor determined by fertility and migration rates as well as exogenous policy (characterized by social security replacement rates), once the dynamics of capital and thus the capital-labor ratio is determined, factor prices, relative wages of each group, factor demands and consumption allocations of all private households follow directly from the firm's optimality conditions and the household budget constraints. The dynamics of the capital labor ratio itself is determined from private household savings decisions and the asset market clearing condition.

We will proceed with the analysis of the model "from the back", first characterizing wages for a given sequence of the capital-labor-ratio, then demonstrating that in the model all households optimally choose the same saving rate, which then in turn determines the law of motion for the capital-labor ratio. We finally provide comparative statics with respect to the size of migration flows, as summarized by the migration rate μ_t.

4.5.1 Firm Optimization and Equilibrium Wages

The representative firm hires three types of labor $L_t(hi), L_t(lo, na), L_t(lo, fo)$, combines them into a labor composite L_t and uses this labor and capital K_t to produce output. Profit maximization implies that the gross return on capital and the wage per unit of the labor

[9] For analytical convenience, in the simple model we consolidate the social security and general government revenue budget; the quantitative model will separate these two budgets, as is realistic for the German case.

composite equal the marginal products of capital and labor, respectively:

$$\begin{aligned} 1 + r_t &= R_t = \alpha k_t^{\alpha-1} && (8) \\ w_t &= (1-\alpha) k_t^{\alpha}. && (9) \end{aligned}$$

Furthermore, the wage per unit of *time* for a worker of type (s, i) is determined by the product of its labor efficiency units $\epsilon(s, i)$, the wage per efficiency unit of the labor composite w_t and the marginal product of labor of type (s, i) in producing the labor composite L_t, that is,

$$w_t(s, i) = w_t \cdot \epsilon(s, i) \cdot \frac{\partial L_t}{\partial L_t(s, i)} \tag{10}$$

Exploiting equations (2) and (3) yields as wages (and thus labor incomes) as functions of the common wage per labor efficiency units as well as the relative scarcity of different demographic groups, whose impact is controlled by the substitution elasticities between skilled and unskilled labor σ_{lh} and between unskilled labor of natives and migrants σ_{nf}.

$$\begin{aligned} w_t(hi) &= w_t \cdot \left(\frac{L_t}{L_t(hi)} \right)^{\frac{1}{\sigma_{lh}}} && (11) \\ w_t(lo, i) &= w_t \cdot \epsilon(lo, i) \cdot \left(\frac{L_t}{L_t(lo)} \right)^{\frac{1}{\sigma_{lh}}} \cdot \left(\frac{L_t(lo)}{L_t(lo, i)} \right)^{\frac{1}{\sigma_{nf}}} && (12) \end{aligned}$$

Exploiting the market clearing conditions (29) and (30) and the demographic relationships to express labor efficiency units of the different groups in terms of demographic variables gives the following:

Proposition 1. *Equilibrium wages of the different groups are determined as*

$$\begin{aligned} w_t(hi) &= w_t \mathcal{W}_{hi}(\mu_t/\gamma_t^n) \\ w_t(lo, na) &= w_t \mathcal{W}_{lo}(\mu_t/\gamma_t^n) \cdot \mathcal{W}_{na}(\mu_t/\gamma_t^n) \end{aligned}$$

where the exogenous demographic factors $\mathcal{W}_{hi}(\mu_t/\gamma_t^n), \mathcal{W}_{na}(\mu_t/\gamma_t^n)$ are increasing in μ_t/γ_t^n and $\mathcal{W}_{lo}(\mu_t/\gamma_t^n)$ is decreasing in μ_t/γ_t^n. The wage w_t per labor efficiency unit is a strictly increasing function purely of the aggregate capital-labor ratio.

4.5.2 Household Optimization

To derive the equilibrium dynamics of the capital-labor ratio it is useful to restate the household maximization problem in terms of household saving rates

$$s_t(s,i) = \frac{a_{t+1}(s,i)}{w_t(s,i)} \tag{13}$$

With this definition we can rewrite consumption in both periods as

$$c_t(0,s,i) = w_t(s,i)\left[(1-\tau_t) - s_t(s,i)\right] \tag{14}$$

$$c_{t+1}(1,s,i) = w_t(s,i)R_{t+1}\left[s_t(s,i) + \frac{\rho_{t+1}\tau_t}{R_{t+1}}\right] \tag{15}$$

and the objective function of the household becomes

$$\begin{aligned} U_t(s,i) = (1+\beta)\ln(w_t) + \beta\ln(R_{t+1}) + (1+\beta)\ln\left(\frac{w_t(s,i)}{w_t}\right) \\ + \ln\left((1-\tau_t) - s_t(s,i)\right) + \beta\ln\left(s_t(s,i) + \frac{\rho_{t+1}\tau_t}{R_{t+1}}\right) \end{aligned} \tag{16}$$

This expression clarifies the three forces impacted by population ageing and migration. First, demographic changes affect general equilibrium aggregate factor prices (w_t, R_{t+1}) unless we analyze a small open economy. Second, it changes relative wages of the different population groups, as summarized by proposition 1. Third, it changes the relative return on the social security system measured by $\frac{\rho_{t+1}}{R_{t+1}}$, and with it, potentially the optimal saving decisions of households. With log-utility the optimal saving rate is independent of the first two forces.

Taking first order conditions with respect to (16) gives the optimal saving rate as

$$s_t(s,i) = \frac{\beta(1-\tau_t) - \frac{\rho_{t+1}}{R_{t+1}}\tau_t}{1+\beta} \tag{17}$$

Note that the saving rate is identical across all population groups and only depends on the fiscal side of the model characterizing the PAYGO social security system. The only remaining endogenous variable in the saving rate and thus in the welfare of a given generation is the relative return of the social security system $\frac{\rho_{t+1}}{R_{t+1}}$. Using the budget constraint of the government (7) and noting that $N_{t+1}(i,1) = N_t(i,0)$ we have

$$\begin{aligned}\frac{\rho_{t+1}}{R_{t+1}} &= \frac{\tau_{t+1}}{\tau_t R_{t+1}} \frac{\sum_{s,i} w_{t+1}(s,i) N_{t+1}(s,i,0) - \kappa_{t+1} w_{t+1} L_{t+1}}{\sum_{s,i} w_t(s,i) N_t(s,i,0)} \\ &= \frac{\tau_{t+1}}{\tau_t R_{t+1}} \frac{(1-\kappa_{t+1}) w_{t+1} L_{t+1}}{w_t L_t} = \frac{(1-\kappa_{t+1})\tau_{t+1}}{\tau_t} \frac{w_{t+1}}{R_{t+1} w_t} \gamma^L_{t+1}\end{aligned}$$

where $\gamma^L_{t+1} = \frac{L_{t+1}}{L_t}$ is the growth rate of aggregate labor supply in efficiency units, and a function purely of the exogenous demographics of the model, as lemma 1 below shows. The general equilibrium term $\frac{w_{t+1}}{R_{t+1}w_t}$ is still endogenous and depends on the dynamics of the capital-labor ratio. To establish a benchmark we first characterize the saving rate and welfare in a small open economy where the interest rate R is constant and exogenous, which, from the firm optimality conditions, implies a constant exogenous wage $w_t = w$ per labor efficiency unit and a constant exogenous capital-labor ratio.

4.5.3 The Savings Rate and Welfare in Partial Equilibrium (Small Open Economy)

With an exogenous interest rate R the term $\frac{w_{t+1}}{R_{t+1}w_t}$ in equation (18) is exogenous and equals $\frac{w_{t+1}}{R_{t+1}w_t} = \frac{1}{R}$. The following proposition immediately follows from equations (17) and (16):

Proposition 2. *In a small open economy, the equilibrium saving rate and welfare of an individual of type (s,i) born at time t are given by*

$$\begin{aligned}s_t(s,i) &= \frac{\beta(1-\tau_t) - (1-\kappa_{t+1})\tau_{t+1}\frac{\gamma^L_{t+1}}{R}}{1+\beta} = s_t \\ U_t(s,i) &= (1+\beta)\ln(w) + \beta\ln(R) + (1+\beta)\ln\left(\frac{w_t(s,i)}{w_t}\right) \\ &+ \beta\ln(\beta) - (1+\beta)\ln(1+\beta) + (1+\beta)\ln\left(1-\tau_t + (1-\kappa_{t+1})\tau_{t+1}\frac{\gamma^L_{t+1}}{R}\right)\end{aligned}$$

4.5.4 The Dynamics of the Capital-Labor Ratio in General Equilibrium

In general equilibrium the ratio $\frac{w_{t+1}}{R_{t+1}w_t}$ is endogenous and requires one to solve for the dynamics of the capital-labor ratio. The market-clearing condition on the capital market implies

$$K_{t+1} = \sum_{s,i} a_{t+1}(s,i) N_t(0,s,i) = \sum_{s,i} s_t(s,i) w_t(s,i) N_t(0,s,i) = s_t w_t L_t$$

and thus

$$\begin{aligned}
\frac{K_{t+1}}{L_{t+1}} &= k_{t+1} = s_t \frac{(1-\alpha)k_t^{\alpha}}{\gamma_{t+1}^{L}} && (18)\\
\frac{w_{t+1}}{R_{t+1}w_t} &= \frac{(1-\alpha)k_{t+1}^{\alpha}}{\alpha k_{t+1}^{\alpha-1}(1-\alpha)k_t^{\alpha}} = \frac{(1-\alpha)s_t}{\alpha\gamma_{t+1}^{L}} && (19)\\
\frac{\rho_{t+1}}{R_{t+1}}\tau_t &= \frac{\tau_{t+1}}{\tau_t}\frac{(1-\kappa_{t+1})w_{t+1}}{R_{t+1}w_t}\gamma_{t+1}^{L}\tau_t = \frac{(1-\kappa_{t+1})\tau_{t+1}(1-\alpha)s_t}{\alpha} && (20)
\end{aligned}$$

Equations (17) and (20) can be solved for the saving rate in general equilibrium, which in turn determines general equilibrium welfare. These results are summarized in the following

Proposition 3. *The general equilibrium saving rate and welfare of an individual of type (s,i) born at time t are given by*

$$\begin{aligned}
s_t(s,i) &= s_t = \frac{\alpha\beta(1-\tau_t)}{\alpha(1+\beta)+(1-\alpha)(1-\kappa_{t+1})\tau_{t+1}} && (21)\\
U_t(s,i) &= (1+\beta)\ln(w_t) + \beta\ln(R_{t+1}) + (1+\beta)\ln\left(\frac{w_t(s,i)}{w_t}\right)\\
&+ \beta\ln(\beta) + (1+\beta)\ln(1-\tau_t) + (1+\beta)\ln\left(\frac{\alpha+(1-\alpha)\tau_t}{\alpha(1+\beta)+(1-\alpha)(1-\kappa_{t+1})\tau_{t+1}}\right)
\end{aligned}$$

4.6 Comparative Statics: An Increase in the Migration Rate μ

In this subsection we derive the comparative statics of the model with respect to the migration rate μ_t and the fertility rate (population growth rate) γ_t^n of the native population. From propositions 2 and 3 we know that these are completely determined by the demographic factors driving relative wages $\mathcal{W}_{hi}(\mu_t/\gamma_t^n), \mathcal{W}_{na}(\mu_t/\gamma_t^n)$ as well as the growth in aggregate labor $\gamma_{t+1}^L(\mu_t,\gamma_t^n)$. The following lemma, proved in appendix A, summarizes the impact of migration and fertility rates on these exogenous demographic factors.

Lemma 1. *Consider a change in the migration and/or native fertility rate (μ_t,γ_t^n)*

1. *The relative wage factors $\mathcal{W}_{hi}(\mu_t/\gamma_t^n), \mathcal{W}_{na}(\mu_t/\gamma_t^n)$ are strictly increasing in μ_t/γ_t^n and $\mathcal{W}_{lo}(\mu_t/\gamma_t^n)$ is strictly decreasing in μ_t/γ_t^n.*

2. *The growth rate of aggregate labor $\gamma_{t+1}^L(\mu_t,\gamma_t^n)$ is strictly increasing in μ_t and γ_t^n if the changes in μ_t,γ_t^n are permanent. The share of migrants in labor $\frac{N_t(0,lo,fo)}{L_t}$ and thus κ_t is strictly increasing in μ_t if the changes in μ_t,γ_t^n are permanent.*

Equipped with this result and propositions 2 and 3 we now can state

Theorem 1. *Consider an unexpected but permanent increase in the migration rate μ_t.*

1. *First consider a small open economy:*

   (a) *Welfare of all young native households is negatively impacted by an increase in the effective cost from migrants* κ_{t+1}*, positively impacted by an increase in the relative return on social security* $\frac{\gamma^L_{t+1}}{R}$*, and from the relative wage effect* $\mathcal{W}_{hi}(\mu_t/\gamma^n_t)$ *is unambiguously positive for high-skilled natives, but* $\mathcal{W}_{lo}(\mu_t/\gamma^n_t) \cdot \mathcal{W}_{na}(\mu_t/\gamma^n_t)$ *is ambiguous for low-skilled natives.*

   (b) *Therefore as long as migrants are not too costly (*$\tilde{\kappa}_{t+1}$ *and thus* κ_{t+1} *is sufficiently small), welfare of young high-skilled natives at the time of the migration boom,* $U_t(hi, na)$ *increases due to the boom.*

   (c) *The welfare consequences for young low-skilled natives* $U_t(lo, na)$ *are ambiguous, but positive as long as their relative wages do not decline too much. This is the case as long as native and migrant low-skilled labor is sufficiently non-substitutable relative to skilled vs. unskilled labor (i.e. as long as* σ_{nf} *is sufficiently small relative to* σ_{lh}*).*

2. *In general equilibrium the migration cost and the relative wage effects are identical to those in the small open economy and the impact on the relative return on social security* $\frac{\gamma^L_{t+1}}{R}$ *is absent. The wage level* w_t *falls and the real return* R_{t+1} *increases, and the overall general equilibrium effect* $(1+\beta)\ln(w_t) + \beta\ln(R_{t+1})$ *is negative as long as the capital share* α *is sufficiently large or the increase in labor in* t *and* $t+1$ *is of similar magnitude.*[10] *In this case the welfare consequences from the migration boom shift down for all groups relative to the small open economy.*

The proof follows directly from lemma 1 as well as propositions 2 and 3. A similar theorem can be derived for a decline in the population growth rate of the native population. The main upshot of the simple model is that the welfare consequences of the 2015-106 immigration boom will depend on four factors: i) the relative wage effects determined by the relative substitution pattern of skilled, unskilled native and skilled native labor, ii) the adjustment of the PAYGO pension system, iii) the costs to administer the migration system and iv) general equilibrium level effects on wages and interest rates which are likely adverse. We now seek to quantify these effects in a more realistic large-scale overlapping generations economy.

[10] The appendix provides conditions on the fundamentals for which this is true, and they are easily verifiable in the quantitative model.

5 The Quantitative Model

The quantitative model we employ is a large-scale overlapping generations model in the tradition of Auerbach and Kotlikoff (1987), but with time-varying, deterministic demographic structure. The key model ingredients are i) a detailed demographic model that accurately describes migrant flows into and out of the country, ii) a production technology that allows for flexible substitution patterns of workers with different migratory background and leads to relative wages that depend on the relative labor supplies of the different population groups, iii) a household sector making consumption-savings and labor supply decisions, and iv) a government that administers the migration system, a basic social safety net, a pay-as-you-go social security system and that collects taxes.

We now first describe the underlying demographic model that captures the flow of migrants and asylum seekers into Germany. We then turn to the description of the economic model, its production technology, endowments and preferences of households, as well as government policies. The recursive formulation of the household problem and the definition of equilibrium is relegated to the appendix.

To provide an overview and set up notation, Table 1, summarizes the state variables used in the model. We refer to it at various places of the remaining description.

Table 1: List of State Variables

State Var.	Values	Interpretation
j	$j \in \{0, 1, \ldots, J\}$	Model Age
s	$s \in \{lo, me, hi\}$	Skill (education)
i	$i \in \{na, ho, rw, as\}$	Region of Origin
g	$g \in \{fe, ma\}$	Gender
m	$m \in \{si, co\}$	Marital status
e	$e \in \{em, re, rl\}$	Labor Market Status
a	$a \geq 0$	Assets

5.1 Demographics and Population Flows

We distinguish between the *na*tive population and the foreign-born population. Foreigners are composed of those that entered the country as regular immigrants and those that came as refugees and are *as*ylum seekers.[11] The basic difference between native households and

[11] We use the terms "refugees" and "asylum seekers" interchangeably. Empirically the latter group includes all successful asylum seekers as well as those waiting for a decision of their application, and finally those that have either been denied protection or lost their humanitarian residence title but remain in the country.

foreigners is in their labor productivity, their access to government transfers as well as the fact that labor inputs supplied by natives and foreigners are imperfect substitutes in production.

We consider four population groups, denoted by $i \in \{na, hi, rw, as\}$, which we also refer to as "citizenship" (in an economic, not in a legal sense). Within the group of regular immigrants, we distinguish between the stock originating from high income OECD countries (ho) and the rest of the world (rw). We assume that each population group is composed of three education groups, the *lo*w, *me*dium, and *hi*gh skilled, denoted by $s \in \{lo, me, hi\}$. Within each group we consider two genders of individuals, $g \in \{fe, ma\}$, of *fe*male and *ma*le workers. We assume that mortality and fertility rates are homogeneous across skill groups.

Households are born at age $j = 0$ and live at most until age $J > 0$. The number of people alive at time t of age j from region i and of gender g is denoted by $N_t(j, i, g)$, the number of people dying between period t and $t+1$ and from age j to $j+1$ is denoted by $D_{t+1}(j+1, i, g)$ and the net inflow of immigrants of this group by $M_{t+1}(j + 1, i, g)$, which may be negative in case there is net emigration. We further define by $\varsigma_t(j, i, g) = 1 - \frac{D_{t+1}(j+1,i,g)}{N_t(j,i,g)}$ the time-, age-, population group- and gender-specific survival rate. We restrict survival rates to be the same across genders, $\varsigma_t(j, i, fe) = \varsigma_t(j, i, ma) = \varsigma_t(j, i)$. Although this is a counterfactual restriction on demographic dynamics—females have higher survival rates than males—it significantly simplifies the economic model where we assume that both members of couple households have the same age and die jointly. Also, denote by $\mu_t(j, i, g) = \frac{M_{t+1}(j+1,i,g)}{N_t(j,i,g)}$ the net migration rate, i.e., the percentage net addition to the stock of (j, i, g) type individuals from period t to $t + 1$.

For most of the analysis we model the dynamics of immigrants into the country in terms of net flows $M_t(j, i, g)$ and thus implicitly assume that the gross flow is equal to the net flow. However, two additional model elements concerning asylum seekers deserve mention: some have to leave the country, and some "assimilate" and become regular rw immigrants. Each period the stock $N_t(j, as, g)\varsigma_t(j, as)$ of asylum seekers that survives to the next period faces the probability π^l of having to leave the country. Those that stay face a probability π^{ar} to assimilate to the rw population group. Denoting by $M^f_{t+1}(j+1, as, g)$ the inflow from foreign countries to that group, the net immigration flow to group as is thus

$$M_{t+1}(j + 1, as, g) = M^f_{t+1}(j + 1, as, g) - \left(\pi^l + (1 - \pi^l)\pi^{ar}\right) N_t(j, as, g)\varsigma_t(j, as)$$

and therefore

$$\mu_t(j, as, g) = \mu^f_t(j, as, g) - \left(\pi^l + (1 - \pi^l)\pi^{ar}\right) \varsigma_t(j, as).$$

Likewise, we assume that in each period a fraction π^{rh} of the stock of population group rw assimilates to population group ho. Denoting by $M^f_{t+1}(j+1, rw, g)$ the inflow from foreign countries to population group rw, the net inflow to the population group rw is thus

$$\begin{aligned} M_{t+1}(j+1, rw, g) = M^f_{t+1}(j+1, rw, g) + (1-\pi^l)\pi^{ar}\varsigma_t(j, as)N_t(j, as, g) \\ - \pi^{rh}\varsigma_t(j, rw)N_t(j, rw, g) \end{aligned}$$

and thus

$$\mu_t(j, rw, g) = \mu^f_t(j, rw, g) + (1-\pi^l)\pi^{ar}\varsigma_t(j, as)\frac{N_t(j, as, g)}{N_t(j, rw, g)} - \pi^{rh}\varsigma_t(j, rw).$$

Correspondingly, denoting by $M^f_{t+1}(j+1, ho, g)$ the inflow from foreign countries to population group ho, the total inflow to the population group ho is

$$M_{t+1}(j+1, ho, g) = M^f_{t+1}(j+1, ho, g) + \pi^{rh}\varsigma_t(j, rw)N_t(j, rw, g)$$

and thus

$$\mu_t(j, ho, g) = \mu^f_t(j, ho, g) + \pi^{rh}\varsigma_t(j, rw)\frac{N_t(j, rw, g)}{N_t(j, ho, g)}.$$

The dynamics for the size of each population group is then determined according to:

$$\begin{aligned} N_{t+1}(j+1, i, g) &= N_t(j, i, g) - D_{t+1}(j+1, i, g) + M_{t+1}(j+1, i, g) \\ &= N_t(j, i, g)\left(\varsigma_t(j, i) + \mu_t(j, i, g)\right), \end{aligned} \tag{22}$$

with terminal condition $D_{t+1}(J+1, i, g) = N_t(j, i, g)$ and $M_{t+1}(J+1, i, g) = 0$, that is, at age J all individuals die and no more migrants enter the country. This concludes the description of the exogenous mortality and migration processes.

Turning now to fertility, denote by $\chi_t(j, i)$ the time t, age j, group i specific fertility rate. We assume an exogenous sex ratio at birth and denote by ϕ the fraction of baby girls (which is assumed to be constant over time and across population groups). We further assume that all newborns of group i are natives. We denote by j_f the first fertile age of a woman and by j_c the age of *c*ompleted fertility. The number of native newborns of gender $N_{t+1}(0, n, g)$

in period $t+1$ is then given by

$$N_{t+1}(0,na,fe) = \phi \sum_{j=j_f}^{j_c} \chi_t(j,i) \sum_{i\in\{na,ho,rw,as\}} N_t(j,i,fe) \tag{23a}$$

$$N_{t+1}(0,na,ma) = (1-\phi) \sum_{j=j_f}^{j_c} \chi_t(j,i) \sum_{i\in\{na,ho,rw,as\}} N_t(j,i,fe). \tag{23b}$$

Since all babies born in Germany are treated as natives, the age 0 population in the foreign population groups are those that migrated from t to $t+1$ to Germany as babies, thus for $i \in \{ho, rw, as\}$ we have

$$N_{t+1}(0,i,g) = M_{t+1}(0,i,g).$$

5.2 Technology

Output Y_t is produced with a neoclassical production function that displays constant returns to scale in capital K_t and a labor aggregate L_t. Firms operate in perfectly competitive output and factor markets, and thus earn zero profits in equilibrium. Given these assumptions, without loss of generality we consider the problem of a representative firm. We assume a Constant Elasticity of Substitution (CES) aggregate production function of the form

$$Y_t = \left(\alpha K_t^{1-\frac{1}{\vartheta}} + (1-\alpha)(A_t L_t)^{1-\frac{1}{\vartheta}}\right)^{\frac{1}{1-\frac{1}{\vartheta}}}.$$

where ϑ is the substitution elasticity between capital and the labor aggregate. Aggregate labor in turn is a CES aggregate of labor supplied by the different skill groups $s \in \{le, me, hi\}$, $L_t(s)$ with substitution elasticity σ_{lmh}:

$$L_t = \left(\sum_{s\in\{lo,me,hi\}} L_t(s)^{1-\frac{1}{\sigma_{lmh}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{lmh}}}}.$$

Labor of skill group s in turn is the CES aggregate of natives and foreigners with substitution elasticity σ_{nf} giving

$$L_t(s) = \left(L_t(s,na)^{1-\frac{1}{\sigma_{nf}}} + \tilde{L}_t(s,fo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}}.$$

With respect to the foreign population stock, we further distinguish between different countries of origin, and thus the education specific foreign (or immigrant) labor input is disaggregated further with substitution elasticity σ_{hr} as

$$\tilde{L}_t(s,fo) = \left(L_t(s,ho)^{1-\frac{1}{\sigma_{hr}}} + \left(\sum_{i\in\{rw,as\}} L_t(s,i) \right)^{1-\frac{1}{\sigma_{hr}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{hr}}}}.$$

Note that we thereby assume that conditional on education and experience, population groups rw and as are perfect substitutes in production.[12] As lowest nests we assume perfect elasticities of substitution across age and gender[13] and thus $L_t(s,i) = \sum_{j=j_a}^{J} L_t(j,s,i)$, $L_t(j,s,i) = \sum_{g\in\{fe,ma\}} \epsilon(j,s,i,g)L_t(j,s,i,g)$. Capital is assumed to depreciate at constant rate δ. The first-order conditions of the firm problem are provided in Appendix B.

5.3 Households

The recursive formulation of the life-cycle household model is contained in Appendix B. Here we describe the main elements.

5.3.1 Marital Status

Agents of gender g may either live as *si*ngles or as a *co*uple, thus the "marital status" is $m \in \{si, co\}$. For simplicity, we assume that marital status is known from the start of economic live at age j_a. We denote by $\pi^m(i,g)$ the exogenous probability of finding a partner at age j_a, which is population group and gender specific. Accordingly, a fraction of individuals remains single and another fraction forms couples. Thus, there are three types of households by gender: single females, single males and couples. To reduce the dimensionality of the state space we assume that couples always feature partners of the same age j and the same citizenship i. We allow for imperfect assortative matching across skill groups s. We further assume that there is no possibility of divorce and married households live as a couples until they die.

5.3.2 Timing of Work and Retirement

Agents work from age j_a until at most the mandatory retirement age j_r. At age j_a the idiosyncratic elements of the wage process $\epsilon(j,s,i,g)$ realize. Skill s is exogenously given at economic birth and we do not consider any inter-generational spill-overs of skills. There are

[12]This is due to data limitations. We have too few observations on asylum seekers in the data, which inhibits the estimation of a substitution elasticity parameter.

[13]Again, this assumption is due to data limitations, as the production function is estimated at the level of the defined groups, and there are too few observations to make the production function more flexible.

three skill levels, low, $medium$ and $high$, $s \in \{lo, me, hi\}$. While agents know their skill levels already at age j_a, for an initial working period $j \in \{j_a, \ldots, j_s\}$ agents of skill s lose some time endowment $\varrho(s) \in (0,1)$, which stands in for time spend on formal education, which increases in the skill level, $j_{hi} > j_{me} > j_{lo} = j_a - 1$, i.e., the low skilled have full time endowment from age j_a onwards. Labor supply can be chosen from the discrete set $\{l_1, \ldots, l_n\}$, where $l_1 = 0$. Asylum seekers are not allowed to work for the first three months after arrival. We model this by adjusting the set of possible labor supply choices to $\varpi\{l_1, \ldots, l_n\}$ and calibrate $\varpi = \frac{3}{4}$. There is an early retirement window, i.e., for age $j \in \{j_e, \ldots, j_r - 1\}$ agents can choose to retire early. For simplicity, we assume joint retirement by couples. We denote the employment status by $e \in \{em, re, rl\}$, where em is employment, re is early and rl is late (or regular) retirement, both of which we take to be an absorbing state.

5.3.3 Endowments

Agents (males or females) are endowed with one unit of productive time. An agent of skill s, age j, "citizenship" i, gender g earns an hourly gross wage of

$$w_t(s,i)\epsilon(j,s,i,g) \tag{24}$$

where $w_t(s,i)$ is determined from the firm side and $\epsilon(j,s,i,g)$ is age, skill, nationality and gender specific productivity, , cf. Section 5.2.

In case individuals choose zero hours ($l = 0$) they are labeled as "unemployed" and receive asset-tested lump-sum social assistance pay. Social assistance pay further depends on family status and the number of children in a household. To capture these institutional features we denote social assistance pay by $b_t^u(a,n,m)$ where a are household asset holdings, m is marital status, n is the number of children living in the household. Means testing is such that transfers are not paid out if household assets exceed threshold $\underline{a}_t(m,n)$, which depends on marital status and the number of children in the household, thus

$$b_t^u(a,n,m) = \begin{cases} \bar{b}_t^u(m,n) & \text{if } a(\cdot) \leq \underline{a}_t(m,n) \\ 0 & \text{otherwise.} \end{cases} \tag{25}$$

In retirement, agents earn a retirement income, which depends on all fixed observable characteristics that measure productivity, s, i, g. According to legislation there are early and late retirement adjustment factors according to which pension payments are adjusted by the actual age of retirement. We approximate this by letting retirement fall into two brackets for early and late (respectively regular) retirement. Thus, if the age of retirement falls in the bracket $[j_e, j_l)$ then the retirement state is re, if it is in bracket $[j_l, j_r]$ the retirement state is rl. The elements of pension benefits accruing at the individual level are stored in variable $p(s,i,g,e)$, where it is understood that $p(\cdot) = 0$ for $e = em$. Pension benefits are further scaled by an aggregate factor υ_t^p, which clears the aggregate pension budget in each period, cf. Section 5.4. We additionally introduce social assistance pay in old-age at some level $\underline{b}_t^p(m)(a,n,m)$, which, as the social assistance pay during the working period, is means tested, cf. equation (25), depends on marital status, the number of children co-residing with retired households and grows exogenously at rate λ.[14] Thus, pension benefits are given by

$$b_t^p(a,n,s,i,g,m,e) = \begin{cases} 0 & \text{for } e = em \\ \upsilon_t^p \cdot p(s,i,g,e) + & \\ \qquad \max\{\underline{b}_t^p(a,n,m) - \upsilon_t^p \cdot p(s,i,g,e), 0\} & \text{otherwise.} \end{cases} \tag{26}$$

Agents start their economic life with zero assets. From then on they have access to a risk-free savings technology with gross interest rate r_t. Assets of couples are pooled. In case singles or both members of a couple die, assets are confiscated and redistributed as accidental bequests, lump-sum within population subgroups j, s, i to all households of that group. We denote these transfers from accidental bequests by $tr_t(j,s,i)$.

For asylum seekers, we distinguish between the first period in which they are asylum seekers and all other periods in which they are accepted or tolerated (we do not distinguish between those).[15] We denote the seeking state by indicator $\mathbb{1}_a$, which is equal to one in the first period after arrival. As asylum seekers they are allowed to work, except for the first three months. Accordingly the labor market states are $l_i \in \frac{3}{4} \cdot \{l_1, \ldots, l_n\}$. Working is subject to the priority review, which decreases their productivity and is reflected in our productivity estimates. If they do not work, then they receive transfer payments $b_t^a(n,m)$, which as the social insurance payments, are means tested and adjusted to household size. If they do work, transfer payments are reduced one for one. At the end of the first period, conditional on surviving to the next period they face a probability π^l with which they have to leave the country and, conditional on staying, a probability π^{ar} with which they assimilate to the foreign population group rw. The remaining fraction $(1-\pi^l)(1-\pi^{ar})$ stays in state as as accepted or tolerated asylees and the seeking indicator $\mathbb{1}_a$ accordingly switches to zero. From now on, asylees who remain in state as have full access to the German social insurance scheme but their labor productivity is lower than for population group rw. At the end of

[14] The age of completed fertility in the data is age $j_c = 50$. Since own households form at the age of 17, some children may live in households that are already retired.

[15] According to factual legislation, some are non-accepted asylees but are tolerated to stay. Of others the status may still be pending after one year. Economically, there is little difference across these different types.

each period they continue to face the leaving and assimilation shocks conditional on surviving with respective probability π^l and conditional probability π^{ar}. Asylees take into account the leaving probability in their decision problem and we assume that the continuation value when leaving is the discounted utility from consumption of the annuitized value of their total wealth in each period, assuming that they work full time each period, with all details provided in Appendix B. Like the native population, a fraction $\pi^m(as, g)$ of asylum seekers of gender g is married. We assume that all shocks to their respective status—the leaving shock with probability π^l and the assimilation shock with probability π^{ar}—hit both members of a couple simultaneously.

Similar to asylum seekers, foreigners from RW face a constant, state-independent probability to assimilate to population group HIOECD denoted by π^{rh}. Finally, all agents pay contributions to PAYG financed social security and health insurance, non-linear labor income taxes, consumption taxes and capital income taxes all of which we specify in Section 5.4.

5.3.4 Preferences

Households derive per period utility from the consumption of a market good c and leisure. While agents know their education at age j_a, agents at age $j_a \leq j \leq j_s$ are still in formal education and thus experience a reduction of time endowment by factor $\varrho(s)$. The household per period utility function of a single of gender g, skill s at age j is thus

$$u\left(\frac{c}{1+\zeta n}, 1 - \mathbb{1}_{j \leq j_s}\varrho(s) - l\right)$$

where indicator $\mathbb{1}_{j \leq j_s}$ takes value 1 if $j \leq j_s$. ζ is a child equivalence parameter and n denotes the number of children assigned to the household.

The problem of couples is cast in the setup of a unitary household model—i.e., both partners jointly make consumption / savings decisions and choose the optimal labor supply of both partners. Individual utilities of both partners are weighted with equal and constant Pareto weights. Thus, the per-period household utility of a couple is given by

$$U\left(\frac{c}{1+\zeta n+\xi}, 1 - l(fe), 1 - l(ma)\right) = u\left(\frac{c}{1+\xi}, 1 - l(fe)\right) + u\left(\frac{c}{1+\xi}, 1 - l(ma)\right)$$

where ξ denotes an adult equivalence parameter.

5.4 Government

There are three separate government budgets, one for the pension system, one for the health insurance system and one for the general tax and transfer system.

Pension System. Labor income is taxed at the linear rate τ_t^p to finance pension income. We assume that all contributions to the pension system are paid by workers and are tax exempt. We also assume a balanced budget in the pension system, thus in each period the sum of contributions are equal to all layouts.

Health Insurance System. In addition, earnings (labor income and pension income) are taxed at rate τ_t^h to finance average age and time-specific health expenditures of households $b_t^h(j)$. These transfers are used to cover health expenditures that perfectly restore the health stock. We neither model health shocks nor a curing technology explicitly. Thus payments at the household level, expenditures on health and transfer payments received, net up to zero and the average transfer payments $b_t^h(j)$ only show up explicitly as expenditures of the health care system. The budget of the health insurance system is assumed to be balanced and thus with constant expenditures $b_t(j)$ an aging population leads to an increase of the contribution rate.

General Tax and Transfer System. Apart from running the pension and health insurance systems, the government also collects linear taxes on consumption at rate τ_t^c, and on capital at rate τ_t^k. Labor income (net of pension contributions) and pension income is taxed by applying a non-linear labor income tax code $T(m)(y(m))$, where $y(m)$ is taxable income. Taxable income and the tax code differ by marital status, which reflects joint taxation of married couples:

$$T(m)(y(m)) = \begin{cases} 2T(y(m)) & \text{if } m = co \\ T(y(m)) & \text{if } m = si \end{cases} \quad \text{and} \quad y(m) = \begin{cases} \frac{1}{2}y(m) & \text{if } m = co \\ y(m) & \text{if } m = si, \end{cases}$$

where $y(m)$ is taxable income of the household, i.e., the sum of all labor income (net of pension contributions) and pension income. Government revenues are used to finance an exogenous stream of government expenditures G_t, transfers to unemployed households b_t^u, transfers to asylum seekers, b_t^a, and transfers to leavers b_t^l, as well as administrative expenses per asylum seeker g_t^a. We do not model government debt.

Thus, the budget constraint of the general tax and transfer system writes as

$$G_t + E_t + TR_t = \tau_t^c C_t + \tau_t^k r_t K_t + \sum_j N_{t,j} \int T_t(y_t) d\Phi_{t,j}$$

where E_t denotes aggregate administrative expenses on asylum seekers during their fist year in the country. TR_t denotes aggregate government transfers to households as social assistance benefits, transfers to asylum seekers and transfer payments to leavers. The formal definition of equilibrium is contained in the appendix.

6 Calibration

Almost all parameters are calibrated externally, to aggregate data or are based on our empirical estimates. We calibrate endogenously the discount factor β to match the risk-free savings return, respectively the capital to output ratio in the data, and gender specific leisure weights in the utility function to match average hours worked. These parameters are calibrated to match average moments during period 1980 to 2010 in the our baseline model. A summary of the calibration is contained in Table 6, provided in Appendix C.

6.1 Time

The initial steady state is assumed in 1960 (model period $t = 0$), the first year for which we have comprehensive population data from the Human Mortality Database (HMD). On the basis of mortality rates taken from HMD we compute in 1960 a steady state population distribution with a constant population, taking as given the size of the age-0 population in 1960. From 1961 we take actual population data, that is we assume that, by surprise, the economy jumps to the actual demographic dynamics extracted from beginning of year 1961. The period until (including) year 2012 is a phase-in period. With this phase-in period we insure that the demographic distribution in the model is consistent with the actual demographic dynamics in the data and that the dynamics of macroeconomic aggregates and their distribution in our main period of interest starting in year 2013 is not affected by our initialization in 1960/61.

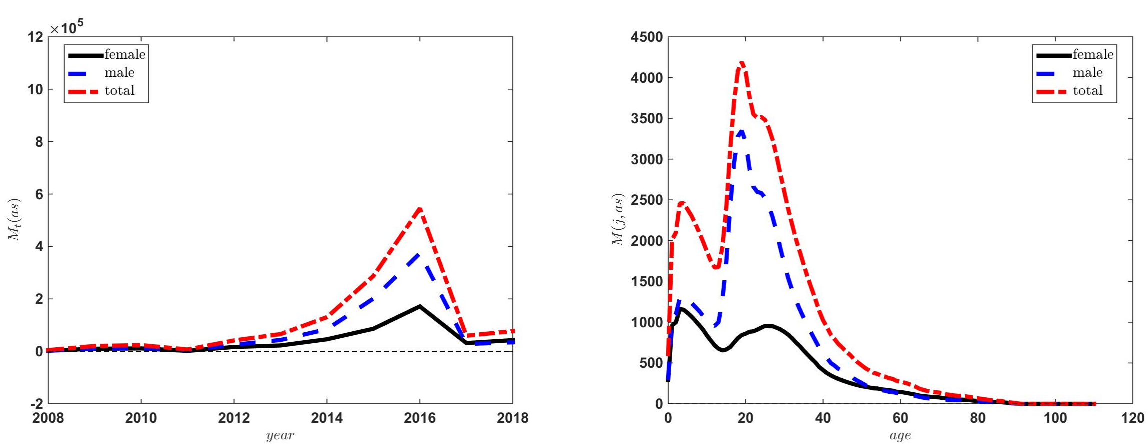
From 2013 onwards we consider three alternative demographic scenarios across which we vary the intensity of low-skill immigration to Germany. In our *baseline* demographic model variant we assume time varying and age-specific mortality and fertility rates and time varying migration numbers as observed in the data but we ignore the migration inflow of population groups rw and as from 2013-2018. For natives we assume a linear reversal to zero migration from 2018 to 2022. For the group of foreigners from HIOECD, we assume a linear trends reversal to the long-run average immigration in this group, again from 2018 to 2022. The *high refugee migration* demographic model variant takes the immigration wave of these years by the population of asylum seekers as given. We model this additional inflow of immigrants as a surprise zero probability event, and again assume a trend reversal between 2018 to and 2022. Finally, the *high migration* demographic model variant additionally assumes the higher migration numbers from the rest of the world population in the years 2013 to 2018 and a trend reversal from 2018 to 2022, which we again treat as a zero probability event.

6.2 Population

All details on the assumptions underlying the population dynamics in all three demographic model variants are described in Appendix C.1. We take data on the population stock available for the period 2008 to 2019 from the German Federal Statistical Office (Statistisches Bundesamt/Destatis; HMD) and from the Central Foreign Population Registry (Ausländerzentralstatistik, AZR) to compute migration flows to the four population groups summarized in Figure 2. It shows the strong spike in the inflow of these immigrants from 2013 to 2017.

Figure 2: Net Migration, Population Group as

(a) Aggregate Inflow (b) Age Distribution

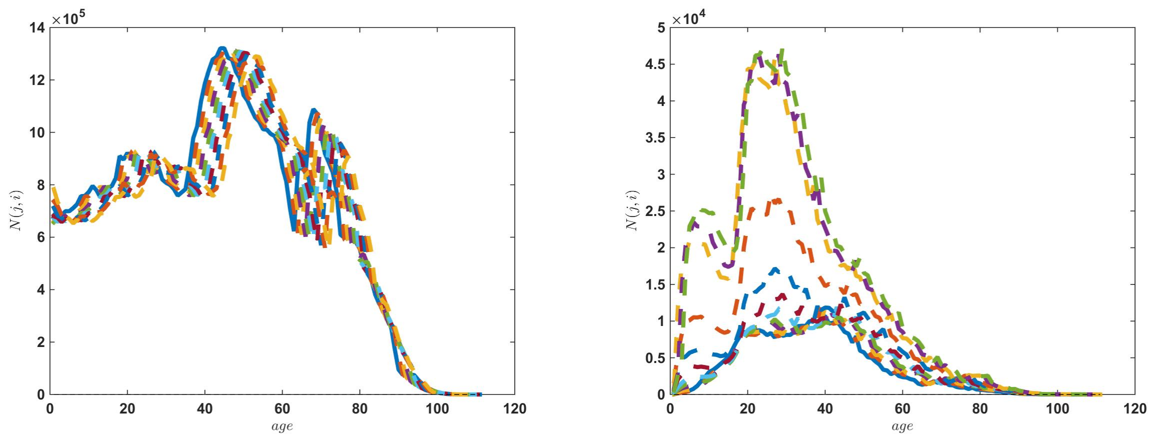


Notes: Migration inflow of asylees. Panel (a): aggregate net immigration, Panel (b): average age distribution of net immigration during 2008-2019.

Figure 3 shows the corresponding age distribution in the native population and in the population of population group AS (the respective distributions for the other population groups, HIOECD and RW, are shown in Appendix C, Figure 15). Overall, the age distribution in the foreign population stock is much younger than the one of the native population.

Figure 3: Age Distribution of Population Stock

(a) Group na (b) Group as



Notes: Age distribution in the population during 2008-2019 among *na*tives and foreigners of the population group *as*ylees.

We further extract mortality rates from the Human Mortality Database, estimate a Lee-Carter model (Lee and Carter 1992) for predicting future rates and hold those constant from year 2100 onwards. Finally, we combine data from the Federal Statistical Office on age-specific fertility rates with the population stock data and the number of births to determine age and time specific fertility distributions. We assume that those are identical for all groups and adjust them such that from 2100 onwards the number of newborns is constant. We thus reach a stationary population distribution by about 2200.

During the phase-in period from 1960 to 2012 we have the exact data on the population stocks only from 2008 onwards. Leading towards 2008 we forward shoot on the population dynamics using data on the annual flow of migration and distribute those across the four groups such that we minimize the distance between the model implied population stocks in the four groups in 2008 and the respective actual population stock.

6.3 Firms

For the estimation of the elasticities of substitution in the production function, we reorder the nesting structure introduced in Section 5 so that age, respectively experience, moves up by one nest. This is described in Appendix C.3. For each education group we bin individuals into age (experience) groups, indexed by $\bar{j}$. The change allows us to exploit more variation in the data. Consider the elasticity of substitution between immigrants and natives: it is identified by variation—over time and across education and experience groups—of the relative hours worked of natives and immigrants and of the relative wages of natives and immigrants, see for example Borjas (2003).

With these modifications we obtain the elasticities of substitution summarized in Table 2.[16] These estimates point to a relatively low degree of substitutability across education groups, consistent with estimates from other studies for Germany.[17] The obtained elasticity of substitution between natives and immigrants lies in between similar estimates for Germany found in the literature.[18] These estimates point to a relatively low degree of substitutability across education groups, consistent with estimates from other studies for Germany.[19] The obtained elasticity of substitution between natives and immigrants lies in between similar estimates for Germany found in the literature.[20] Finally, the degree of substitutability within the group of foreigners is highest.

Table 2: Parameter Estimates: Substitution Elasticities

	Education (σ_{lmh})	Foreigners/Natives (σ_{nf})	Within Foreigners (σ_{hr})
σ	2.96	12.19	23.14

In terms of the remaining parameters of the production function we set $\alpha = 0.33$ and set $\delta = 0.05$. The rate of exogenous technological progress is set to $\lambda = 0.015$. Throughout, we detrend the economy by the technology level and can think of detrended wages from (33). We normalize the initial technology level A_0 such that the detrended wage rate (33b) is equal to one. We also normalize the education s, group i specific productivity profiles $\epsilon(j, s, i)$ such

[16] The point estimates of the inverse (and negative) elasticities with clustered standard errors in parantheses are $\sigma_{lmh} = 0.34(0.13)$, $\sigma_{nf} = 0.08(0.016)$, and $\sigma_{hr} = 0.04(0.01)$.

[17] The point estimate in D'Amuri, Ottaviano, and Peri (2010) is 2.0, and thus basically identical to ours, while Brücker and Jahn (2011) estimate an elasticity of about 6.5. For the United States, estimates are typically slightly lower: Borjas (2003) estimates an elasticity of about 1.3, and Katz and Murphy (1992) of about 1.4. This is not surprising, as we are using three education groups in the case of Germany, whereas the US estimates are based on coarser education categories.

[18] Felbermayr, Geis-Thöne, and Kohler (2010) find a substitution elasticity around 7, D'Amuri, Ottaviano, and Peri (2010) of about 22, and Brücker and Jahn (2011) about 15-20, respectively. For comparison, Ottaviano and Peri (2008) also find a slightly higher estimate of around 20 for the US.

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that in the steady state of the model we match the wage premia across groups that are implied by the age wage profiles $w(s,i)\epsilon(j,s,i,g)$.

6.4 Households

6.4.1 Age

Households start their economic life at age $j_a = 17$, thus education of the low skilled is completed at age $j_{lo} = 16$. Age of completion of education of the medium skilled is set to $j_{me} = 20$, and of the high skilled it is $j_{hi} = 24$. Consistent with the data on fertility rates the first fertile year is $j_f = 15$, and fertility is completed by the age of $j_c = 50$. The early retirement age is $j_{re} = 63$ and the late retirement age is $j_{rl} = 67$. The maximum age agents can reach is $J = 100$.

6.4.2 Preferences

The per-period utility function features logarithmic utility from consumption and linear additive utility from leisure according to

$$\ln(c) + \phi(g)\left(1 - \mathbb{1}_{j \leq j_s} - l\right)^{\frac{1}{1-\frac{1}{\psi}}}$$

with gender specific leisure share parameters $\phi(g)$ and elasticity parameter ψ. We fix $\psi = 1$, thus consider a log utility specification, and calibrate $\phi(g)$ to match average hours worked of both sexes giving $\phi(fe) = 0.814$ and $\phi(ma) = 0.39$.

Households discount future utility at rate β. We calibrate it to match a rate of return on capital of 4%, which is consistent with a capital to output ratio of 3.6. This gives $\beta = 0.973$.

6.4.3 Taste Shocks

Throughout we adopt extreme value type I distributed taste shocks ϵ to smooth the various discrete choice decision problems (e.g., labor supply choices, endogenous retirement decision) in the model, following, e.g., Iskhakov, Jørgensen, Rust, and Schjerning (2017). We set the scale parameter of taste shocks, $\sigma_\epsilon = 0.1$.

6.4.4 Marital Status

To calibrate the marriage probability we estimate the fraction of married women by country of origin in our micro data, which are summarized in Table 3 giving the respective model inputs for $\pi^m(i, fe)$. Together with the number of women from the population model in a given year at age j_a we can compute the number of males that are married. Dividing by the number of males at age j_a then gives the marriage probability for males, which is thus time varying (in our notation we ignore this time dependency).

Table 3: Fraction of Married Women

Natives	Foreigners Group hi	Foreigners Group rw
0.6529	0.7477	0.7275

6.4.5 Skill Distribution

Table 4 summarizes the skill distribution in the four population groups. The three skill groups refer following educational degrees. High skilled are graduates from university and college, medium skilled captures the various vocational degrees of the German education system, and low skilled are those with only general elementary schooling or without any formal education. Observe that the fraction in the respective population group among the high skilled does not vary that much compared to the fraction of the low skilled. Among group as about 50% have no formal education.

Table 4: Skill Distribution in Population

	Females			Males		
Educ s / Region i	low	medium	high	low	medium	high
Natives	0.0625	0.7121	0.2253	0.0381	0.7058	0.2562
Foreigners ho	0.2414	0.5576	0.2010	0.2055	0.5692	0.2254
Foreigners rw	0.2245	0.5515	0.2240	0.1680	0.6829	0.1491
Foreigners as	0.5270	0.2580	0.2150	0.5019	0.2381	0.2600

Notes: Shares with educational degree $s \in \{lo, me, hi\}$ among population groups $i \in \{na, ho, rw, as\}$ by gender.

Appendix C.4 further provides the sorting probabilities $\pi^s(s(g') \mid s(g), i, g)$.

6.4.6 Wage Process

Recall from (24) that hourly wages are

$$w_t(s, i)\epsilon(j, s, i, g).$$

We assume that there is a constant gender specific shifter of wage profiles such that $\epsilon(j, s, i, g) = \epsilon(j, s, i)\epsilon(g)$. As discussed in Section 5.2, asylum seekers and foreigners from the "rest of the world" are perfect substitutes, an assumption we make for reasons of data limitations. Thus, we treat asylum seekers separately, and estimate their productivity relative to "rest of the world" foreigners, which we translate into the calibrated assimilation probability π^{ar} in Section 6.4.7. For the remaining groups $i \in \{na, ho, rw\}$, we normalize $\epsilon(ma) = 1$ and estimate $\epsilon(fe) = 0.8981$. Next, the productivity profiles $\epsilon(j, s, i)$, respectively age wage profiles $w(s, i)\epsilon(j, s, i)$, are estimated from individual data for males by Mincer regressions of log wages on population group and education specific second-order polynomials in age and a set of fixed effects.[21] Figure 16 in Appendix C displays the age wage profiles for natives in Panel (a) and foreigners from group "rest of the world" in Panel (b) for the three education categories $s \in \{lo, me, hi\}$.[22]

6.4.7 Immigrants' Leaving and Assimilation Probabilities

We have to assign numbers to the leave probability π^l, and the assimilation probability π^{ar} of asylees, and to the assimilation probability π^{rh} of immigrants in the rest of the world group. To compute the leave probability, we take data on the flow of leavers from the Federal Office for Migration and Refugees (Bundesamt für Migration und Flüchtlinge, BAMF). Since we do not distinguish in our analysis between involuntary and voluntary leaves, we base our computation on the total number of leaves. We relate those to the stock of asylum seekers in a given year for the period 2008-2018. The average ratio is about 6% and is roughly stable. We thus take $\pi^l = 0.06$. In case of leaving, asylum seekers are also assumed to have lower labor productivity in the country they have to migrate to, which is reflected in parameter η. Since most asylum seekers came from Syria, we proxy productivity differences by estimating aggregate production functions for Germany and Syria and by comparing the resulting Solow residual. On average, relative Solow residuals suggest $\eta = 0.45$.

We estimate a productivity shifter $\Delta_p(\text{t})$ that reduces the productivity of asylees as relative to the rest of the world group, where t is time since migration. Our empirical specification of productivity differences between the two groups is

$$\epsilon(j, s, i, as) = \Delta_p(\text{t})\epsilon(j, s, i, rw).$$

[21] The Mincer regressions are specified to be exactly consistent with the first order conditions of the firm problem. Given persistent wage differences between East and West Germany, see Heise and Porzio (2019), we also adjust wages for a east german wage penalty

[22] Population group "high income OECD countries", ho, is in between.

In the estimation, we assume a that $\Delta_p(\mathrm{t})$ is linear in time since migration, i.e.

$$\Delta_p(\mathrm{t}) = \Delta_p(0) + m_{\Delta_p}\mathrm{t}$$

We take a sample from SOEP of males who have completed their education and who work at least 520 hours. We then control log wages for a set of explanatory variables,[23] and fit $\Delta_p(\mathrm{t})$ to the relative residual wages of asylum seekers to immigrants from the rest of the world. We obtain $\hat{\Delta}_p(\mathrm{t}=0) = 0.75$ and $\hat{m}_{\Delta_p} = 0.0023$. This implies that the half time to close the productivity gap between the two groups is about 53 years, which is consistent with an annual assimilation probability $\pi^{ar} = 0.013$.

In order to estimate the assimilation probability of *rw* immigrants to *ho* immigrants, we use a more flexible alternative to the above, and fit separately local polynomials to the residual wages of *ho* immigrants and residual wages of *rw* immigrants as a function of time since migration, respectively.[24] We find that the initial gap is closed half-way after about 20.4 years, which is consistent with an annual assimilation probability $\pi^{rh} = 0.033$. Finally, observe that asylees face labor market restrictions in the first year after entry, which, as described in Section 5 we model by reducing the set of feasible hours by factor $\varpi = 3/4$.

6.5 Government

6.5.1 Transfer Payments to Asylees and Administrative Expenses

Transfer Payments $b^a_t(\cdot)$ Our data on transfer payments to asylum seekers is based on the Asylum-Seekers' Benefits Act which was introduced in 1993 to determine the entitlements for asylum seekers[25]. The act applies to asylum seekers who filed an application for protection, those obliged to leave Germany as result of rejection of application and those with a temporary suspension of removal.[26] We base our calibration on the most recent data we have for years 2011 to 2019, which are split up according to singles and couples and children in three age categories. Based on this data the transfer schedule $b^a_t(m, n)$, taking

[23]We control for year fixed effects, Education fixed effects, time-and age-varying education premia, age fixed effects, household size, marital status, and marriage and divorce effects.

[24]These are the profiles shown in Figure 1 in the introduction.

[25]Consequently, data on transfer payments to asylum seekers is not available before 1994.

[26]The benefits include food, housing, heating, healthcare, personal hygiene, assistance in sickness, pregnancy and birth as well as and household durables and consumables. In October, 2015 the law was revised and the level of social benefits were raised furthermore, it substituted 'in cash' benefits for 'in kind' benefits for asylum seekers staying in initial reception centers. Those moved to other decentralized locations receive benefits in cash or kind depending upon the decisions of local authorities which are regulated by Federal states. The 2015 reforms also state that the asylum seekers are entitled to standard social benefits and full healthcare after receiving social benefits under Asylum Seekers' Benefits Act for 15 months.

the average over years in prices of 2010 and assuming that transfers increase linearly in the number of children, is

$$b_t^a(m,n) = 2844 \cdot n + \begin{cases} 4392 & \text{if } m = si \\ 7248 & \text{if } m = co. \end{cases}$$

Administrative Expenses g^a In addition to the direct transfer payments to asylum seekers, estimated administrative and labor costs per asylum seeker are sizeable. Czerny (2019) estimates administrative costs in 2010 prices of 2908 Euro of annual labor costs and 4968 Euro of annual administrative costs per asylum seeker in prices of 2010. On this basis we set $g_t^a = 7876$.

Leaving Transfers b_t^l**.** The Reintegration and Emigration Programme for Asylum-Seekers in Germany (REAG/GARP) provides financial support to asylum seekers and recognized refugees who volunteer to return to their country of origin or a third country of reception. The program is jointly financed by the federal states and the federal government of Germany.[27] The program provides assistance with travel cost, financial travel assistance, medical costs, one-time financial start-up assistance. Data on the number of departures under assisted return programs and related costs are not public. However, some figures can be extracted from the BAMF publications. The cost of assisted return per refugee grew from 686 Euro in 2003 to 1288 Euro per adult in 2008. The rise in cost is mainly due to a decrease in the number of returnees from 11835 in 2003 to 2799 in 2008 (BAMF).

In our model we do not distinguish between voluntary and involuntary leaves.[28] We thus first compute the total expenses in the years 2003 to 2008 and then divide those by the total number of leavers in those years. The resulting average for 2005-2008 in prices of 2100 is about 166 Euro per person. We thus set $b_t^l = 166$ and do not distinguish between administrative costs and direct transfers to the refugees.

[27]There are also other programs that regionally operate in different states. REAG/GARP is the leading program recognized for assisted return of refugees and asylum seekers in Germany. Among other criteria the provision of these benefits depends on the nationality of the asylum seekers.

[28]The share of voluntary leavers to which these transfer payments apply fluctuates between about 10% and 40% with an average of 33% for 2000-2018.

6.5.2 Social Assistance Pay

We base the transfer schedule of social assistance pay on Hartz IV payments in 2019, which include base payments and transfer payments for living expenses and heating.[29] Transfers differ by household type increase non-linearly in the number of children. We compute average payments per chid which gives the following schedule

$$b_t^u(m,n) = 2074 \cdot n + \begin{cases} 7948 & \text{if } m = si \\ 12547 & \text{if } m = co. \end{cases}$$

6.5.3 Taxes and Government Expenditures

We approximate the German labor income tax code by the Benabou (2002) tax function

$$T(y) = y - \omega_0 y^{1-\omega_1},$$

where ω_0 is a tax level parameter and ω_1 is a tax progressivity parameter. Based on the estimates of Holter and Krueger (2019) we set $\omega_0 = 0.8929$ and $\omega_1 = 0.2035$. The consumption tax rate is set to the current level of $\tau^c = 19[\%]$ in the steady state, which we adjust along the transition to clear the government budget. Capital income taxes at held constant at $\tau_t^k = 25\%$, in line with current legislation. From the government budget constraint we obtain as an average for the period 1980 to 2010 for this calibration an endogenous $\frac{G}{Y} = 9.45\%$. Along the transition we hold per capita government expenditures $\frac{G_t}{N_t}$ constant.

6.5.4 Pension System

Given that inter-generational transfers are key for our results we thereby impose more discipline on the calibration of the model also during the phase-in period than we do for other tax rates. We base the calibration of the pension system on data up to 2012 and then apply the German pension adjustment formula so that the aggregate pension income component, the current pension value, evolves according to

$$\upsilon_t^p = \upsilon_{t-1}^p \cdot \frac{\bar{w}_t}{\bar{w}_{t-1}} \frac{1 - \iota_t - \tau_t^p}{1 - \iota_{t-1} - \tau_{t-1}^p} \cdot \left(\frac{RQ_t}{RQ_{t-1}} \right)^{-\alpha^p}. \tag{27}$$

Thus, the current pension value, υ_t^p, is determined recursively by three factors, the growth rate of average wages $\bar{w}_t$, the change of taxes and the ratio of pensioners to workers RQ_t. α^p

[29] For the data, see https://www.bmas.de/DE/Themen/Arbeitsmarkt/Grundsicherung/Leistungen-zur-Sicherung-des-Lebensunterhalts/2-teaser-artikelseite-arbeitslosengeld-2-sozialgeld.html.

is a sensitivity parameter reducing the current pension value υ_t^p when the ratio of pensioners to workers RQ_t increases.[30] In this formula before the pension reform of 2003, $\alpha^p = 0$ and the private contribution factor $\iota_t = 0$. In the reform year 2003, α^p was set to 0.25 and ι_t increased linearly from 0 to 0.04 over a period of 8 years and is accordingly set to $\iota_t = 0.04$ since 2011. However, as a consequence of the political process the formula was not applied in year 2008/09 when wages decreased in the aftermath of the financial crisis and was instead replaced by (nominal) pension guarantees. We therefore apply the actually observed contribution rates until 2012 (cf. Appendix C.5), and compute the market clearing replacement rate. From 2012 onwards, we apply (27) and the budget constraint of the pension system together with the law of motion of the current pension value determine the time paths of τ_t^p, υ_t^p. For the remainder of the analysis we also define the benefit rate of the pension system as $\rho_t^p = \frac{\upsilon_t^p}{\bar{w}_t}$. It is important to note that this is an equilibrium object of the pension system which is related to, but not identical in its level, the replacement rate often referred to in the policy debate.[31]

6.5.5 Health Care System

We extract a relative age profile of health care expenditures from data by the German public health insurance for years 2010 to 2017.[32] We normalize these data by GDP taking out time effects and compute the average profile, see Appendix C.5. Next, we hold constant these relative expenditure profiles and feed into the model a time series of average health care contribution rates, also shown in Appendix C.5. For years 1960 to 2012 (again prior to the start of our main experiment) we take the series of contribution rates and the endogenously determined incomes to compute total contributions to health insurance. We adjust the (normalized) spending profile in each year such that the year by year budgets of the health insurance system clear. For our predictions beyond year 2019 we hold the age expenditure profile constant and adjust the contribution rate endogenously to clear the budget of the health care system.[33]

[30] The formula is an approximation to actual legislation, see Ludwig and Reiter (2010).

[31] The gross replacement rate in the policy debate refers to the average pension income of the standard pensioner ("Eckrentner"), who has contributed to the pension system over 45 years and earned average wages. We do not define such a standard pensioner.

[32] We thank Friedrich Breyer for sending us the data.

[33] We thus assume that reductions of health care expenditures in an aging society according to the morbidity compression hypothesis (Fries 1980), and increases due to the medication hypothesis Crimmins and Beltrán-Sánchez (2010) and the "Eubie-Blake effect" Breyer, Lorenz, and Niebel (2015) offset each other.

7 Quantitative Analysis of the Migration Wave

7.1 Population Dynamics

Point of departure of our analysis are the exogenous population dynamics. Figure 4 shows in Panel (a) the sum of net immigration in our three demographic scenarios. Observe that in the baseline scenario, net immigration to Germany is negative in 2016. The reason is an exceptionally high net emigration of German natives. The long-run average emigration of natives is small, around -23'000. In our projections, we abstract from emigration by setting long-run emigration to zero. At the peak of the refugee wave in 2015, aggregate migration increased to 1,2 Million in the data (as well as in our high migration scenario). As a consequence of this inflow, the German population increases to about 83 million in 2022 and then starts decreasing. According to our high migration scenario it is projected to decrease to 76 million in 2070 and thus relative to the baseline demographic model the size of the total population will increase by 6% in 2070. In Appendix D, Figure 19, we further show the fraction in the population in all four regions. In the high migration scenario the fraction of natives decreases from 88% in 2010 to 81% by 2050. For the same years, the fraction from HIOECD countries increases from 4.5% to 6%, from RW from 6% to 9% and the fraction of the asylum seeking, respectively refugee, population increases from 1.4% to 3.5%.

Figure 4: Migration & Total population

(a) Total Net Migration (b) Total population

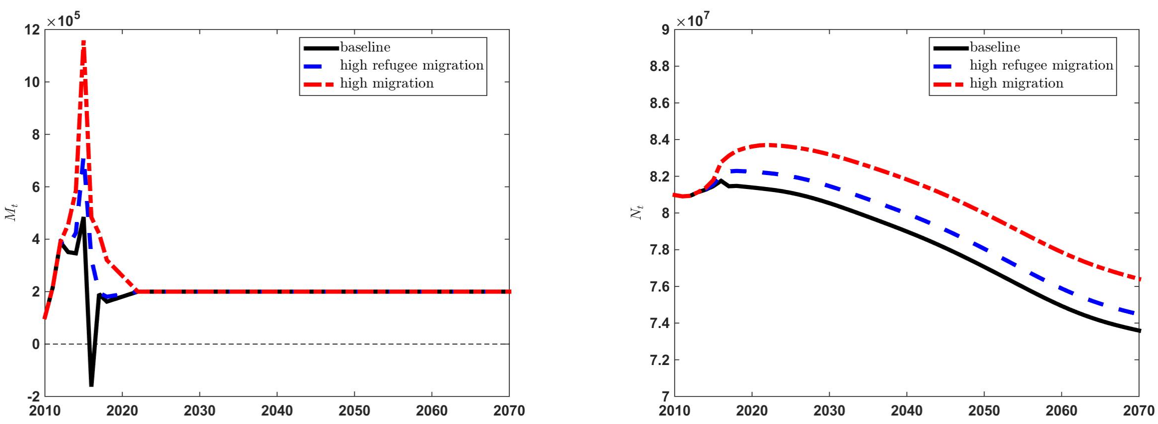
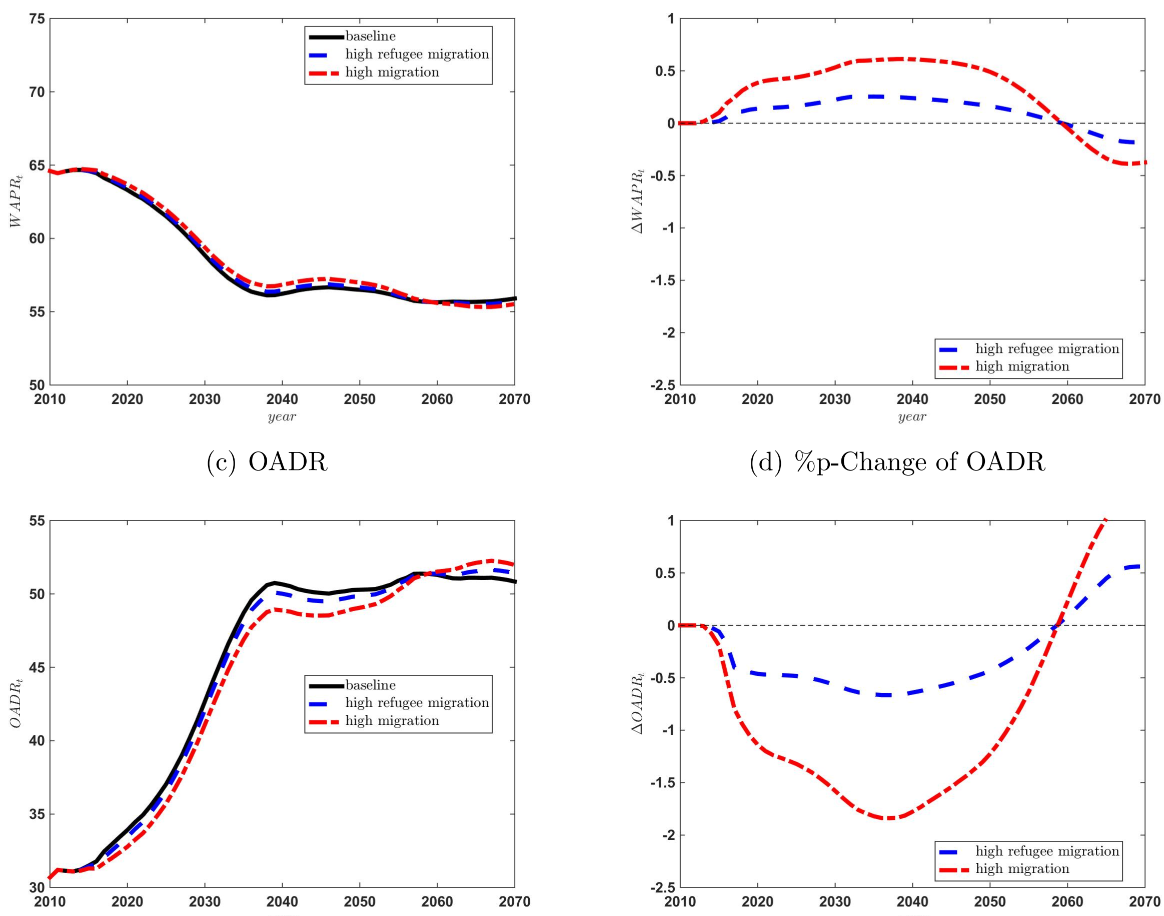


Figure 5 plot the working age population ratio, the fraction of working age population aged $j_a = 17$ to $j_{rl} - 1 = 66$ to the total population as well as the old-age dependency ratio, which is the fraction of the population in retirement age of ages $j_{rl} = 66$ to $J = 110$ to the working age population. These plots show that our analysis of the migration wave is cast against the background of an aging population. In the baseline demographic scenario, the old-age dependency ratio will increase from 30% in 2010 to 50% in 2040 and the working age population ratio falls over the same time period from 65% to 55%. The inflow of young immigrants has strong effects on these demographic statistics, in particular on the old-age dependency ratio. It decreases by 2% until 2040 in the high migration scenario. The figure also shows the effects of the boom-bust nature of our migration experiment of Figure 4. Towards 2050/60 the young migrants of the 2015s start to retire which decreases the working age population and increases the old-age dependency ratio relative to the baseline demographic scenario.

Figure 5: Dependency Ratios

(a) WAPR (b) %p-Change of WAPR



7.2 Results for the Closed Economy

As our baseline for the evaluation of the macroeconomic and distributional consequences of these demographic developments we consider a closed economy. In this baseline, population aging and the inflow of migrants affect not only relative prices of labor of different population groups, but also total factor prices (the marginal products of labor and capital) as in the simple model of Section 4. Understanding these mechanisms serves as a useful benchmark although Germany is, of course, by no means a closed economy. As part of our sensitivity analyses we also consider a small open economy (SOE) variant below. For each of the three population scenarios, we hold constant government expenditures per refugee, and government consumption expenditures per capita. The budget is cleared through adjusting consumption taxes.

7.2.1 Social Security System

We first analyze the fiscal consequences of the migration flow starting with the key variables of the pension system shown in Figure 6. We simplify the analysis and, in contrast to the current legislation, hold constant the retirement age bracket.[34] As a consequence of population aging the contribution rate in the pension system increases from 20% in 2010 to almost 27% in 2040. Correspondingly, the benefit rate—which, as emphasized in Section 6, is not the same object as the replacement rate often referred to in the policy debate—falls by 8 percentage points. The figure also shows that the migration inflow has quite strong effects on both variables; in the high migration scenario the contribution rate decreases by up to 0.6%p and the benefit rate increases by a similar amount, which increases the implicit return of the pension system. Furthermore, as already seen for the working age population and the old-age dependency ratios, the figure shows the reversal of these changes after 2060 when the young migrants retire.

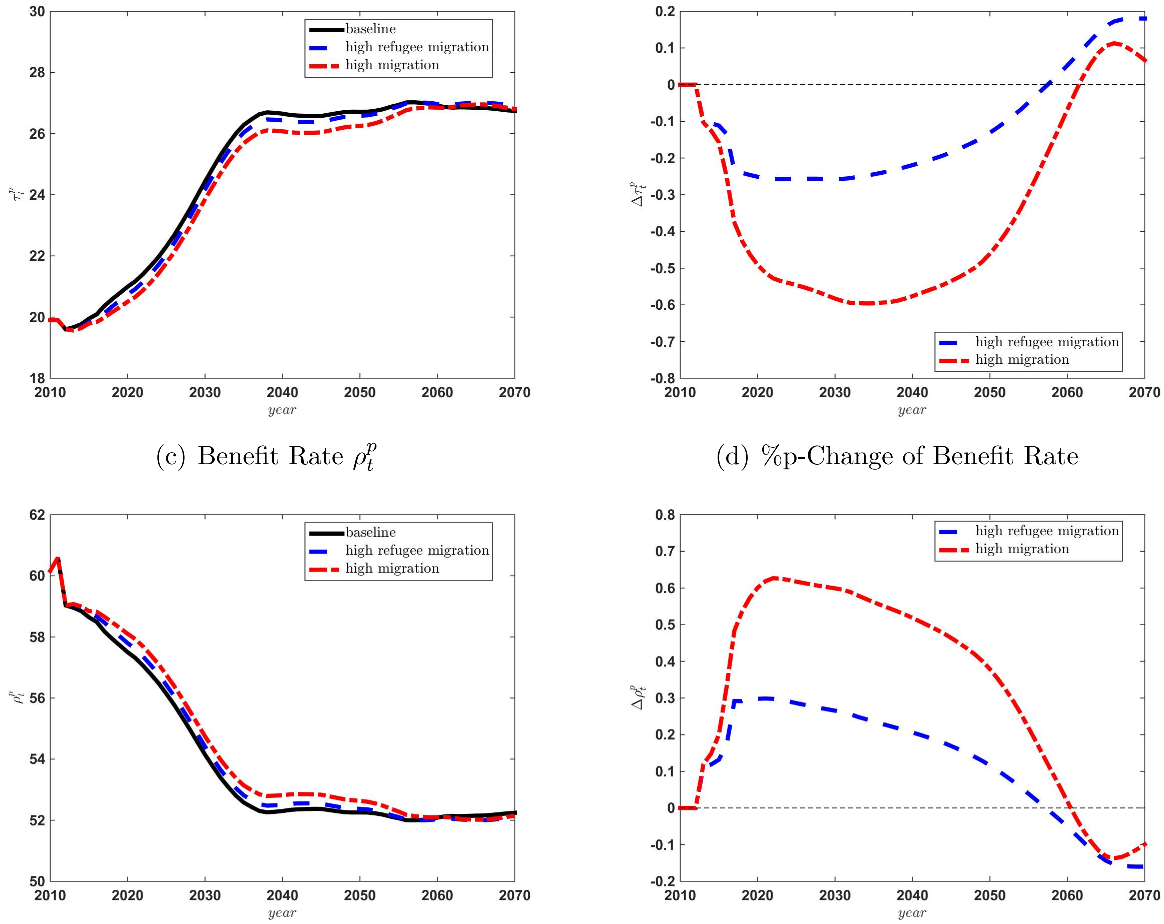
7.2.2 Government Expenditures and Consumption Taxes

Recall that we assume constant government expenditures per refugee, and constant government consumption expenditures per capita along the transition. Figure 20 in Appendix D shows the time path of the sum of government consumption expenditures and expenditures for refugees as a fraction of GDP. Along the transition the expenditure ratio increases by about 1%p because of a reduction of output relative to trend, shown below. Because of the administrative outlays on refugees, the total government expenditure to GDP ratio increases by about 0.3%p after the migration shock.

Consumption taxes adjust to close to budget and the time path is shown in Figure 7. Similar to the contribution rate to the pension system, the consumption tax rate increases

[34] For the differential effects across the migration scenarios the interactions between the increase of the retirement age and the inflow of migration for their aggregate and distributive effects are largely irrelevant.

Figure 6: Contribution & Replacement Level



(a) Contribution Rate τ_t^p

(b) %p-Change of Contribution Rate

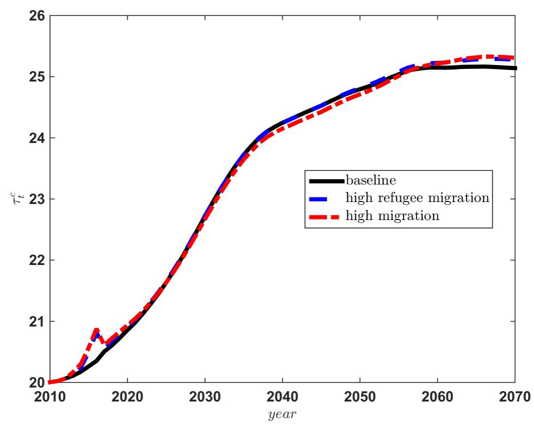
(c) Benefit Rate ρ_t^p

(d) %p-Change of Benefit Rate

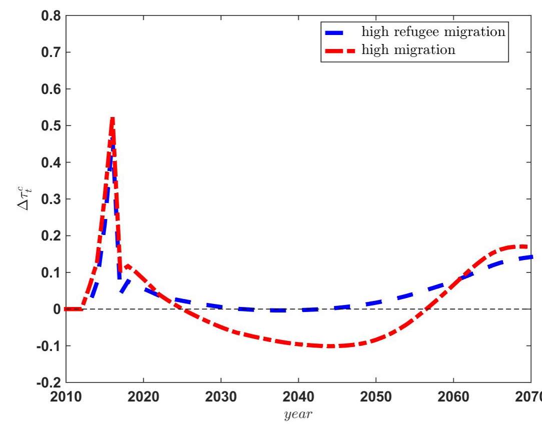
by about 5%p along the transition. The reason for this trend increase is that the given government outlays have to be financed through taxes but the tax base deteriorates because of the shrinkage of the work force in an aging population. Financing the incoming refugees leads to a non-negligible increase of the consumption tax rate by 0.5%p in the short run, because of the administrative expenses and because refugees are more likely to receive social assistance pay. When the young migrants have entered the labor market and when the aging of the overall population peaks around 2040, the consumption tax rate is lower in the high migration scenario. Not so in the refugee migration scenario which is a consequence of the lower productivity of this group of immigrants. Also notice that, as previously, we observe the reversal to higher consumption tax rates when the young migrants start to retire towards 2050/60.

Figure 7: Consumption Taxes

(a) Consumption Tax Rate τ_t^c



(b) %p-Change of Cons. Tax Rate



7.2.3 Macroeconomic Aggregates

We next turn to macroeconomic aggregates, de-trended per capita GDP $\frac{Y_t/N_t}{A_t}$ and per capita consumption $\frac{C_t/N_t}{A_t}$. By de-trending we isolate the effects of demographic changes. Thus if these variables go down it means that they go down *relative* to a constant trend growth.

Observe from Figure 21 in Appendix D that detrended per capita GDP and consumption decrease along the transition of the economy and that the decrease of per capita consumption is smoother which reflects life-cycle consumption smoothing over time. However, drawing welfare conclusions from this observation would be flawed. While per capita aggregate variables play a central role in the public debate, they are an inappropriate measure for the welfare effects of demographic change (and of migration inflows) from the perspective of individuals. Per capita variables are computed along the cross section of a given year; what is relevant for welfare of individuals is, however, the evolution of wages and rates of capital returns over time, see e.g. Krueger and Ludwig (2007).

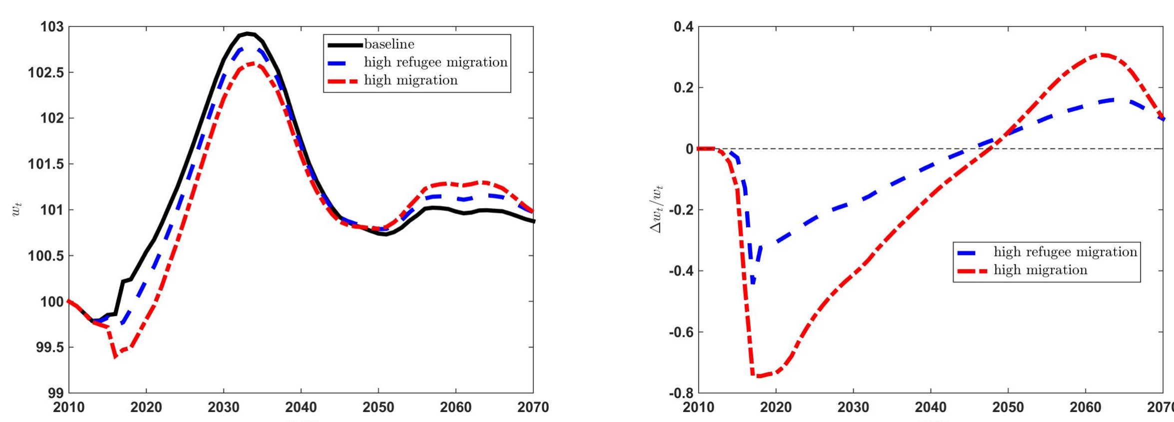
The immigration of mainly low-skilled persons leads to a considerable drop in both variables, and we again observe non-linear changes reflecting first the increasing entry into the labor market of the young immigrants and towards 2050 the effects of the boom-bust feature of the migration wave. A reduction of per capita variables in response to an inflow of mainly low-skilled immigrants is not surprising. The aggregate consequences of an inflow of young workers are like an increase of the birth rate; low productive people increase the head count while their contribution to output is limited. Again, this does not allow to draw conclusions on the welfare consequences of such an inflow for those who live along the transition. To draw welfare conclusions we have to study rates of return and wages to which we turn next.

7.2.4 Rate of Return and Wages

Rate of Return and Marginal Product of Labor. Figure 8 shows the marginal product of labor w_t and Figure 22 in Appendix D its mirror image, the rate of return to capital r_t. In our baseline scenario the rate of return to capital decreases by about 0.5%p, consistent with but slightly lower than found in previous studies for Germany, e.g., Börsch-Supan, Ludwig, and Winter (2006). The marginal product of capital, which is one key factor of wages of the different population groups, naturally shows the opposite trend. As a consequence of the inflow of immigrants, the marginal product of labor decreases by about 0.7 percent. In our model, low skilled immigrants arrive without any assets and thus the capital stock decreases. At the same time aggregate labor increases (mildly). Both forces reduce the capital stock per efficiency unit thereby reducing the marginal product of labor and increasing the rate of return to capital. The reduction of the marginal product of labor has welfare deteriorating consequences for young agents, the increase of the rate of return is beneficial to medium aged to old households alive in 2013 who have substantial positive asset holdings. Importantly, after the initial drop the gap between the marginal product of labor in the high refugee migration and the high migration scenarios gradually closes until 2050 as the young immigrants accumulate wealth so that the capital stock per unit of efficiency k_t increases. When they start to retire towards 2050/60 scarcity of labor in the economy increases relative to the baseline demographic model and thus the marginal product of labor increases and the rate of return decreases.

Figure 8: Marginal Product of Labor

(a) MPL (b) %-Change of MPL

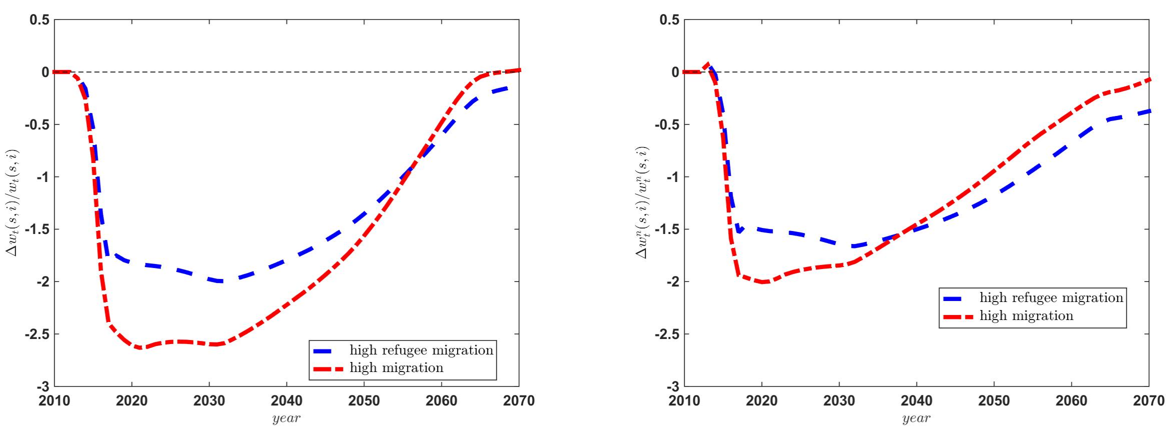


Wages of Low-Skilled Natives. As to the effects on wages we focus on low-skilled natives and relegate a discussion of other skill and population groups to Appendix D. Low skilled natives make up for about 5% of the population.[35] Figure 9 shows the percent changes of aggregate gross and net wages of low-skilled natives, $w_t(s,i)$ for $s = lo, i = na$; the corresponding levels are shown in Figure 23 in Appendix D. Gross wages increase in an aging society because of the increasing relative scarcity of the work force, which mirrors the increase of the marginal product of labor analyzed above. However, as a consequence of the increasing contribution rates to the PAYG pension system net wages fall.

The migration inflow reduces gross wages of the low skilled natives by 2.5% in the high migration scenario and the gross wage effects are negative throughout the entire projection window but become less strong after 2030. The net wage change is milder in both migration scenarios but also negative throughout the entire projection period.

Figure 9: %-Changes of Gross & Net Wages, Low-Skilled Natives

(a) %-Change of Gross Wages (b) %-Change of Net Wages



Gross Wage Decomposition for Low Skilled Natives. For interpretational purposes we decompose gross wages into the marginal product of labor and additional terms that reflect the relative scarcity of skills and of native workers, similar to the simple model of Section 4. We get for gross wages of low skilled natives after substitution of the different

[35] The population share of natives is roughly 87% in 2013, cf. Figure 19 in Appendix D, and share of natives with a low education is about 5%, cf. Table 4. In comparison, low-skilled foreigners from HIOECD countries make up for about 1% of the total population; for regions RW and AS the shares are 1.5% and 1%, respectively. Thus, the total share of the low skilled in the population is about 8.5%.

nests of the aggregate production function that

$$\frac{w_t(j,lo,na)}{\epsilon(j,lo,na)} = w_t \cdot \underbrace{\left(1+\Theta_t(me,lo)^{1-\frac{1}{\sigma_{lmh}}} + \Theta_t(hi,lo)^{1-\frac{1}{\sigma_{lmh}}}\right)^{\frac{1}{\sigma_{lmh}-1}}}_{=\mathcal{W}_t^s(lo)} \cdot \underbrace{\left(1+\Theta_t(fo,na \mid lo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{\sigma_{nf}-1}}}_{=\mathcal{W}_t^{fn}(lo)}$$

where $\Theta_t(s,lo) = \frac{L_t(s)}{L_t(lo)}$ for $s \in \{me, hi\}$ is the ratio of the CES aggregates of workers with skill s to the CES aggregate of low-skilled workers and $\Theta_t(fo,na \mid lo) = \frac{\tilde{L}_t(lo,fo)}{L_t(lo,na)}$ is the ratio of the CES aggregate of foreign to the CES aggregate of native workers of low skill. These terms measure the relative scarcity of the respective labor aggregates. They in turn enter into expressions for the relative wage effects of this relative scarcity. Specifically, we refer to $\mathcal{W}_t^s(s)$ as the *relative scarcity wage effect of skill group s*, and to $\mathcal{W}_t^{fn}(s)$ as the *relative scarcity wage effect of foreign workers of skill group s*.

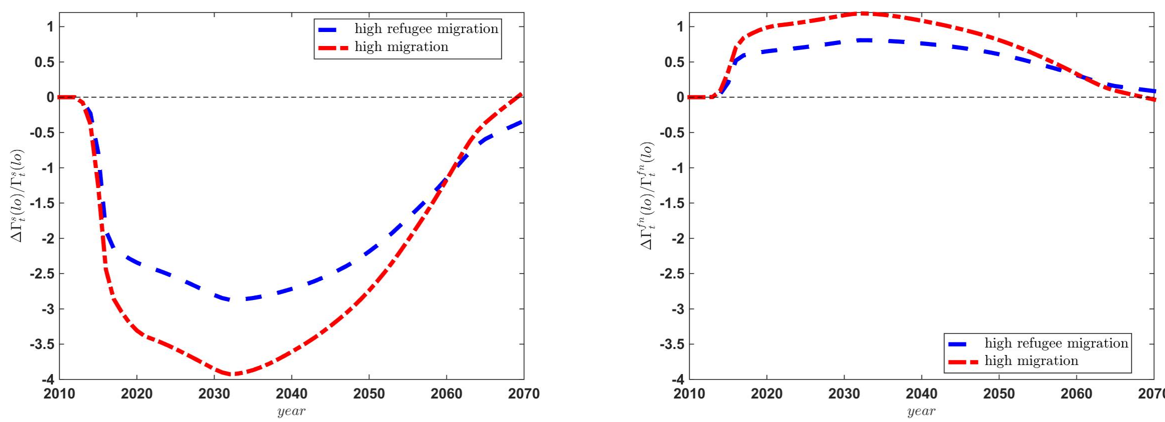
Our estimates of the substitution elasticities $1 < \sigma_{lmh} < \infty$ and $1 < \sigma_{nf} < \infty$ from Section 6 suggest that workers of different education and of different countries of origin are relative substitutes. Then three effects from an inflow of low skilled immigrants on low-skilled natives' wages are at work, as in the simple model of Section 4. First, as argued above an inflow of workers with zero assets decreases capital and increases aggregate labor supply thus reducing the capital intensity k_t which decreases gross wages. Second, an inflow of low-skilled foreign workers increases the relative scarcity of low skilled natives, i.e., it increases the skill ratio $\Theta_t(fo,na \mid lo)$, which, c.p., increases gross wages of native low skilled workers. Third, an increase of low-skilled workers increases the relative scarcity of medium and high skilled workers relative to low skilled workers, i.e., it decreases the skill ratios $\Theta_t(s,lo)$, for $s \in \{me, hi\}$, which, c.p., decreases wages of (native) low skilled workers.

Figure 24 in Appendix D displays the changes in the skill ratios $\Theta_t(\cdot)$. Due to the inflow of relatively low-skilled workers, high- and medium-skilled workers become relatively scarce. Since the skill decomposition of refugees and of foreigners from RW features stronger differences to natives in the medium skill group than among the high-skilled, this scarcity effect is more pronounced for $\Theta_t(me,lo)$ than for $\Theta_t(hi,lo)$. This increase of the relative abundance of low skilled workers contributes to a reduction of gross wages. The effect is stronger than the increase of the relative scarcity of natives to foreigners of low skill, shown by term $\Theta_t(fo,na \mid lo)$.

How those relative scarcities of workers translate into wage effects also depends on the respective substitution elasticities. The total effect is measured by the relative scarcity wage effect terms $\mathcal{W}_t^s(lo)$ and $\mathcal{W}_t^{fn}(lo)$; their changes are shown in Figure 10. As a consequence of the strong changes of the skill ratios shown in Figure 24 and of the low estimate of the elasticity of substitution across skill groups, the wage effect due to the relative abundance of low skilled workers is substantially more strongly negative than the positive effect from the relative scarcity of native workers. This, in combination with the reduction of the marginal product of labor shown in Figure 8 explains the reduction of gross wages shown in Figure 9.

Figure 10: Change of Wage Terms, Low-Skilled Natives

(a) $\Delta\mathcal{W}_t^s(lo)/\mathcal{W}_t^s(lo)$ (b) $\Delta\mathcal{W}_t^{fn}(lo)/\mathcal{W}_t^{fn}(lo)$



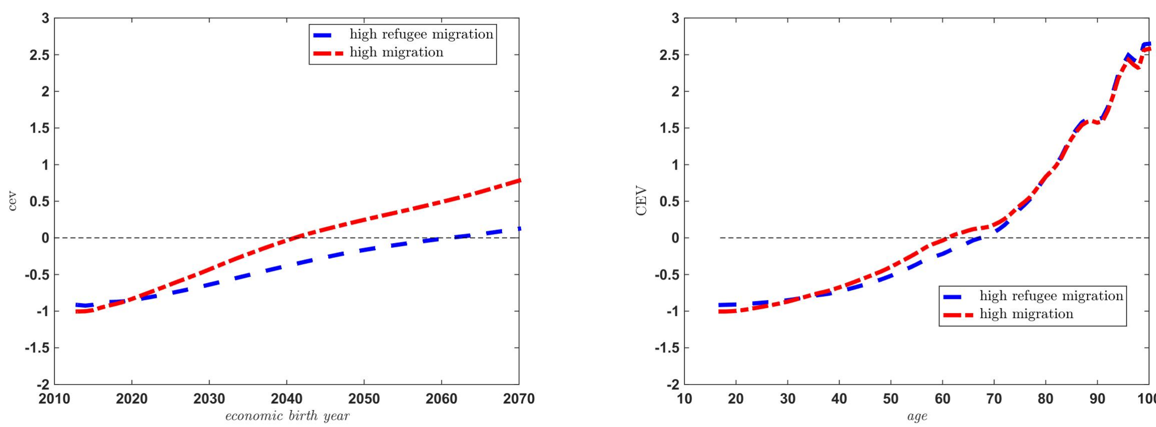
7.2.5 Distribution of Welfare Changes

Finally, we analyze the welfare consequences of the different population scenarios. We compute consumption equivalent variation (CEV) between the high refugee migration scenario and the baseline scenario, as well as between the high overall migration scenario relative to the baseline scenario. CEV is measured as the percent change in consumption over the life-cycle a cohort of education s and nationality i would require as compensation in the baseline scenario in order to be indifferent to the respective migration scenario. Thus, positive numbers indicate welfare gains from a specific migration scenario. Panel (a) of Figure 11 shows the CEV of economically newborn (i.e., age $j_a = 17$) low-skilled natives over time. The figure displays very significant heterogeneity across individuals by the time of birth. Currently alive low skilled newborns experience a welfare loss of about 1% in terms of CEV from both migration scenarios. These losses gradually decline to zero over time, and turn into welfare gains even for low skilled natives after 2040 for the high migration scenario, and by 2060 for the refugee migration scenario.

Panel (b) shows the corresponding CEV for all low skilled native cohorts currently alive in 2013, starting from age $j_a = 17$. In both scenarios all age groups alive in 2013 among the low-skilled natives are worse off from the low skilled immigration until retirement. Older low-skilled individuals currently alive benefit, on account of the increased return to capital and the positive impact of the young migrants on social security benefits.

Figure 11: Consumption Equivalent Variation (CEV) in %, Low-Skilled Natives

(a) By Birth Cohort over Time　　　(b) Generations Alive in 2013



We complement this analysis by showing in Figures 28 and 29 of Appendix D the CEVs for cohorts born along the transition for all education groups and nationality groups and the corresponding CEV for all agents alive in 2013. This shows that there are very significant welfare gains for current medium and high skilled natives and also gains for future newborns until at least 2040. Given the relatively small share of the native low skilled population it is therefore likely that a distribution scheme is possible that compensates them for their losses, which, in the current version of the paper, we do not characterize explicitly.

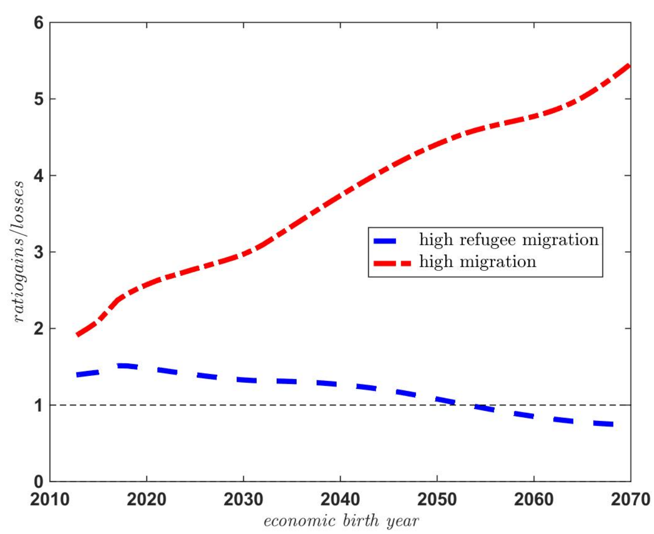
To see the potential for such a scheme, we compute the present discounted value of the consumption increase that cohorts experience under the compensation by the CEV. For each cohort alive in $t_0 = 2013$ we compute the discounted gain

$$\mathcal{G}(j(t_0), s, i) = g_c(j(t_0), s, i) \sum_{j=j(t_0)}^{J} \prod_{t=t_0+1}^{t_0+j-j(t_0)} \left((1+r_t)^{-1} \cdot \varsigma_t(j(t_0)+t-t_0, i)\right) \bar{c}_{t_0+j-j(t_0)}(j, s, i), \tag{28}$$

where $\bar{c}_t(j, s, i)$ is average age j consumption of skill group s, nationality group i and $j(t_0)$ is the age of the cohort born in period $t_0 - j(t_0)$ in period t_0. Figure 30 in Appendix D displays these terms weighted by the population shares in the respective groups, which shows that overall gains are substantially larger than losses. To summarize this in one number we divide the population-weighted sum of the total gains by the according total loss (in absolute terms) in year 2013, which gives 4.84 in the high refugee migration scenario and 5.58 in the high migration scenarios. Thus, the gains are about 5 times larger than the total losses.

We repeat this calculation for cohorts economically born along the transition of the economy, i.e., we apply equation (28) for all cohorts t_0 economically born between 2013 and 2070. Figure 31 in Appendix D displays these terms weighted by the population shares in the respective groups, which again suggests that in the high migration scenario overall gains are larger than losses. In the refugee migration scenario, findings are different. Likewise, Figure 12 displays the ratio of aggregate gains and losses for cohorts born in 2013 to 2070. For newborn cohorts in the high refugee migration scenario, total gains for cohorts born in t_0 exceed total losses until about 2050, when losses start to dominate, which stems from the retirement of the immigrants. Yet, in the high migration scenario, the ratio of gains to losses is substantially higher and increasing over time.

Figure 12: Gains to Losses Ratio



7.3 Sensitivity Analyses

We investigate the sensitivity focussing on the afore gains losses comparison, which we summarize in Table 5. Our first set of experiments varies the economic environment. First, we turn to a small open economy by holding constant the rate of return and thus the marginal product of labor at their respective levels in steady state. We thereby shut down the welfare deteriorating effects of the decreasing marginal product of labor, a mechanism we already emphasized in the analysis of the simple model in Section 4. As expected, welfare losses are now less pronounced for the current young and future generations of low skilled natives so that the ratio of gains to losses increases.

Next, we consider an increase of the assimilation probability of asylum seekers from $\pi^{ar} = 0.013$ to $\pi^{ar} = 0.026$. We view this as a policy parameter that can be changed by relaxing labor market frictions for asylum seekers. While welfare gains from the perspective of low skilled natives are only mildly affected, gains increase for other population groups and thus the ratio of gains to losses increases.

Table 5: Average Ratio of Gains and Losses

Average Ratio of G/L	Alive in 2013		Newborns 2010-2070	
Variant	Ref Scen	High Mig Scen	Ref Scen	High Mig Scen
Baseline	4.74	5.49	0.79	7.34
SOE	5.67	8.69	1.22	10.82
$\pi^{ar} = 0.026$	4.94	5.65	0.93	7.65
Origin PSE	5.04	7.27	0.83	8.60
Skills PSE	13.94	20.23	0.67	22.38

We next investigate the sensitivity of our findings with respect to our parameter estimates of the substitution elasticities. One scenarios assumes perfect substitution within foreigners and between foreigners and natives by setting $\sigma_{hr} = \sigma_{nf} = \infty$. In the first scenario, labor market competition for low-skilled natives is stronger and thus welfare losses increase, e.g., of the current newborns the CEV falls from -1% to -1.5%. However, since the relative scarcity of natives is now more pronounced, their welfare gains increase. This effect dominates and thus the ratio of gains to losses increase. In the second labor market competition for the low skilled natives is less severe. We now observe welfare gains for low skilled natives (as well as for almost all other population groups) and thus the ratio of gains to losses increases quite substantially.

8 Conclusion

In this paper we have constructed a quantitative overlapping generations economy with rich cross-sectional heterogeneity among the native Germany population to study the macroeconomic and distributional consequences of the recent migration wave. We found that net wages of unskilled natives deteriorate in the short run and in the long run as an increased number of unskilled refugees compete with these natives on the labor market and as administrative expenses on (mainly) low skilled immigration increase. We also document that these welfare losses are dominated by substantial welfare gains for other population groups.

We have abstracted from a number of aspects when modeling migrant inflow and behaviour that might be quantitatively important. First, even though we have modelled skill assimilation of migrants, this was not driven by choice (conscious human capital accumulation), but by chance. Similarly, although we have considered the possibility of return migration as an exogenous stochastic event, especially economic migrants and successful asylum seekers face a choice of whether to remain in Germany, and if so, how long. Although our focus has been on the outcome for native Germans, an equally important question concerns the economic consequences for the migrants themselves, conditional on the assumption that the decision to leave their home countries was driven by exogenous shocks (in the case of Syrian refugees, the civil war). However, addressing this question would require modeling the economic future of the migrants' home country, which is a daunting task especially in the case of the current refugees. We therefore leave this question to future research.

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A Details and Proofs for the Simple Model

A.1 Definition of Equilibrium

Definition 1. *Given an initial capital stock K_0, an exogenous population $\{N_t(0,s,i), N_t(1,s,i)\}$ and government policy $\{\rho_t\}$ an equilibrium is a sequence of allocations and prices such that*

1. *Given wages $w_t(s,i)$, interest rates R_{t+1} and policies $\tau_t, b_{t+1}(s,i)$ for each t and each type (s,i) the allocation $c_t(0,s,i), c_{t+1}(1,s,i), a_{t+1}(s,i)$ maximizes lifetime utility (5) subject to the budget constraints (4).*

2. *Interest rates and wages (R_t, w_t) satisfy the marginal product pricing equations (8) and (8), and type-specific wages are given by (10).*

3. *Government policies satisfy the budget constraint (7).*

4. *Markets clear:*

   (a) Labor Markets

$$L_t(hi) = N_t(0, hi, na) \tag{29}$$

$$L_t(lo,i) = \epsilon(lo,i)N_t(0,lo,i) \qquad \text{for } i \in \{na, fo\} \tag{30}$$

   (b) Capital Market

$$K_{t+1} = s_t w_t L_t \tag{31}$$

   (c) Goods Market

$$C_t + K_{t+1} = K_t^{\alpha} L_t^{1-\alpha} \tag{32}$$

Equilibrium in the small open economy is defined in a similar fashion, but the capital market clearing condition is replaced by the condition that the real interest rate $R_t = R$ is fixed by the world capital market, which then from the firm's optimality conditions pins down the constant wage $w_t = w(R)$ and capital-labor ratio $k_t = k(R)$.

A.2 Relative Wages as Functions of Demographics

We summarize wages as functions of demographic variables as:

$$
\begin{aligned}
\frac{L_t}{L_t(hi)} &= \frac{\left(L_t(lo)^{1-\frac{1}{\sigma_{lh}}} + L_t(hi)^{1-\frac{1}{\sigma_{lh}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}}}{L_t(hi)} = \left(\left(\frac{L_t(lo)}{L_t(hi)}\right)^{1-\frac{1}{\sigma_{lh}}} + 1\right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}} \\
\frac{L_t}{L_t(lo)} &= \left(\left(\frac{L_t(hi)}{L_t(lo)}\right)^{1-\frac{1}{\sigma_{lh}}} + 1\right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}} \\
\frac{L_t(lo)}{L_t(hi)} &= \frac{L_t(lo)}{L_t(lo,fo)} \cdot \frac{L_t(lo,fo)}{L_t(hi)} = \left(\left(\frac{\epsilon(lo,na)(1-\omega)\gamma_t^n}{\epsilon(lo,fo)\mu_t}\right)^{1-\frac{1}{\sigma_{nf}}} + 1\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \cdot \frac{\epsilon(lo,fo)\mu_t}{\omega\gamma_t^n} \\
\frac{L_t(hi)}{L_t(lo)} &= \frac{L_t(hi)}{L_t(lo,fo)} \cdot \frac{L_t(lo,fo)}{L_t(lo)} = \left(\left(\frac{\epsilon(lo,na)(1-\omega)\gamma_t^n}{\epsilon(lo,fo)\mu_t}\right)^{1-\frac{1}{\sigma_{nf}}} + 1\right)^{\frac{-1}{1-\frac{1}{\sigma_{nf}}}} \cdot \frac{\omega\gamma_t^n}{\epsilon(lo,fo)\mu_t} \\
\frac{L_t(lo)}{L_t(lo,fo)} &= \frac{\left(L_t(lo,na)^{1-\frac{1}{\sigma_{nf}}} + L_t(lo,fo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}}}{L_t(lo,na)} \\
&= \left(\left(\frac{\epsilon(lo,na)(1-\omega)\gamma_t^n}{\epsilon(lo,fo)\mu_t}\right)^{1-\frac{1}{\sigma_{nf}}} + 1\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \\
\frac{L_t(lo)}{L_t(lo,na)} &= \frac{\left(L_t(lo,na)^{1-\frac{1}{\sigma_{nf}}} + L_t(lo,fo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}}}{L_t(lo,na)} \\
&= \left(\left(\frac{\epsilon(lo,fo)\mu_t}{\epsilon(lo,na)(1-\omega)\gamma_t^n}\right)^{1-\frac{1}{\sigma_{nf}}} + 1\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}}
\end{aligned}
$$

$$
\begin{aligned}
w_t(hi) &= w_t \cdot \left(\frac{L_t}{L_t(hi)}\right)^{\frac{1}{\sigma_{lh}}} = w_t \cdot \left(\left(\frac{L_t(lo)}{L_t(hi)}\right)^{1-\frac{1}{\sigma_{lh}}} + 1\right)^{\frac{\frac{1}{\sigma_{lh}}}{1-\frac{1}{\sigma_{lh}}}} \\
&= w_t \cdot \left(\left(\left(\left(\frac{\epsilon(lo,na)(1-\omega)\gamma_t^n}{\epsilon(lo,fo)\mu_t}\right)^{1-\frac{1}{\sigma_{nf}}} + 1\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \cdot \frac{\epsilon(lo,fo)\mu_t}{\omega\gamma_t^n}\right)^{1-\frac{1}{\sigma_{lh}}} + 1\right)^{\frac{1}{\sigma_{lh}-1}} \\
&= w_t \cdot \left(\left(\left(\left(\frac{\epsilon(lo,na)(1-\omega)}{\omega}\right)^{1-\frac{1}{\sigma_{nf}}} + \left(\frac{\epsilon(lo,fo)\mu_t}{\omega\gamma_t^n}\right)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \cdot\right)^{1-\frac{1}{\sigma_{lh}}} + 1\right)^{\frac{1}{\sigma_{lh}-1}} \\
&= w_t \cdot \mathcal{W}_{hi}(\mu_t/\gamma_t^n) \\
w_t(lo,na) &= w_t \cdot \epsilon(lo,na) \cdot \left(\frac{L_t}{L_t(lo)}\right)^{\frac{1}{\sigma_{lh}}} \cdot \left(\frac{L_t(lo)}{L_t(lo,na)}\right)^{\frac{1}{\sigma_{nf}}} \\
&= w_t \cdot \epsilon(lo,na) \\
&\quad \cdot \left(\left(\left(\left(\frac{\epsilon(lo,na)(1-\omega)}{\omega}\right)^{1-\frac{1}{\sigma_{nf}}} + \left(\frac{\epsilon(lo,fo)\mu_t}{\omega\gamma_t^n}\right)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{-1}{1-\frac{1}{\sigma_{nf}}}}\right)^{1-\frac{1}{\sigma_{lh}}} + 1\right)^{\frac{1}{\sigma_{lh}-1}} \\
&\quad \cdot \left(\left(\frac{\epsilon(lo,fo)\mu_t}{\epsilon(lo,na)(1-\omega)\gamma_t^n}\right)^{1-\frac{1}{\sigma_{nf}}} + 1\right)^{\frac{1}{\sigma_{nf}-1}} \\
&= w_t \mathcal{W}_{lo}(\mu_t/\gamma_t^n) \cdot \mathcal{W}_{na}(\mu_t/\gamma_t^n)
\end{aligned}
$$

It follows from direct inspection that $\mathcal{W}_{hi}(\mu_t/\gamma_t^n), \mathcal{W}_{na}(\mu_t/\gamma_t^n)$ are strictly increasing in μ_t/γ_t^n and $\mathcal{W}_{lo}(\mu_t/\gamma_t^n)$ is strictly decreasing in μ_t/γ_t^n.

A.3 Proof of Lemma 1 and Theorem 1

For lemma 1, we want to arrive at an expression for $\gamma_{t+1}^L = \frac{L_{t+1}}{L_t}$. Recall from (2) and (3) that

$$
L_t = \left(L_t(lo)^{1-\frac{1}{\sigma_{lh}}} + L_t(hi)^{1-\frac{1}{\sigma_{lh}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}}
$$

$$
L_t(lo) = \left(L_t(lo,na)^{1-\frac{1}{\sigma_{nf}}} + L_t(lo,fo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}}
$$

Work on (3):

$$
\begin{aligned}
L_t(lo) &= \left(\left(\epsilon(lo,na) N_t(0,lo,na)\right)^{1-\frac{1}{\sigma_{nf}}} + \left(\epsilon(lo,fo) N_t(0,lo,fo)\right)^{1-\frac{1}{\sigma_{nf}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \\
&= \left(\left(\epsilon(lo,na)(1-\omega)\gamma_t^n N_{t-1}(0)\right)^{1-\frac{1}{\sigma_{nf}}} + \left(\epsilon(lo,fo)\mu_t \gamma_t^n N_{t-1}(0)\right)^{1-\frac{1}{\sigma_{nf}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} \\
&= \left(\left(\epsilon(lo,na)(1-\omega)\gamma_t^n\right)^{1-\frac{1}{\sigma_{nf}}} + \left(\epsilon(lo,fo)\mu_t \gamma_t^n\right)^{1-\frac{1}{\sigma_{nf}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}} N_{t-1}(0) \\
&= \Lambda(\gamma_t^n, \mu_t) N_{t-1}(0) = \Lambda_t N_{t-1}(0)
\end{aligned}
$$

Use this in (2) to get

$$
\begin{aligned}
L_t &= \left(\left(\Lambda(\cdot) N_{t-1}(0)\right)^{1-\frac{1}{\sigma_{lh}}} + \left(\omega \gamma_t^n N_{t-1}(0)\right)^{1-\frac{1}{\sigma_{lh}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}} \\
&= \left(\left(\Lambda(\cdot)\right)^{1-\frac{1}{\sigma_{lh}}} + \left(\omega \gamma_t^n\right)^{1-\frac{1}{\sigma_{lh}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{lh}}}} N_{t-1}(0) \\
&= \Omega(\Lambda(\gamma_t^n, \mu_t), \gamma_t^n) N_{t-1}(0) = \Omega_t(\Lambda_t, \gamma_t^n) N_{t-1}(0).
\end{aligned}
$$

Thus we get

$$
\begin{aligned}
\gamma_{t+1}^L &= \frac{\Omega(\Lambda(\gamma_{t+1}^n, \mu_{t+1}), \gamma_{t+1}^n) N_t(0)}{\Omega(\Lambda(\gamma_t^n, \mu_t), \gamma_t^n) N_{t-1}(0)} \\
&= \frac{\Omega(\Lambda(\gamma_{t+1}^n, \mu_{t+1}), \gamma_{t+1}^n)}{\Omega(\Lambda(\gamma_t^n, \mu_t), \gamma_t^n)} \gamma_t \\
&= \frac{\Omega(\Lambda(\gamma_{t+1}^n, \mu_{t+1}), \gamma_{t+1}^n)}{\Omega(\Lambda(\gamma_t^n, \mu_t), \gamma_t^n)} \left(\gamma_t^n + \mu_t\right) \\
&= \frac{\Omega_{t+1}}{\Omega_t} \left(\gamma_t^n + \mu_t\right) \\
&= \gamma_t^n + \mu_t \text{ if } \gamma_{t+1}^n = \gamma_t^n, \text{ and } \mu_{t+1} = \mu_t
\end{aligned}
$$

We make the following:

Observation 1. *1. Fix γ^n and consider a permanent change of μ_t from $\mu^l > 0$ to $\mu^h > \mu^l$ in period t. Since $\Lambda_{t+1} = \Lambda_t$ we have $\Omega_{t+1} = \Omega_t$ and thus γ_{t+1}^L jumps to $\gamma^n + \mu^l$.*

2. Fix μ and consider a permanent change of γ^n from $\gamma^{nl} > 0$ to $\gamma^{nh} > \gamma^{nl}$ in period t. Since $\Lambda_{t+1} = \Lambda_t$ and $\Omega_{t+1}(\Lambda_{t+1}, \gamma^{nh}) = \Omega_t(\Lambda_t, \gamma^{nh})$ we have that γ_{t+1}^L jumps to $\gamma^{nh} + \mu$.

The proof of theorem 1 then follows directly from lemma 1 as well as propositions 2 and 3. The only non-trivial part is to sign the general equilibrium effect. For this note that

$$\begin{aligned}
(1+\beta)\ln(w_t) + \beta\ln(R_{t+1}) &= (1+\beta)\ln((1-\alpha)k_t^{\alpha}) + \beta\ln(\alpha k_{t+1}^{\alpha-1}) \\
&= \upsilon + (1+\beta)\alpha\ln(k_t) - (1-\alpha)\beta\ln(k_{t+1}) \\
&= \upsilon + (1+\beta)\alpha\ln(k_t) - (1-\alpha)\beta\left[\ln(s_t) + \alpha\ln(k_t) - \ln(\gamma_{t+1}^{L})\right] \\
&= \upsilon + \alpha(1+\alpha\beta)\ln(k_t) - (1-\alpha)\beta\left[\ln(s_t) - \ln(\gamma_{t+1}^{L})\right] \\
&= \upsilon + \alpha(1+\alpha\beta)\ln(K_t) - (1-\alpha)\beta\ln(s_t) \\
&- [\alpha(1+\alpha\beta) + (1-\alpha)\beta]\ln(L_t) + (1-\alpha)\beta\ln(L_{t+1}).
\end{aligned}$$

where υ is a constant. The period t capital stock K_t is pre-determined. The saving rate s_t increases with the per-capita immigration cost κ_{t+1} which in turn rises as more migrants come in, increasing the capital-labor ratio in period $t+1$ and thus reducing the real interest rate. This is the first negative general equilibrium effect (which would be absent if there are no resource costs for the newley arriving migrants, i.e. if $\kappa_{t+1} = 0$). Second, both L_t as well as $\gamma_{t+1}^{L} = L_{t+1}/L_t$ increase when μ_t increases permanently. As long as α is sufficiently large (trivially, if $\alpha = 1$), or as long as $\frac{\partial\ln(L_t)}{\partial\mu} \approx \frac{\partial\ln(L_{t+1})}{\partial\mu}$ (both of these terms only depend on model-exogenous variables) the general equilibrium effect of a permanent increase in migration flows is negative.

Remark 1. *Also note that in the absence of a resource cost ($\kappa_{t+1} = 0$) the saving rate is invariant to demographics, and an increase in migration triggers a decline in the current capital-labor ratio k_t and a further decline in future capita-labor ratios k_{t+s} through the permanent increase in the growth rate of labor γ_{t+s}^{L}. In the long-run the GE effect of these declines is negative as long as the economy remains dynamically efficient. To see this, observe that for all $t \geq 1$ the welfare difference along the transition is*

$$\begin{aligned}
\Delta\left[(1+\beta)\ln(w_t) + \beta\ln(R_{t+1})\right] &= (1+\beta)\left(\ln(w_t) - w_0\right) + \beta\left(\ln(R_{t+1}) - R_0\right) \\
&= (1+\beta)\alpha\left(\ln(k_t) - \ln(k_0)\right) - (1-\alpha)\beta\left(\ln(k_{t+1}) - \ln(k_0)\right).
\end{aligned}$$

For $t \to \infty$ this term is negative if

$$\frac{\alpha}{1-\alpha} > \frac{\beta}{1+\beta}.$$

It is straightforward to verify from the corresponding social planner's problem that this is the condition for dynamic efficiency of the economy. In the short run, for the period $t = 1$ old generation the effect is positive because the wage effect is absent. For all newborn generations *along the transition, the effect is negative if the capital share α is sufficiently large—notice that dynamic efficiency is thus only a necessary condition for the effect to be negative for all newborns along the transition—, because for all $t \geq 1$ the welfare change is negative if*

$$
\begin{aligned}
& (1+\beta)\alpha\,|(\ln(k_t)-\ln(k_0))| - (1-\alpha)\beta\,|(\ln(k_{t+1})-\ln(k_0))| > 0 \\
\Leftrightarrow \quad & \frac{\alpha}{1-\alpha}\frac{|(\ln(k_t)-\ln(k_0))|}{|(\ln(k_{t+1})-\ln(k_0))|} > \frac{\beta}{1+\beta}.
\end{aligned}
$$

and by the monotonic decline of the capital stock we know that $\frac{|(\ln(k_t)-\ln(k_0))|}{|(\ln(k_{t+1})-\ln(k_0))|} < 1$.

B Quantitative Model Appendix

B.1 First-Order Conditions of Firm Problem

Denote by $k_t = \frac{K_t}{A_t L_t}$ the "capital intensity", respectively the capital stock per efficiency unit of labor. Then, the first-order conditions of the static firm problem are given by

$$r_t = \alpha k_t^{-\frac{1}{\vartheta}} \left(\alpha k_t^{1-\frac{1}{\vartheta}} + (1-\alpha)\right)^{\frac{\frac{1}{\vartheta}}{1-\frac{1}{\vartheta}}} - \delta \tag{33a}$$

$$w_t = A_t(1-\alpha)\left(\alpha k_t^{1-\frac{1}{\vartheta}} + (1-\alpha)\right)^{\frac{\frac{1}{\vartheta}}{1-\frac{1}{\vartheta}}} \tag{33b}$$

$$w_t(s) = w_t\left(\frac{L_t}{L_t(s)}\right)^{\frac{1}{\sigma_{lmh}}} \tag{33c}$$

$$\tilde{w}_t(s,k) = w_t(s)\left(\frac{L_t(s)}{\tilde{L}_t(s,k)}\right)^{\frac{1}{\sigma_{nf}}}, \text{ for } k \in \{na, fo\} \tag{33d}$$

$$w_t(s,ho) = \tilde{w}_t(s,fo)\left(\frac{\tilde{L}_t(s,fo)}{L_t(s,ho)}\right)^{\frac{1}{\sigma_{hr}}} \tag{33e}$$

$$w_t(s,o) = \tilde{w}_t(s,fo)\left(\frac{\tilde{L}_t(s,fo)}{\sum_{o\in\{rw,as\}}\epsilon(s,o)L_t(s,o)}\right)^{\frac{1}{\sigma_{hr}}}, \text{ for } o \in \{rw, as\} \tag{33f}$$

$$w_t(j,s,i,g) = w_t(j,s,i) = w_t(s,i) \tag{33g}$$

and notice that $w_t(s,na) = \tilde{w}_t(s,na)$.

B.2 Annuity Income Stream of Leavers

Total wealth of a leaver includes the value of assets at the end of period t at age j, a one time lump-sum payment by the German government b_t^l, and the discounted value of their future labor income. We assume that leavers would not earn a social security income in the country they migrate to, that there is neither a social insurance system nor a labor income tax scheme in the respective country, and that accidental bequests are taxed at a confiscatory rate. We further compute the continuation value in a partial equilibrium, taking the current period wage and interest rate as given.

Total wealth of a leaver with education s and gender g beginning of period $t+1$, age $j+1$, is thus

$$W_{t+1}(j+1,s,g) = a' + b_t^l + \eta \cdot \sum_{p=j}^{j_r-1} \left(\frac{1}{1+r_{t+1}}\right)^{p-j} \epsilon(j,s,i,g) w_{t+p-j}(p,s,g) l_n$$

where $\eta \in (0,1)$ is a productivity scaling parameter, reflecting lower productivity in the country they migrate to as well as labor income taxation. The annuity stream is accordingly

$$y_{t+1}^p(s,g) = \frac{r_{t+1}}{1+r_{t+1}} \frac{(1+r_{t+1})^{J-j}}{(1+r_{t+1})^{J-j}-1} W_{t+1}(j+1,s,g). \tag{34}$$

B.3 Recursive Household Problem

State Variables. We collect state variables as follows, also see Table 1: age $j \in \{j_a, \dots, J\}$, education $s \in \{lo, me, hi\}$, economic nationality $i \in \{na, ho, rw, as\}$, gender $g \in \{fe, ma\}$, marital status $m \in \{si, co\}$, employment status $e \in \{em, re, rl\}$, and assets $a \in \mathcal{A}$. For couples, the state space includes the education level $s(fe), s(ma)$ of both partners.

In addition, for agents in employment state $e = em$ (workers) all objects below are written as discrete choice-specific and, thus, are additionally indexed by discrete choice $d \in \{em, ret\}$ where em denotes the choice not to retire and ret denotes the choice to retire if aged $j \in \{j_e, \dots, j_r - 1\}$ (i.e. the choice ret is available only in the retirement window). If ret is chosen in period t, j, then in the beginning of the next period $t+1, j+1$ the agent moves to employment state re if $j < j_l$, or to employment state rl if $j_l \leq j < j_r$. Next, em choice includes a number of sub-choices $em \in \{sa, pt, ft\}$ where sa denotes choice to work zero hours and receive social assistance benefits, pt is part-time work, ft refers to full-time work. Below we do not write those employment sub-choices explicitly and it is understood that the value functions in employment, conditional on staying not retired, $V_t(j, \cdot, e = em)$ are upper envelopes of discrete hours choice specific value functions.

For asylum seekers the problem is slightly more complex because of the leaving shock and the assimilation shock. Also, immigrants from the rest of the world face an assimilation shock. We therefore first describe the problems of groups $i \in \{na, ho\}$ and then turn to relevant extensions for the remaining two population groups.

Dynamic Problem of Retired Households, $j \in \{j_r, \ldots, J\}, i \in \{na, ho\}, e \in \{re, rl\}$**.** Retired singles solve[36]

$$V_t(j, s, i, g, m = si, e, a) = \max_{c,a'} \left\{ U\left(\frac{c}{1+\zeta n}, 1\right) + \beta \varsigma_t(j, i) V_{t+1}(j+1, s, i, g, m = si, e, a') \right\}$$

subject to

$$\begin{aligned} a' &= (a + tr_t(j, s, i))(1 + r_t(1 - \tau_t^k)) + y_t^p(si) - (c(1 + \tau_t^c) + T(si)(y^p(si))) \geq 0 \\ y_t^p(si) &= (1 - \tau_t^h) b_t^p(a, s, n, i, g, m = si, e). \end{aligned}$$

For couples, the state space is larger and the budget constraint is adjusted. Recall that couples are assumed to die together with probability $1 - \varsigma_t(j, i)$. Thus, couples solve

$$\begin{aligned} V_t(j, s(fe), s(ma), i, m = co, e) = \max_{c,a'} \Big\{ & U\left(\frac{c}{1+\zeta n + \xi}, 1, 1\right) \\ & + \beta \varsigma_t(j, i) V_{t+1}(j+1, s(fe), s(ma), i, m = co, e, a') \Big\} \end{aligned}$$

subject to

$$\begin{aligned} a' &= (a + tr_t(co))(1 + r_t(1 - \tau_t^k)) + y_t^p(co) - (c(1 + \tau_t^c) - T(co)(y^p(co))) \geq 0 \\ tr_t(co) &= \sum_{g \in \{fe, ma\}} tr_t(s(g), j, i) \\ y_t^p(co) &= (1 - \tau_t^h) \sum_{g \in \{fe, ma\}} b_t^p(a, n, s, i, g, co, e) \end{aligned}$$

Dynamic Problem of Working Households in Last Working Period, $j = j_r - 1, i \in \{na, ho\}, e = em$**.** At age j households who are already retired, $e \in \{re, rl\}$, solve the problem described above. Single households who worked until age $j_r - 2$ solve at age $j = j_r - 1$ the following endogenous retirement decision problem

$$\mathbb{1}_r(j, s, i, g, m = si, e = em, a) = \begin{cases} 1 & \text{if } V_t(j, s, i, g, m = si, e = em, d = ret, a) > \\ & \qquad V_t(j, s, i, g, m = si, e = em, d = em, a) \\ 0 & \text{otherwise} \end{cases}$$

[36]Recall that $\varsigma_{tJi} = 0$ so that terminal (and trivial) decision problem of singles and couples at age J are nested in this description.

and we denote the associated upper envelope of the value functions by

$$W_t(j,s,i,g,m=si,e=em,a)=\max\left\{V_t(e=em,d=em,\cdot),V_t(e=em,d=ret,\cdot)\right\}.$$

To facilitate computations, we augment the discrete choice problem above with i.i.d. taste shocks that follow extreme value type I distribution (see e.g. Iskhakov, Jørgensen, Rust, and Schjerning (2017)). Thus, the modified discrete decision problem writes as

$$W_t(j,s,i,g,m=si,e=em,a)=E\max\left\{V_t(e=em,d=em,\cdot)+\sigma_\epsilon\epsilon(em),\ V_t(e=em,d=ret,\cdot)+\sigma_\epsilon\epsilon(ret)\right\},$$

where σ_ϵ denotes the scale parameter of taste shifters $\epsilon(d)$ [37]. Given the distributional assumption, the expectation above can be written in closed form using the logsum formula (for more details see McFadden et al. (1973)) and, thus, we obtain:

$$W_t(j,s,i,g,m=si,e=em,a)=\sigma_\epsilon\log\left[\exp\left\{\frac{V_t(e=em,d=em,\cdot)}{\sigma_\epsilon}\right\}+\exp\left\{\frac{V_t(e=em,d=ret,\cdot)}{\sigma_\epsilon}\right\}\right].$$

Augmenting the discrete problem with taste shifters gives computational benefits because it allows to smooth primary and secondary kinks that arise due to the non-convex nature of the problem. Below we describe discrete choice specific dynamic problems - retirement and working, respectively [38].

The choice specific dynamic problem for retirement $d=ret$ is

$$V_t(j,s,i,g,m=si,j,e=em,d=ret,a)=\max_{c,a'}\left\{U\left(c,1\right)+\beta\varsigma_t(j,i)V_{t+1}(j+1,s,i,g,m=si,e=rl,a')\right\}$$

subject to

$$\begin{aligned}a'&=(a+tr_t(j,s,i))(1+r_t(1-\tau_t^k))+y_t^p(si)-(c(1+\tau_t^c)+T(si)(y_t^p(si)))\geq 0\\ y_t^p(si)&=(1-\tau_t^h)b_t^p(a,n,s,i,g,si,rl).\end{aligned}$$

In turn, the choice specific problem for working writes as

$$V_t(j,s,i,g,m=si,e=em,d=em,a)=\max_{c,l,a'}\left\{U\left(c,1-l\right)+\beta\varsigma_t(j,i)V_{t+1}(j+1,s,i,g,m=si,e=rl,a')\right\}$$

[37]Note that in the current version these taste shifters are used as a pure computational device. However, in next versions we intend to give them structural interpretation and calibrate the scale parameter so as to match employment / retirement rates as observed in the data.

[38]In the computational implementation we always operate on discrete choice-specific value functions.

subject to

$$a' = (a + tr_t(j,s,i))(1 + r_t(1 - \tau_t^k)) + y_t(si) + \mathbb{1}_{l=0} b_t^u(a,n,si) - c(1 + \tau_t^c) - T(si)(y_t(si)) \geq 0$$
$$y_t(si) = (1 - \tau_t^p - \tau_t^h) w_t(j,s,i)\epsilon(j,s,i,g)l$$

where the indicator $\mathbb{1}_{l(g)}$ takes the value of one if labor supply of the agent is zero.

Likewise, recalling that couple households retire and die jointly, couples who worked until age $j_r - 2$ choose at age $j = j_r - 1$

$$\mathbb{1}_r(j,s,i,m=co,e=em,a) = \begin{cases} 1 & \text{if } V_t(j,s(fe),s(ma),i,m=co,e=em,d=ret,a) > \\ & \qquad V_t(j,s(fe),s(ma),i,m=co,e=em,d=em,a) \\ 0 & \text{otherwise,} \end{cases}$$

and we denote the associated upper envelope of the choice specific value functions by

$$W_t(j,s(fe),s(ma),i,m=co,e=em,a) = \max\left\{V_t(e=em,d=em,\cdot), V_t(e=em,d=ret,\cdot)\right\}.$$

Again, the smoothed discrete problem writes as

$$W_t(j,s(fe),s(ma),i,m=co,e=em,a) = \sigma_\epsilon \log\Big[\exp\Big\{\frac{V_t(e=em,d=em,\cdot)}{\sigma_\epsilon}\Big\} + \exp\Big\{\frac{V_t(e=em,d=ret,\cdot)}{\sigma_\epsilon}\Big\}\Big].$$

The choice specific dynamic problems are in turn

$$V_t(j,s(fe),s(ma),i,m=co,e=em,d=ret,a) = \max_{c,a'}\Big\{U\left(\frac{c}{1+\zeta n+\xi},1,1\right)$$
$$+ \beta\varsigma_t(j,i)V_{t+1}(j+1,s(fe),s(ma),i,g,m=co,e=rl,a')\}$$

subject to

$$a' = (a + tr(co))(1 + r_t(1 - \tau_t^k)) + y_t^p(co) - (c(1 + \tau_t^c) - T(co)(y_t(co))) \geq 0$$
$$tr_t(co) = \sum_{g\in\{fe,ma\}} tr_t(s(g),j,i)$$
$$y_t^p(co) = (1 - \tau_t^h) \sum_{g\in\{fe,ma\}} b_t^p(a,n,s,i,g,co,rl)$$

and

$$V_t(j,s(fe),s(ma),i,m=co,e=em,d=em,a) = \max_{c,a',l(fe),l(ma)} \left\{ U\left(\frac{c}{1+\zeta n+\xi}, l-l(fe), 1-l(ma)\right) \right.$$
$$\left. + \beta\varsigma_t(j,i)V_{t+1}(j+1,s(fe),s(ma),i,m=co,e=rl,a') \right\}$$

subject to

$$\begin{aligned}
a' &= (a+tr(co))(1+r_t(1-\tau_t^k)) + y_t(co) + b_t^u(co) - (c(1+\tau_t^c) + T(co)(y_t(co))) \geq 0 \\
tr_t(co) &= \sum_{g\in\{fe,ma\}} tr_t(s(g),j,i) \\
b_t^u(co) &= \sum_{g\in\{fe,ma\}} \mathbb{1}_{l(g)=0} b_t^u(a,n,co) \\
y_t(co) &= (1-\tau_t^p-\tau_t^h)w_t(j,s,i) \sum_{g\in\{fe,ma\}} \epsilon(j,s,i,g)l(g).
\end{aligned}$$

Dynamic Problem of Working Households in Late Retirement Window $j \in \{j_l,\ldots,j_r-2\}, i \in \{na,ho\}, e=em$**.** We here focus on the description of the decision problem in the late retirement window; adjustments for the early retirement window are described next. At age j households who are already retired ($e \in \{re,rl\}$) solve the problem in retirement described above. The maximization problem of households who worked until age $j-1$ solve at age j the same problem as for age $j=j_r-1$ where for state $e=em$ in period t,j the continuation utilities for singles and couples are given by the upper envelope of discrete choice specific value functions (retirement versus non-retirement)

$$\begin{aligned}
&W_{t+1}(j+1,s,i,g,m=si,e=em,a') \\
&\text{and} \\
&W_{t+1}(j+1,s(fe),s(ma),i,m=co,e=em,a'),
\end{aligned}$$

respectively. Thus, we solve for singles

$$\mathbb{1}_r(j,s,i,g,m=si,e=em,a) = \begin{cases} 1 & \text{if } V_t(j,s,i,g,m=si,e=em,d=ret,a) \\ & \qquad > V_t(j,s,i,g,m=si,e=em,d=em,a), \\ 0 & \text{otherwise,} \end{cases}$$

The upper envelope of the value function is accordingly denoted by

$$W_t(j, s, i, g, m = si, e = em, a) = \max\left\{V_t(e = em, d = em, \cdot), V_t(e = em, d = ret, \cdot)\right\},$$

and the smoothed problem writes as

$$W_t(j, s, i, g, m = si, e = em, a) = \sigma_\epsilon \log\left[\exp\left\{\frac{V_t(e = em, d = em, \cdot)}{\sigma_\epsilon}\right\} + \exp\left\{\frac{V_t(e = em, d = ret, \cdot)}{\sigma_\epsilon}\right\}\right].$$

For the choice $d = ret$ the decision problem is analogous to the problem at age $j = j_r - 1$ and for $d = em$ the dynamic problem is

$$\begin{aligned} V_t(j, s, i, g, m = si, e = em, d = em, a) = \max_{c,l,a'} \Bigg\{ & U\left(\frac{c}{1 + \zeta n}, 1 - l\right) \\ & + \beta \varsigma_t(j, i) W_{t+1}(j + 1, s, i, g, m = si, e = em, a') \Bigg\} \end{aligned}$$

with the constraint as above.

We solve an analogous problem for couples:

$$\begin{aligned} & \mathbb{1}_r(j, s(fe), s(ma), i, g, m = co, e = em, a) = \\ & \qquad \begin{cases} 1 & \text{if } V_t(j, s(fe), s(ma), i, m = co, e = em, d = ret, a) \\ & \qquad > V_t(j, s(fe), s(ma), i, m = co, e = em, d = em, a) \\ 0 & \text{otherwise.} \end{cases} \end{aligned}$$

and we denote the upper envelope of the choice specific value functions by

$$W_t(j, s(fe), s(ma), i, m = co, e = em, a) = \max\left\{V_t(e = em, d = dem, \cdot), V_t(e = em, d = ret, \cdot)\right\},$$

with the smoothed version being given by

$$W_t(j, s(fe), s(ma), i, m = co, e = em, a) = \sigma_\epsilon \log\left[\exp\left\{\frac{V_t(e = em, d = em, \cdot)}{\sigma_\epsilon}\right\} + \exp\left\{\frac{V_t(e = em, d = ret, \cdot)}{\sigma_\epsilon}\right\}\right].$$

For the choice $d = ret$ the decision problem is analogous to the one for $j = j_r - 1$ and for $d = em$ the choice specific problem is

$$
\begin{aligned}
V_t(j, s(fe), s(ma), i, m = co, e = em, d = em, a) = \max_{c, a', l^f, l^m} \Bigg\{ U\left(\frac{c}{1 + \zeta n + \xi}, 1 - l(fe), 1 - l(ma)\right) \\
+ \beta \varsigma_t(j, i) W_{t+1}(j + 1, s(fe), s(ma), i, m = co, e = em, a') \Bigg\}
\end{aligned}
$$

and the constraint is the same as for $j = j_r - 1$.

Dynamic Problem of Working Households in Early Retirement Window $j \in \{j_e, \ldots, j_l - 1\}, i \in \{na, ho\}, e = em$**.** In the early retirement window the dynamic problem is analogous to the one just described for the late retirement window. The discrete choice is as before between continuing to work $d = em$ and retiring $d = ret$, but upon choosing retirement the agent moves to early retirement state $e = re$ in the next period.

Dynamic Problem of Working Households Prior to Entering the Retirement Window $j = j_e - 1, i \in \{n, h, r\}, e = em$**.** The structure is the same as previously, but now there is no longer an option to retire in the current period available whereas the continuation value as before has to take into account the retirement option.

Dynamic Problem of Working Households in Core Working Period $j \in \{j_s, \ldots, j_e - 2\}, i \in \{n, h, r\}, e = em$**.** The structure is the same as previously, where continuation values at t, j for singles and couples are no longer the upper envelopes of the discrete decision problems described above (i.e. retirement and non-retirement), $W_{t+1}(\cdot)$ but the value functions

$$
\begin{aligned}
&V_{t+1}(j + 1, s, i, g, m = si, e = em, a'), \\
&V_{t+1}(j + 1, s(fe), s(ma), i, m = co, e = em, a'),
\end{aligned}
$$

respectively.

Dynamic Problem of Households $i \in \{na, ho\}, j \in \{j_a, \ldots, j_s\}, e = em$**.** The dynamic problem is the same as described above, but the current period utility payoff of households of skill s features the time loss parameter, and thus is

$$
U\left(\frac{c}{1 + \zeta n}, 1 - \varrho(s) - l\right).
$$

Modifications for Asylees, $i = as$. Asylum seekers enter as singles or couples, which we inform by the respective fractions in the data. Due to differences in access to the social insurance system and transfer payments to asylees as well as labor market restrictions, the problem of asylees in the first year of entry is different from other years, which we store in indicator $\mathbb{1}_a$. After that initial year, asylum seekers have full access to the labor market and the social insurance system. At the end of each period conditional on surviving asylum seekers face the risk of having to leave with respective probability π^l and, conditional on not leaving, they may assimilate to population group rw with probability π^{ar}, thus the unconditional probability of assimilating to group rw is $(1-\pi^l)\pi^{ar}$ and the unconditional probability of staying in population group as is $(1-\pi^l)(1-\pi^{ar})$. For the remainder of the description we focus on asylum seekers as working couples after the age of marriage and spell out later the adjustments needed for other stages of the life-cycle, respectively for singles.

Focusing on a couple, let us first compute the continuation value in case of leaving. A couple being forced to leave at age $j+1$ receives in each period a permanent income stream of

$$y_t^a(s(fe), fe) + y_t^a(s(ma), ma)$$

which we compute for both partners in a couple according to equation (34). In each period, the couple then enjoys flow utility from the consumption of the annuity in each period, $U(y^a(fe) + y^a(ma), 1 - l(fe), 1 - l(ma))$, and thus the value function in case of being forced to leave—under the additional assumption of full-time employment of both spouses—can be computed recursively as

$$\begin{aligned} &V(j+1, s(fe), s(ma), i = as, m = co, \mathbb{1}_l = 1, a') = \\ &\qquad U\left(\frac{y^a(fe) + y^a(ma)}{1 + \zeta n + \xi}, 1 - l_n(fe), 1 - l_n(ma)\right) + \\ &\qquad\quad \beta \varsigma_{t+1}(j+1, as) V(j+2, s(fe), s(ma), i = as, m = co, \mathbb{1}_l = 1, a'') \end{aligned}$$

subject to

$$a'' = a'(1 + r_0) + \mathbb{1}_{j \leq j_r - 1} \cdot \eta \cdot \sum_{g \in \{fe, ma\}} w(t+1, s(g), j+1, as, g) l(g) - y^a(g)$$

where indicator $\mathbb{1}_{j \leq j_r - 1}$ is equal to one if the household is of working age $j \leq j_r - 1$. Productivity shifter $\eta \in (0, 1)$ reflects lower productivity in the country they migrate to.

Problem of Asylum Seekers at Age $j \in \{j_a, \ldots, j_e - 2\}$. We only look at this snapshot of the problem for a couple. The problem of an asylum seeking couple before (early) retirement reads as

$$
\begin{aligned}
&V_t(j, s(fe), s(ma), as, m = co, e = em, \mathbb{1}_a, a) = \\
&\qquad \max_{c,a',l(fe),l(ma)} \left\{ U\left(\frac{c}{1+\zeta n+\xi}, 1-l(fe), 1-l(ma)\right) + \beta\varsigma_t(j,i) \right. \\
&\qquad\qquad +\pi^l V_{t+1}(j+1, s(fe), s(ma), as, m = co, \mathbb{1}_l = 1, , a') \\
&\qquad (1-\pi^l)\left(\pi^{ar} V_{t+1}(j+1, s(fe), s(ma), i = rw, m = co, e' = em, a')\right. \\
&\qquad\qquad +(1-\pi^{ar}) V_{t+1}(j+1, s(fe), s(ma), i = as, m = co, e' = em, \mathbb{1}_a = 0, a'))\}
\end{aligned}
$$

subject to

$$
\begin{aligned}
a' &= (a + tr_t(co))(1 + r_t(1-\tau_t^k)) + y_t(co) + \mathbb{1}_a b_t^a(co) + (1-\mathbb{1}_a) b_t^u(co) \\
&\quad - (c(1+\tau_t^c) + T(co)(y_t(co))) \geq 0 \\
tr_t(co) &= \sum_{g\in\{fe,ma\}} tr_t(s(g), j, as) \\
y_t(co) &= \sum_{g\in\{fe,ma\}} w_t(s, j, as, g)\epsilon(s, j, as, g) l(g) \\
b_t^a(co) &= \max\left\{0, b_t^a(n, co) - \sum_{g\in\{fe,ma\}} w_t(s, j, as, g)\epsilon(s, j, as, g) l(g)\right\} \\
\tilde{y}_c &= y_c - T^c(y_c) + b_c^a \\
b_t^u(co) &= \sum_{g\in\{fe,ma\}} \mathbb{1}_{l(g)=0} b_t^u(a, n, co),
\end{aligned}
$$

and $l(g) \in \varpi \{l_1, \ldots, l_n\}$ if $\mathbb{1}_a = 1$.

Immigrants from Other Population Groups. Like asylum seekers, fraction $\pi^m(i, g)$ for $g \in \{fe, ma\}$, $i \in \{ho, rw\}$ of regular (or economic) immigrants from other population groups enters as a couple. Unlike asylum seekers they have full access to the labor market and to the German social insurance system in the first period after arrival and they do not face any leave or assimilation probabilities. In addition, immigrants from group rw face in each period the probability to assimilate to group ho with respective probability π^{rh}, which they take into account in their continuation values.

C Calibration Appendix

The calibration is summarized in Table 6.

Table 6: Preliminary Calibration of Benchmark Model

Parameter	Interpretation	Value	Stage
	Population		
$N_t(j,i)$	Population Stock Data	Section 6.2	1
j_a	Age at labor market entrance	17	1
j_l	Age of educ completion low-skilled	16	1
j_m	Age of education completion middle-skilled	20	1
j_h	Age of education completion high-skilled	24	1
j_f	Fertility Age	15	1
j_c	Age of completing fertility	50	1
j_{re}	Early Retirement Age	63	1
j_{rl}	Late Retirement Age	67	1
J	Max. Lifetime	100	1
$\varrho(s)$	Fraction of time endowment lost while completing education level s	0	1
ϖ_a	Fraction of labor supply states while seeking asylum	0.75	1
$\{\varsigma_t(j,i)\}$	Survival rates	Section 6.2	1
$\pi^m(i,g)$	Marriage probability	Table 3	1
$\pi(s' \mid s)$	Probability to match with partner of education s'	Table 7	1
ϕ	Fraction of baby girls	0.48	1
$\{\chi_t(j,i)\}$	Fertility rates	Section 6.2	1
π^l	Leaving probability	0.06	1
π^{ar}	Assimilation probability $as \Rightarrow rw$	0.013	1
π^{rh}	Assimilation probability $rw \Rightarrow hi$	0.033	1
$\phi(s,i)$	Fraction of skill s among population i	Table 4	1
	Labor Productivity		
$\epsilon(j,s,i)$	Age Profile	Figure 16	1
$\epsilon(g)$	Productivity Shifter by Gender	[0.8981,1]	1
$\{l_1,...,l_n\}$	Discrete labor supply levels	$\{0, 0.18, 0.36\}$	1
η	Relative productivity in of leavers	0.45	1
	Preferences		
θ	Relative risk aversion parameter	1	1
$\phi(g)$	Weight on leisure in utility	[0.814,0.39]	2
ψ	Leisure curvature parameter in utility	1	1
β	Time discount rate (per annum)	0.973	2
σ_ϵ	Scale parameter of taste shocks	1	1

	Production		
α	Capital share	0.33	1
δ	Depreciation rate	0.05	1
λ	Rate of technological progress	0.015	1
ϑ	Elast. of substitution b/w capital and labor	1	1
σ_{lmh}	Elast. of substitution b/w labor of different skill levels	2.96	1
σ_{nf}	Elast. of substitution b/w fo and na	12.19	1
σ_{hr}	Elast. of substitution b/w ho and rw	23.14	1
	Government		
ρ^p	Pension replacement rate	Budget Balance	2 [39]
α^p	Sensitivity parameter in the pension formula	0 (0.25) [40]	1
τ^p	Pension contribution rate	Figure 17	1 (2) [41]
τ^h	Health system contribution rate	Figure 17	1
ι	Private contribution factor	0 (0.04) [42]	1
b^u	Social assistance benefits	Section 6.5.2	1
$\bar{a}^b$	Assets threshold for social benefits eligibility	0	1
$\underline{b}^p$	Social assistance benefits for the elderly (minimum pension)	b^u	1
b^a	Transfer payments to asylum seekers	Section 6.5.1	1
$\{b^h(j)\}$	Health insurance payments	Figure 18	1
τ^c	Consumption tax rate (in steady-state)	19%	1
τ^k	Capital income tax rate	25%	1
ω_0	Income tax level parameter	0.8929	1
ω_1	Income tax progressivity parameter	0.2035	1
G/N_{2013}	Per capita government consumption	0.023	2

Note: This table summarizes the calibration for the benchmark economy. Stage: 1: first stage (calibrated outside the model), 2: second stage parameter.

[39]Note: Along the transition this is an equilibrium object.

[40]Before the pension reform of 2003 it is zero, thereafter it is 0.25.

[41]Note: Along the transition, from 2013 onwards both pension contribution and replacement rates are equilibrium objects.

[42]Before the pension reform of 2003 it is zero, thereafter it linearly increases to 0.04 until 2011.

C.1 Population Model

Our population stock data is comes from the German Federal Statistical Office (Statistisches Bundesamt/Destatis; HMD) and from the Central Foreign Population Registry (Ausländerzentralstatistik, AZR). In this data foreigners include all persons who do not have German citizenship, and we have explicit information on the stock of first and second generation foreigners. A first generation foreigner is a person that was born outside Germany, whereas a second generation foreigner in the data is born in Germany but holds foreign nationality. By our economic perspective we consider second generation foreigners as natives irrespective of their legal citizenship, cf. equation (23), and accordingly assign them to population group na. With this assumption, we first construct the age-specific population stock $N_t(j, i, g)$ for groups $i \in \{na, ho, rw, as\}$ for the years $2008 - 2019$.

Next, we impute from this data the implied net addition to the population stock $M_t(j, i, g)$ from the law of motion of the population in equation (22), taking into account the adjustments of the dynamics that are implied by the assimilation probability π^{ar} and the leave probability π^l. We refer to the net change of the stock also as the migration flow.[43]

To compute this net flow from (22) we also need data on age, group, and time specific mortality rates. We take those from the Human Mortality Database (HMD) for years 1960-2017 and, since we lack data on group specific mortality rates, we assume that all immigrants immediately after entry have the same mortality process as the average German population and thus set $\varsigma_{tji} = \varsigma_{tj}\ \forall i$.

For the predictions of the population beyond year 2019, we make the following assumptions:

1. For all groups $\{na, rw, ho, as\}$ we compute the average age distribution of constructed net migration numbers $\bar{M}(j, i, g)$ over the years 2007-2018. We assume that aggregate migration in each group reverts to a long-run average until 2022. This reversal takes place according to the timing assumptions for each scenario described in Section 6.1. To compute long-run average migration in each group we assume—consistent with conventional assumptions by the German Federal Statistical Office (Statistisches Bundesamt)—that total migration over all groups is $200,000$ annually and then distribute this total migration to the three groups ho, rw, as according to the relative shares during the years 2008-2012.

[43]The advantage of constructing the flow data from the information on the population stock is that we can meaningfully measure the net addition to the stock caused by migration. Also, direct information on flows features statistical inaccuracies because of double counting of multiple within year migration. The disadvantage is that we do have to make assumptions on mortality and survival rates for all population groups. However, mortality is relevant only at higher ages at which migration numbers are close to zero.

2. Age and group specific fertility distributions are constant at their respective age specific averages taken over the years 2007-2018 until year 2100. Thereafter, fertility rates adjust such that the number of newborns is constant in each period. With this assumption (and with the assumption of constant survival rates and constant migration numbers) the population will reach a stationary distribution with constant population growth by about year 2200.

3. Survival rates increase according to the predictions from the Lee-Carter model until year 2100 and are constant thereafter.

During the phase-in period from 1960 to 2012 we have the exact data on the population stocks only from 2008 onwards. Leading towards 2008 we forward shoot on the population dynamics using data on the annual flow of migration and distribute those across the four groups such that we minimize the distance between the model implied population stocks in the four groups in 2008 and the respective actual population stock.

The next subsections contain a more detailed description of the construction of fertility rates, mortality rates and migration numbers.

C.1.1 Fertility Rates

In the data the number of newborns is

$$N_{t+1}(0,i) = \sum_{j=j_f}^{j_c} f_t(j,i) N_t(j,i,fe)$$

where $f_t j, i$ is the group i age j and time t specific fertility rate. Since we lack information on $f_t(j,i)$ and on the number of newborns for all population groups , we construct fertility rate as follows. We take time and age specific fertility rates of the average German population from the Federal Statistical Office and on the number of birth from the Human Mortality Database, separately for East and West Germany. Based on the stock of the population in both regions, we next adjust the age- and time-specific fertility rates such that the fertility distribution is consistent with the number of newborns. We then take the population weighted average of the East and West German constructed data.

C.1.2 Mortality Rates

We take a time series of gender specific mortality rates for 1950 to 2017 from the Human Mortality Database, computed as the weighted average of East and West German mortality rates, and decompose mortality rates as

$$\ln(1 - \varsigma_t(j, g)) = a(j, g) + b(j, g)d_t(g)$$

where $\varsigma_t(j, g)$ is the survival rate applying the Lee-Carter procedure (Lee and Carter 1992). Next, we assume that the estimated time specific factor $\hat{d}_t(g)$ obeys a unit root process

$$\hat{d}_{t+1}(g) = \alpha(g) + \hat{d}_t(g) + \epsilon_t t + 1(g).$$

Based on the estimates $\left\{\hat{a}(j, g), \hat{b}(j, g)\right\}_{j=0}^{J}, \hat{d}_t(g), \hat{\alpha}(g)$ we predict (future) survival rates by setting to zero the innovation terms $\hat{\epsilon}_t(g)$ and initialize the process assuming that $\hat{\hat{d}}_0(g) = \hat{d}_0(g)$.

After construction of the population numbers (and the migration flows, see next subsection) we take population weighted average survival rates and recompute the population dynamics.

C.1.3 Migration Numbers

We construct the net addition to the respective population stock in group i by backing out the net flow from equation (22):[44] Since we lack data on group specific mortality rates, we assume that all immigrants immediately after entry have the same mortality process as the average German population and thus set $\varsigma_t(j, i, g) = \varsigma_t(j, g)\ \forall i$.

Figure 13 summarizes the constructed migration flows in the three groups of the foreign population $\{ho, rw, as\}$.

Figure 14 contains the according age distribution of the migration flow.

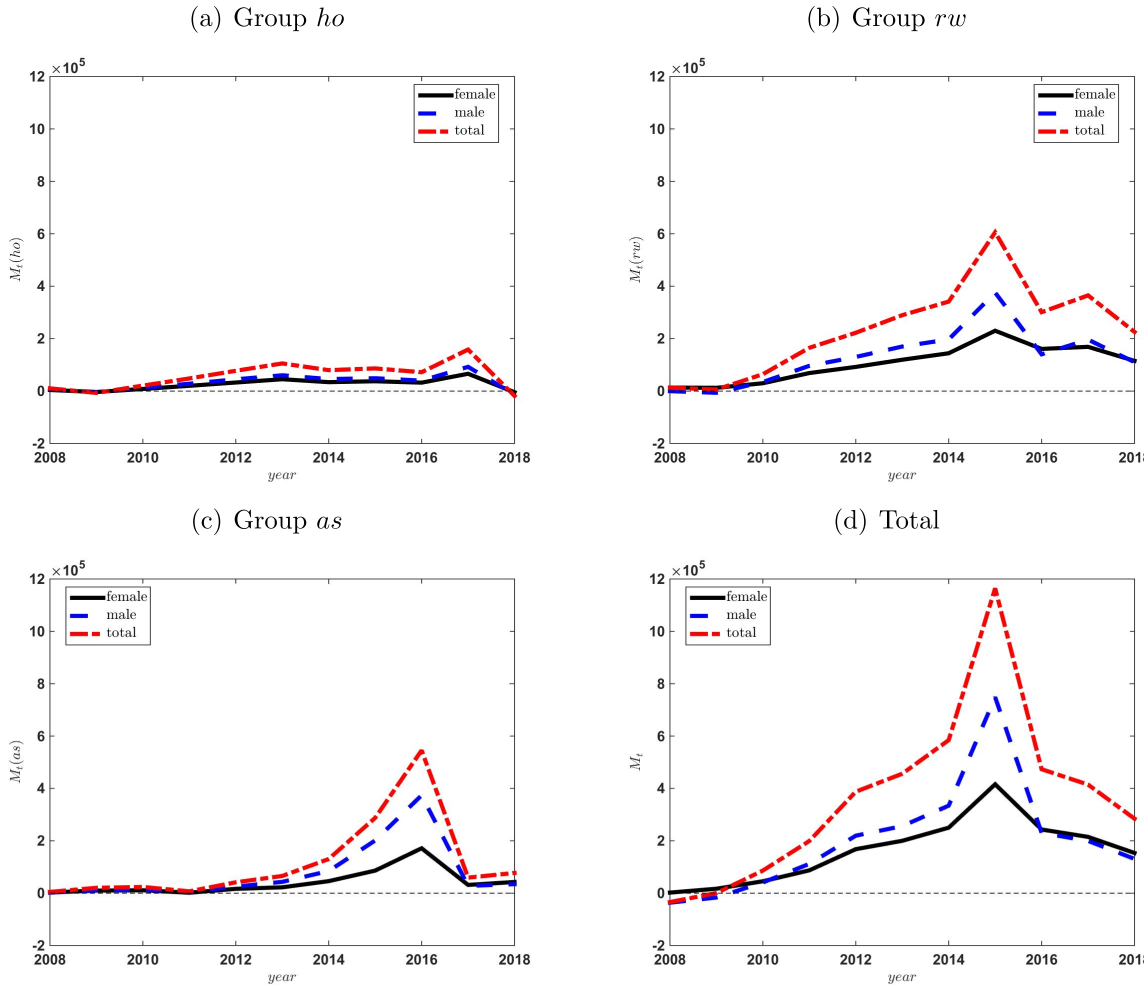
Finally, Figure 15 shows the age distribution of the population in groups $i \in \{na, ho, rw, as\}$.

C.2 Age Wage Profiles

Figure 16 displays the age wage profiles for natives and for foreigners from RW. Age wage profiles for foreigners from HIOECD are similar to those of natives.

[44] In the data, the population stock is reported at the end of a given calendar year which we accordingly interpret as the beginning of the next calendar year. Thus the population stock reported in the data at the end of calendar year 2007 is taken to be the population stock at the beginning of year 2008.

Figure 13: Net Migration Flows



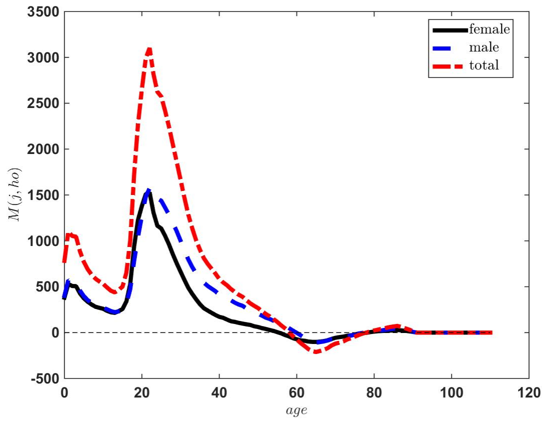
Notes: Migration

C.3 Technology

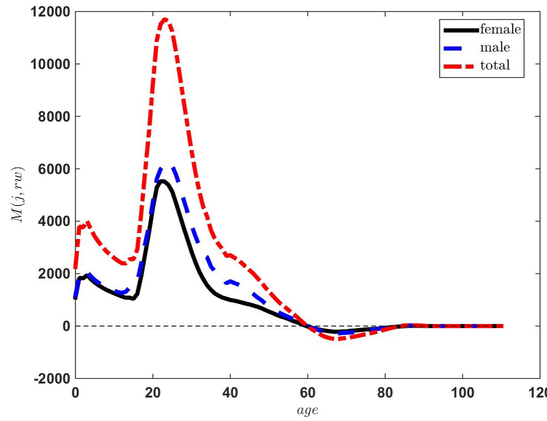
For the estimation of the substitution elasticities in production, we reorder the nesting and assume that age, respectively experience, moves up by one nest. We can thereby exploit more variation in the data for the estimation of the substitution elasticity across immigrant groups. We also consider three experience groups by averaging households across age, which we index by $\bar{j}$. The number of experience groups is denoted by by $n_{\bar{j}}$. Experience group $\bar{j} = 1$ is for $1-9$ years of labor market experience, group $\bar{j} = 2$ for $10-19$ years, and group $\bar{j} = 3$ for more than 20 years, respectively. We assume a perfect elasticity of substitution across these

Figure 14: Age Distribution of Net Migration

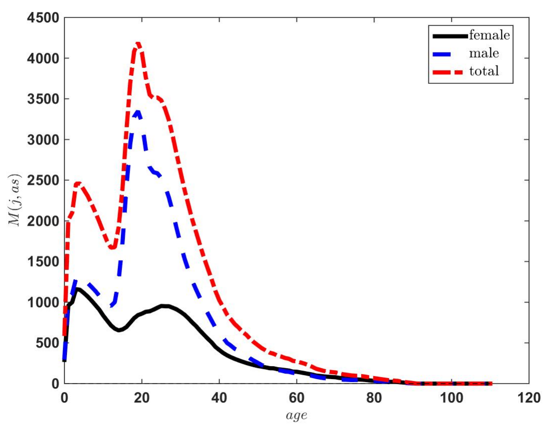
(a) Group *ho*



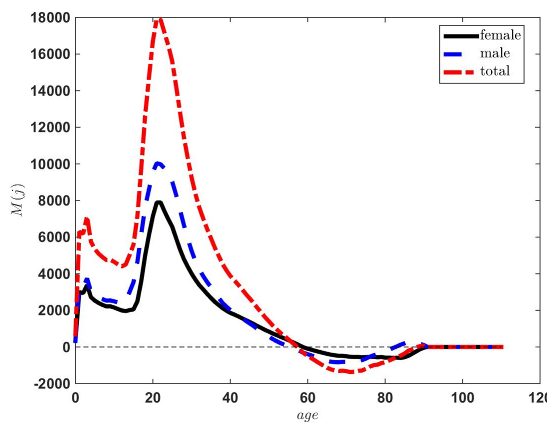
(b) Group *rw*



(c) Group *as*



(d) Total



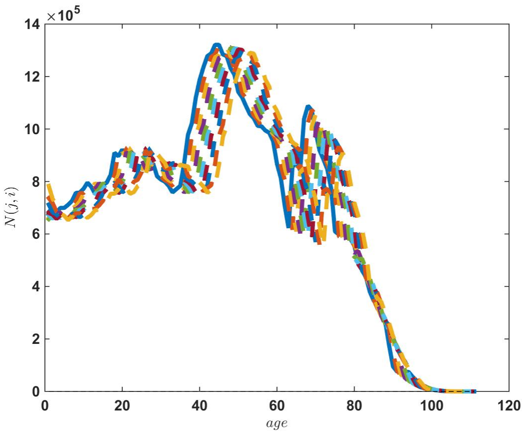
Notes: Migration

groups.[45] Furthermore, consistent with the literature, e.g., D'Amuri, Ottaviano, and Peri (2010), we introduce productivity parameters in all nests. Those are normalized to one such that, within each nest, the model minimizes the distance to the wage premium and uses hours worked as the right-hand side variable. Given the homogoeneity of the production function, it is straightforward to show that these productivity scaling parameters can be mapped into the labor productivity $\epsilon(j, s, i, g)$.

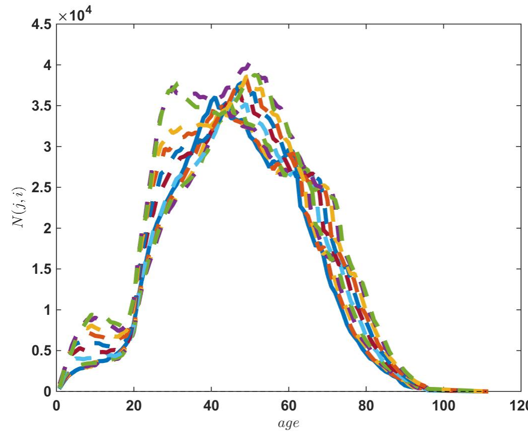
[45]Unrestricted estimation of the substitution elasticity yields a very large substitution elasticity, which is basically perfect.

Figure 15: Age Distribution of Population Stock

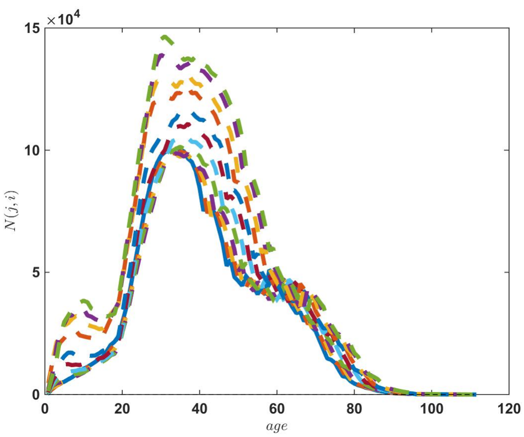
(a) Group *na*



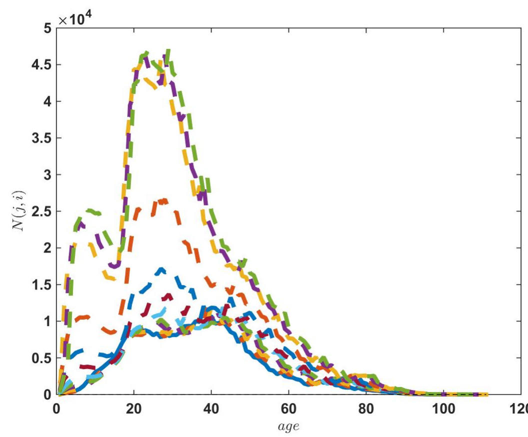
(b) Group *ho*



(c) Group *rw*



(d) Group *as*



Notes: Age distribution in the population during 2008-2019 among *na*tives and foreigners of the population groups high income OECD countries *ho*, rest of the world countries *rw* and *as*ylees.

With these assumptions, our nesting is

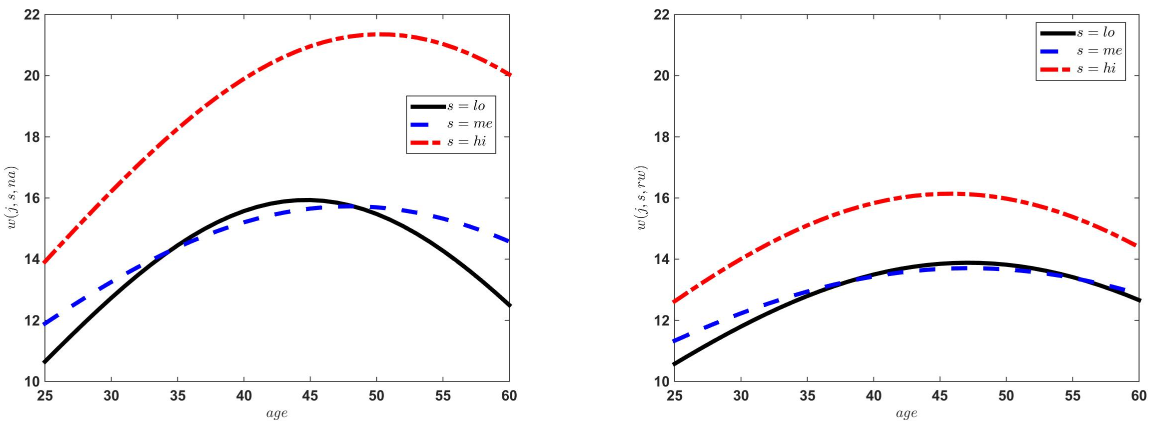
$$\tilde{L}_t = \left(\sum_{s \in \{lo,me,hi\}} \tilde{\epsilon}(s) \tilde{L}_t(s)^{1-\frac{1}{\sigma_{lmh}}} \right)^{\frac{1}{1-\frac{1}{\sigma_{lmh}}}} .$$

Next, labor of skill group s is the aggregate of different age (experience) groups $\bar{j}$

$$\tilde{L}_t(s) = \sum_{\bar{j}=1}^{n_{\bar{j}}} \tilde{\epsilon}(s, \bar{j}) \tilde{L}_t(s, \bar{j})$$

Figure 16: Age Wage Profiles

(a) Natives (b) Foreigners from RW



Notes: Predicted age wage profiles for natives and foreigners from the population group rest of the world (RW, rw) for the three skill categories $s \in \{lo, me, hi\}$.

In turn, these experience group specific labor inputs are the CES aggregate of $n$atives and $f$oreigners giving

$$\tilde{L}_t(s, \bar{j}) = \left(\tilde{\epsilon}(s, \bar{j}, na)\tilde{L}_t(s, \bar{j}, na)^{1-\frac{1}{\sigma_{nf}}} + \tilde{\epsilon}(s, \bar{j}, fo)\tilde{\tilde{L}}_t(s, \bar{j}, fo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{nf}}}}.$$

where $\tilde{\tilde{L}}_t(s, \bar{j}, fo)$ is labor input of a CES aggregate of foreigners given by

$$\tilde{\tilde{L}}_t(s, \bar{j}, fo) = \left(\tilde{\epsilon}(s, \bar{j}, h)\tilde{L}_t(s, \bar{j}, h)^{1-\frac{1}{\sigma_{hr}}} + \left(\sum_{i \in \{rw, as\}} \tilde{\epsilon}(s, \bar{j}, i)\tilde{L}_t(s, \bar{j}, i)\right)^{1-\frac{1}{\sigma_{hr}}}\right)^{\frac{1}{1-\frac{1}{\sigma_{hr}}}}.$$

In turn, those skill, experience group, and nationality specific labor inputs are aggregates of men and women, assuming a perfect substitution elasticity

$$\tilde{L}_t(s, \bar{j}, i) = \sum_{g \in \{fe, ma\}} \tilde{\epsilon}(s, \bar{j}, i, g)\tilde{L}_t(s, \bar{j}, i, g)$$

and we restrict $\tilde{\epsilon}(s, \bar{j}, i, g) = \tilde{\epsilon}(s, \bar{j}, i)\tilde{\epsilon}(g)$.

C.4 Sorting Patterns

Table 7 contains the information on sorting patterns by gender and education. Each entry gives the probability $\pi^s(s(g') \mid s(g), i, g)$ that a person of nationality $i \in \{na, ho, rw, as\}$ of gender $g \in \{fe, ma\}$ marries a person of opposite gender g' with education $s(g')$ and the same region of origin[46].

Table 7: Sorting Across Skills

	Females			Males		
Educ s	low	$medium$	$high$	low	$medium$	$high$
			Natives			
low	0.11	0.03	0.02	0.21	0.07	0.03
$medium$	0.7	0.67	0.33	0.62	0.75	0.48
$high$	0.19	0.3	0.65	0.16	0.18	0.49
			High Income OECD			
low	0.45	0.2	0.18	0.39	0.24	0.04
$medium$	0.5	0.61	0.17	0.4	0.65	0.32
$high$	0.05	0.19	0.65	0.21	0.11	0.64
			Rest of the World			
low	0.33	0.11	0.04	0.57	0.23	0.12
$medium$	0.56	0.75	0.46	0.36	0.58	0.31
$high$	0.1	0.14	0.5	0.07	0.18	0.57

Notes: Sorting matrix: each entry is the probability of an agent of gender $g \in \{fe, ma\}$ and education $s \in \{lo, me, hi\}$ to marry a partner with education $s' \in \{lo, me, hi\}$.

C.5 Social Insurance

Figure 17 shows the contribution rates to the German PAYG pension system and to the public health insurance system (including long-term care insurance).

Our data on health expenditures cover ages 0-99 for years 2010-2017. We normalize these expenditures by nominal GDP data (which leads to almost identical profiles for all years pointing to strong time effects) and take the average across these years. Figure 18 shows the age profile for females and males.

[46] Recall that we assume perfect assortative matching within regions.

Figure 17: Contribution Rates to Social Security & Health Insurance

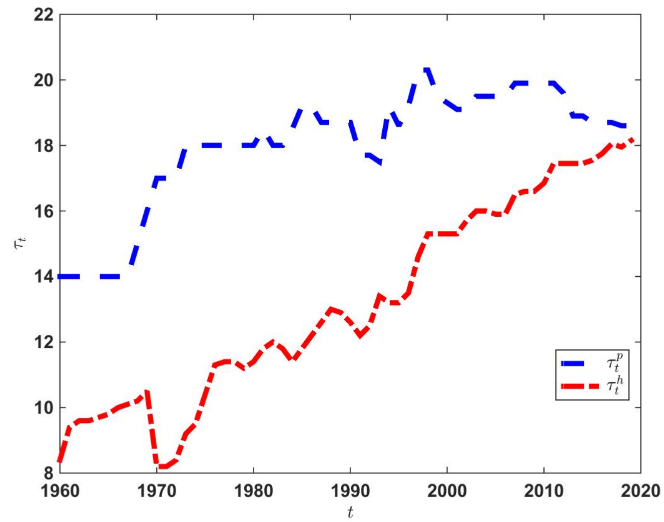
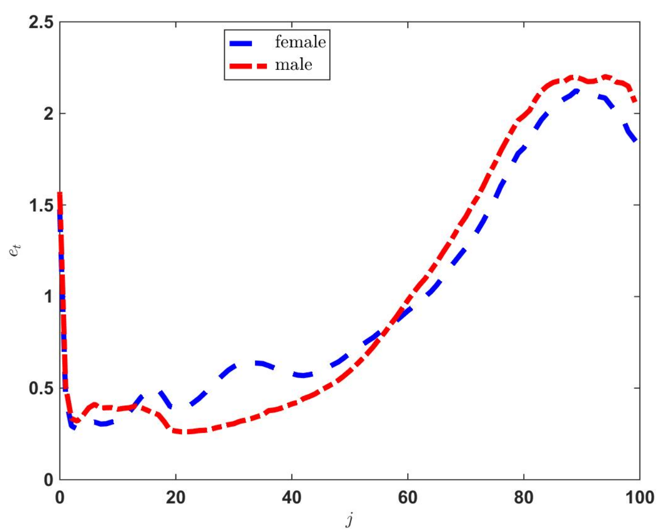


Figure 18: Health Expenditures over the Life-Cycle [Index, centralized data]



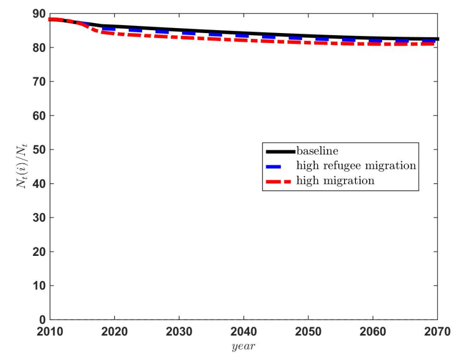
D Appendix: Further Results

D.1 Population Shares by Groups

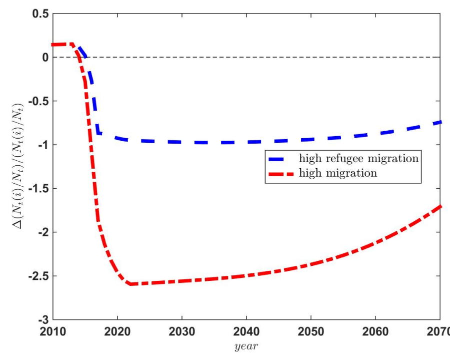
Figure 19 shows the population shares by region of origin and their changes relative to the baseline scenario.

Figure 19: Population Shares by Region of Origin

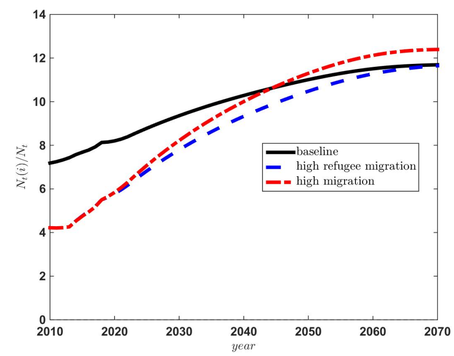
(a) Natives



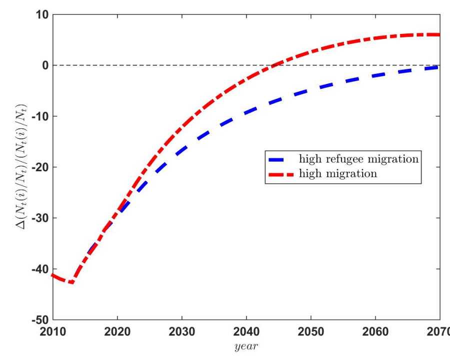
(b) %-Change Natives



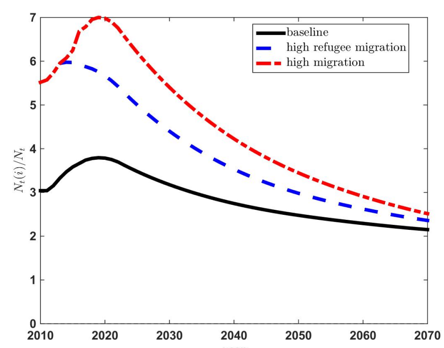
(c) Foreigners, HIOECD



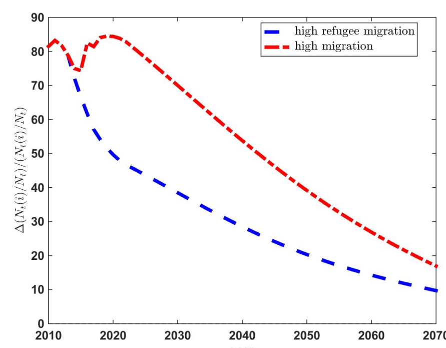
(d) %-Change HIOECD



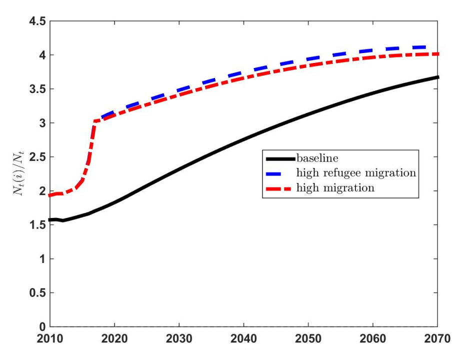
(e) Foreigners, RW



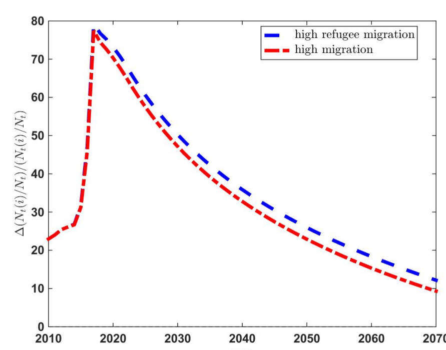
(f) %-Change RW



(g) Foreigners, AS



(h) %-Change AS

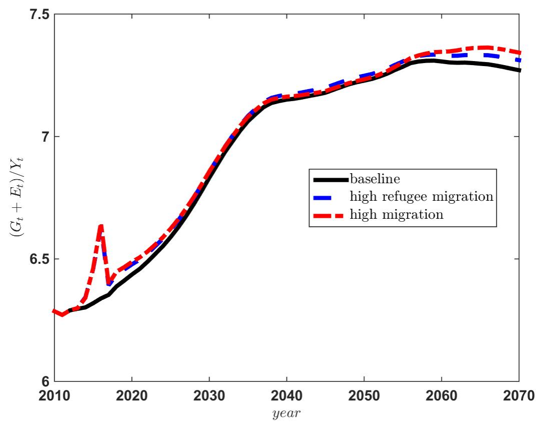


D.2 Government Expenditures

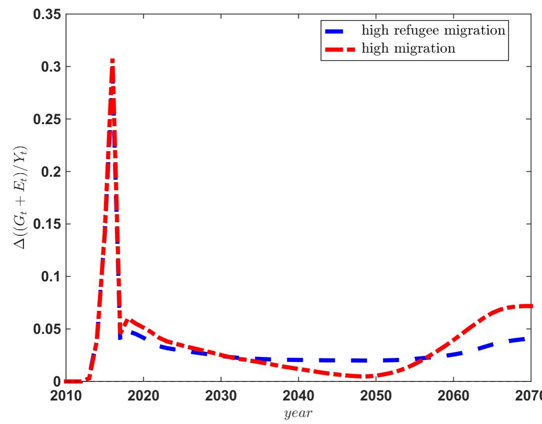
Figure 20 shows total government expenditures as the sum of government consumption G_t and administrative outlays to finance incoming refugees E_t.

Figure 20: Total Government Expenditures

(a) Total Gov. Exp. to GDP $(G_t + E_t)/Y_t$



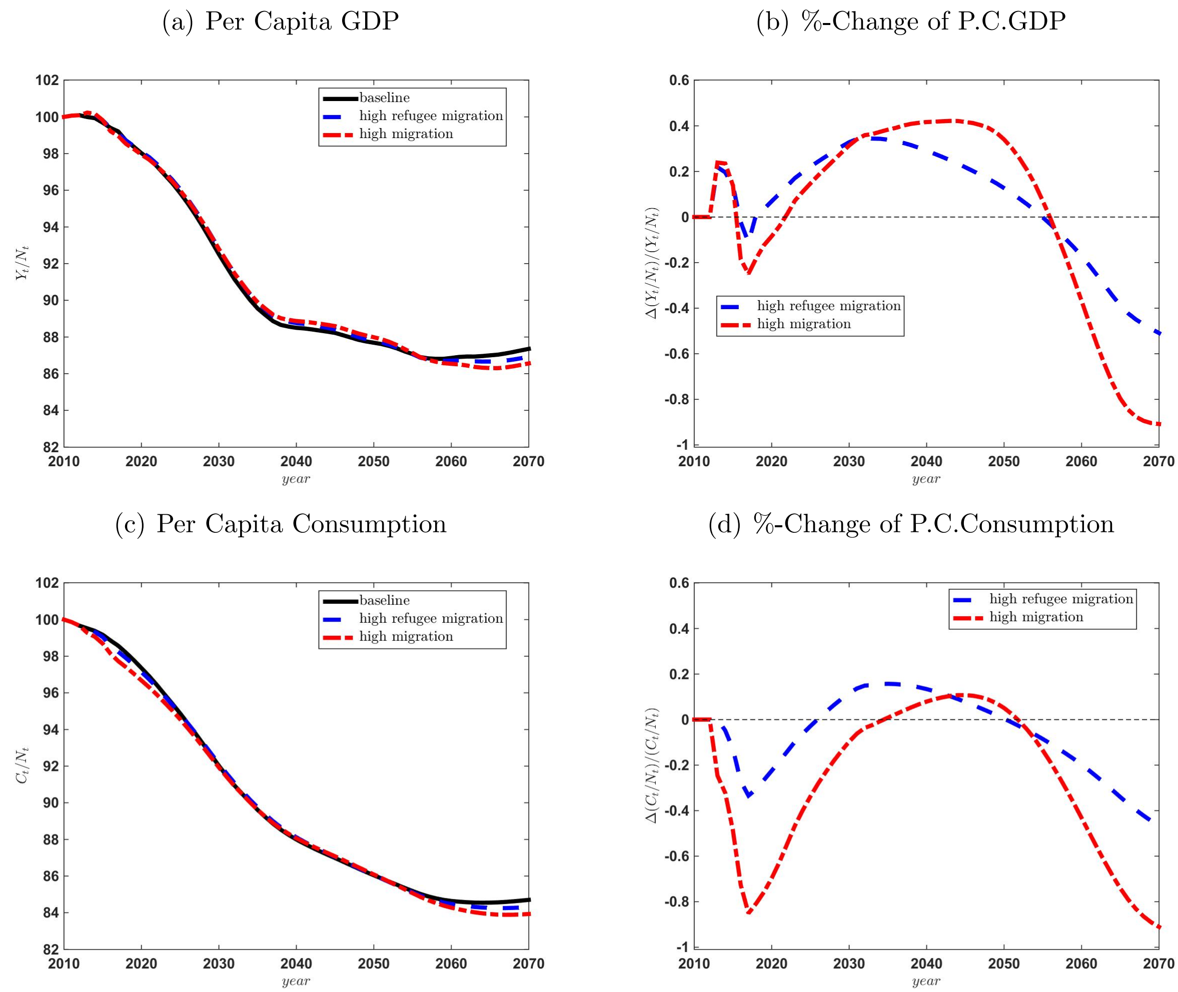
(b) %p-Change of Total Gov. Exp. to GDP



D.3 Per Capita GDP and Consumption

Figure 21 de-trended per capita GDP and consumption, where de-trending is by the technology level A_t.

Figure 21: Detrended Per Capita GDP & Consumption [Index]



D.4 Rate of Return & Wages

Figure 22 shows the rate of return to capital and its change to the baseline demographic model. Figure 23 shows gross and net wages of low skilled natives.

Figure 22: Rate of Return

(a) Rate of Return

(b) %p-Change of Rate of Return

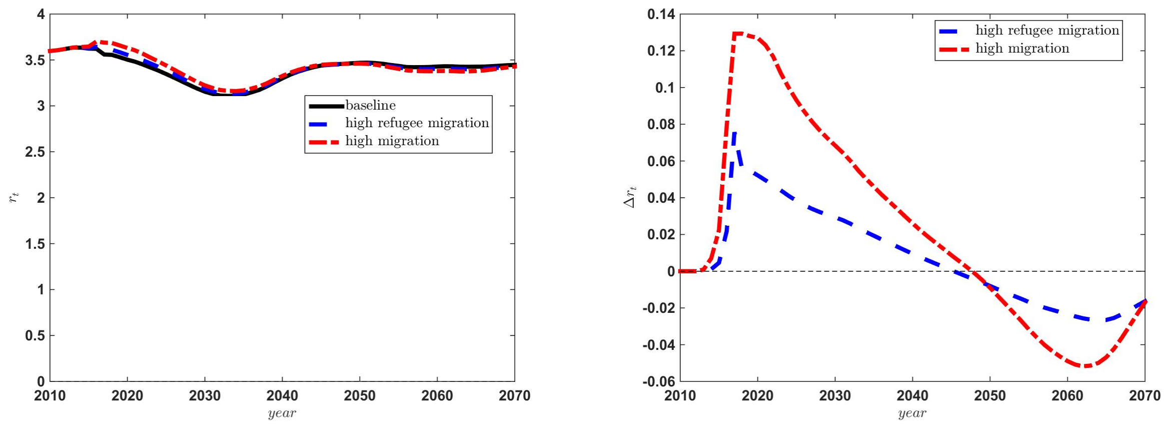
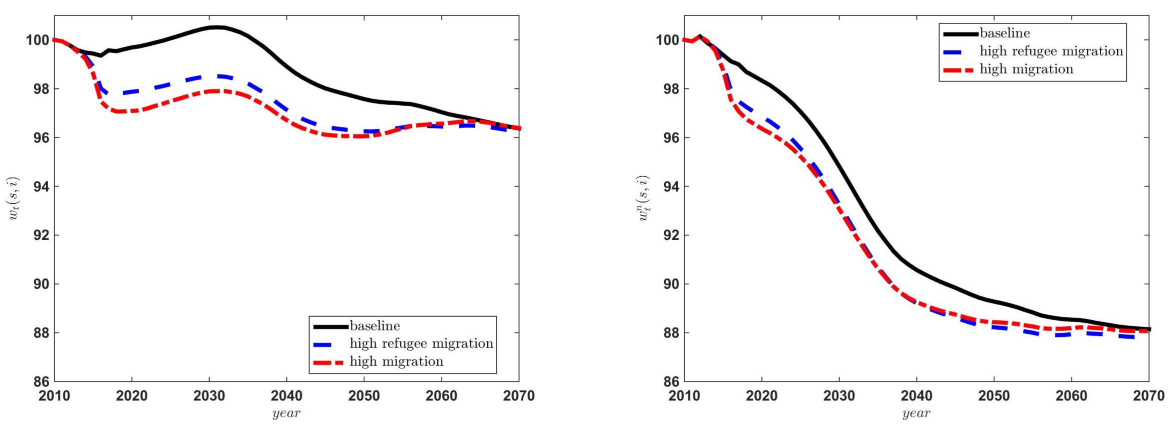


Figure 23: Gross & Net Wages, Low-Skilled Natives

(a) Gross Wages

(b) Net Wages

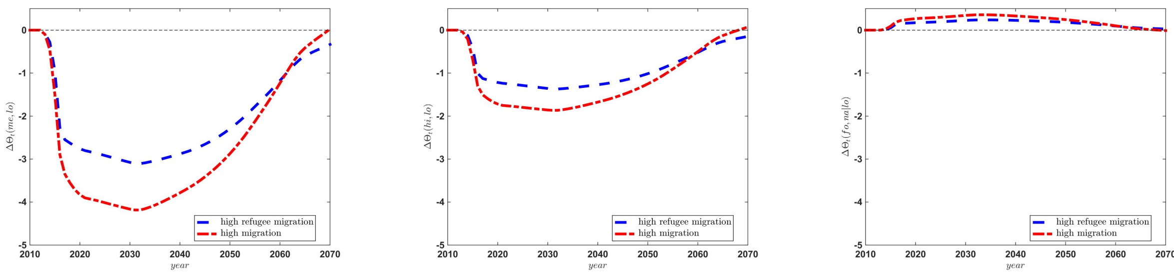


D.5 Wage Changes

Figure 24 displays the change of the skill ratios for the low-skilled natives.

Figure 24: Change of Skill Ratios, Low-Skilled Natives

(a) $\Delta\Theta_t(me, lo)$ (b) $\Delta\Theta_t(hi, lo)$ (c) $\Delta\Theta_t(fo, na \mid lo)$



D.6 Wage Changes: All Population Groups

We investigate the gross and net wage changes for other skill groups and countries of origin.

Wages of Foreigners from HIOECD. Observe that we get for low skilled foreigners from HIOECD, ho, that

$$\frac{w_t(lo, ho, j)}{\epsilon(lo, ho, j)} = w_t \cdot \left(1 + \Theta_t(me, lo)^{1-\frac{1}{\sigma_{lmh}}} + \Theta_t(hi, lo)^{1-\frac{1}{\sigma_{lmh}}}\right)^{\frac{1}{\sigma_{lmh}-1}} \cdot \underbrace{\left(1 + \Theta_t(na, fo \mid lo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{\sigma_{nf}-1}}}_{=\mathcal{W}_t^{nf}(lo)} \cdot \underbrace{\left(1 + \sum_{i \in \{rw, as\}} \Theta_t(i, ho \mid lo)^{1-\frac{1}{\sigma_{hr}}}\right)^{\frac{1}{\sigma_{hr}-1}}}_{=\mathcal{W}_t^{hr}(lo,ho)}.$$

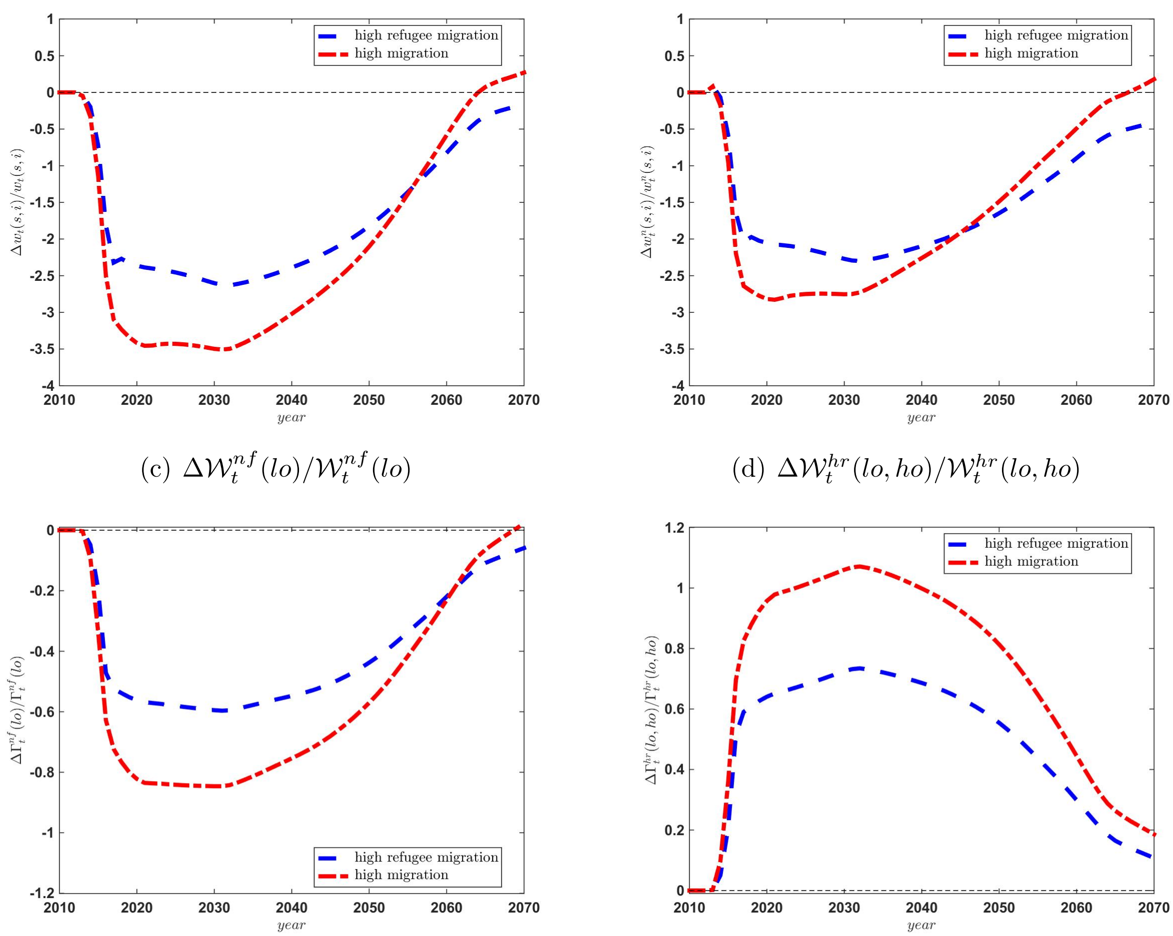
where

$$\Theta_t(i, ho \mid lo) = \frac{L_t(lo, i)}{L_t(lo, ho)}$$

and thus as an additional effect relative to the decomposition of wages of low skilled natives, the relative scarcity of workers of nationality group $i \in \{rw, as\}$ to group ho and the substitution elasticity within the foreign population group σ_{hr} is relevant. Since substitution between groups ho and rw, respectively as, is imperfect, term $\mathcal{W}_t^{hr}(lo, ho)$ may be positive.

Figure 25 shows wages and wage components of foreigners from HIOECD countries. In contrast to the wages of low skilled natives net wages go down, and only increase in the long run. The reason is that the relative abundance effect of foreign workers is quite strong, compared to the mildly positive effect through $\mathcal{W}_t^{hr}(lo, ho)$.

Figure 25: Change of Wages and Wage Components, Low-Skilled Foreigners, Group HIOECD



(a) %-Change Gross Wages

(b) %-Change Net Wages

(c) $\Delta\mathcal{W}^{nf}_t(lo)/\mathcal{W}^{nf}_t(lo)$

(d) $\Delta\mathcal{W}^{hr}_t(lo,ho)/\mathcal{W}^{hr}_t(lo,ho)$

Wages of Foreigners from RW and AS. Likewise, we get for low skilled foreigners from RW, rw, that

$$\frac{w_t(lo,rw,j)}{\epsilon(lo,rw,j)} = w_t \cdot \left(1+\Theta_t(me,lo)^{1-\frac{1}{\sigma_{lmh}}} + \Theta_t(hi,lo)^{1-\frac{1}{\sigma_{lmh}}}\right)^{\frac{1}{\sigma_{lmh}-1}} \cdot \underbrace{\left(1+\Theta_t(na,fo \mid lo)^{1-\frac{1}{\sigma_{nf}}}\right)^{\frac{1}{\sigma_{nf}-1}}}_{=\mathcal{W}^{nf}_t(lo)} \cdot \underbrace{\left(1+\Theta_t(rw \mid lo)^{1-\frac{1}{\sigma_{hr}}}\right)^{\frac{1}{\sigma_{hr}-1}}}_{=\mathcal{W}^{hr}_t(lo,rw)} .$$

where

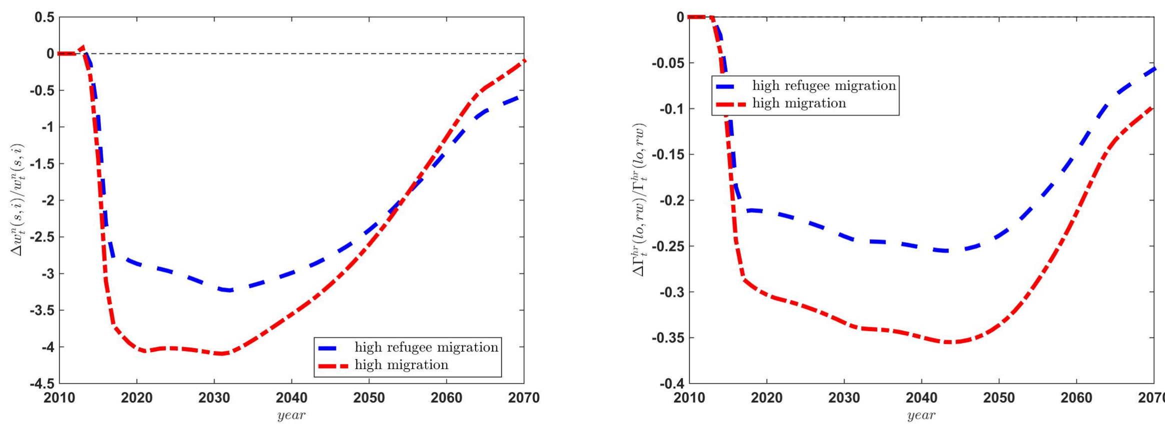
$$\Theta_t(rw \mid lo) = \frac{L_t(lo, ho)}{L_t(lo, rw) + L_t(lo, as)}.$$

Figure 26 shows wages and wage components of the foreign population groups RW and AS. Now $\mathcal{W}_t^{hr}(lo, rw)$ is relevant, which is negative and therefore all terms in this decomposition are negative. Thus, net wage decreases are strongest for this group of the population.

Figure 26: Change of Wages and Wage Components, Low-Skilled Foreigners, Groups RW and AS

(a) %-Change Net Wages, Group rw

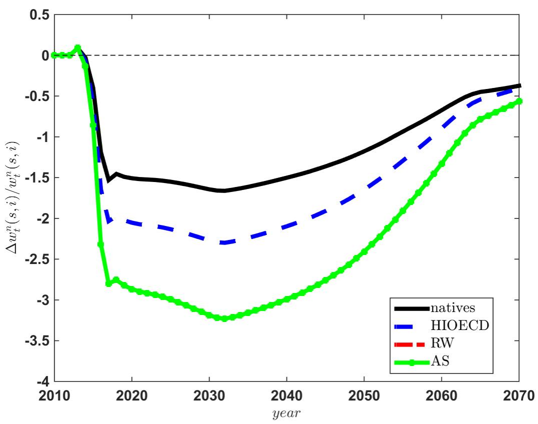
(b) $\Delta\mathcal{W}_t^{hr}(lo, rw)/\mathcal{W}_t^{hr}(lo, rw)$



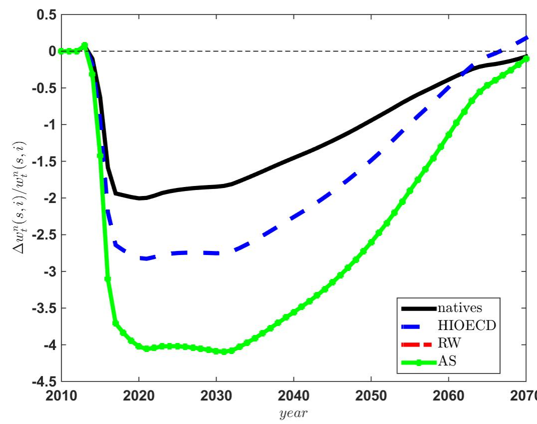
Finally, Figure 27 summarizes the net wage changes for all population groups. We observe that medium and high skilled natives and foreigners from HIOECD countries all experience wage increases.

Figure 27: Net Wage Changes Across Skill and Nationality Groups

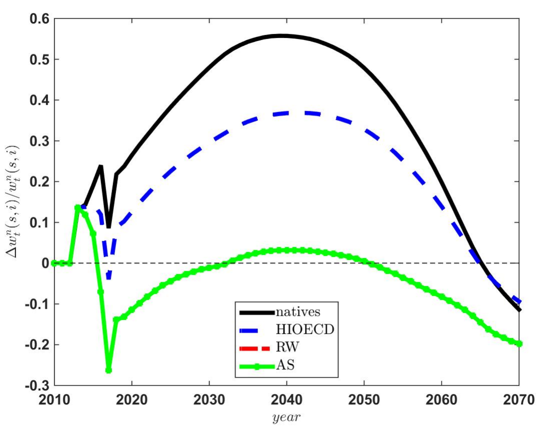
(a) Low Skilled, Refugee Migration



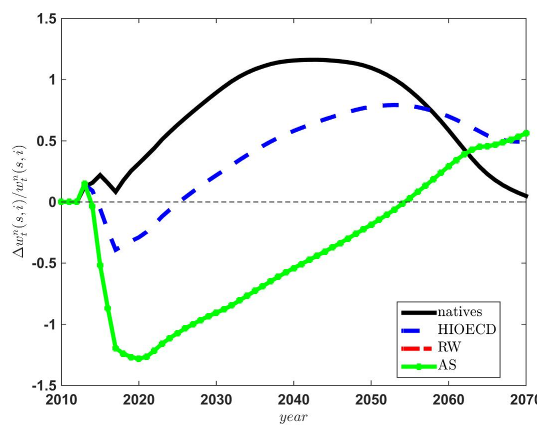
(b) Low Skilled, High Migration



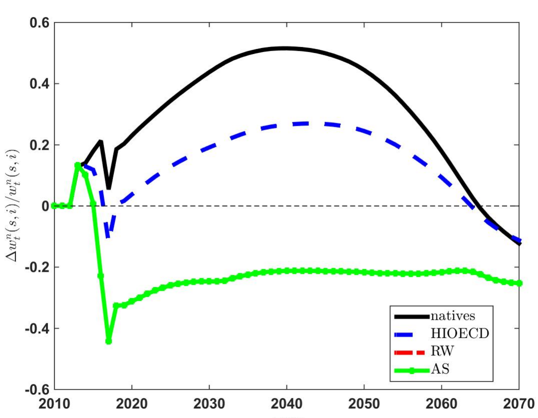
(c) Medium Skilled, Refugee Migration



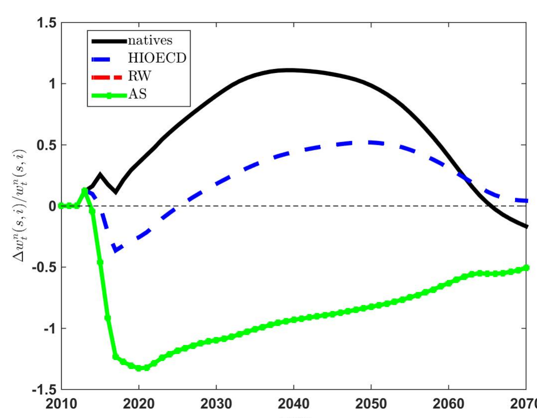
(d) Medium Skilled, High Migration



(e) High Skilled, Refugee Migration



(f) High Skilled, High Migration

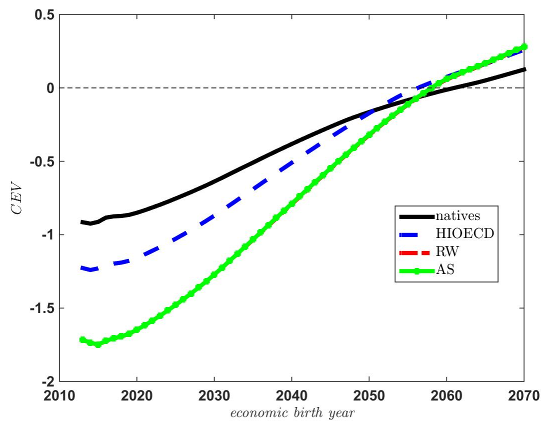


D.7 CEV

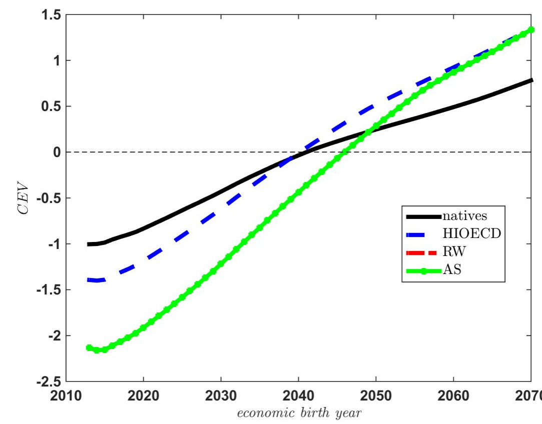
Figure 28 shows the CEV for cohorts born along the transition for all education groups, and Figure 29 the corresponding CEV for all agents alive in 2013.

Figure 28: CEV at Economic Birth Across Skill and Nationality Groups

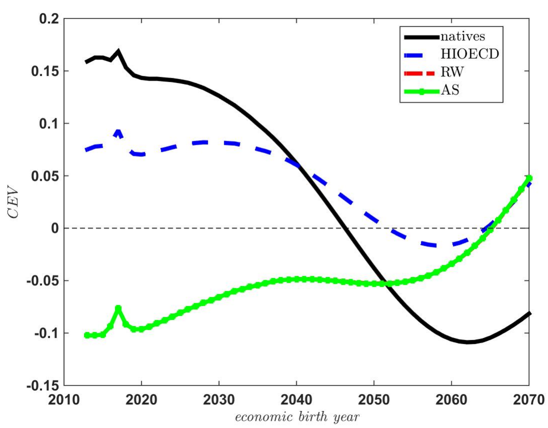
(a) Low Skilled, Refugee Migration



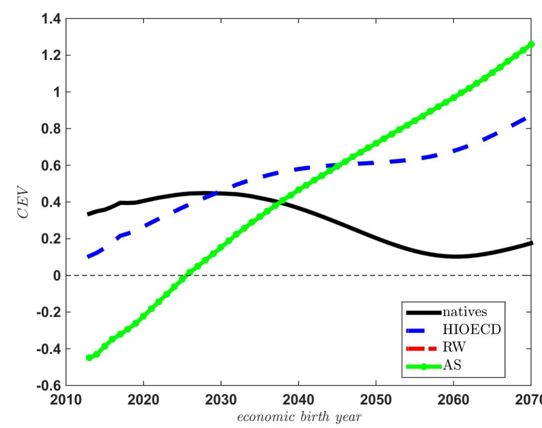
(b) Low Skilled



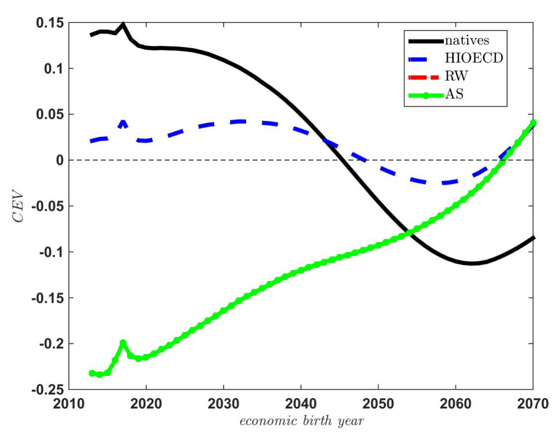
(c) Medium Skilled, Refugee Migration



(d) Medium Skilled



(e) High Skilled, Refugee Migration



(f) High Skilled

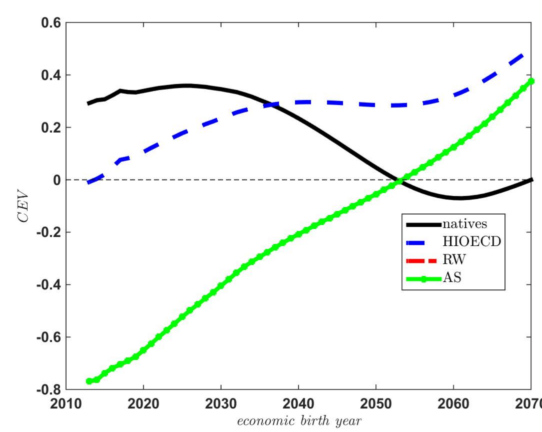
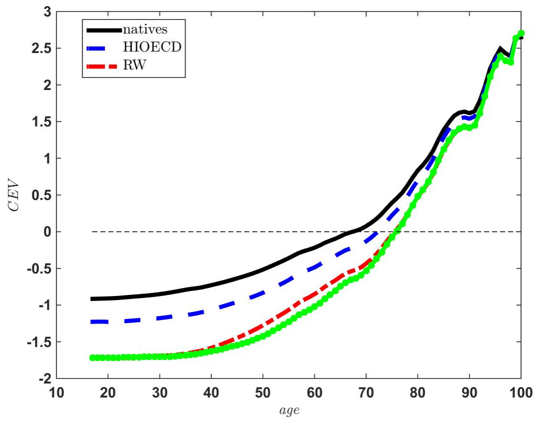
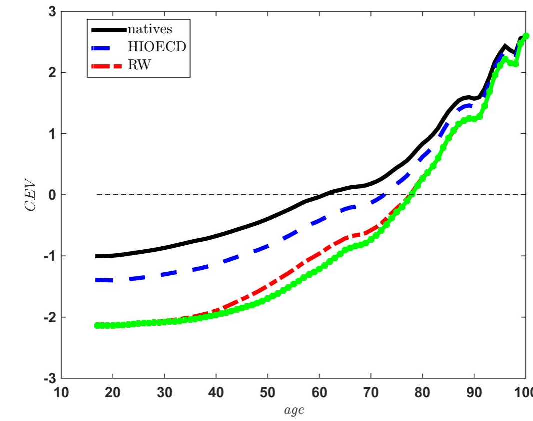


Figure 29: CEV of Generations Alive in 2013 Across Skill and Nationality Groups

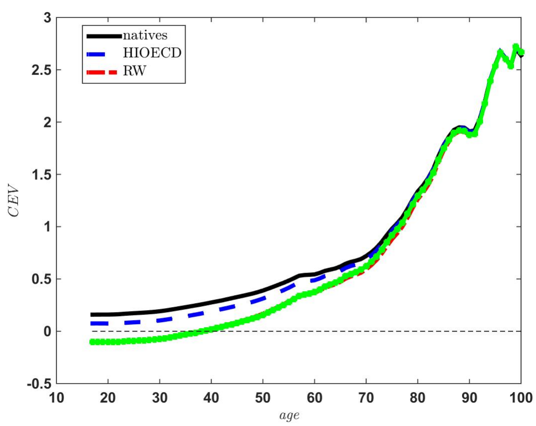
(a) Low Skilled, Refugee Migration



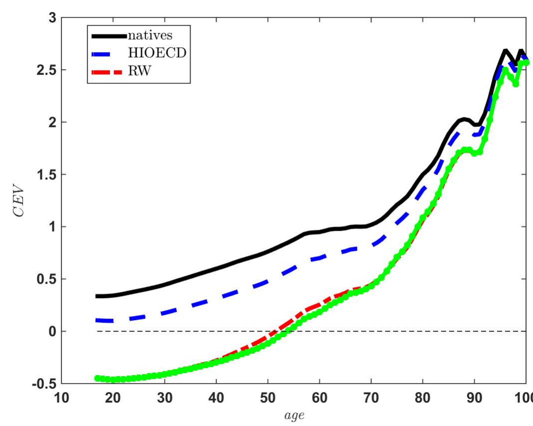
(b) Low Skilled



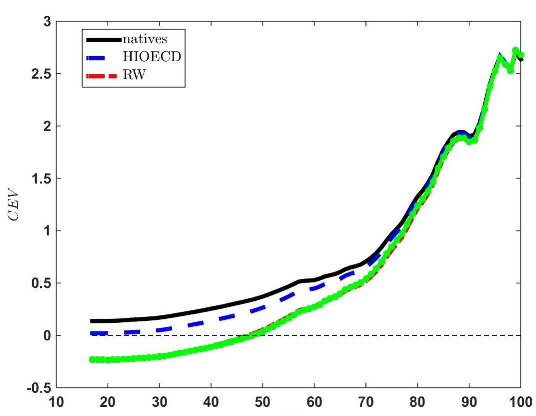
(c) Medium Skilled, Refugee Migration



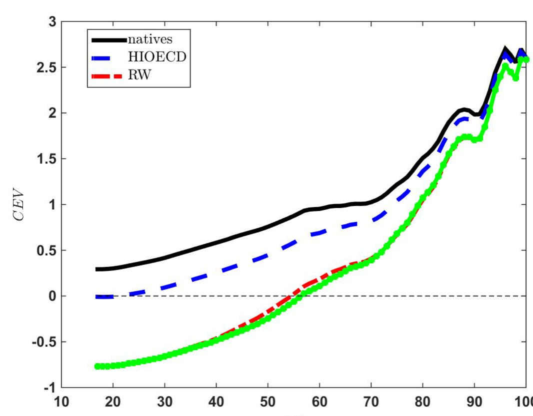
(d) Medium Skilled



(e) High Skilled, Refugee Migration



(f) High Skilled

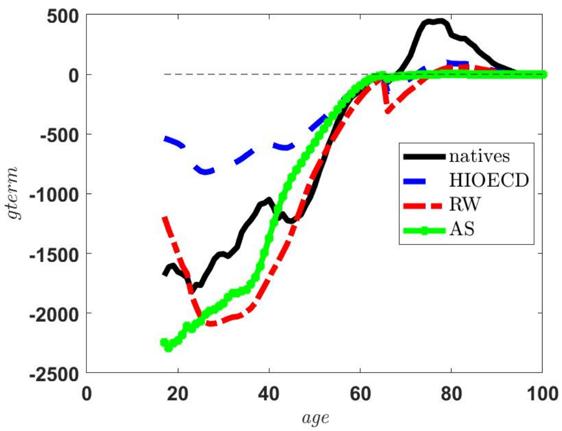


D.8 Discounted Gains and Losses

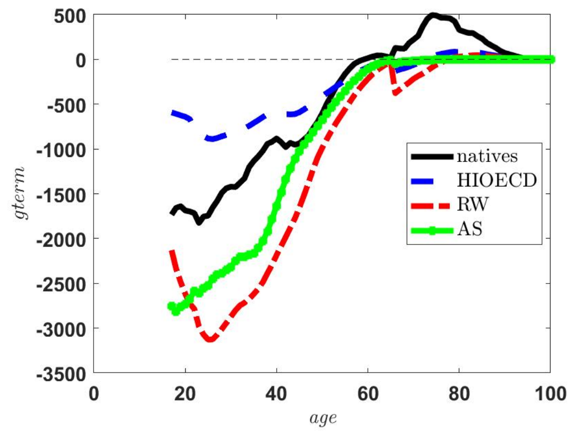
Figure 30 shows the discounted gains and loss terms defined in equation (28) for all generations alive in 2013 by nationality and education groups, weighted with the respective group size.

Figure 30: Discounted Gains & Losses of Generations Alive in 2013

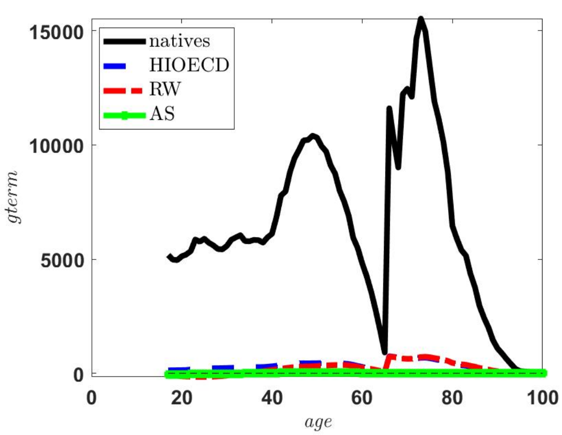
(a) Low Skilled, Refugee Migration



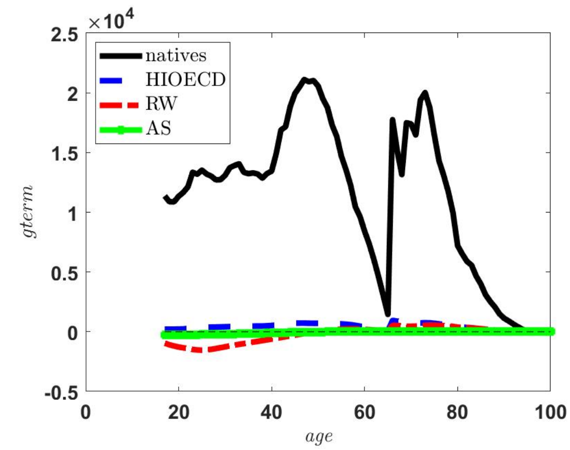
(b) Low Skilled, High Migration



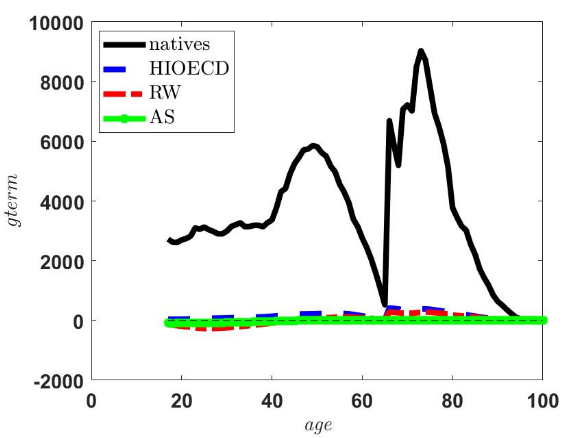
(c) Medium Skilled, Refugee Migration



(d) Medium Skilled, High Migration



(e) High Skilled, Refugee Migration



(f) High Skilled, High Migration

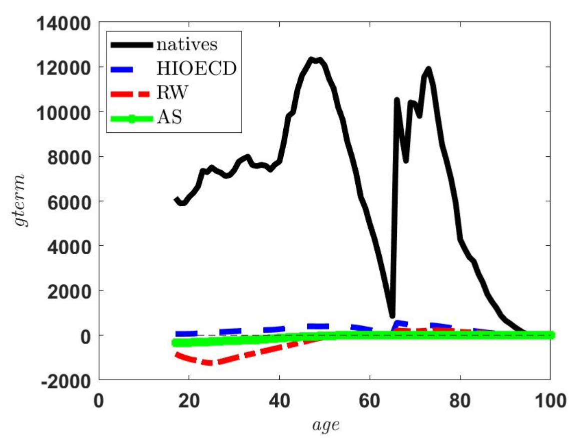
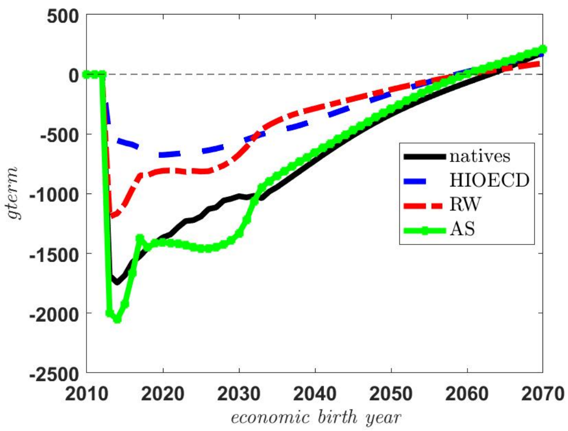
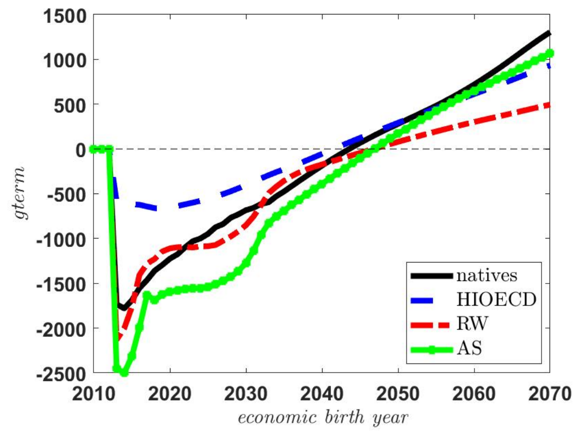


Figure 31: Discounted Gains & Losses for Cohorts over Time

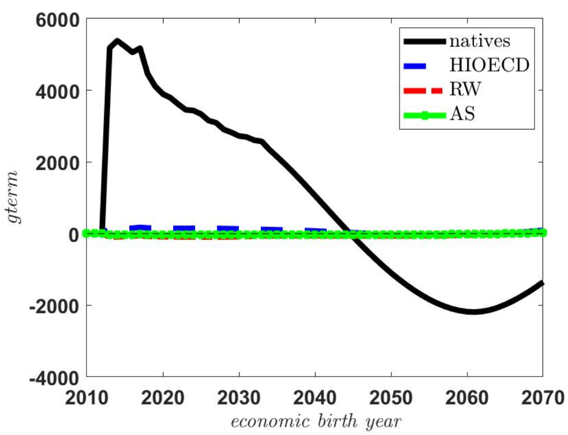
(a) Low Skilled, Refugee Migration



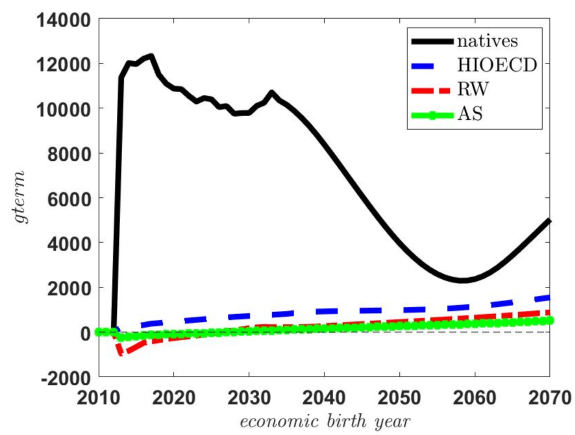
(b) Low Skilled, High Migration



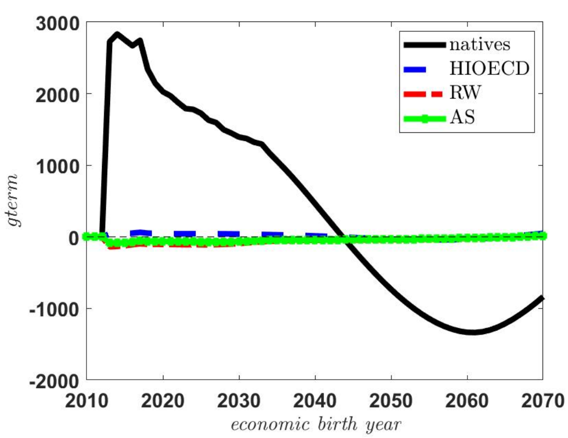
(c) Medium Skilled, Refugee Migration



(d) Medium Skilled, High Migration



(e) High Skilled, Refugee Migration



(f) High Skilled, High Migration