Demographic Change, Migration and Public Pensions - A Macroeconomic Analysis

Marius Bickmann

Veröffentlichung als Dissertation in der Wirtschaftswissenschaftlichen Fakultät der Technischen Universität Dortmund

Dortmund, Dezember 2018

Acknowledgements

I wrote this thesis during my time as a doctoral student at TU Dortmund University and the Ruhr Graduate School in Economics. I want to express my deep gratitude to several people who accompanied me along the way and supported me in the process of writing this thesis.

First of all, I owe a debt of gratitude to my main supervisor Ludger Linnemann, who provided me with an ideal environment allowing me to complete this dissertation. I benefited greatly from his advice and guidance as well as from the freedom he granted me to pursue my research interests. I also want to thank him for making available the resources necessary to participate in many conferences and to share my work with the international research community.

I want to greatly thank Burkhard Heer for his valuable advice on forming research questions and developing macroeconomic models. Participating in his doctoral course on computational economics laid the foundations for my future work and aroused my interest in the topics central to this dissertation. Furthermore, I am grateful to Hippolyte d'Albis, especially for our intense discussions during my visit at the Paris School of Economics. I also want to express my thankfulness to Philip Jung for referring this thesis.

Being a student at the Ruhr Graduate School in Economics was decisive for developing as a researcher. It presents a great network and allowed me to gain enriching insights into topics beyond my own research focus.

Completing this dissertation would not have been possible without the unwavering support of my family. I am extraordinarily grateful to my wife Lucía for her encouragement throughout all phases of the dissertation. I also want to thank my brothers for their understanding and counsel. Lastly, I owe my deepest gratitude to my parents. I could count on their trust and unconditional support at any time.

Contents

List of Figures

List of Tables

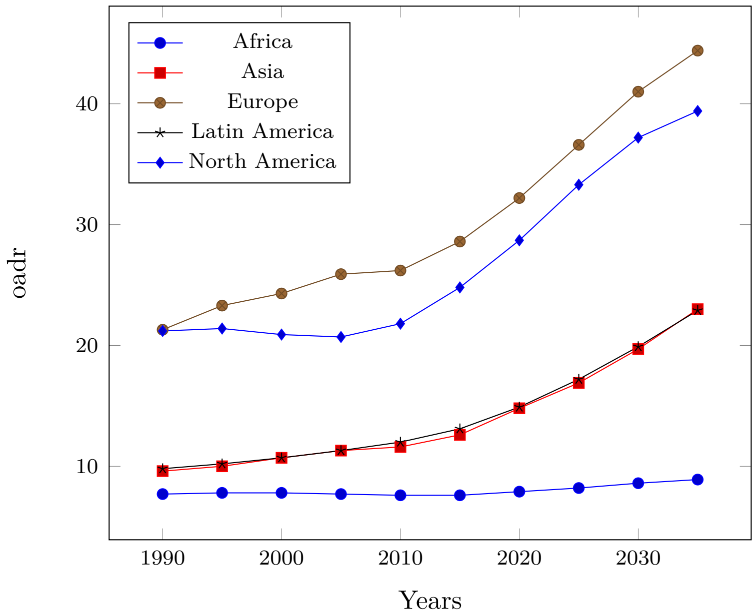
1. Introduction

The demographic change poses great challenges for countries, in particular regarding the sustainability of their social security systems. A possible remedy for the negative consequences of population aging are higher levels of immigration because it could counteract the shrinking of the labor force. Several macroeconomic studies have investigated the characteristics of migration flows necessary to alleviate the fiscal pressure in aging economies by comparing immigration scenarios that differ regarding the number of immigrants, as well as with respect to their age and skill composition (e.g. Storesletten (2000), Storesletten (2003) and Fehr et al. (2004)). However, two important questions in this context have been left unanswered so far: Firstly, how do changes in wages or adjustments in the social security system caused by population aging shape migration incentives and which size of migration flows should we expect in the future? To put it differently, which migration pattern arises in general equilibrium, i.e. if the determinants of migration incentives are themselves influenced by the aging process? Secondly, what are the redistributional effects between countries induced by international migration flows? This dissertation seeks to provide structural answers to both questions. In particular, I focus on the case of the European Union and analyze the triangular relationship between population aging, public pensions and intra-European migration.

While demographic change is a global phenomenon, the pattern of population aging differs remarkably around the world. Figure 1.1 plots the observed and projected old-age dependency ratio[1] (oadr) for the five large world regions. As can be seen, there is a clear division between the old societies of North America and Europe on the one side, and the younger societies of Africa, Asia and Latin America on the other. However, among the second group, Asia and Latin America also undergo a rapid aging process that started about two decades ago. Even though all European societies are confronted with fundamental shifts in the population structure, the speed of the aging process still varies considerably between the countries. In this respect, figure 1.2 displays the oadr for several large European states. Whereas Germany, France, Italy and Spain all exhibited a roughly similar share of old-age individuals in

[1]The old-age dependency ratio is defined as the ratio of population aged over 65 per 100 population 20-64.

Figure 1.1: Old-Age Dependency Ratio - World



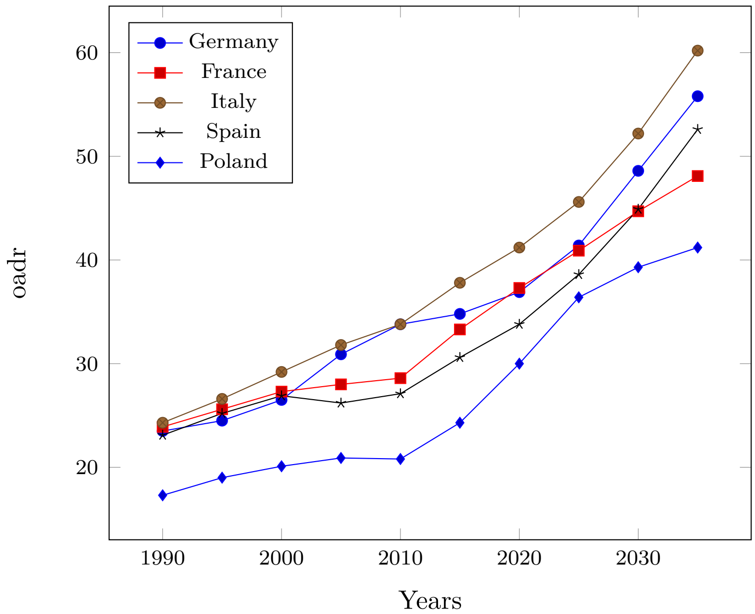
Source: United Nations (2018).

1990, the oadrs follow different paths from there on. Specifically, France is predicted to have a significantly younger population than the other three countries in 2035. Further, Poland was substantially younger than all other states in 1990, but it now experiences a severe aging process, which is made visible by the steep increase in the oadr from 2010 on.

The projected intra-European differences in demographic trends imply that macroeconomic consequences of population aging vary from one country to the other. This asymmetry in macroeconomic effects is enhanced by the great institutional heterogeneity of European public pension systems. Hence, even if the aging process was identical among all countries, differences in the generosity of the country-specific pension systems would imply that each economy is exposed to a different burden brought about by the increasing share of retirees.

In the wake of European integration, the member states have agreed to allow for a free movement of goods, labor and capital within the common European market. From an open economy perspective one therefore has to expect that deviations in demographic evolutions induce spill-over effects between the economies. One potential transmission channel is given by cross-country capital flows driven by country-specific variations in aggregate saving and investment rates. In particular, compositional shifts in the population structure have important implications for aggregate savings for at least two reasons: Firstly, saving rates vary along the life-cycle, such that shifts in a country's age distribution directly change aggregate savings. Secondly, a larger share of retirees increases the expenditure burden of public pension systems leading to either higher contribution rates for workers or lower pension benefits. These changes in social

Figure 1.2: Old-Age Dependency Ratio - Europe



Source: United Nations (2018).

security additionally impact savings. On the other side, firms adjust their investment decisions in response to a declining workforce. In this context, two important contributions discussing the linkage between the demographic transition and global capital flows are given by Krueger and Ludwig (2007) and Attanasio et al. (2007). However, these studies only concentrate on the mobility of capital, thereby ignoring the mobility of labor as another channel for possible spill-over effects.

My dissertation aims at closing this gap by studying the interaction of both capital and labor mobility in a model with country-specific aging processes. Even though a certain degree of migration incentives from lower income to higher income economies is likely to persist, migration pressure is shown to vary along the demographic transition. Thus, migration flows become a function of the aging process. Since migration movements additionally influence future population dynamics through their impact on population growth rates, migration has to be understood as both a determinant and a consequence of demographic change. Incorporating (partly) endogenous population dynamics in a quantitative macroeconomic model constitutes a broadening of the existing literature which has always relied on purely exogenous demographics projections (see additionally e.g. Heer and Irmen (2014)).

Having analyzed the pattern of migration flows along the demographic transition, it is necessary to subsequently ask for their economic implications. My dissertation highlights three main channels through which labor movements affect the macroeconomy: Firstly, migration has a positive long-term effect on the working age to population ratio[2] in the receiving country, whereas it enhances the degree of aging in the sending

[2]The working age to population ratio (wapr) is generally defined as the ratio between the group of

country. These demographic shifts alleviate the fiscal pressure on the social security system in the country experiencing immigration, but increase the fiscal burden in the emigration country. Secondly, as long as the skill composition of migrants deviates from the skill composition of non-migrants in the host and sending region, relative wages of skill groups are affected by labor movements. Lastly, migrants differ from natives regarding their life-cycle savings, consumption and labor supply profile as long as they take the possibility of return migration into account. These differences are shown to play an important role in evaluating the total effect of labor movements. Overall, migration therefore entails redistributional effects within and between economies.

This thesis consists of three self-contained chapters that together provide a comprehensive analysis of the determinants and implications of intra-European migration with a special focus on its role in the context of demographic change. Chapter 2 presents a two-country large-scale OLG model in which capital and migration flows respond two differences in the generosity of public pension systems. In a quantitative analysis, I apply the model to the case of Germany and Austria. The selection of this case study is motivated by the observation that despite all the countries' similarities, Austria runs the much more costly PAYG system. Starting with a closed economy scenario, one observes a lower per capita capital stock in Austria caused by lower individual savings due to higher contribution rates. The introduction of capital mobility then induces a capital reallocation from Germany to Austria until interest rates are equalized. Allowing for labor mobility in the next step triggers migration flows in the opposite direction: Austrian workers escape the higher financial burden of the social security system until the accompanying wage increase is large enough to eliminate migration incentives. Repeating the analysis for the predicted demographic scenario of 2050 reveals that the labor reallocation is enhanced by population aging.

Chapter 3 extends the model introduced beforehand along several dimensions: First of all, while chapter 2 focuses on a comparative statics analysis, the model is now applied to study migration flows along the demographic transition. Further, it allows for a complex demographic structure in which endogenous migration flows alter population dynamics in all regions under consideration. Lastly, it is enlarged to a three-country set-up, consisting of two sending regions (Poland and Southern Europe) and one destination region (Germany). Assuming a preference heterogeneity of agents as in Klein and Ventura (2009), I calibrate the model to match observed net migration from the two sending regions to Germany. The model predicts a decrease in the German net immigration rate in the next decades. This result can be decomposed into a demographic effect and changes in migration incentives. Further, the level of net immigration is shown to depend on the policy reaction to the demographic change. In particular, if governments in the sending regions choose to stabilize current replacement rates

working age individuals and total population.

thereby placing the fiscal burden on workers, emigration pressure increases, which in turn accelerates population aging.

Finally, chapter 4 deals with the distributional implications of migration in greater detail, while taking labor movements as exogenously given. In particular, I study the case of Germany and Poland and calibrate the model to match the characteristics of the Polish migrant population regarding its overall size, as well as its age and skill composition. The macroeconomy is affected by migration through three different channels: labor supply, capital formation and public pensions. In accordance with the empirical migration literature, I employ a production function featuring imperfect substitutability of skill-types. Further, the model's open economy framework enables a comprehensive analysis of return migration. Integrating the possibility of return into the migrant's decision problem generates larger per capita savings of migrants. Specifically, return migration introduces a precautionary savings motive caused by the desire of consumption smoothing on the one hand, and the possibility of a significant drop in labor income upon returning, on the other. Differences in savings behavior between migrants and non-migrants imply that labor movements alter the capital to labor ratio. Since structural empirical studies ignore this channel, I argue that they are prone to produce biased estimates of wage effects. Overall, the quantitative analysis suggests that Polish migration to Germany induces a welfare redistribution between low-skilled workers in each country, resulting in moderate welfare losses in Germany, but substantial welfare gains in Poland.

2. Factor Mobility and Non-Harmonized Public Pension Systems

2.1 Introduction

The creation of a single market involving a free movement of goods, services, capital and people is the long-term political goal of the European Union. Since the treaty of Maastricht in 1992, many steps towards the achievement of this goal have been taken. However, social security arrangements have remained mainly under the domain of national policies. Among the different social security systems, one observes a wide heterogeneity regarding both their institutional structure and their generosity. With free movement of capital and labor on the one side, and the non-harmonization of social security systems on the other, Europe finds itself in a situation of incompleteness. The following study aims at analyzing the consequences of this incompleteness while concentrating on the role of public pensions that make up the largest share of social security expenditures. In particular, I investigate how migration decisions are influenced by differences in public pension systems and what macroeconomic effects follow from the migration flows arising. I further explore the role of capital mobility, firstly, to compare it to the effects of labor mobility and secondly, to analyze the interaction between the two dimensions of factor movements. Besides studying the effects on prices and aggregates, I conduct a welfare analysis in order to determine how the utility of individuals in one country is affected by the design of the public pension system in the other. All model results are recomputed for the demographic scenario of the year 2050 as aging will put severe pressure on public pension systems. To address the research question, I set up a two-country large-scale overlapping generation model whereby the two regions are calibrated to resemble Austria and Germany. The model reduces the complexity of a migration decision to a single trade-off between possible gains from the foreign pension system and the costs involved in the migration process. Hence, the paper does not aim at replicating observed migration pattern, but to uncover the underlying economic forces resulting out of the coexistence of factor mobility and country-specific social security arrangements.

Concerning the effects of capital mobility, the model predicts capital inflows into the economy with the more generous public pension system (Austria) thereby increasing domestic wages and decreasing the interest rate. Free movement of labor allows individuals to choose under which public pension system they want to live. In the model economy, individuals prefer living in the country with the less generous public pension system (Germany). How strong migration responses are depends highly on the level of moving costs. However, compared to empirical estimates, moving costs must be extremely large to make migration too costly. For reasonable estimates (up to 100% of annual GDP per capita), the model predicts a significant reallocation of labor. Labor mobility increases wages in Austria due to the outflow of workers and the increase in the capital to worker ratio. With regard to the welfare effects, both capital and labor mobility are shown to reduce utility costs stemming from the public pension system in Austria, whereas the opposite holds for Germany. Overall, aging is predicted to increase the migration pressure considerably. Nevertheless, the model also suggests that with appropriate policy reforms, the additional pressure could be significantly mitigated.

My paper builds on a large field of literature that has analyzed the effects of public pension systems. Building on the seminal work by Auerbach and Kotlikoff (1987), İmrohoroğlu et al. (1995) are the first to study welfare effects of PAYG systems in the context of a large-scale OLG model. While early work has concentrated mostly on closed economy models, several studies in the last decade have shifted the attention to open economy settings. Further, this specific literature not only focuses on public pensions but rather on how the interaction of demographic change and PAYG systems affects the economy. Krueger and Ludwig (2007) demonstrate that capital mobility induces significant spill-over effects of the faster aging process and the more generous public pension systems in Europe on the U.S. economy. Moreover, Börsch-Supan et al. (2006) analyze, inter alia, intra-European capital flows, whereas Attanasio et al. (2007) investigate the effects of the demographic transition in the industrialized world on developing countries. All these models have in common that capital mobility is the only dimension of factor mobility, hence they do not feature an endogenous migration decision.[1] On the contrary, Klein and Ventura (2009) who study the long-term welfare effects from abolishing all barriers to labor mobility, set up a two-country model that treats migration as a life-cycle decision influenced by individual preferences, resource costs of moving and skill losses when working abroad. By taking their model as the basic building block, my contribution consists of introducing the dimension of labor mobility to the quantitative open economy literature on public pensions and demographic change. In the class of two-period OLG models, several studies discussed the question of whether non-harmonized public pension systems allow for an efficient

[1] Within these models, migration is exogenously given since it is contained in the demographic projections.

resource allocation in the presence of factor mobility. Homburg and Richter (1993) argue that even a harmonization of country-specific pension systems is generally not sufficient for supporting an efficient labor allocation if there are differences in population growth rates. Breyer and Kolmar (2002) provide a more detailed discussion of the same problem. They conclude that an equalization of pension payments is sufficient to guarantee efficiency if labor is perfectly mobile. In the case of restricted labor mobility, however, a complete centralization of pension systems might become necessary. While these studies offer substantial insights into the mechanisms at work in my model, they differ from my paper, since their approach is purely theoretical. On the contrary, my model exhibits a quantitative nature and is calibrated to match the observed population structure, the generosity of the pension systems and migration costs.

The paper is organized as follows. In section 2.2, I provide an overview about the heterogeneity in costs and benefits of public pension systems in Europe. Thereafter, I describe the theoretical model (section 2.3). The calibration is outlined in section 2.4 and section 2.5 presents the numerical results. Finally, section 2.6 concludes.

2.2 Pension Systems in Europe

Public pensions account for the largest share of total expenditure on social security in Europe. According to Eurostat (2018), the EU-28 countries devoted 44.2% of their social protection expenditure to old-age benefits in 2014. The second largest category was that of sickness and health-care, with a share of 28%. Public pension benefits are further large compared to total economic activity: In the same year, the EU-28 countries spent on average about 13% of GDP on old-age benefits. Even though this figure is large in every single member state, there are still significant differences with respect to how much of its income a country spends on public pensions. Table 2.1 shows the differences among selected member states.

The heterogeneity displayed by table 2.1 is striking. The costs of the Austrian pension system exceed the German ones by about 2 percentage points (costs expressed relative to GDP). Almost the same holds true for France. According to OECD (2013), Italy runs the most expensive public pension system in Europe. In contrast, the Spanish one is relatively modest, which is further undercut by the UK.

Whereas the previous table reflected the cost side, table 2.2 reflects the spending side and displays the net replacement rates in the respective country. The net replacement rate is defined as "the individual net pension entitlement divided by net pre-retirement earnings, taking account of personal income taxes and social security contributions paid by workers and pensioners" (OECD, 2013, p. 140). Net replacement rates are shown for different earning classes, where "1" corresponds to the average earner, "0.5"

Table 2.1: Public Expenditures on Public Pensions

Country	Level % of GDP
Austria	**13.5**
Belgium	10
France	13.7
Germany	**11.3**
Italy	15.4
Portugal	12.3
Spain	9.3
United Kingdom	6.2

Source: OECD, Pensions at a Glance (2013).

Table 2.2: Net Replacement Rates

Country	0.5	1	1.5
Austria	**91.2**	**90.2**	**86.2**
Belgium	72.9	50.1	39.9
France	75.9	71.4	60.9
Germany	**55.9**	**55.3**	**54.4**
Italy	78	78	77.9
Portugal	77.7	67.8	68.4
Spain	79.5	80.1	79.8
United Kingdom	61.7	38	27.2

Source: OECD, Pensions at a Glance (2013).

to 50% of average earnings and "1.5" to 150% of average earnings, respectively. As it is the case with expenditures on social security, we see a wide heterogeneity. The average net replacement rate of the average earner in the EU-27 countries is 56.6%. Hence, Germany lies slightly below this average, Austria on the other hand exceeds it by far. In particular, only Hungary has a higher net replacement rate than Austria (for average earners) in Europe. For Germany and Austria, the two countries in the focus of this study, it is true that the more expensive public pension system also grants the higher replacement rates. Comparing the two tables, however, we find country pairs for which this relation does not hold. For example, in Spain, net replacement rates are slightly higher than those in Italy, whereas the expenditures on public pensions in Italy exceed those in Spain considerably. In general, it is of course not only the replacement rate that determines the actual costs of a pension system. Other factors include the demographic structure, labor force participation and regulations concerning the retirement age.

2.3 Model

The economic environment is described by a large-scale two-country OLG model. The modeling of the production side and the migration decision closely follows Klein and Ventura (2009).

2.3.1 Production

Each country $x \in \{h, f\}$ produces a single good using a CRS technology containing capital, labor and land as inputs. The latter input factor is assumed to be fixed and immobile. Its presence in the production function implies jointly diminishing returns to labor and capital. The profit maximization problem of the firm reads:

$$\max_{K_{x,t},L_{x,t}} \pi_{x,t} = Y_{x,t} - w_{x,t}L_{x,t} - (r_{x,t} + \delta)K_{x,t} - R_{x,t}F_x \tag{2.1}$$
$$s.t. \quad Y_{x,t} = A_{x,t}K_{x,t}^{\lambda}L_{x,t}^{\sigma}F_x^{1-\lambda-\sigma}.$$

In equilibrium, factor prices equal their marginal products. They are given by:

$$r_{x,t} = \lambda A_{x,t}K_{x,t}^{\lambda-1}L_{x,t}^{\sigma}F_x^{1-\lambda-\sigma} - \delta \tag{2.2}$$

$$w_{x,t} = \sigma A_{x,t}K_{x,t}^{\lambda}L_{x,t}^{\sigma-1}F_x^{1-\lambda-\sigma} \tag{2.3}$$

$$R_{x,t} = (1 - \lambda - \sigma) A_{x,t} K_{x,t}^{\lambda} L_{x,t}^{\sigma} F_{x}^{-\lambda-\sigma}. \tag{2.4}$$

TFP ($A_{x,t}$) is assumed to grow over time at the constant rate ρ.

2.3.2 Households

Demographics

In each period, a new generation of households is born in both countries. Populations grow at the rate n. Agents may live up to a maximum age of J and retire at age R. In each country x, they face an idiosyncratic mortality risk and survive from age j to age $j+1$ with probability $\psi_{x,j}$, where $\psi_{x,0} = 1$ and $\psi_{x,J} = 0$.

Decision Problem

Besides a standard life-cycle saving and consumption decision, households choose their location of residence. I assume that once an agent has migrated, she will not move back to her country of birth, hence there is no return migration. If agents decide to migrate in period t, they have to pay a fix costs of m and then become active in the other region in period $t+1$. Due to the delay in the migration process, agents necessarily spend their first period of life in their country of origin. Further, they can migrate in all periods of their working life except the last.[2] Households are credit constrained throughout their whole life ($a_j \geq 0 \;\; \forall \;\; j$). Hence, they cannot borrow against future income (including pension claims) to pay the moving costs. Further, annuity markets are closed by assumption.

The model features heterogeneous agents. Households differ with respect to psychic costs they face when living abroad (μ_s). Preference types $s \in S$ are realized at birth and fixed over the life-cycle. The distribution of preference types is described by the density $\alpha(s)$.

For any given time period and in each country, households maximize lifetime utility in the beginning of age 1:

$$\max \sum_{j=1}^{J} \beta^{j-1} (\prod_{k=1}^{j} \psi_{k-1}) \left[\frac{c_j^{1-\gamma}}{1-\gamma} - \mu_s \mathbb{1}_{x_j \neq y} \right]. \tag{2.5}$$

where x_j is destination at age j and y denotes the agent's birthplace. The indicator function implies that individuals only suffer from psychic costs when they reside in the foreign destination ($x_j \neq y$). These costs are constant and do not vanish over time. γ is

[2] Note that this assumption simplifies the problem without affecting the results since there is no gain from migrating in the periods excluded (see section 2.3.2).

the standard CRRA parameter governing the inter-temporal elasticity of substitution. Following Klein and Ventura (2009), I use $-x$ to denote the *other* location. Hence, if an individual is born in x and moves abroad, her new location is given by $-x$. The budget constraint in period t for the working period of an individual of age $j \in [1, R]$ residing in either home or foreign reads:

$$\begin{cases} (1+r_t)a_t(j) + w_{x,t}(1-\tau_{x,t})\bar{h}\epsilon(j) + tr_t = a_{t+1}(j+1) + c_t(j) + \varphi_t(j)m_{x,t} & \text{if} \quad x_t(j) = y \\ (1+r_t)a_t(j) + w_{-x,t}(1-\tau_{-x,t})\bar{h}\epsilon(j)(1-\theta) + tr_t = a_{t+1}(j+1) + c_t(j) & \text{if} \quad x_t(j) \neq y. \end{cases} \tag{2.6}$$

I will now explain the different income sources of the households. Firstly, agents derive income from wealth which may consist of two assets, capital and land. Both asset types are divisible and individuals can invest abroad. In the open economy, two no-arbitrage conditions have to hold. The first is an intra-regional one, demanding the equalization of returns on capital and land. The second is an inter-regional one and requires equal returns on investment at home and abroad:

$$1 + r_{x,t} = \frac{p_{x,t} + R_{x,t}}{p_{x,t-1}} \tag{2.7}$$

$$r_t = r_{x,t} \quad \forall x \in \{h, f\}. \tag{2.8}$$

This makes both assets identical from the agent's perspective and justifies why individual wealth can be summarized in one single variable: $a_t(j) = k_t(j) + \sum_{x=h,f} p_{x,t-1} f_x(j)$.

The second income source is labor. Supply of labor ($\bar{h}$) is exogenous and does not differ between the regions. Wage income is taxed at the contribution rate of the pension system in each country. Labor income varies over the life-cycle due to an age-dependent efficiency profile (ϵ) and exogenous TFP growth. If agents have decided to migrate, they earn the foreign wage and pay the foreign contribution rate. Potentially, they experience efficiency losses when working abroad (θ). $\varphi_t(j)$ is equal to one if the agent migrates in t. Lastly, individuals receive a lump-sum transfer tr_t from a supranational authority.

The budget constraints for the retirement period is defined as:

$$(1+r_t)a_t(j) + \pi_t(j_m) + tr_t = a_{t+1}(j+1) + c_t(j). \tag{2.9}$$

In the retirement period, individuals save and consume and receive benefits π which - if the individual has moved abroad - are a function of the period of migration as explained in the next section.

Pension Benefits

In each country $x \in \{h, f\}$ there is a PAYG system in place collecting contributions from the currently working and distributing it to the retirees. The retirement systems are organized according to a *place of residence* principle, i.e. workers acquire pension claims in each country they work. Individual pension claims are set by the following rule:

$$\pi_t(j_m) = \frac{j_m b_{x,t} + (R - j_m) b_{-x,t}}{R} \quad \text{for} \quad 0 < j_m \leq R, \tag{2.10}$$

where $b_{x,t}$ ($b_{-x,t}$) are the pension payments in the home (foreign) country and j_m is defined as the highest age at which the individual still works in her country of origin (equal to the period of moving if the agent migrates). R is identical in both countries. For an individual who does not move, $j_m = R$ holds so that her pension claims are equal to those paid in her country of birth ($\pi_t(R) = b_{x,t}$). If an individual has migrated, the function $\pi_t(j_m)$ basically forms a weighted average of the pension benefits paid in both countries whereby the weights are determined by how much time has been spent in each destination. Due to the dependence of pension benefits on the point of time of migration, j_m enters the household optimization problem as a state variable.

2.3.3 Supranational Authority

Due to the idiosyncratic mortality risk and the absence of annuity markets, a certain fraction of individuals in every period dies with positive asset holdings. I assume that there is a supranational authority collecting the bequests of the deceased and redistributing them in a lump-sum fashion to the survivors (tr_t). The assumption of a supranational authority - instead of country-specific authorities - is necessary to avoid that the transfer payments influence the migration decision.

2.3.4 Recursive Formulation

The household problem can be represented in a recursive way. Define the vector of state variables as $z = (a, s, j, j_m, x, y)$. To depict the value function we have to distinguish between different cases. If the individual has migrated in the past, the value function $V_t(z)$ is obtained by:

$$
\begin{aligned}
& V_t(a,s,j,j_m,-x,x) = \max_{c,a'}\Big[U(c)+\beta\psi_{x,j}V_{t+1}(a',s,j+1,j_m,-x,x)\Big] \qquad (2.11)\\
& s.t. \quad c+a' = \begin{cases} (1+r_t)a + w_{-x,t}(1-\tau_{-x,t})\bar{h}\epsilon(j)(1-\theta)+tr_t & \text{if } j \le R \\ (1+r_t)a+\pi_t(j_m)+tr_t & \text{if } j>R \end{cases}\\
& c,a' > 0, V_t(a,s,J+1,j_m,-x,x)=0.
\end{aligned}
$$

If migration has not taken place yet, the value function for a working agent with $j < R$ reads:

$$
\begin{aligned}
& V_t(a,s,j,j,x,x) = \max_{c,a',\varphi}\Big[U(c)+\beta\psi_{x,j}\Big\{\varphi V_{t+1}(a',s,j+1,j,-x,x) \qquad (2.12)\\
& +(1-\varphi)V_{t+1}(a',s,j+1,j+1,x,x)\Big\}\Big]\\
& s.t. \quad c+a' = (1+r_t)a+w_{x,t}(1-\tau_{x,t})\bar{h}\epsilon(j)+tr_t\\
& c,a'>0, \varphi\in\{0,1\}.
\end{aligned}
$$

And for an agent of age $j \ge R$:

$$
\begin{aligned}
& V_t(a,s,j,R,x,x) = \max_{c,a'}\Big[U(c)+\beta\psi_{x,j}V_{t+1}(a',s,j+1,R,x,x)\Big] \qquad (2.13)\\
& s.t. \quad c+a' = \begin{cases} (1+r_t)a+w_{x,t}(1-\tau_{x,t})\bar{h}\epsilon(j)+tr_t & \text{if } j=R \\ (1+r_t)a+\pi_t(R)+tr_t & \text{if } j>R \end{cases}\\
& c,a'>0, V_t(a,s,J+1,R,x,x)=0.
\end{aligned}
$$

2.3.5 Equilibrium

I define $\Phi_t(a;s,j,j_m,x,y)$ as the mass of people with asset stock $a\in A$, type $s\in S$, age $j\in[1,J]$, last period of working in country of birth $j_m\in[1,R]$, residence $x\in\{h,f\}$ and place of birth $y\in\{h,f\}$ in period t.

Definition 1. A competitive equilibrium consists of sequences of individual functions for the household, $\{V_t(\cdot),c_t(\cdot),a'_t(\cdot),\varphi(\cdot)\}_{t=0}^{\infty}$, sequences of production plans for the firms $\{K_{x,t},L_{x,t}\}_{t=0,x\in\{h,f\}}^{\infty}$, prices $\{w_{x,t},r_{x,t},p_{x,t},R_{x,t}\}_{t=0,x\in\{h,f\}}^{\infty}$, transfers $\{tr_t\}_{t=0}^{\infty}$, policies $\{\tau_{x,t},b_{x,t}\}_{t=0,x\in\{h,f\}}^{\infty}$, and measures $\{\Phi_t\}_{t=0}^{\infty}$ such that

1. Given prices and transfers, $c_t(\cdot),a'_t(\cdot),\varphi(\cdot)$ solve the individual's dynamic problem and $V_t(\cdot)$ are the associated value functions.

2. Factor prices satisfy (2.2),(2.3),(2.4).

3. Transfers are given by:

$$tr_{t+1} = \sum_{y\in\{h,f\}} \sum_{x\in\{h,f\}} \sum_{j=1}^{J-1} \sum_{j_m=1}^{R} \int_{\mathbb{R}\times\mathcal{S}} a_t'(a,s;j,j_m,x,y)(1-\psi_{y,j})(1+r_{t+1}) \quad (2.14)$$
$$d\Phi_t(a,s;j,j_m,x,y).$$

4. The social security budget clears in both countries:

$$\tau_{x,t}w_{x,t}L_{x,t} = Pen_{x,t}, \quad (2.15)$$

where pension payments in country x are given by:

$$\begin{aligned} Pen_{x,t} = & \sum_{j=R+1}^{J} b_{x,t}\Phi_t(\mathbb{R},\mathcal{S};j,R,x,x) \quad (2.16) \\ & + \sum_{j=R+1}^{J} \sum_{j_m=1}^{R} \frac{R-j_m}{R} b_{x,t}\Phi_t(\mathbb{R},\mathcal{S};j,j_m,x,-x). \\ & + \sum_{j=R+1}^{J} \sum_{j_m=1}^{R} \frac{j_m}{R} b_{x,t}\Phi_t(\mathbb{R},\mathcal{S};j,j_m,-x,x). \end{aligned}$$

5. Markets clear in all t and x

$$L_{x,t} = \sum_{j=1}^{R} \bar{h}\epsilon(j)\Phi_t(\mathbb{R},\mathcal{S};j,j,x,x) + \sum_{j=2}^{R} \sum_{j_m=1}^{j-1} \bar{h}\epsilon(j)(1-\theta)\Phi_t(\mathbb{R},\mathcal{S};j,j_m,x,-x). \quad (2.17)$$

$$A_{t+1}^{w} = \sum_{y\in\{h,f\}} \sum_{x\in\{h,f\}} \sum_{j=1}^{J-1} \sum_{j_m=1}^{R} \int_{\mathbb{R}\times\mathcal{S}} a_t'(a,s;j,j_m,x,y)d\Phi_t(a,s;j,j_m,x,y), \quad (2.18)$$

where total assets have to be distributed among capital and land:

$$A_{t+1}^{w} = K_{t+1}^{w} + \sum_{x\in\{h,f\}} p_{x,t}F_x. \quad (2.19)$$

The aggregate resource constraint is given by:

$$\sum_{x\in\{h,f\}} Y_{x,t} + (1-\delta)K_t^w = \sum_{y\in\{h,f\}} \sum_{x\in\{h,f\}} \sum_{j=1}^{J} \sum_{j_m=1}^{R} \int_{\mathbb{R}\times\mathcal{S}} c_t(a,s;j,j_m,x,y) \quad (2.20)$$
$$d\Phi_t(a,s;j,j_m,x,y) + K_{t+1}^w + \sum_{x\in\{h,f\}} \sum_{j=1}^{R-1} \sum_{j_m=1}^{j} \int_{\mathbb{R}\times\mathcal{S}} \varphi_t(a,s;j,j_m,x,x)m_{x,t}$$
$$d\Phi_t(a,s;j,j_m,x,x).$$

6. There are no arbitrage-opportunities as expressed by (2.7) and (2.8).

7. The cross-sectional measure is generated as explained appendix 2.C.

Definition 2. A stationary equilibrium is a competitive equilibrium in which all individual functions are constant over time and all aggregate variables grow at a constant rate.

In the stationary equilibrium, both the population growth rate and the TFP growth rate are constant and identical in both regions. Assume that there exists a common balanced growth path along which the capital to output ratios are constant. Then, the growth rate of aggregate output in both regions is given by: $g = \left[(1+\rho)(1+n)^{\sigma}\right]^{\frac{1}{1-\lambda}}$.[3] With the growth rate of output at hand, the price of land in the stationary equilibrium can be derived as follows. The return on land (2.4), can also be written as:

$$R_{x,t} = \frac{(1-\lambda-\sigma)Y_{x,t}}{F_x}.$$

From (2.7), it then follows that the price of land in period t can be rearranged in the following way:[4]

$$P_{x,t} = \frac{\frac{(1-\lambda-\sigma)Y_{x,t+1}}{F_x} + P_{x,t+1}}{1+r}.$$

One can now substitute recursively for future land prices thereby expressing the current price of land as the discounted presented value of all future output per unit of land multiplied by the land share. To obtain a finite solution for the current land price, the interest rate must be larger than the output growth rate:

$$P_{x,t} = \frac{(1-\lambda-\sigma)}{r-g}\frac{Y_{x,t+1}}{F_x}. \tag{2.21}$$

This is exactly the case when the economy is on a dynamically efficient BGP.[5]

[3] Derivation is given in appendix 2.D.3.

[4] Note that the interest rate loses its time index since it is constant in the stationary equilibrium.

[5] İmrohoroğlu et al. (1999) show that including a fixed factor in an OLG model (in the same fashion as in my model) can have important implications for the welfare effects of pension systems. Basically, the presence of the fixed factor rules out the possibility of dynamic inefficiency, i.e. an overaccumulation of capital. The possibility of eliminating dynamic efficiency, however, is an important feature of PAYG systems and might lead to significant welfare gains. In an economy that is always dynamically efficient, PAYG systems have much less scope for being welfare improving.

2.4 Calibration

2.4.1 Demographics

I choose the parameter values such that the two regions resemble Germany and Austria. I compute results for two demographic scenarios, one referring to the year 2013 and the other to the year 2050. For both scenarios I set the region-wide population growth rate to zero.[6] The differences in the demographic scenarios are then described by differences in the idiosyncratic survival probabilities. The corresponding data on age-specific and country-specific mortality risk, including the forecast for 2050, is taken from Eurostat (2015a). I set the maximum age equal to 95, whereby agents enter the model at age 23. I further assume agents in both regions to retire at age 65. By plotting the population distribution in Germany corresponding to the years 2013 and 2050, figure 2.1 documents the significant change in demographic structures. In particular, we see a considerable reduction of the population mass among younger ages, and a corresponding increase at older ages.

Figure 2.1: Invariant Population Distribution

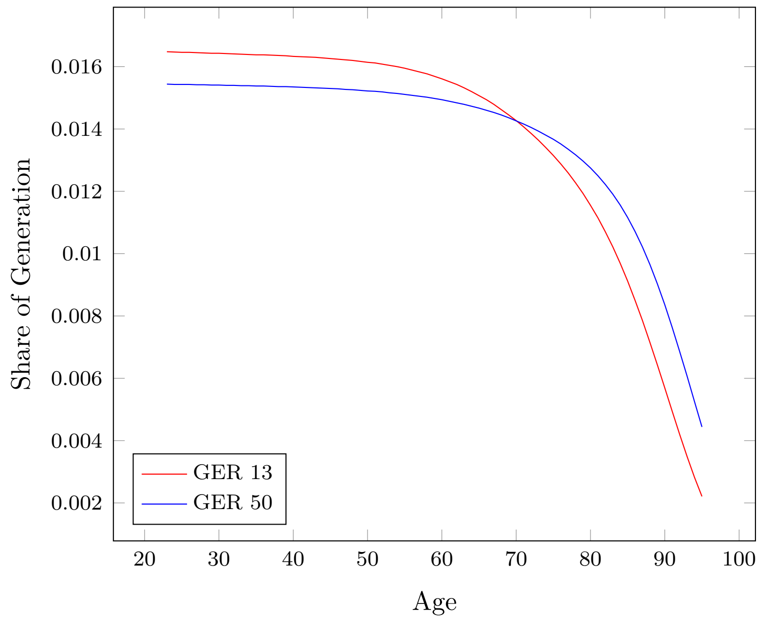


Table 2.3: Producitvity and Preference Parameters

Parameters	Value	Explanation
β	0.978	Discount factor
γ	2	IES
θ	0	Efficiency loss
λ	0.317	Capital share
σ	0.632	Labor share
δ	0.081	Depreciation rate
f	1	Land per woker
ω_{AT}	0.1045	Relative population share Austria
A_{GER}, A_{AT}	1	TFP factor
ρ	0.01	TFP growth rate

IES $\triangleq$ Elasticity of Substitution.

2.4.2 Productivity and Preference Parameters

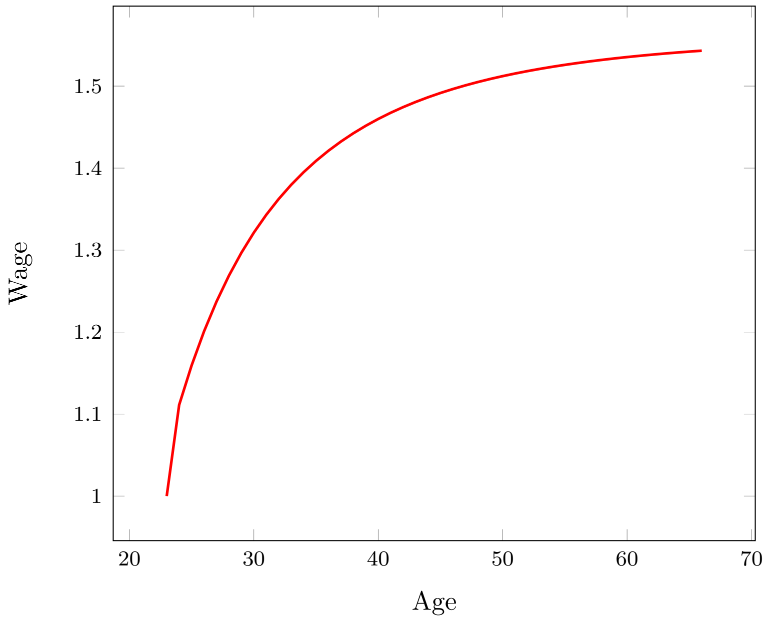
The productivity and preference parameters are mainly set in accordance with Klein and Ventura (2009) who use US data to pin down the values for the capital, labor and land share in the production as well as for the depreciation rate. They are summarized in table 2.3. I re-calibrate the discount factor to match their targeted capital to output ratio (2.18). The stock of land per worker is assumed to be equal in both regions and normalized to one thereby ensuring that - in the absence of labor mobility - wage gaps do not result from differences in endowments of land. The parameter γ governing the intertemporal elasticity of substitution in the CRRA utility function is set equal to two as common in the literature. For the benchmark calibration I assume the efficiency loss to be equal to zero which is based on the assumption that cultural differences between Germany and Austria are too small to actually affect productivity. In appendix 2.A, I present a sensitivity analysis for a small value of efficiency loss. ω_{AT} denotes the relative population share of Austria in the economy without labor mobility. I calibrate this parameter with respect to the relative population sizes in 2013 (Eurostat, 2015b). Lastly, I set the annual TFP growth rate (ρ) to 1%.

2.4.3 Wage Profile

The empirical wage profile is taken from Rupert and Zanella (2015) who analyze life-cycle profiles for hours, wages and earnings. This constitutes a deviation from the

[6] Note that population growth is actually already negative in both countries in 2013, whereas it is only slightly negative in Austria. In 2050, population growth rates are projected to fall even further. However, forecasts suggest that the demographic trend stabilizes towards the end of the century. I assume the demographic transition to be completed in 2050 and hence set the corresponding growth rate to zero. To capture the effect of aging, I also set the growth rate of 2013 equal to zero, otherwise the change in the demographic structure from 2013 to 2050 would seem less significant than it actually is.

Figure 2.2: Empirical Wage Profile



related literature which mostly refers to an efficiency index constructed by Hansen (1993) to obtain the shape of the life-cycle wage profile. Hansen (1993) estimates life-cycle efficiency by computing relative average hourly earnings for different age-sex groups over the years 1979 to 1987 on the basis of CPS and BLS data. Rupert and Zanella (2015) use much more up to date data to conduct their analysis. One of their data sources is also the CPS, the other is the PSID. After the full release of the 2011 wave, the PSID data set now covers individual life-cycle profiles over 43 years. Whereas the Hansen efficiency index implies a hump-shaped wage profile, the PSID indicates rising wages over the life-cycle for cohorts who have entered the labor market during the 1960s.[7] Note that even though wages do not fall, the findings by Rupert and Zanella (2015) are not in conflict with the usual wisdom that earning profiles are falling over the life-cycle. However, earnings result from both wages and hours worked. As shown by the authors, labor supply is indeed falling towards the end of the working life. I will use the wage profile of the youngest cohort in the in the PSID data set (born between 1942 and 1946). It is restricted to men. As pointed out by Rupert and Zanella (2015), this restriction is reasonable since female labor supply exhibited significant changes in the period considered. The profile is depicted in figure 2.2. The wage at age 23 is normalized to one.

[7]Using a pseudo panel constructed with CPS data, Rupert and Zanella (2015) find that wages decrease slightly, however, 10-15 years later than implied by the Hansen efficiency index. Otherwise, the life-cycle profiles obtained from both data sets are almost identical.

2.4.4 Pension System

The data used to calibrate the pension system are provided by OECD (2013). In particular, I choose the social security variables to match the net replacement rates of average earners in each country in 2013. The net replacement rate (ζ_x) has to fulfill the following equation:

$$b_{x,t} = \zeta_x \frac{1}{R} \sum_{j=1}^{R} w_{x,t-(R-1)+j} \bar{h} \epsilon(j)(1 - \tau_{x,t-(R-1)+j}). \tag{2.22}$$

The social security budget clears. Hence, $\tau_{x,t}$ and $b_{x,t}$ can be solved from (2.15),(2.16) and (2.22). Note that this calibration procedure implies that a migrant's replacement rate differs from that of a stayer since she has to work at least the first period in his country of origin. The net replacement rates of Germany and Austria are given by $\zeta_{GER} = 0.553$ and $\zeta_{AT} = 0.902$, respectively.

2.5 Results

I solve the model in the following way: First of all, the analysis is restricted to stationary equilibria. Further, I aim at identifying the effects of each dimension of factor mobility. Therefore, I first solve the model for a closed economy scenario, in which both countries coexist in autarky. In the second step, I compute the stationary equilibrium associated with capital mobility alone. In the third step, I additionally allow for labor mobility. Besides analyzing the effects of factor mobility on aggregates and prices, I further conduct a welfare analysis. Next, I repeat the procedure outlined for the demographic scenario of the year 2050.

2.5.1 Capital Mobility

Table 2.4 compares the stationary equilibrium for two specific model variants: The closed economy and the one with mobile capital and immobile labor. I start with explaining the results of the first. Due its size, aggregate variables of Austria are much smaller than the German ones.[8] Further, net foreign asset positions are necessarily zero. Since both countries solely differ with respect to their public pension arrangement (besides the idiosyncratic mortality risk, whereas the differences are very small), the much more generous pension system in Austria decreases saving incentives relative to the German economy resulting in higher interest rates. The lower saving incentives are also expressed in the lower per capita capital stock. Since the marginal productivity of

[8] See table 2.3 for the relative population share in the non-migration case.

labor increases in the capital stock, wages need to be lower, too. The difference in land prices is explained by (2.21): The output per unit of land is smaller in Austria, and hence, so is the land price. In the closed economy, household income equals domestic production. Due to lower investment, production possibilities in Austria are suppressed which pushes down per capita consumption.

Introducing capital mobility leads to an equalization of both interest rates and wages: Given the calibration of the land share, (2.8) reduces to the equalization of the capital to land ratios: $\frac{K^{GER}}{F^{GER}} = \frac{K^{AT}}{F^{AT}}$. If this holds, (2.3) then additionally implies $w_{AT} = w_{GER}$. After the introduction of capital mobility, the lower saving incentives in Austria prevail. Therefore, an equalization of interest rates can only be achieved through capital flows from Germany to Austria. In the new stationary equilibrium, Austria exhibits a strongly negative net foreign asset position (expressed relative to domestic GDP), while the German one is positive, but relatively modest.[9] Capital flows from Germany to Austria lead to an increase in the Austrian capital stock and in its production (both in aggregate as well in per capita terms). As a result of the inflow of capital, the Austrian interest rate decreases while the wage increases. Exactly the opposite is true for Germany. Pension benefits in both countries respond proportionally to wages thereby leaving the contribution rates unchanged. Price changes necessarily affect life-cycle consumption. A priori, the effect on per capita consumption is unclear since interests and wages respond in different directions. In total, per capita consumption in Austria decreases significantly, while there is a slight increase in per capita consumption in Germany. It remains to mention that from a region-wide perspective, the effect of capital mobility is only redistributive in nature: Neither the world capital stock nor world production are significantly affected.

2.5.2 Labor Mobility

The question of how migration decisions are influenced by the generosity of public pension systems connects to a field of literature that studies the welfare implications of pension systems to find the optimal replacement rate. The connection consists in the following way: Individuals deciding whether to move to another country with a different social security arrangement basically ask which system grants them the higher lifetime utility. Hence, before turning to the quantitative results, one can refer to the literature on optimal pensions to provide a motivation for the qualitative results of the model. In a recent study, Heer (2018) finds that the optimal replacement rate in the US economy amounts to approximately 5%. In an earlier study, İmrohoroğlu et al. (1999) claim that the optimal replacement rate is equal to zero. These results lead to the conclusion that the models commonly used to analyze the effects of pension

[9]Note that the difference in the size of the effect in both regions stems from the fact that Austria is relatively small compared to Germany.

Table 2.4: Effects of Capital Mobility

	Closed	Capital Mobility	
	Abs. value	Abs. value	% Change
Aggregates			
K^w	0.9978	0.9966	-0.12%
K_{AT}	0.095	0.1038	8.91%
K_{GER}	0.9025	0.8928	-1.07%
Y^w	0.4568	0.4567	-0.03%
Y_{AT}	0.0463	0.0476	2.74%
Y_{GER}	0.4105	0.4091	-0.34%
NFA_{AT}	0	-1.2025	
NFA_{GER}	0	0.1393	
Prices			
r_{AT}	0.0730	0.0643	-11.94%
r_{GER}	0.0632	0.0643	1.69%
w_{AT}	0.9413	0.9671	2.74%
w_{GER}	0.9704	0.9671	-0.34%
b_{AT}	0.3447	0.3542	2.74%
b_{GER}	0.2413	0.2404	-0.34%
p_{AT}	0.5228	0.6234	19.24%
p_{GER}	0.6380	0.6233	-2.30%
τ_{AT}	0.2460	0.2460	0.00%
τ_{GER}	0.1651	0.1651	0.00%
Per capita			
k_{AT}	0.9123	0.9935	8.91%
k_{GER}	1.0078	0.9970	-1.07%
c_{AT}	0.3627	0.3450	-4.90%
c_{GER}	0.3664	0.3684	0.56%

Note: NFA denotes the net foreign asset position, here expressed relative to domestic GDP. Per capita units refer to region-specific averages.

schemes can not rationalize the high replacement rates observed in European countries. Therefore, - ceteris paribus - individuals in the model presented here prefer living in the economy with the lower replacement rate, i.e. Austrians would prefer living in the German economy. There are three mechanisms in the model that prevent all Austrian citizens from migrating to Germany. Firstly, the disutility of living abroad to which a certain fraction of individuals is exposed. Secondly, migration comes at a cost. Hence, even though the German pension system is preferable, the migration process itself might be too costly. Thirdly, migration outflows in one country lead to a rise in the domestic wage relative to the foreign one. Using (2.2), (2.3) and (2.8), the relative wage of Austria can be written as:

$$\frac{w_{AT}}{w_{GER}} = \Big(\frac{L_{AT}/F_{AT}}{L_{GER}/F_{GER}}\Big)^{\frac{1-\lambda-\sigma}{\lambda-1}}. \tag{2.23}$$

Since the exponent is smaller than zero, a decrease in the Austrian labor input accompanied by an increase in the German one, rises the Austrian wage. In the new stationary equilibrium, migration incentives have vanished since the higher wage in Austria overcompensates the welfare loss stemming from the more generous pension system.[10]

Before describing the effects of labor mobility, some further remarks concerning the parameter choice have to be made. The distribution of preference types as well as the parameter of moving costs have been left unspecified so far. Regarding the former, it is important to recall that I restrict the analysis to stationary equilibria. In this respect, an important property outlined in Klein and Ventura (2009) carries over to my model: The stationary equilibria are independent of the distribution of utility costs as long as zero is in the support of the distribution, i.e. as long as there are agents facing no disutility from migrating. Those agents will always migrate if it is economic beneficial. The exact distribution of preference types then only controls the speed of convergence from one stationary equilibrium to the other. Since I do not analysis the transitional dynamics, it is sufficient to assume that there is a certain fraction (possibly small) with zero utility costs from living abroad, while the remaining part faces positive costs. Regarding the costs of moving, the parameter m could in principle be taken from empirical studies. Bayer and Juessen (2012) estimate migration costs from US interstate migration data using a structural model that explicitly takes self selection problems into account. This proves to be important because a model neglecting self

[10]Note that the given assumptions rule out migration in the steady state. In particular, the model presumes a constant rate of newborns over time (see appendix 2.C). Hence, as long as migration takes place, the population of the sending country decreases. Continuing shifts in the population distribution, however, are not compatible with a stationary equilibrium since they induce changes in factor prices (see e.g. (2.23)). To support migration as a steady state outcome it would be required to decouple population growth from migration, i.e. assume $n = 0$ irrespective of the level of migration.

selection might lead to upward-biased estimates of migration costs.[11] The authors come up with a cost estimate of about two-third of average annual household income. However, despite the fact that Bayer and Juessen (2012) provide a reliable estimate of moving costs, the pattern of migration are known to differ greatly between Europe and the US. This impedes a direct transferability, but the estimate might still serve as a benchmark. Further, results in my model are highly sensitive with respect to the choice of m. Hence, I will report the results for a given range of moving costs.

Figure 2.3: Stationary Population Distribution

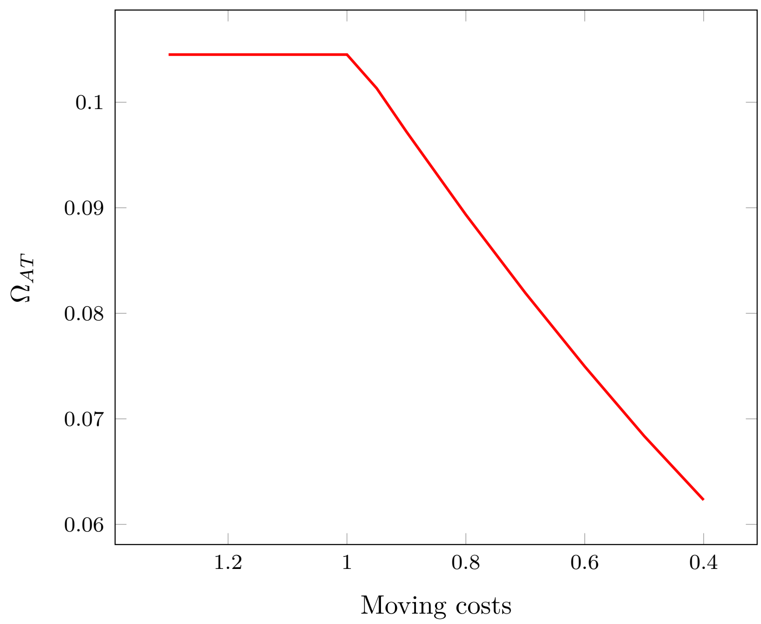


Figure 2.3 plots the population share of Austria in the new stationary equilibrium (Ω_{AT}) as a function of moving costs, which are themselves expressed as a share of annual GDP per capita. Every point on the curve corresponds to one stationary equilibrium associated with the specific level of moving costs. Basically, figure 2.3 answers the following question: After barriers to labor mobility have been removed, by how much does the relative population share of Austria have to be reduced such that the effect on wages is strong enough to switch off migration incentives. The range of migration costs comprises the values between 130% and 40% of annual GDP per capita. Between 1.3 and 1, the curve is flat, i.e. in this range moving costs are too high to induce migration. In the remaining interval, the curve is almost linearly declining thereby showing a significant reallocation of labor. For the lowest point in the interval, the Austrian population is decreased by more than 30%. To set the results in relation to the estimate by Bayer and Juessen (2012), note that due to the negative net foreign

[11] The reason is that the joint distribution of income and location of individuals results partly from past migration choices since migrants might have moved to the region where they are most productive. Therefore, if one does not take self selection into account, low migration rates might be attributed to high migration costs, whereas they just might be low because individuals have already selected themselves in their preferred region.

asset position, annual average household income in Austria is lower than annual GDP per capita. More precisely, in the economy without labor mobility, the estimate of Bayer and Juessen (2012) corresponds to $m = 0.62\%$ which would involve a significant reallocation of labor.

Table 2.5 summarizes the effects of introducing labor mobility to the model. Results are displayed for two values of moving costs, one equal to 90% and the other equal to 60% of annual GDP per capita. The first row in the category *Aggregates* refers to the relative population share of Austria (Ω_{AT}). For a value of 90% one already sees a significant migration response. For 60%, the outflow of Austrian workers is extremely large. Moreover, the wage effect discussed beforehand becomes quantitatively visible. Austrian wages increase, while German wages decline. Interest rates fall in both countries. This is due to the fact that now more people live in Germany and therefore more people have a higher saving propensity. Again, pension benefits adjust proportionally to wages which leaves contribution rates unchanged. On the aggregate level, Austrian figures decline because of the decrease in its relative population share. As in the case with capital mobility alone, the no arbitrage condition requires capital flows from Germany to Austria. In absolute terms, the net foreign asset position becomes less negative in Austria (+5.9%) and less positive in Germany (−5.1%). One channel to explain this observation is the following. Due the inflow of workers, it requires higher investment in the German economy. However, lower wages in this region imply lower savings which reduces the foreign claims. Recall that the NFA figures in table 2.5 refer to the net foreign asset position relative to domestic GDP. Therefore, the change in Austrian net foreign assets is negative because the absolute NFA position increases by less than GDP decreases. While the introduction of capital mobility led to a decline in average consumption in Austria, labor mobility rises the figure. Note that despite this increase, average consumption is still below the closed economy level.

2.5.3 Welfare Analysis

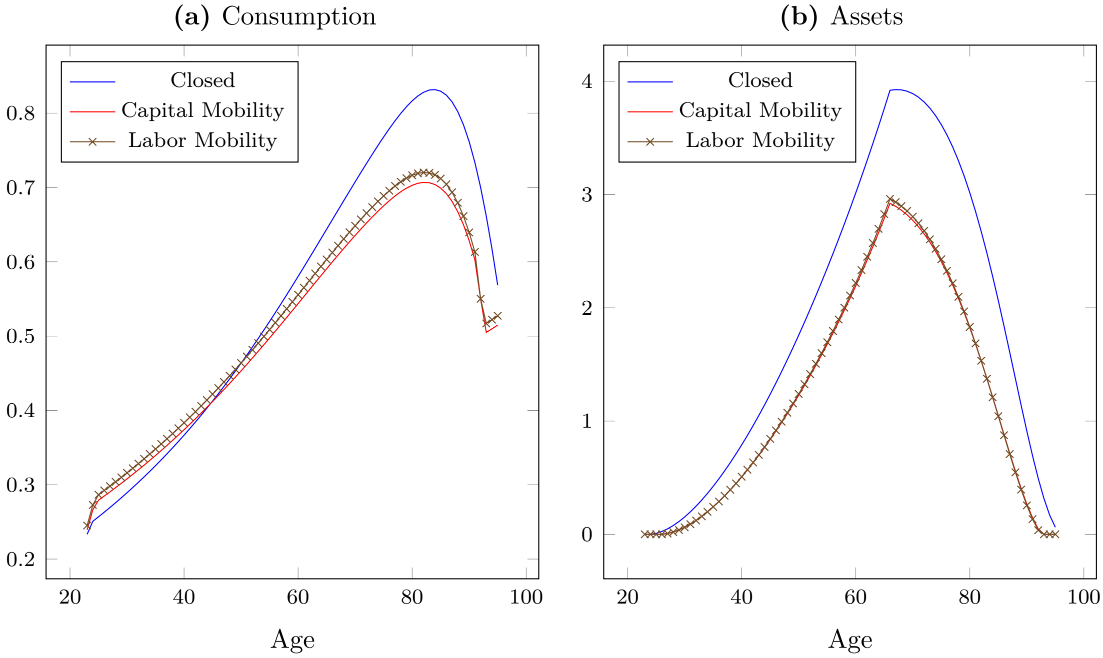
This section aims at uncovering the welfare implications of the interaction of factor mobility and non-harmonized public pension systems. In the preceding part of the section I showed that capital mobility decreases average consumption in Austria whereas labor mobility reverses the effect without leading it back to the closed economy level. However, lifetime utility is not determined by average consumption but by its allocation over the life-cycle. Figure 2.4 depicts the Austrian life-cycle profiles of both consumption and assets for different model variants. Due to the decline in the interest rate and the increase in wages, agents in the economy with capital mobility shift consumption to the earlier stages of life. Further, the overall asset holdings decline. By introducing labor mobility, wages increase further and the consumption profile shifts

Table 2.5: Effects of Labor Mobility

	Capital Mobility	Capital and Labor Mobility			
	Abs. value	Abs. value	% Change	Abs. value	% Change
Aggregates		mc=0.9		mc=0.6	
Ω_{AT}	0.1045	0.0971	-7.09%	0.0749	-28.29%
K^w	0.9966	0.9972	0.06%	0.9989	0.23%
K_{AT}	0.1038	0.0971	-6.53%	0.0765	-26.30%
K_{GER}	0.8928	0.9002	0.83%	0.9224	3.31%
Y^w	0.4567	0.4568	0.02%	0.4569	0.05%
Y_{AT}	0.0476	0.0445	-6.56%	0.0350	-26.43%
Y_{GER}	0.4091	0.4123	0.78%	0.4219	3.13%
NFA_{AT}	-1.2025	-1.2107	-0.68%	-1.2372	-2.89%
NFA_{GER}	0.1393	0.1310	-5.92%	0.1042	-25.21%
Prices					
r_{AT}	0.0643	0.0642	-0.09%	0.0640	-0.39%
r_{GER}	0.0643	0.0642	-0.09%	0.0640	-0.39%
w_{AT}	0.9671	0.9726	0.57%	0.9922	2.60%
w_{GER}	0.9671	0.9667	-0.04%	0.9655	-0.16%
b_{AT}	0.3542	0.3562	0.57%	0.3634	2.60%
b_{GER}	0.2404	0.2403	-0.04%	0.2400	-0.16%
p_{AT}	0.6234	0.5831	-6.46%	0.4607	-26.09%
p_{GER}	0.6233	0.6289	0.89%	0.6458	3.61%
τ_{AT}	0.2460	0.2460	0.00%	0.2460	0.00%
τ_{GER}	0.1651	0.1651	0.00%	0.1651	0.00%
Per capita					
k_{AT}	0.9935	0.9996	0.61%	1.0211	2.77%
k_{GER}	0.9970	0.9970	0.00%	0.9971	0.01%
c_{AT}	0.3450	0.3467	0.50%	0.3527	2.26%
c_{GER}	0.3684	0.3681	-0.08%	0.3671	-0.35%

Note: The first column contains the outcomes of the stationary equilibrium shown in table 2.4. The second and fourth columns contain values of stationary equilibria associated with labor mobility. The second corresponds to migration costs equal to 90% of annual GDP per capita, the fourth to 60% of annual GDP per capita. Columns three and five display the percentage changes relative to the stationary equilibrium with immobile labor.

Figure 2.4: Life-Cycle Profiles



Note: The graphs refer to the Austrian economy. Moving costs are equal to 60% of annual GDP per capita.

upwards.[12] How do these adjustments affect utility? To address this question I compute the consumption equivalent measure (Δ) to display the change in welfare. In particular, Δ denotes the percentage change in consumption necessary to make the individual indifferent between living in the closed and open economy. Δ is calculated from:

$$(1+\Delta)^{1-\gamma} V_{closed} = V_{open}, \tag{2.24}$$

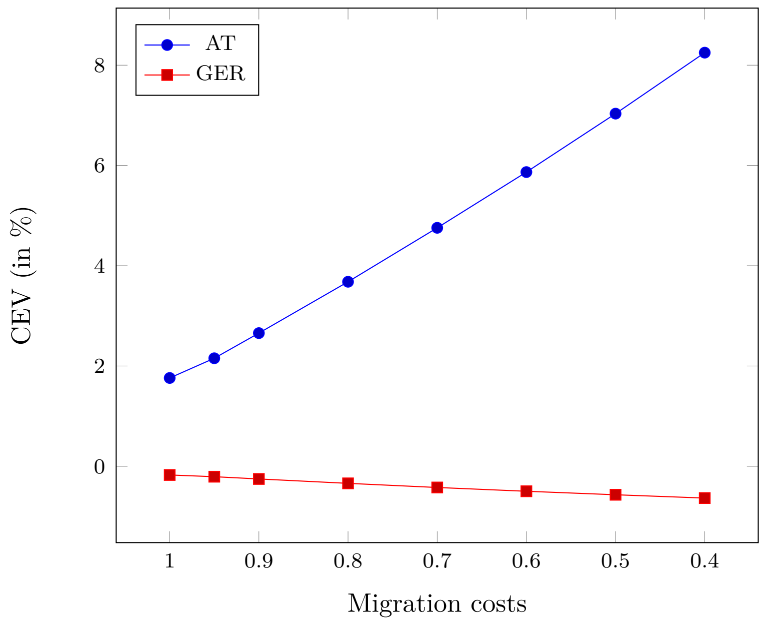
where V is stationary lifetime utility. The welfare effects are depicted in figure 2.5. Again, results are plotted for a certain range of moving costs. The highest level of moving costs considered amounts to 100% of annual GDP per capita which is exactly the lowest value for which migration is too costly. Hence, at the most left point of the x-axis one sees the pure welfare effect of capital mobility. From there onward, migration takes place and contributes to the welfare change. One can see that the introduction of capital mobility rises welfare in Austria and decreases it in Germany. Further, the lower migration costs and the stronger the reallocation of labor, the more pronounced are the welfare effects (while not changing the direction). So why does the different shape of the consumption profile in figure 2.4 induce a welfare gain? First of

[12]Note that the kink in the consumption profiles of the open economies arises because agents have completely dissaved at the late stages of life and just consume their pension benefits (visible in the figure 2.4 b).

all, due to discounting the higher consumption at younger ages implies a positive utility change. Moreover, consumption is reduced where it is already relatively high. Hence, the concavity of the utility function makes the positive welfare effect even stronger. For residents in Germany, welfare changes are much less intense since the effects on prices are smaller.

The results imply an important pattern: The economy with the low replacement rate partly takes over the negative effects of the more generous public pension in the foreign country. Firstly, capital mobility triggers an outflow of capital and decreases wages. Secondly, the inflow of foreign workers reinforces the decrease in wages thereby leading to an overall decline in welfare. On the other hand, the high replacement economy benefits from factor mobility since it attenuates the negative effect of its pension system.

Figure 2.5: Welfare Effects



2.5.4 The Effects of Aging

The results presented so far show that the responses of capital and migration flows to differences in public pension systems can be large. An obvious question is how these results change under the influence of population aging which is predicted to put a severe pressure on public pension systems. Due to its enormous impact, the demographic change will demand serious reforms of the social security systems to maintain their sustainability. For this reason, I follow Krueger and Ludwig (2007) and analyze the consequences of demographic change for three different policy scenarios. Firstly, I consider an adjustment of the social security tax, while keeping the replacement rate constant, i.e. on the level of 2013. Secondly, I adjust the replacement rate, while keeping the contribution tax constant. Lastly, I increase the statutory retirement age to 70 (with a constant replacement rate).

Figure 2.6 extends figure 2.3 by additionally showing the relative population of Austria in 2050 for each policy scenario. The following observations can be made: Keeping the replacement rate constant in both countries shifts the curve to the left. In this scenario, moving costs need to amount to 130% of GDP per capita to make migration too costly. For the lowest level of moving costs depicted, the Austrian population is reduced by almost 50%. The second policy scenario under consideration leaves the contribution rates unchanged. In that case, the model responses are less pronounced. A striking result is that increasing the retirement age to 70 weakens the migration responses relative to the year 2013. The significant differences in the migration responses arise because welfare costs increase non-linearly in the distortionary tax. Hence, although keeping the replacement rate constant increases contribution rates in both countries (and the German one even slightly more, see table 2.6), the welfare loss is considerably larger for agents in the Austrian economy triggering a stronger migration response than in the economy of the year 2013. The opposite is true for the scenario of the increase in the retirement age.

Figure 2.6: Stationary Population Distribution

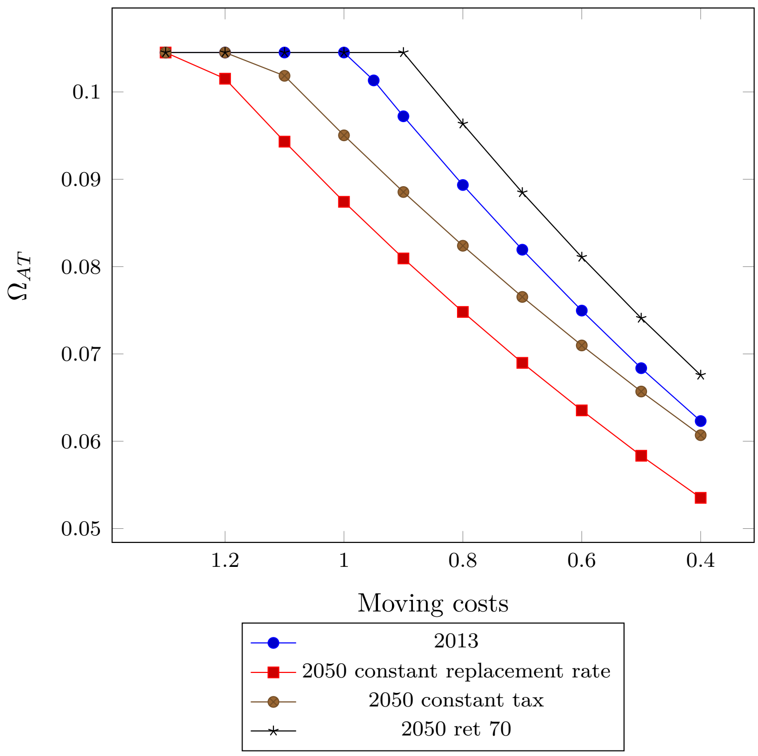


Table 2.6 displays the effect of aging on aggregates and prices, whereby the analysis is restricted to policy scenarios 1 and 3.[13] Everything else equal, population aging has

[13]Results for policy scenario 2 can be found in appendix 2.B.

three (partly opposing) effects on factor prices. Firstly, the higher life expectancy reduces the population share of the young relative to the old. Since in the life-cycle model the young save whereas the old dissave, aggregate savings decline thereby pushing up the interest rate. Secondly, the decrease in the working age to population ratio reduces labor supply and makes labor scarce relative to capital which increases wages and decreases the interest rate. These two effects constitute the *direct effects*. There is an additional *indirect* effect working through the social security system: If the contribution rate has to increase to keep replacement rates stable, this reduces private savings thereby driving up interest rates. Additionally, in the model with labor mobility, the reallocation of labor influences factor prices as described in the previous sections.

For the case of a constant replacement rate, the scarcity of labor increases wages in both countries. Relative to 2013 (for $m = 90\%$), migration responses are considerably larger and the Austrian population decreases by almost 17%. This additional outflow of workers leads to a stronger increase in the Austrian than in the German wage. Concerning the interest rate, the relative abundance of capital and the larger reallocation of labor dominate the other two effects (compositional effect and higher contribution rate) and pushes down the interest rate by about 7%. Even though capital is relatively abundant, the world capital stock decreases in absolute terms. This, in conjunction with lower labor input, decreases world output and per capita consumption in both countries.

If the retirement age is increased, the model shows a different response of factor prices: The decline in the interest rate is less pronounced and wages even decrease. In this context it is crucial that - despite the population aging - the higher retirement age increases the working age to population ratio thereby partly reversing the effects from the first policy scenario. Due to the higher labor supply, wages fall. Further, figure 2.6 shows that in the stationary equilibrium with $R = 70$ and $m = 0.9$, compared to 2013 relatively more people reside in Austria. Hence, wages in Austria are lower. Abstracting from labor movements, the higher working age to population ratio puts downward pressure on the interest rate since it implies larger aggregate savings. This effect is strengthened as the decline in the contribution rates additionally encourages private savings. However, as the reallocation of labor is less strong then in 2013, relatively more people are exposed to the higher replacement rate and exhibit a lower saving propensity. Further, capital becomes relatively scarce towards labor. This counteracts the additional downward pressure on the interest rate by the longer working life and the decrease turns out to be less severe. In total, the higher retirement age leads to a significant increase in world production and average consumption in both regions. The prolonging of the working life[14] therefore seems to be an effective measure to cope

[14]In Krueger and Ludwig (2007), the increase in the retirement age is also shown to significantly mitigate the consequences of demographic change.

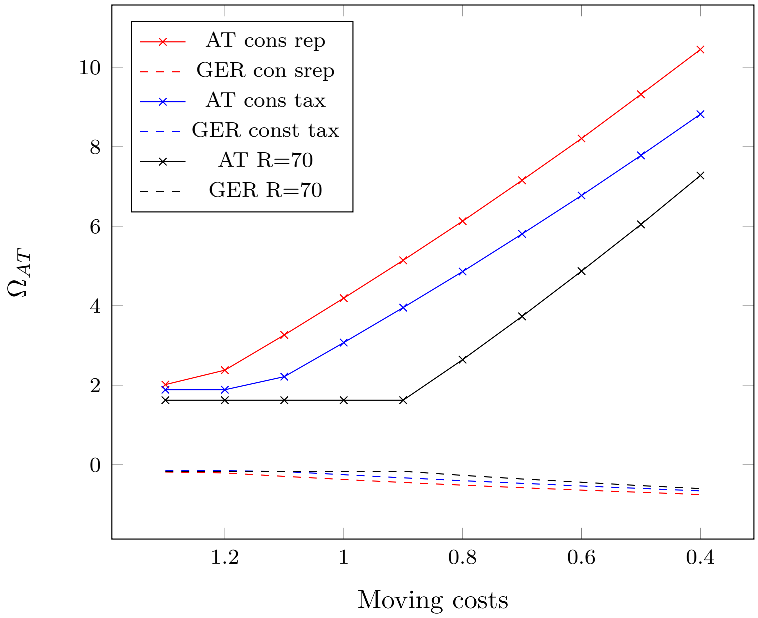
Table 2.6: Demographic Change

	2013	2050			
	Abs. value	Abs. value	% Change	Abs. value	% Change
Aggregates		Constant ζ		R=70	
Ω_{AT}	0.0971	0.0809	-16.65%	0.1045	7.64%
K^w	0.9972	0.9905	-0.68%	1.0580	6.09%
K_{AT}	0.0971	0.0816	-15.96%	0.1104	13.73%
K_{GER}	0.9002	0.9089	0.97%	0.9476	5.27%
Y^w	0.4568	0.4393	-3.83%	0.4816	5.44%
Y_{AT}	0.0445	0.0362	-18.62%	0.0503	13.04%
Y_{GER}	0.4123	0.4031	-2.23%	0.4314	4.63%
NFA_{AT}	-1.2107	-1.3567	-12.07%	-1.0389	14.18%
NFA_{GER}	0.1310	0.1234	-5.87%	0.1210	-7.65%
Prices					
r_{AT}	0.0642	0.0596	-7.17%	0.0633	-1.38%
r_{GER}	0.0642	0.0596	-7.17%	0.0633	-1.38%
w_{AT}	0.9726	1.0050	3.33%	0.9660	-0.68%
w_{GER}	0.9667	0.9842	1.81%	0.9661	-0.06%
b_{AT}	0.3562	0.3515	-1.31%	0.3826	7.41%
b_{GER}	0.2403	0.2369	-1.42%	0.2559	6.47%
p_{AT}	0.5831	0.5186	-11.07%	0.6701	14.92%
p_{GER}	0.6289	0.6719	6.84%	0.6690	6.37%
τ_{AT}	0.2460	0.2799	13.78%	0.2131	-13.37%
τ_{GER}	0.1651	0.1916	16.06%	0.1416	-14.22%
Per capita					
k_{AT}	0.9996	1.0079	0.83%	1.0563	5.67%
k_{GER}	0.9970	0.9889	-0.81%	1.0582	6.14%
c_{AT}	0.3467	0.3320	-4.24%	0.3650	5.27%
c_{GER}	0.3681	0.3507	-4.73%	0.3877	5.34%

Note: The table compares the model outcomes for the years 2013 and 2050. All cases refer to a stationary equilibrium in the model variant with labor mobility. Moving costs are equal to 90% of GDP per capita. The analysis for 2050 is distinguished for the case of a constant replacement rate (columns 2 and 3) and the case of a retirement age of 70 (columns 4 and 5).

with the economic implications of population aging in general and the associated larger responses of factor mobility in particular.[15]

Figure 2.7: Welfare Effects



Note: The consumption equivalent measure is computed relative to the closed economy in 2050. "Cons rep" refers to a constant replacement rate, "cons tax" to a constant contribution rate and "ret 70" to an increase of the retirement age to 70.

The welfare effects for the economy of the year 2050 exhibit a similar pattern to the ones presented in section 2.5.3. Basically, welfare changes resulting from capital mobility alone are close to the ones in figure 2.5. However, due to the larger reallocation of labor under policy scenario 1 and 2, welfare changes are more pronounced.

2.6 Conclusion

Factor mobility between countries that differ regarding the generosity of their pension systems has the potential to significantly impact prices, aggregates and welfare. As a general finding, the model shows that capital and labor movements induce a welfare redistribution between countries. Those states running less generous PAYG systems loose, whereas those granting a higher level of social protection benefit from factor movements.

The study quantifies the effects of factor mobility using a two-country large-scale OLG model calibrated to resemble a common economic area consisting of Austria and Germany. With a replacement rate of 90.2% for average earners, Austria runs a much

[15]A few words of caution are required here. As explained before, setting the common population growth rate in 2050 to zero may understate the degree of the demographic change. Under negative population growth rates, the effects of the first two scenarios might be larger, whereas the increase in the retirement age might not be strong enough to overcompensate the negative effects of aging.

more generous public pension system than Germany which grants a replacement rate of 55.3% for the average earner. Facing the higher net replacement rate, Austrian citizens in the model economy exhibit a lower saving propensity than Germans leading to a higher interest rate and a lower wage. The introduction of capital mobility to the model triggers large capital flows between the countries. In the new stationary equilibrium, Austria features a strongly negative net foreign asset position, equal to 120% of Austrian GDP. Likewise, the Austrian interest rate falls by about 1 percentage point while the wage increases by almost 3%. Extending the model by labor mobility leads to an outflow of workers from Austria whereas the strength of the reallocation effect depends highly on the level of moving costs. The threshold at which moving costs are just low enough to induce a positive migration response is equal to 100% of annual GDP per capita. For a level of 90%, the new stationary equilibrium is characterized by a reduction of the Austrian population by about 7%. Since more people reside in the low-replacement economy, the region-wide interest rate decreases slightly, while the wage in Austria increases relative to the German one (0.6%). Overall, factor mobility and the associated changes in factor prices allow for a welfare improving life-cycle consumption path in Austria, while the opposite holds for Germany. Population aging will challenge the sustainability of European welfare states. The model predicts that the aging process considerably increases the economic forces resulting from capital and labor mobility. Keeping the replacement rate on the level of 2013, the economy of the year 2050 exhibits a threshold of moving costs (for inducing migration flows) of 130% of annual GDP per capita. Further, the effects on factor prices, aggregates and welfare are significantly stronger. However, the model also predicts that suited policy reforms are able to limit the economic forces released by population aging. In this regard, an increase of the retirement age to 70 is shown to be an effective measure.

Appendix 2.A Sensitivity Analysis: Skill Loss

Figure 2.8: Stationary Population Distribution

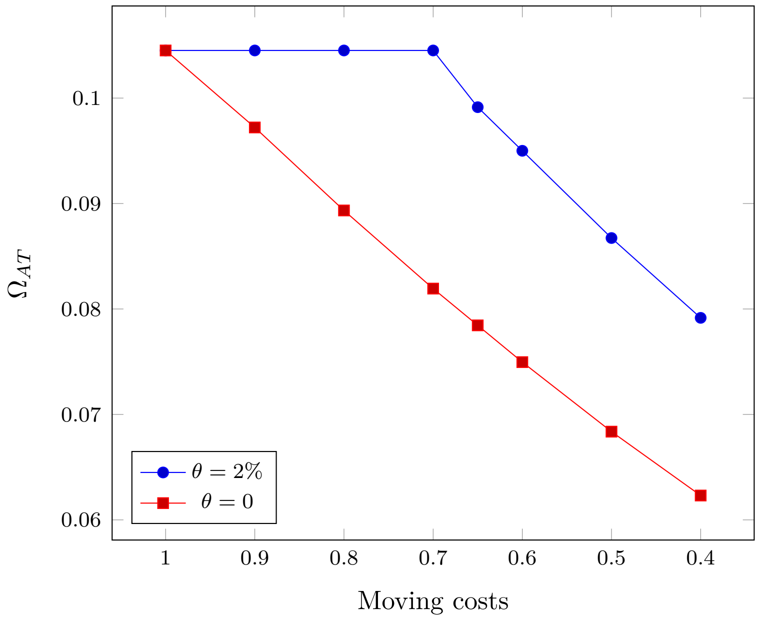


Table 2.8 shows the reallocation of labor in 2013 for the case without skill losses (as in figure 2.3) and for the case with a skill loss equal to 2%. Introducing skill losses extends the interval of moving costs for which migration is too costly (until m=70%) and therefore weakens the migration pressure significantly. In this context, two aspects should be noted. Firstly, compared to the benchmark estimate taken from Bayer and Juessen (2012), the migration response is still positive for $m = 0.62$. Secondly, in the economy of the year 2050, the curve would be further shifted to the left. Overall, the exercise suggests that the degree of labor movements depends strongly on the cultural similarity between countries.

Appendix 2.B Effects of Aging - Constant Contribution Rate

Table 2.7: Demographic Change II

	2013	2050	
	Abs. value	Abs. value	% Change
Aggregates		Constant τ	
Ω_{AT}	0.0971	0.0885	-8.82%
K^w	0.9972	1.0273	3.02%
K_{AT}	0.0971	0.0919	-5.28%
K_{GER}	0.9002	0.9354	3.91%
Y^w	0.4568	0.4444	-2.70%
Y_{AT}	0.0445	0.0398	-10.54%
Y_{GER}	0.4123	0.4046	-1.86%
NFA_{AT}	-1.2107	-1.2362	-2.11%
NFA_{GER}	0.1310	0.1218	-7.04%
Prices			
r_{AT}	0.0642	0.0561	-12.55%
r_{GER}	0.0642	0.0561	-12.55%
w_{AT}	0.9726	1.0099	3.83%
w_{GER}	0.9667	0.9963	3.06%
b_{AT}	0.3562	0.3104	-12.85%
b_{GER}	0.2403	0.2066	-14.02%
p_{AT}	0.5831	0.6128	5.09%
p_{GER}	0.6289	0.7251	15.29%
Per capita			
k_{AT}	0.9996	1.0384	3.88%
k_{GER}	0.9970	1.0263	2.94%
c_{AT}	0.3467	0.3352	-3.30%
c_{GER}	0.3681	0.3525	-4.25%

Note: The table compares the model outcomes for the years 2013 and 2050. All cases refer to a stationary equilibrium in the model variant with labor mobility. Moving costs are equal to 90% of GDP per capita.

Appendix 2.C Cross-Sectional Measure

We start with the newborns:

$$\Phi_{t+1}(A,S;1,1,x,y)=\begin{cases}N_{x,t+1}(1)\int_S \alpha(s)ds & \text{if } 0\in A \text{ and } x=y\\ 0 \text{ else}\end{cases},$$

where $N_{x,t+1}(1)$ is the mass of newborns in region region x in period $t+1$. Newborns arrive according to a constant birth rate (br): $N_{x,t+1}(1)=\Omega_{x,t}br$, where $\Omega_{x,t}$ denotes the relative population of region x in period t.

Due to endogenous migration, one has to keep track of the movements of agents across regions over time. The policy function associated with the migration decision is used to describe the following recursion. I start with the mass of individuals located in region x who still reside in region x in the next period (who did not move). For $1<j<R$:

$$\begin{aligned}&\Phi_{t+1}(A,S;j+1,j+1,x,x)\\&=\int_{\mathbb{R}\times\mathcal{S}}(1-\varphi(a,s;j,j,x,x))I\{a'_t(a,s;j,j,x,x)\in A\}d\Phi_t(a,s;j,j,x,x)\psi_{x,j},\end{aligned}$$

and for $R\leq j<J$

$$\Phi_{t+1}(A,S;j+1,R,x,x)=\int_{\mathbb{R}\times\mathcal{S}}I\{a'_t(a,s;j,R,x,x)\in A\}d\Phi_t(a,s;j,R,x,x)\psi_{x,j}.$$

Further, agents might have migrated from region $-x$ to region x. The mass of foreign-born in region x in period $t+1$ comprises those who already have migrated in the past and those who migrate in period t. For the new arrivals of age $j\in[2,R-1]$:[16]

$$\begin{aligned}\Phi_{t+1}(A,S;j+1,j,x,-x)=\int_{\mathbb{R}\times\mathcal{S}}&\varphi(a,s;j,j,-x,-x)I\{a'_t(a,s;j,j,-x,-x)\in A\}\\&d\Phi_t(a,s;j,j,-x,-x)\psi_{-x,j},\end{aligned}$$

For the past arrivals of age $j\in[2,J-1]$ and all $j_m\in[1,\min\{j-1,R-1\}]$:

$$\begin{aligned}\Phi_{t+1}(A,S;j+1,j_m,x,-x)=\int_{\mathbb{R}\times\mathcal{S}}&I\{a'_t(a,s;j,j_m,x,-x)\in A\}\\&d\Phi_t(a,s;j,j_m,x,-x)\psi_{-x,j}.\end{aligned}$$

[16] $j=R-1$ is the last period in which an agent can migrate.

Appendix 2.D Computation

In the following section I address two features of the model that require adjustments of rather standard algorithms used to compute stationary equilibria in large-scale OLG models. Firstly, the non-concavity of the household problem and secondly the steady state indeterminacy.

2.D.1 Applying the Endogenous Grid Method to Non-Concave Problems

To deal with the non-concavity, I follow Fella (2014) who generalizes the endogenous grid method (EGM) developed by Carroll (2006). The discrete choice contained in the migration decision and the fix costs of moving make the choice set non-convex. This, in turn, implies that the optimal policy correspondence may not be continuous and that the value function may not be differentiable. In this case, one usually has to rely on global solution methods which have the disadvantage of being notoriously slow. The basic idea behind the algorithm developed by Fella (2014) is to partition the problem into one part where the highly efficient method by Carroll (2006) can be smoothly applied and into another one where a global solution method is required.

EGM reverses the standard solution method for finding the optimal next period asset level. The standard procedure involves setting up a grid $\mathcal{G}_A$ for the initial asset level and solves the Euler equation for each point on the grid. On the contrary, the endogenous grid method defines a grid for the next period asset level ($\mathcal{G}_{A'}$) and solves the Euler equation backwards. Since the Euler equation is often linear in the initial asset level, but non-linear in the next period asset stock, the EGM avoids costly root finding and reduces computational time considerably.

In general, for non-concave problems the Euler equation is neither necessary nor sufficient for a global maximum, however, Fella (2014) argues that in the class of problems considered here the Euler equation still holds at a local maximum. Building on this property, the algorithm divides the grid for future assets ($\mathcal{G}_{A'}$) into a *concave region* ($\mathcal{G}^{c}_{A'}$) where the Euler equation is both necessary and sufficient and into a *non-concave region* ($\mathcal{G}^{nc}_{A'}$) where a global solution method is used to verify the solution obtained by EGM. If both solutions coincide, i.e. the local maximum is also a global one, the solution is saved, otherwise it is discarded. The important feature of the algorithm is that the use of the slower global method is restricted to a subset of $\mathcal{G}_{A'}$. To identify the non-concave region, one ought to take a look at the first order condition associated with the Bellmann equation:

$$U'(a, a') = \beta\psi_j \frac{\partial V(a', \tilde{z})}{\partial a'},$$

where $\tilde{z}$ denotes all state variables but the next-period asset choice. The Euler equation is sufficient for $a'_i \in \mathcal{G}_{A'}$ to be a global maximum, if a'_i is the unique intersection between the upward sloping curve $U'(a, a')$ and the downward sloping curve $\frac{\partial V(a', \tilde{z})}{\partial a'}$. The intersection is unique if for all $a'_j \in \mathcal{G}_{A'}$, it holds that $\frac{\partial V(a'_j, \tilde{z})}{\partial a'} > \frac{\partial V(a'_i, \tilde{z})}{\partial a'}$ for all $j < i$ and $\frac{\partial V(a'_j, \tilde{z})}{\partial a'} < \frac{\partial V(a'_i, \tilde{z})}{\partial a'}$ for all $j > i$. The regions of the value function for which this condition is not fulfilled delimits the non-concave region. Given $\tilde{z}$, the boundaries of the non-concave region (v_{min}, v_{max}) can be computed as the lowest value of $V(a', \tilde{z})$ and the highest value of $V(a', \tilde{z})$ for which the condition above does not hold. To project the boundaries onto the grid of future assets, one can calculate $\bar{i}$ as the smallest i for which $V(a'_i, \tilde{z}) < v_{min}$ and $\underline{i}$ as the largest i for which $V(a'_i, \tilde{z}) > v_{max}$. The non-concave region is then given by $\mathcal{G}^{nc}_{a'} = \{a'_{\underline{i}+1}, \cdots, a'_{\bar{i}-1}\}$.

In the following I outline the pseudo code. I restrict the description to a preference type $s \in S$ who actually migrates.

1. In period J: For all $j_m \in [1, R-1]$, all $x \in \{h, f\}$ and all $a_i \in \mathcal{G}_A$ obtain

$$\begin{aligned}
c(a_i, s, J, j_m, -x, x) &= (1+r)a_i + \pi(j_m) + tr \\
a'(a_i, s, J, j_m, -x, x) &= 0 \\
V(a_i, s, J, j_m, -x, x) &= u(c(a_i, s, J, j_m, -x, x)) \\
V_a(a_i, s, J, j_m, -x, x) &= u_c(c(a_i, s, J, j_m, -x, x))(1+r) \\
\Lambda_a(a_i, s, J, j_m, -x, x) &= \Big(\frac{V_a(a_i, s, J, j_m, -x, x)}{1+r}\Big)^{\frac{-1}{\eta}}.
\end{aligned}$$

   Note that I compute a transformation of the derivative of the value function $(\Lambda_a(\cdot))$. The idea is to use the transformation for the interpolation since it is much more linear than the derivative of the value function itself.

2. In period $j = J-1, \ldots, R+1$: The function $\Lambda_{a'}(a', s, j+1, j_m, -x, x)$ is known from the previous step. Invert it to obtain $V_{a'}(\cdot)$. For all $j_m \in \{1, R-1\}$, all $x \in \{h, f\}$ and $a'_i \in \mathcal{G}_{A'}$, solve

$$u_c = \beta\psi_j V_{a'}(a'_i, s, j+1, j_m, -x, x),$$

   in conjunction with the budget constraint for consumption (c_i) and beginning of period assets (a^{beg}_i). One can then save the policy functions and update the value functions. Note that this involves interpolation since policy and value functions have to be defined on the grid $\mathcal{G}_A$. Therefore interpolate policy and value functions for all $a_i \in \mathcal{G}_A$.

$$
\begin{aligned}
c(a_i, s, j, j_m, -x, x) &= c_i \\
a'(a_i, s, j, j_m, -x, x) &= a'_i \\
V(a_i, s, j, j_m, -x, x) &= u(c(a_i, s, j, j_m, -x, x)) + \beta\psi_j V(a'_i, s, j+1, j_m, -x, x) \\
V_a(a_i, s, j, j_m, -x, x) &= u_c(c(a_i, s, j, j_m, -x, x))(1+r) \\
\Lambda_a(a_i, s, j, j_m, -x, x) &= \Big(\frac{V_a(a_i, s, j, j_m, -x, x)}{1+r}\Big)^{\frac{-1}{\eta}}.
\end{aligned}
$$

3. In period $j = R, \ldots, 1$: The individual cannot migrate in the last period of working life (R). During the remaining periods, however, migration is possible. After migration has been taken place, the problem becomes concave since she cannot migrate back. For an individual who has not migrated, I first compute the continuation value associated with migrating and then the one associated with staying. As above, for all $a_i \in \mathcal{G}_A$:

$$
\begin{aligned}
v(a_i, s, j, j, x, x)^{stay} &= u(c^{stay}(a_i, s, j, j, x, x)) + \beta\psi_j V(a'_i, s, j+1, j+1, x, x) \\
v(a_i, s, j, j, x, x)^{migrate} &= u(c^{migrate}(a_i, s, j, j, x, x)) + \beta\psi_j V(a'_i, s, j+1, j, -x, x).
\end{aligned}
$$

Note that the problem of non-concavity arises when computing the value v^{stay} since $V(a'_i, \cdot)$ may not be differentiable due to the discrete choice as displayed in (2.12). Therefore, I apply the refinement of the EGM as outlined before. For all $a_i \in \mathcal{G}_A$, obtain:

$$V(a_i, s, j, j, x, x) = \max\{v(a_i, s, j, j, x, x))^{stay}, v(a_i, s, j, j, x, x))^{migrate}\}$$

Further, if $v(a_i, s, j, j, x, x)^{migrate} > v(a_i, s, j, j, x, x)^{stay}$:

$$
\begin{aligned}
\varphi(a_i, s, j, j, x, x) &= 1 \\
j_m &= j.
\end{aligned}
$$

2.D.2 Indeterminacy of Stationary Equilibria

As Klein and Ventura (2009) point out, the presence of moving costs implies a indeterminacy of stationary equilibria. More precisely, lump-sum costs of moving create a continuum of population distributions and hence a continuum of pairs of wages and pensions in both countries, for which there are no migration incentives. This has the following implication for the computation. As standard, one can iterate over the the aggregate variables $\{K^w, \Omega_{AT}, Tr\}$ to obtain a solution for the stationary equilibrium.[17] However, the values computed by the algorithm describe only one solution in the entire interval of all possible stationary equilibria. This raises the question of which stationary equilibrium to choose. Starting from the non-migration stationary equilibrium, I look for the new stationary equilibrium with the population distribution that is closest to the non-migration one. At this point, migration will just have stopped. In order to find this specific stationary equilibrium, I have to apply a numerical routine that scans the interval of possible population distributions $[\Omega_1^-, \Omega_1^+]$[18], whereby the first value equals the lowest relative population size in Austria consistent with a stationary equilibrium and the second value equals the highest one (the value of interest). The routine follows Klein and Ventura (2009) and can be summarized as follows:

- Take the non-migration (Ω_1^{*nomig}) and the migration stationary equilibrium computed (Ω_1^{*mig}) as inputs. Since $\Omega_1^{*mig} \leq \Omega_1^+$ holds, the solution has to be part of the interval $[\Omega_1^{*nomig}, \Omega_1^{*mig}]$. Hence, set $[\Omega_1^-, \Omega_1^+] = [\Omega_1^{*mig}, \Omega_1^{*nomig}]$.

- Guess $\Omega_1^0 \in [\Omega_1^-, \Omega_1^+]$. Solve for a stationary equilibrium with Ω_1^0 assuming that no one moves.

- Verify whether the stationary equilibrium is stable when migration is allowed: If not, set $\Omega_1^+ = \Omega_1^0$ and return to step 2. Otherwise set $\Omega_1^- = \Omega_1^0$ and return to step 2.

- Iterate until $\frac{|\Omega_1^+ - \Omega_1^-|}{\Omega_1^+} \leq \epsilon$

2.D.3 Output Growth Rate

The object of interest is the growth rate of aggregate output for a given constant population growth rate n, and TFP growth rate ρ. I drop the index x, since growth rates are identical in both regions.

$$\begin{aligned}
\frac{Y_{t+1}}{Y_t} &= \frac{A_{t+1} K_{t+1}^{\lambda} N_{t+1}^{\sigma} F^{1-\lambda-\sigma}}{A_t K_t^{\lambda} N_t^{\sigma} F^{1-\lambda-\sigma}} \\
&\Leftrightarrow \frac{(1+\rho) A_t (1+g_k)^{\lambda} K_t^{\lambda} (1+n)^{\sigma} N_t^{\sigma} F^{1-\lambda-\sigma}}{A_t K_t^{\lambda} N_t^{\sigma} F^{1-\lambda-\sigma}} \\
&\Leftrightarrow (1+g) = (1+\rho)(1+g_k)^{\lambda}(1+n)^{\sigma}.
\end{aligned}$$

[17] Note that one only has to iterate over the relative population distribution of one country since $\Omega_{GER} = 1 - \Omega_{AT}$ follows directly.

[18] The subscript 1 indicates the first region.

Along the BGP, the capital to output ratio is constant which implies $g = g_k$. From this it follows:

$$(1+g) = (1+\rho)(1+n)^{\sigma}(1+g)^{\lambda}$$
$$\Leftrightarrow g = \left[(1+\rho)(1+n)^{\sigma}\right]^{\frac{1}{1-\lambda}} - 1.$$

3. Demographic Change and Labor Mobility

3.1 Introduction

All European economies face severe challenges in the light of future demographic change that entails important consequences for the evolution of both factor prices and returns to the PAYG systems. Even though all societies are aging, the pattern of the demographic transition differs between the countries. Moreover, European countries exhibit a heterogeneity with respect to the institutional design of their public pension systems. As a consequence, population aging imposes disparate burdens on national social security. Both the differences in aging processes and the non-harmonization of public pension systems give rise to possible spill-over effects between European economies.

So far, macroeconomic studies have focused on capital mobility as a possible channel for these spill-over effects. Thereby they have treated migration, another dimension of the open economy, as purely exogenous, either by relying on migration forecasts (Krueger and Ludwig, 2007) or by comparing alternative immigration scenarios (Storesletten, 2000). My contribution to the literature is to analyze and quantify endogenous migration flows between European countries along the demographic transition. In particular, I investigate how changes in relative factor prices and in relative returns to the tax and transfer system induced by populating aging influence the decision of foreigners to migrate to Germany. Within the framework of a multi-country OLG model I account for two sending regions, Southern Europe and Poland. Both regions exhibited positive net emigration rates towards Germany in the past. Further, all countries under investigation allow a free movement of workers between them. Modeling two sending regions explicitly is important in order to capture the distinctive regional pattern of population aging and the differences in the generosity of the public pension systems. An important feature of my model is the presence of a fixed factor in the production function as in Klein and Ventura (2009) or İmrohoroğlu et al. (1999). It has two main effects. Firstly, it establishes a direct link between differences in aging patterns and the evolution of relative wages resulting into a significant variation in migration incentives along the demographic transition. Secondly, it implies that migration has an opposing effect on wages in Germany and on wages in the sending regions. The fixed factor therefore influences both the shape of migration flows and their macroeconomic effects.

The analysis is divided into different steps. Firstly, I use the model to predict migration flows to Germany over the next decades. Secondly, I analyze their consequences for macroeconomic aggregates, prices and benefits. Thirdly, I perform a welfare analysis that sheds light on the distributional effects between countries resulting out of intra-European migration movements.

The demographic change will require reforms of the social security system to ensure financial sustainability thereby giving rise to different policy scenarios. On the one hand, the financial burden could be placed on pension benefits while keeping the contribution tax stable. On the other hand, the contribution rate could adjust to match a certain replacement rate. The analysis is carried out for each policy scenario. In both variants, net immigration rates in Germany are predicted to fall over the course of the century. However, net immigration exhibits a higher level in the second policy scenario. One of the key insights of the quantitative analysis is that despite the moderate size of endogenous migration flows, they still have strong macroeconomic implications. This can be explained by the *dual* effect of migration: In this growth model with an explicit demographic structure, immigration directly increases labor supply, but it also indirectly increases the future workforce by enhancing population growth. Endogenous migration leads to decreasing gross wages in Germany and increasing gross wages in the sending regions. Likewise, migration induces higher returns to the social system in Germany, i.e. higher benefits or lower taxes[1], whereas the opposite holds true for the sending regions. In general, the simulation exercise reveals that benefits (or taxes) are significantly more elastic with respect to migration flows than wages. The reason for this lies in the mobility of capital: The negative impact of a higher labor supply on gross wages is counteracted by an inflow of capital accompanying immigration. The welfare effects of the predicted migration flows crucially depend on the policy scenario. In the case of constant contribution rates, older German cohorts experience moderate welfare gains due to higher benefits during retirement. For younger generations, these welfare gains decrease over time since the reduction in gross wages becomes more pronounced. One observes the opposite welfare effects in the sending regions. In case of a rising contribution rate, distortions from the pension system are generally larger since they directly affect net wages. Consequently, the mitigation of those distortions due to immigration induces considerable welfare gains in Germany that grow along the demographic transition. These positive welfare effects are, however, mirrored by significant welfare losses in the sending regions that are especially severe in Poland.

My paper connects to and extends a field of literature dealing with the quantitative

[1] In the paper I will use the terms *tax* and *contribution rate* interchangeably.

analysis of macroeconomic implications of demographic change. In the context of an open economy model, Krueger and Ludwig (2007) shed light on the importance of spill-over effects induced by capital flows between Europe and the United States. Moreover, Börsch-Supan et al. (2006) analyze, inter alia, intra-European capital flows, whereas Attanasio et al. (2007) investigate the effects of the demographic transition in the industrialized world on developing countries. Focusing on closed economy models, more recent papers embed complex decision problems on both household and firm side to study more closely the reactions of market participants to the demographic change. Ludwig et al. (2012) add a Ben-Porath human capital technology, whereas Geppert (2015) further accounts for a discrete college decision. On the firm side, Heer and Irmen (2014) explore the role of an endogenous growth mechanism through labor-saving technological change. The modeling approach of the migration decision is taken from Klein and Ventura (2009) who study the long-run effects of unrestricted labor mobility while abstracting from realistic demographics or social security.

Moreover, some studies addressed the question of whether immigration can resolve the fiscal problems caused by rapid population aging. Storesletten (2000) sets up a general equilibrium OLG model and computes the size and composition of immigration necessary to balance the U.S. government budget and thus to prevent a tax increase. He finds that selective immigration policies aiming at attracting working age high-skilled and medium-skilled workers can dampen the pressure for higher taxes. Importantly, however, an increase in immigrants with the age and skill composition of the migrant population in 1990 does not alleviate the need for reform. In a similar spirit, but abstracting from general equilibrium effects, Storesletten (2003) argues that the fiscal net present value of a young working migrant is positive in Sweden, while the corresponding value of an average new immigrant is negative. Further, Fehr et al. (2004) compare the general equilibrium effects of different immigration scenarios in the U.S., Japan and the EU. In contrast to Storesletten (2000), the authors include population projections to explicitly study the demographic transition. Overall, they find that even doubling immigration cannot mitigate the negative consequences of the decline in the workforce. My paper provides two important insights these earlier studies do not account for. Firstly, I show that migration flows respond to changes in the economic environment along the demographic transition. Hence, comparing exogenous variations in future migration levels ignores the question of whether such immigration flows would arise in general equilibrium. Secondly, I do not only analyze the consequences of immigration in the destination region, but explicitly quantify the effects of emigration in the sending regions. Concluding, it should be pointed out that my paper does not claim to capture all dimensions of migration decisions. An important reason for individuals to migrate that I do not account for is the escape of unemployment as analyzed in Hassler et al. (2005).

The paper is organized as follows. In section 3.2, I describe the underlying theoretical model and define the equilibrium conditions. Subsequently, section 3.3 discusses the calibration strategy. Section 3.4 covers the main positive results of the benchmark model, including the predicted pattern of migration movements and their impact on prices and aggregates. The previous analysis is revisited for a different policy scenario in section 3.5. Lastly, based on this positive analysis, I further shed light on the welfare implications of intra-European migration flows.

3.2 Model

3.2.1 Regions

The entire model economy consists of three different regions, one destination region (d) and two sending regions (s_1, s_2). Individuals living in either s_1 or s_2 can migrate to d, however, migration is not possible between the sending regions and individuals in d are assumed to be immobile. Migration is further modeled as an irreversible decision, hence, there is no return migration. In the quantitative analysis, the destination region will be calibrated to resemble Germany. One of the sending regions will depict Poland, and the other will represent a joint region of Southern Europe comprising Italy, Spain, Portugal and Greece.

3.2.2 Demographics

The main driving force for the dynamics in the model is the demographic evolution in each of the regions. In contrast to the related literature, however, demographics are not completely exogenous but depend on endogenous migration choices by model agents. Consequently, a fully comprehensive description of the demographic structure needs to rely on the agents' policy functions. I delegate this to appendix 3.A and present here a simplified version.

Based on a pre-determined stationary age distribution in the initial steady state, population dynamics in the sending regions are described by:

$$\begin{aligned}
\mathcal{N}_{t+1,j+1,s_i} &= \mathcal{N}_{t,j,s_i}\Big((1-\tilde{m}_{t,j,s_i})\psi_{t,j,s_i} + m_{t,j,s_i}\Big) \\
m_{t,j,s_i} &= 0 \ \ \textit{if} \ \ j > 20 \\
\mathcal{N}_{t+1,0,s_i} &= \sum_{j=15}^{50} f_{t,j,s_i}\mathcal{N}_{t,j,s_i}
\end{aligned} \tag{3.1}$$

And for the destination region:

$$
\begin{aligned}
\mathcal{P}_{t+1,j+1,d} &= \mathcal{P}_{t,j,d}\psi_{t,j,d} + \mathcal{N}_{t,j,d}m_{t,j,d} \\
\mathcal{P}_{t+1,j+1,s_1} &= \Big(\mathcal{P}_{t,j,s_1} + \mathcal{N}_{t,j,s_1}\tilde{m}_{t,j,s_1}\Big)\psi_{t,j,s_1} \\
\mathcal{P}_{t+1,j+1,s_2} &= \Big(\mathcal{P}_{t,j,s_2} + \mathcal{N}_{t,j,s_2}\tilde{m}_{t,j,s_2}\Big)\psi_{t,j,s_2} \\
\mathcal{N}_{t,j,d} &= \mathcal{P}_{t,j,d} + \mathcal{P}_{t,j,s_1} + \mathcal{P}_{t,j,s_2} \\
m_{t,j,d} &= 0 \quad \textit{if} \quad j > 20 \\
\mathcal{N}_{t+1,0,d} &= \sum_{j=15}^{50} f_{t,j,d}\mathcal{N}_{t,j,d}
\end{aligned}
\tag{3.2}
$$

As it can be seen, the demographic model of the destination region exhibits a more complex structure. But let us first focus on the similarities: In all regions, agents become economically active at the age of 20. Further, individuals live up to a maximum age of 95. Until then, they survive from one period to the other with a probability of $\psi_{t,j,x}$. Newborns arrive according to the fertility rates $f_{t,j,x}$. Hence, both mortality risk and fertility rates depend on time (t), age (j) and region (x). The entire simulation period spans the years from 1950 to 2300.[2]

The two demographic models differ due to endogenous migration. In general, migration shapes a country's population in the following way: Firstly, it contains an endogenous part ($\tilde{m}_{t,j,s_i}$) covering the net emigration rate from sending region s_i. Secondly, migration consists of an exogenous part ($m_{t,j,x}$) which refers to country's x net migration rate towards the rest of the world. Both migration rates are age-specific. In contrast to $\tilde{m}_{t,j,s_i}$, $m_{t,j,x}$ can be either positive (net immigration) or negative (net emigration).

The population distribution of the sending regions is captured in $\mathcal{N}_{t,j,s_i}$. Note that $\mathcal{N}_{t,j,s_i}(1 - \tilde{m}_{t,j,s_i})$ denotes the population in region s_i after the endogenous migrants have moved. Exogenous migrants, however, arrive according to the pre-endogenous-migration population. Further, before arriving in d, endogenous migrants are still subject to mortality risk.

The population in d for each age j and at any point in time t is given by $\mathcal{N}_{t,j,d}$ which, in turn, consists of three terms: The number of natives and previous exogenous migrants ($\mathcal{P}^d_{t,j,d}$) and the number of previous migrants from both sending regions ($\mathcal{P}^d_{t,j,s_1}$,$\mathcal{P}^d_{t,j,s_2}$). Importantly, I assume that endogenous migrants remain to be exposed to the mortality risk of their home region thereby ensuring that differences in survival probabilities do not influence migration decisions. Consequently, the population in d

[2] The length of this time span is common in this literature. Going far back in time serves to minimize the influence of the artificial initial steady state on the demographic transition in the 21st century. Moreover, it is necessary to grant a long fading out period to ensure a convergence to a final steady state.

includes agents with different mortality risk. Therefore, the recursions in (3.2) have to be stated for each group separately.

Concerning the exogenous migrants, I follow Krueger and Ludwig (2007) and assume that all migrants are equally distributed among the age groups less than or equal to 20. This allows for a symmetric treatment of natives and exogenous migrants.

3.2.3 Production

The production side is equivalent to the one in Klein and Ventura (2009): All regions produce one single good using a CRS production technology requiring land (F), labor (L) and capital (K) as input factors:

$$Y_{x,t} = Z_{x,t} K_{x,t}^{\nu} L_{x,t}^{\sigma} F_x^{1-\nu-\sigma} \tag{3.3}$$

for $x \in \{d, s_1, s_2\}$. $Z_{x,t}$ denotes the technology level in the respective region. Even though $Z_{x,t}$ is allowed to differ in levels, it grows at a common rate g in all countries. Land is assumed to be fixed implying jointly diminishing returns to labor and capital. Further, the capital and labor share parameters ν and σ are constant over time and across regions. Capital depreciates at a country independent rate δ. Finally, perfect competition among firms requires an equalization of the input factors' marginal products and their prices:

$$r_{x,t}^{k} = \nu Z_{x,t} K_{x,t}^{\nu-1} L_{x,t}^{\sigma} F_x^{1-\nu-\sigma} - \delta \tag{3.4}$$

$$w_{x,t} = \sigma Z_{x,t} K_{x,t}^{\nu} L_{x,t}^{\sigma-1} F_x^{1-\nu-\sigma} \tag{3.5}$$

$$r_{x,t}^{f} = (1-\nu-\sigma) Z_{x,t} K_{x,t}^{\nu} L_{x,t}^{\sigma} F_x^{-\nu-\sigma} \tag{3.6}$$

3.2.4 Households

In the following section I describe the decision problem of an individual in a sending region. Agents in the destination country face a similar optimization problem, however, they cannot migrate.

Preference Heterogeneity

I follow Klein and Ventura (2009) and allow for a preference heterogeneity among individuals in the sending regions. In particular, agents differ with respect to utility costs they have to bear when living abroad (μ_κ), whereby κ denotes the preference type which is realized at birth and fixed over the life-cycle. This specific model feature serves mainly two purposes. First of all, the fact that a fraction of the population suffers from large utility costs in the foreign destination ensures that only a certain part of the workforce leaves the home country. Furthermore, it allows to match simulated and empirically observed net migration rates by calibrating the preference distribution.

Life-Cycle Decisions

Agents make life-cycle choices concerning consumption, savings and labor supply. Further, they can decide to migrate in every period of their working life, except for the last one ($j < R$).[3] Denoting age with j and period of time with t, lifetime utility of an agent in sending region s_i with preference type κ can then be written as:

$$\max \sum_{j=1}^{J} \beta^{j-1} (\prod_{k=1}^{j} \psi_{t+k-1,k-1}) \left[\frac{(c_{t+j-1}^{\gamma}(j)(1-l_{t+j-1}(j))^{1-\gamma})^{1-\eta}}{1-\eta} - \mu_{\kappa} \mathbb{1}_{x_{t+j-1}(j) \neq s_i} \right]$$

$\frac{1}{\eta}$ denotes the intertemporal elasticity of substitution and γ describes the relative weights of consumption and leisure. All these standard parameters of the utility function are assumed to be equal across countries. $x(j)$ refers to the place of residence at age j. Due to the indicator function the disutility term only enters the household problem if the agents' place of residence is not equal to her place of birth ($x(j) \neq s_i$). The budget constraint can be expressed as follows:

$$(1 + r_t)a_t(j) + e_{s_i,t}(j) = a_{t+1}(j + 1) + c_t(j) \tag{3.7}$$

A part of individuals' income is derived from assets ($a_t(j)$). In particular, they can invest in both capital and land. Each asset type is divisible. Further, agents are allowed to invest abroad. This gives rise to two no-arbitrage conditions that have to hold in equilibrium in the open economy:

$$1 + r_{x,t} = \frac{p_{x,t} + r_{x,t}^{f}}{p_{x,t-1}} \tag{3.8}$$

$$r_t = r_{x,t} \quad \forall x \in \{d, s_1, s_2\}. \tag{3.9}$$

Equation (3.8) defines the intra-regional no-arbitrage condition between both asset

[3] I rule out migration in $j = R$ since there is no possible utility gain from just living abroad during retirement (see section 3.2.4).

types whereby $p_{x,t}$ denotes the price of land in region x and in period t. Equation (3.9), on the other hand, demands an equalization of returns on assets between regions. Under these conditions, asset holdings can be summarized in one single variable.

A further income source is captured in the earnings function $e_{s_i,t}(j)$ consisting of both net labor income and pension benefits:

$$\begin{cases} w_{s_i,t}(1-\tau_{s_i,t})l_t(j)\epsilon(j) & \text{if} \quad j < R \ \ \& \ \ x_t(j) = s_i \\ w_{d,t}(1-\tau_{d,t})(1-\theta)l_t(j)\epsilon(j) & \text{if} \quad j < R \ \ \& \ \ x_t(j) \neq s_i \\ \pi(.) & \text{else.} \end{cases} \tag{3.10}$$

Individuals work until they reach an exogenous retirement age R. If an agent has not migrated she earns the home wage ($w_{s_i,t}$) and pays the home contribution tax ($\tau_{s_i,t}$). Further, her earnings depend on individual labor supply ($l_t(j)$) and the life-cycle efficiency profile ϵ which is identical in all regions. If the agent has migrated in the past, she earns wages paid in d and has to pay the corresponding contribution tax. However, she experiences a skill loss according to θ. Pension benefits are determined by the function $\pi(\cdot)$ as explained in the next section.

Pension Benefits

Each region runs a PAYG system collecting contributions from the working force and providing benefits for the retirees. The exogenous retirement age R is identical in all countries. Benefits are assumed to be independent of individual labor supply over the life-cycle. This assumption is made in order to avoid the additional computational burden associated with introducing a continuous state variable necessary to link individual labor supply and retirement benefits. However, this constitutes a simplification since all pension systems of the countries relevant to this paper feature an earnings-related component (OECD, 2015).

National pension systems are linked via a *place of residence* principle[4], i.e. workers acquire pension claims in each country they work. Individual benefits of migrants consequently depend on the number of periods worked in each destination. Formally, the pension rule is defined as follows:

$$\pi_t(j_m) = \frac{j_m b_{s_i,t} + (R - j_m) b_{d,t}}{R} \quad \text{for} \quad 0 < j_m \leq R, \tag{3.11}$$

$b_{s_i,t}$ refers to the benefits paid to stayers in sending region i whereas $b_{d,t}$ are the

[4]This transferability of pension claims is ensured by European law.

benefits paid to natives in d. j_m is a state variable of the household optimization problem indicating the highest age at which an agent worked in her country of birth. If migration does not take place over the life-cycle, $j_m = R$ holds and the benefits are equal to b_{s_i}. However, if the individual chooses to migrate, she receives a weighted average of benefits paid to non-migrants in both countries.

Recursive Formulation

To illustrate the discrete choice problem associated with migrating, I display the recursive formulation of the household problem for all agents in the economy that actually can migrate, namely working agents ($j < R$) residing in a sending region. Defining the vector of state variables as $z = (a, \kappa, j, j_m, x, s_i)$[5], and denoting the policy function associated with migrating with φ, the decision problem reads:

$$
\begin{aligned}
&V_t(a, \kappa, j, j, x, s_i) = \max_{c,l,a',\varphi} \Big[U(c, l) + \beta\psi_{s_i,t,j} \Big\{ \varphi V_{t+1}(a', \kappa, j+1, j, d, s_i) \qquad (3.12)\\
&+ (1-\varphi)V_{t+1}(a', \kappa, j+1, j+1, s_i, s_i) \Big\} \Big]\\
&s.t. \quad c + a' = (1 + r_t)a + e_{s_i,t}(j)\\
&c, a' > 0, l \in [0, 1], \varphi \in \{0, 1\}.
\end{aligned}
$$

3.2.5 Government

Additionally to administrating the PAYG system, the government in each country collects accidental bequests and spends it on government consumption $G_{x,t}$.

3.2.6 Equilibrium

I define $\Phi_t(a; \kappa, j, j_m, x, y)$ as the mass of people with asset stock $a \in \mathcal{A}$, type $\kappa \in \mathcal{K}$, age $j \in [1, J]$, last period of working in country of birth $j_m \in [1, R]$, place of residence $x \in \{d, s_1, s_2\}$ and place of birth $y \in \{d, s_1, s_2\}$ in period t.

Definition A competitive equilibrium consists of sequences of individual functions for the household $\{V_t(\cdot), c_t(\cdot), l_t(\cdot), a'_t(\cdot), \varphi_t(\cdot)\}_{t=0}^{\infty}$, sequences of production plans for the firms $\{K_{x,t}, L_{x,t}\}_{t=0,x\in\{d,s_1,s_2\}}^{\infty}$, policies $\{\tau_{x,t}, b_{x,t}\}_{t=0,x\in\{d,s_1,s_2\}}^{\infty}$, prices $\{w_{x,t}, r_{x,t}, p_{x,t}, R_{x,t}\}_{t=0,x\in\{d,s_1,s_2\}}^{\infty}$ and measures $\{\Phi_t\}_{t=0}^{\infty}$ such that

1. Given prices and transfers, $c_t(\cdot), l_t(\cdot), a'_t(\cdot), \varphi_t(\cdot)$ solve the individual's dynamic problem and $V_t(\cdot)$ are the associated value functions.

2. Factor prices satisfy (3.4),(3.5),(3.6).

[5] The last element refers to the agent's place of birth, the second last element to the current place of residence.

3. The social security budget clears in each country:

$$\tau_{x,t} w_{x,t} L_{x,t} = Pen_{x,t}, \tag{3.13}$$

where pension payments in country d are given by:

$$\begin{aligned} Pen_{d,t} = b_{d,t} \Bigg[& \sum_{j=R+1}^{J} \Phi_t(\mathcal{A}, \mathcal{K}; j, R, d, d) \\ & + \sum_{i=1}^{2} \sum_{j=R+1}^{J} \sum_{j_m=1}^{R-1} \frac{R - j_m}{R} \Phi_t(\mathcal{A}, \mathcal{K}; j, j_m, d, s_i) \Bigg]. \end{aligned} \tag{3.14}$$

and in country s_i:

$$\begin{aligned} Pen_{s_i,t} = b_{s_i,t} \Bigg[& \sum_{j=R+1}^{J} \Phi_t(\mathcal{A}, \mathcal{K}; j, R, s_i, s_i) \\ & + \sum_{j=R+1}^{J} \sum_{j_m=1}^{R-1} \frac{j_m}{R} \Phi_t(\mathcal{A}, \mathcal{K}; j, j_m, d, s_i) \Bigg]. \end{aligned} \tag{3.15}$$

4. The government budget clears in each region:[6]

$$\begin{aligned} G_{d,t+1} = & \Bigg[\sum_{j=1}^{J-1} \int_{\mathcal{A}\times\mathcal{K}} a'_t(a, \kappa; j, \min\{j, R\}, d, d)(1 - \psi_{d,t,j}) d\Phi_t(a, \kappa; j, \min\{j, R\}, d, d) \\ & + \sum_{i=1}^{2} \sum_{j=2}^{J-1} \sum_{j_m=1}^{\min\{j-1,R-1\}} \int_{\mathcal{A}\times\mathcal{K}} a'_t(a, \kappa; j, j_m, d, s_i)(1 - \psi_{s_i,t,j}) d\Phi_t(a, \kappa; j, j_m, d, s_i) \Bigg] (1 + r_{t+1}). \end{aligned} \tag{3.16}$$

$$\begin{aligned} G_{s_i,t+1} = & \sum_{j=1}^{J-1} \int_{\mathcal{A}\times\mathcal{K}} a'_t(a, \kappa; j, \min\{j, R\}, s_i, s_i)(1 - \psi_{s_i,t,j}) d\Phi_t(a, \kappa; j, \min\{j, R\}, s_i, s_i) \\ & (1 + r_{t+1}). \end{aligned} \tag{3.17}$$

[6] Here, I already used the assumption that accidental bequests are entirely spent on government consumption.

5. Markets clear in d and s_i

$$L_{d,t} = \sum_{j=1}^{R} \int_{\mathcal{A}\times\mathcal{K}} l_t(a,\kappa;j,j,d,d)\epsilon(j)d\Phi_t(a,\kappa;j,j,d,d) \tag{3.18}$$
$$+\sum_{i=1}^{2}\sum_{j=2}^{R}\sum_{j_m=1}^{j-1} \int_{\mathcal{A}\times\mathcal{K}} l_t(a,\kappa;j,j_m,d,s_i)\epsilon(j)(1-\theta)d\Phi_t(a,\kappa;j,j_m,d,s_i).$$

$$L_{s_i,t} = \sum_{j=1}^{R} \int_{\mathcal{A}\times\mathcal{K}} l_t(a,\kappa;j,j,s_i,s_i)\epsilon(j)d\Phi_t(a,\kappa;j,j,s_i,s_i). \tag{3.19}$$

$$A_{t+1} = \sum_{y\in\{d,s_1,s_2\}}\sum_{x\in\{d,s_1,s_2\}}\sum_{j=1}^{J-1}\sum_{j_m=1}^{R} \int_{\mathcal{A}\times\mathcal{K}} a'_t(a,\kappa;j,j_m,x,y)d\Phi_t(a,\kappa;j,j_m,x,y), \tag{3.20}$$

where total assets have to be distributed among capital and land:

$$A_{t+1} = K_{t+1} + \sum_{x\in\{d,s_1,s_2\}} p_{x,t}F_x. \tag{3.21}$$

The aggregate resource constraint is given by:

$$\sum_{x\in\{d,s_1,s_2\}} Y_{x,t} + (1-\delta)K_t = \sum_{y\in\{d,s_1,s_2\}}\sum_{x\in\{d,s_1,s_2\}}\sum_{j=1}^{J}\sum_{j_m=1}^{R} \int_{\mathbb{A}\times\mathcal{K}} c_t(a,s;j,j_m,x,y) \tag{3.22}$$
$$d\Phi_t(a,s;j,j_m,x,y) + \sum_{x\in\{d,s_1,s_2\}} G_{x,t} + K_{t+1}.$$

6. There are no arbitrage-opportunities as expressed by (3.8) and (3.9).

7. The cross-sectional measure is generated as explained in appendix 3.A.

3.3 Calibration

3.3.1 Demographics

Data on demographics including survival, fertility, mortality and migration rates for the years 1950-2100 is taken from United Nations (2015). Regarding Southern Europe, I compute the joint demographic variables as weighted averages, whereby the weights depend on the relative population sizes at each point in time.[7] To be able to simulate

[7]For future periods, weights are formed based on UN projections.

the model until 2300, I follow Krueger and Ludwig (2007) and assume the following: Survival probabilities remain constant from 2100 on and fertility rates adjust so that the number of newborns is identical in each period. This ensures a stationary population distribution in 2200 and the convergence to a new steady state until 2300. A model period is assumed to be 5 years.

3.3.2 Migration Rates

Accounting for a preference heterogeneity among potential migrants allows a matching of simulated and empirically observed migration rates in a given period. In particular, I follow Klein and Ventura (2009) and assume that upon birth, each agent draws her disutility of living abroad (μ_k) from an exponential distribution $f(\lambda_{s_i})$. Given a life-cycle sequence of factor prices, benefits, and taxes, household optimization separates the mass of agents within one cohort into two groups: One that is willing to migrate and another that is not. The distribution parameter λ_{s_i} then determines the relative size of each group and thereby controls the size of the mass of emigrants.

Data on migration flows is taken from Statistisches Bundesamt (2015). I choose λ_{south} to match the average net immigration rate in Germany with respect to Southern Europe over the period 1992-2014 ($\overline{nir}_{south}$).[8] The starting point 1992 corresponds to the year in which the free movement of labor was introduced by the Maastricht treaty. With regard to Poland, however, data on net migration flows is just available from 2007 on.[9] Hence, the calibration target ($\overline{nir}_{pl}$) refers to the period 2007-2014.[10]

Even though this paper focuses on migration movements between a certain set of countries, modeling demographics comprehensively requires taking into account that the model regions are also subject to migration flows towards countries outside the scope of the model. Yet, this entails some conceptual difficulties: Due to the coexistence of exogenous and endogenous migration within the model, one cannot directly use UN migration data ($mig_{t,x}^{UN}$) for the simulation exercise without an appropriate adjustment. This is the case since $m_{t,j,x}$ in (3.1) and (3.2) only refers to migration vis-a-vis the rest of the world, excluding any model region, whereas $mig_{t,x}^{UN}$ comprises total net immigration. However, it is unclear which part of $mig_{t,x}^{UN}$ can be attributed to the net migration flows in between the model economy. To tackle the problem, I assume that the fraction of net migration to Germany stemming from Southern Europe and Poland

[8]Note that even though the endogenous migration rates in 3.2.2 are age-dependent, the calibration target $\overline{nir}_{s_i}$ refers to the total net immigration rate. Neither the migration data from Statistisches Bundesamt (2015) nor from United Nations (2015) are disaggregated by age.

[9]Note that Germany postponed the introduction of free labor mobility towards Poland until 2011.

[10]The periods for the calibration target are not consistent with the length of a model period equal to 5 years. Hence, I assume that with respect to Southern Europe, net immigration rates in 1990 and 1991 are equal to the average of the years 1992 to 1994. Likewise, with respect to Poland, I assume that net immigration rates in 2005 and 2006 are equal to the average of the years 2007 to 2009.

captured in $mig^{UN}_{t,ger}$ is equal to the sum of the calibration targets $\overline{nir}_{south}$ and $\overline{nir}_{pl}$ at any point in time. Hence, I obtain the exogenous migration rates by:

$$
\begin{aligned}
m_{t,ger} =& [mig^{UN}_{t,ger} - \overline{nir}_{south} - \overline{nir}_{south}] \\
m_{t,south} =& [mig^{UN}_{t,south} + \overline{ner}_{south}] \\
m_{t,pol} =& [mig^{UN}_{t,pol} + \overline{ner}_{pol}] \\
& \forall t, j,
\end{aligned}
\tag{3.23}
$$

where $\overline{ner}_{s_i}$ denotes the net emigration rate in a sending region corresponding to the calibration target $\overline{nir}_{s_i}$. These exogenous net migration rates are then used to compute the total number of exogenous net migrants in a respective period. In a second step, they are distributed among the different age groups as explained in 3.2.2.[11]

3.3.3 Further Parameters

The remaining model parameters of the household, production and government sector are either exogenously fixed or chosen to match certain calibration targets in the data. To reduce the computational burden, I do not calibrate these parameters via a moment matching a long the demographic transition as it is done with respect to the preference distribution. Instead, I require the parameters to support the calibration targets in an artificial steady state with the demographic structure of 2015 assuming a region-wide population growth rate of zero and abstracting from endogenous migration. All parameters are summarized table 3.1.

Households

The discount factor β is set to 0.996 in order to generate a wealth to annual output ratio of 4.5. Further, γ defining the importance of consumption relative to leisure is chosen to be 0.255 thereby inducing an average of hours worked equal to 0.275. Both targets are computed using data from Destatis (2016). The parameter η governing the intertemporal elasticity of substitution is set to 2 as common in the literature. The age-dependent efficiency profile is taken from Lagakos et al. (2018) who document life-cycle wage growth in several countries. I specify ϵ to be equal to the reported wage profile of Germany. Skill losses faced by immigrants are set to 10 % in order to account for the average wage gap between natives and migrants in Germany as reported by Brücker et al. (2014).

[11]In United Nations (2015) it is assumed that all net migration rates gradually decrease from 2050 on so that they reach a level of 50% in 2100. I also let $\overline{nir}_{s_i}$ and $\overline{ner}_{s_i}$ in (3.23) adjust accordingly.

Table 3.1: Parameters

Production		Households		Social Security	
Parameter	Value	Parameter	Value	Parameter	Value
σ	0.68	β	0.996	τ_{ger}	0.156
ν	0.276	η	2	τ_{south}	0.199
F_x	$L_{x,steady}$	γ	0.255	τ_{pl}	0.159
A_{ger}	1	θ	0.1	R	65
A_{south}	0.9	J	99		
A_{pl}	0.58	λ_{south}	3.85		
δ	0.07	λ_{pol}	3.95		
g	0.0072				

Note: The values for δ and g are annualized.

Production

Concerning the calibration of production side parameters, it is crucial to pin down an estimate for the land share $1-\nu-\sigma$. Restrictions of German data do not allow for adopting the calibration strategy by Klein and Ventura (2009).[12] Hence, I do the following: I use data from Destatis (2016) to find the labor income share σ, which is about 0.68 for Germany. Then, I assume that the ratio of capital and land share $\frac{\nu}{1-\nu-\sigma}$ is equal to the one in Klein and Ventura (2009). This results into a capital share of 0.276 and a land share of 0.044. Additionally, I assume that the stock of land per unit of labor is equal to one in each region. This implies that wage differences in the calibration steady state are solely due to differences in A_x, which, in turn, are chosen to match cross-country differences in gdp per capita as reported by OECD (2016). Further, I calibrate δ to match an investment share in Germany equal to 0.2 as reported by Destatis (2016). Finally, the tfp growth rate g is chosen to result into an per capita output growth rate of 1%.

Social Security

I use data provided by OECD (2015) to calibrate the public pension system in each region. More precisely, I set contribution rates such that pension payments relative to GDP equal the public expenditure on old age and survivors benefits as reported in the data. Given the tax rate, benefits then adjust to ensure budget clearing. Regarding Southern Europe, the region-wide pensions expenditure are computed as a weighted

[12] Klein and Ventura (2009) calibrate the land share according to the Cooley and Prescott (1995) approach. In particular, they use information on capital income to derive an implicit interest rate that can then be used to calculate the land share via a steady state condition. While estimating capital income for the U.S. also involves some methodological challenges, the problem is more severe with respect to German data since capital income is included in the figure *corporate and wealth profits* which is only reported as a residual figure, i.e. as the difference between national income and labor income.

average of the country-specific expenditures. The weights are determined by the relative population sizes in 2015. The respective expenditures shares amount to 10.6% (Germany), 13.5% (Southern Europe) and 10.8% (Poland). Finally, I let the exogenous retirement age R be equal to 65 in each region.

3.4 Results

The presentation of the model results is divided into different parts. I start with a positive analysis. In this respect, I firstly report a comparison between the initial and final steady state. Secondly, I describe the predicted migration flows and the evolution of factor prices over the forecast period 2015-2100. Thirdly, I compute a counter-factual model scenario in which labor is completely immobile from 2015 on. This allows me to isolate the macroeconomic effects of the endogenous migration flows. Further, I investigate the welfare implications of intra-European migrations flows for generations living through the demographic transition. The different steps of analysis are carried out for two different policy scenarios: In the first one, I assume constant contribution rates and let benefits adjust to ensure a fiscal equilibrium. In the second scenario, I fix the net replacement rates at the level of 2015 and allow the contribution rate to vary.

3.4.1 Comparative Statics

For the initial steady state in 1950 I assume an identical population growth rate of 0.5% in each region and the immobility of labor.[13] Table 3.2 summarizes the percentage change in key economic variables between the initial and final steady state. Demographic change leads to a dramatic shift in the composition of the population which has several implications for the ratio of factor inputs. Firstly, it affects aggregate savings. On the one hand, lower fertility rates and higher survival rates increase the share of older generations thereby reducing aggregate asset holdings since saving is mostly carried out by the young. On the other hand, the decrease in mortality rates implies that agents have to plan their consumption path for a longer time span which - ceteris paribus - increases savings. Secondly, populating aging reduces the size of the workforce thereby making labor relatively scarce to capital. While the first effect entails an upward pressure on the interest rate, effects two and three lead to a downward pressure. The quantitative analysis reveals that the latter two effects dominate: The interest rate in the final steady state is lower by 190 basis points. Further, capital deepening leads to an increase in German wages by 9.2% and to a rise of 8% and 10.3% in the sending regions. As a reaction to lower returns to savings and higher returns to

[13]Hence, labor mobility is introduced as an unexpected shock at the beginning of the transition. This assumption greatly simplifies the computation of the initial steady state since it can be solved as a representative agent problem.

labor, individuals increase average labor supply ($\bar{l}$) by around 20% to 24%. Despite the strong rise of wages, benefits fall by 44% to 52% in the model regions which displays the enormous effect of population aging on public pension systems. Finally, due to capital deepening, output per unit of labor increases in all model regions.

Table 3.2: Steady State Comparison

Variable	Germany	Southern Europe	Poland
r	-1.9	-1.9	-1.9
w	9.2	8.0	10.3
b	-43.7	-45.4	-52.3
Y/L	9.1	8.0	10.4
$\bar{l}$	20.9	21.3	23.8

Note: Numbers refer to the percentage change between final and initial steady state. The change in the interest is reported in terms of percentage points.

3.4.2 Migration Flows

In the following section I present and analyze the migration flows between the model regions in the main period of interest, 2015-2100. In the respective calibration periods, migration data documents an average yearly inflow of about 10.000 net migrants from Southern Europe and about 40.000 from Poland implying yearly net immigration rates in Germany of around 0.052% (Poland) and 0.015% (Southern Europe). Figure 3.1 and 3.2 depict the evolution of migration flows to Germany from the respective region over the century in comparison to the calibration period average. The following characteristics can be observed: Net migration to Germany is predicted to remain positive over the entire forecast period, whereby migration flows from Poland are larger in size. Moreover, the development of migration rates differs between the regions: While there is a clear downward trend in immigration from Poland, there is no such clear trend with respect to Southern Europe. The respective immigration rate falls until the mid of the century, but then starts to rise such that it surpasses the calibration period average at the end of the century. Overall, total net immigration from the sending regions is below its average in the calibration period in each future year.

What drives the course of the net immigration rate? First of all it is determined by the alteration of migration incentives due to a changing economic environment. Individuals in the sending regions base their location choice both on their idiosyncratic utility costs and on the evolution of the relative lifetime income between Germany and their home region, which in turn, depends on the evolution of both relative wages and relative returns on social security contributions. Each of these two variables is directly affected by the pattern of the demographic transition. Figure 3.3 displays the working

Figure 3.1: Immigration from Poland

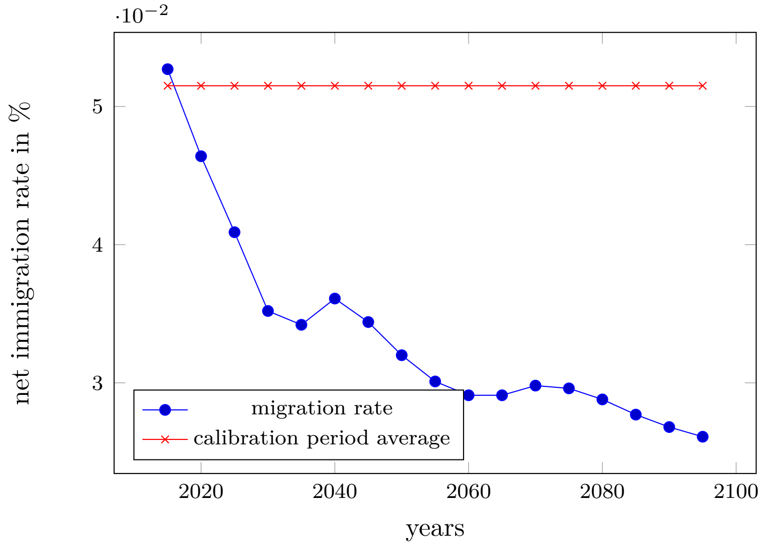


Figure 3.2: Immigration from Southern Europe

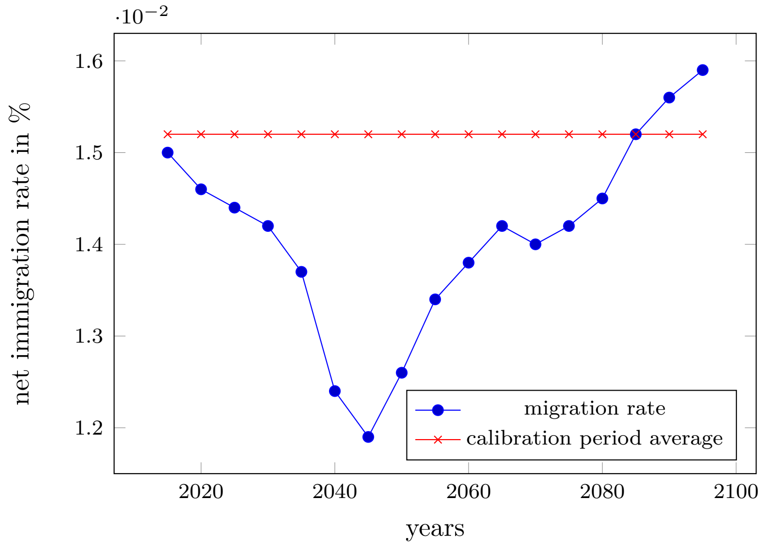
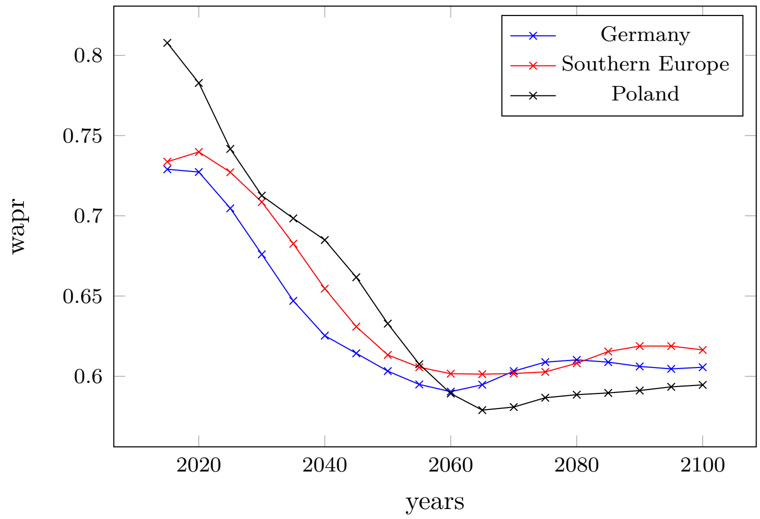


Figure 3.3: Working Age to Population Ratio



Note: The graph depicts the working age to population ratio for the share of population that is economically active.

age to population ratio (wapr) in the model regions over the forecast period. Poland exhibits the youngest population in 2015, however, its wapr declines the fastest over the following decades, so that by around 2060 it is lower than Germany's. Towards the end of the century, the depicted ratios rebound and stabilize on a slightly higher level.

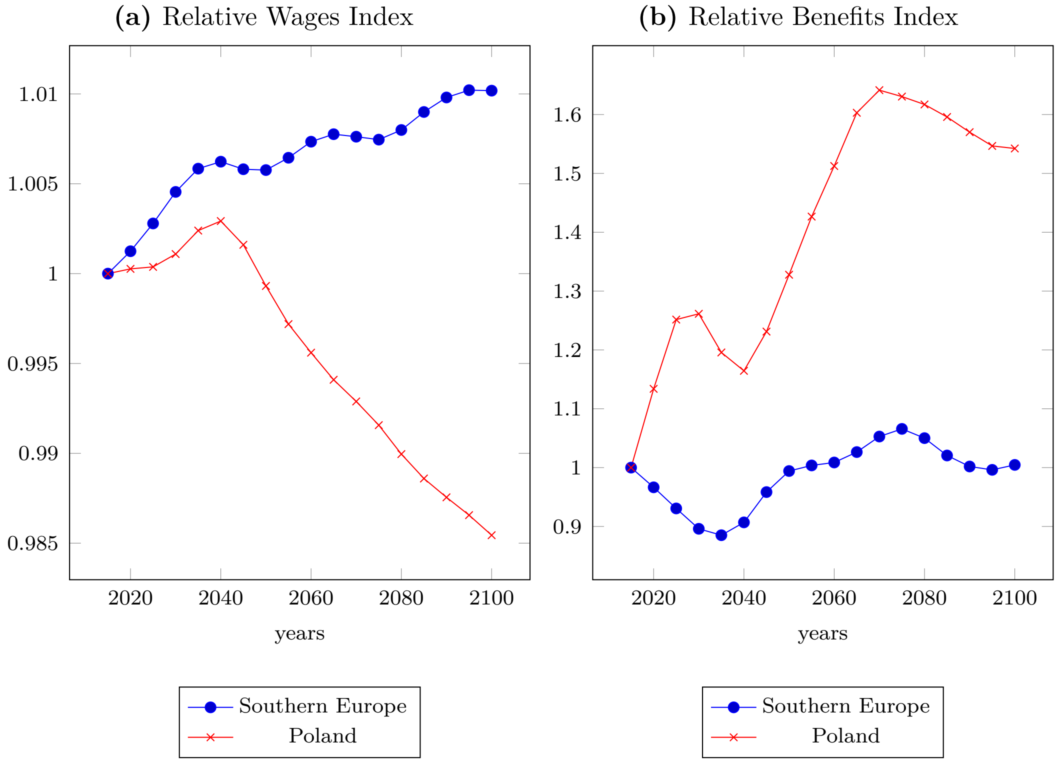
The presence of a fixed factor in the production function in (3.3) implies that differences in aging processes feed back onto relative wages. Not accounting for a fixed factor (as in Krueger and Ludwig (2007)) would implicate that capital mobility equalizes interest rates, capital intensities and thus also wages up to a ratio of tfp differences. Using (3.4),(3.5) and (3.9), relative wages are given by:

$$\frac{w_{d,t}}{w_{s_i,t}} = \left(\frac{Z_{d,t}}{Z_{s_i,t}}\right)^{\frac{1}{1-\nu}} \left(\frac{L_{s_i,t}/F_{s_i}}{L_{d,t}/F_d}\right)^{\frac{1-\sigma-\nu}{1-\nu}} \tag{3.24}$$

Hence, relative wages do not only depend on TFP differences, but also on the relative labor to land ratio which varies along the demographic transition. More precisely, aging entails both a direct and an indirect effect on $L_{x,t}/F_x$: Firstly, it reduces $L_{x,t}$ since the mass of workers gets smaller. Secondly, individuals respond to changes in factor prices by adjusting labor supply. Since $\frac{1-\sigma-\nu}{1-\nu} > 0$, a rise in the relative labor to land ratio leads to a fall in relative wages.

Figures 3.4a and 3.4b depict the evolution of relative wages and benefits over the course of the century. All variables are normalized to their level of 2015. Since the labor to land ratio in Germany falls relative to Southern Europe, $\frac{w_{ger,t}}{w_{south,t}}$ shows a clear positive trend. With respect to Poland, the relative labor to land ratio slightly decreases until 2040 and then continues to rise from there on translating into a significant decline in $\frac{w_{ger,t}}{w_{pl,t}}$. The evolution of benefits is driven by two components. Firstly, by the ratio

Figure 3.4: Wages and Benefits



Note: The graph shows wages and benefits in Germany relative to the ones in the sending regions. All ratios are normalized with respect to the value in 2015.

of aggregate labor input to retirees ($\frac{L_{x,t}}{Ret_{x,t}}$) and secondly, by the wage. As the first component responds much stronger to population aging, it is the main determinant of $b_{x,t}$. Accordingly, relative benefits between Germany and the sending region s_i closely follow the path of ($\frac{L_{d,t}/Ret_{d,t}}{L_{s_i,t}/Ret_{s_i,t}}$). Overall, we observe that the course of relative wages should provide greater incentives for agents in Southern Europe to migrate to Germany, whereas agents in Poland should face weaker incentives. On the contrary, the development of relative benefits rather works in favor of greater migration incentives in Poland. Overall, it should be noted that - in general - wages have a stronger impact on migration incentives because firstly, benefits are lower and secondly, they are received at later stages of the life-cycle and hence subject to larger discounting. However, the magnitude of changes in $\frac{b_{ger,t}}{b_{s_i,t}}$ is much larger than it is in $\frac{w_{ger,t}}{w_{s_i,t}}$.

A measure for how migration incentives change over the demographic transition along with wages and benefits is given by the *threshold disutility* ($\bar{\mu}_{s_i,t}$), i.e. the highest disutility of living abroad accepted by a migrant from region s_i in period t. If income prospects in Germany develop more favorably, individuals are willing to accept higher utility costs such that the *threshold disutility* increases. For the case of Poland, $\bar{\mu}_{pol,t}$ shows a downward trend from 2015 on. Accordingly, the fall in German relative wages clearly dominates the rise in relative benefits, so that Polish workers have a weaker incentive to migrate to Germany. Regarding Southern Europe, $\bar{\mu}_{south,t}$ shows no clear trend until the mid of the century, but then starts to increase which coincides with the time period in which both relative wages and relative benefits in Germany exhibit an upward trend.[14] Hence, the model predicts significantly stronger migration incentives for Southern Europeans in the second half of the century. It is important to note that, overall, the evolution of social security variables is more important for migrants from Southern Europe, since they have to face greater tax distortions in their home region (see table 3.1). While the *threshold disutility* is useful to display the evolution of migration incentives, it cannot directly be interpreted economically. To provide such interpretation, I compute the consumption equivalent variation (CEV) Θ depicting the change in consumption necessary to equalize lifetime utilities of the preference type with zero utility costs ($\mu_\kappa = 0$) and the *marginal migrant*, i.e. the migrant type facing the highest utility costs. The more (less) negative Θ becomes, the stronger (weaker) the incentives to migrate to Germany. In Southern Europe, Θ denotes -5.5% in 2015 and around -6% in 2100. On the contrary, Θ equals -38.6% in Poland at the beginning of the forecast period, but only -37.5% at the end of the century. The graphical illustration of the development of Θ can be found in appendix 3.B.

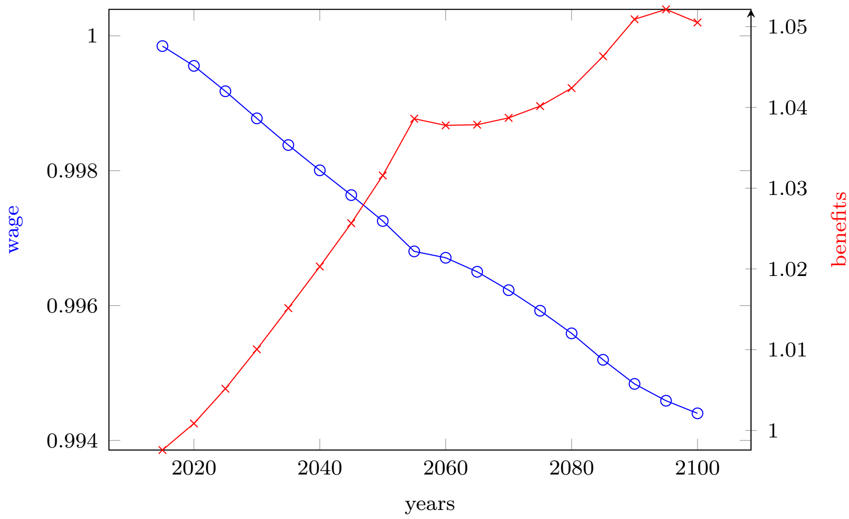
An aspect of the migration pattern that has not been mentioned so far is the age structure of migrants. As a result of the household optimization problem, all migrants in the model leave their home region in their first period of working life. Consequently, the pool of potential migrants equals the share young workers. The aging process, however, implies a shift in the population composition towards the old leading to a decrease in the relative share of newborns. In Poland, 20-25 year olds account for 10.9% of the entire population in 2010, but only for 6.7% in 2030. Hence, the decline in the relative share of the young reduces the mass of potential migrants and thus the immigration rate. The interplay of economic and demographic factors then gives rise to the shape of the curves in figures 3.1 and 3.2. It should be emphasized that the resulting age pattern of migrants is well in line with the data. According to the Statistisches Bundesamt (2016a), the average age of an immigrant from Poland in 2016 was 24.6, as well as 20.7, 22.5, 22.1 and 22.3 for Italy, Spain, Greece and Portugal, respectively.

3.4.3 Counterfactual Analysis

While in the previous section I focused on the analysis of the pattern of migration flows, I now shed light on their ensuing macroeconomic effects. In this regard, I compute a counterfactual model scenario in which labor mobility is abolished at the beginning of the forecast period. This regime change is not foreseen by the agents so that it has no effects on the periods before 2015. Consequently, the comparison of the model

[14] Note that for a cohort becoming economically active in period t, the decisive evolution of benefits is that from $t + R$ on.

Figure 3.5: Wages and Benefits - Germany

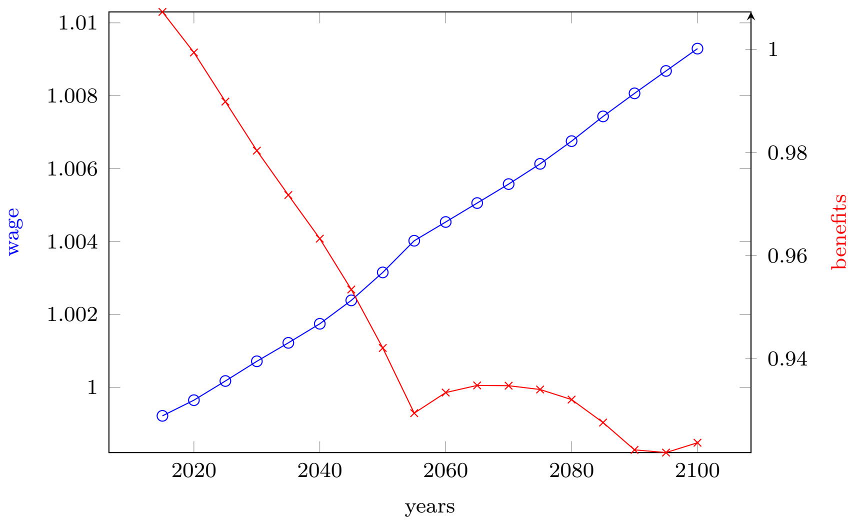


results from the benchmark and the counterfactual model variant allows me to isolate the macroeconomic effects of endogenous migration during the forecast period.

The analysis in the previous section revealed that demographic and economic forces reduce total net immigration in Germany. Nevertheless, the endogenous migration flows still have significant macroeconomic implications. Figures 3.5 and 3.6 depict the evolution of wages and benefits in the model variant with labor mobility relative to the corresponding values from the counterfactual scenario. In the graphical documentation, I focus on Germany and Poland. From a quantitative point of view, a joint characteristic of the figures lies in the relative strength of the effect on wages and benefits: While the migration flows impact wages only marginally, they have a much stronger effect on benefits. For the case of Germany, immigration from Poland and Southern Europe leads to small reduction in wages, but it increases benefits by almost 4% until the mid of the century. The wage reduction is caused by the relatively larger labor force which decreases the marginal productivity of $L_{ger,t}$. Immigration has opposing effects on pensions benefits. On the one hand, $b_{ger,t}$ decreases due to lower wages. On the other hand, immigration improves the labor to retirees ratio and thus broadens the tax base. As is clearly apparent from figure 3.5, the latter effect dominates the former. Vice versa, emigration from Poland results into slightly higher wages (whereas the increase is more pronounced than the wage reduction in Germany) and significantly lower benefits with a reduction of about 7 % towards the mid of the century.

Which mechanisms cause the low responsiveness of wages and the high responsiveness of benefits with respect to migration flows? First of all, it is important to note that the significant changes in benefits are generated by migration flows of a moderate size. However, in the context of this demographic growth model, migration alters the work force in a direct and in an indirect way. Regarding the former, new migrants enter the labor force and increase $L_{ger,t}$. Regarding the latter, additional migrants add

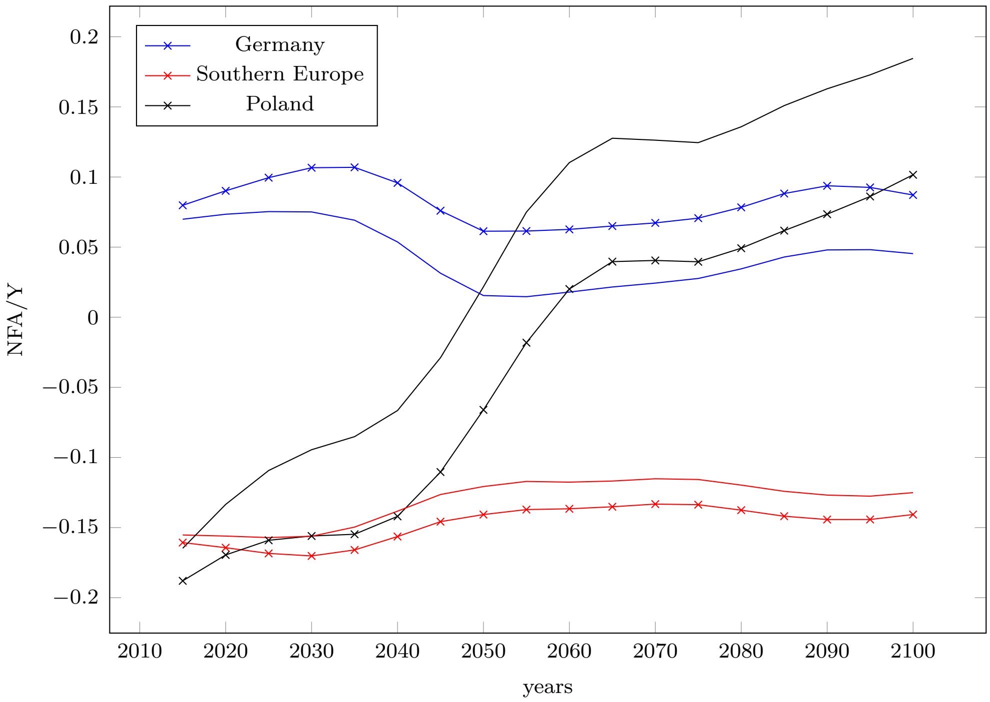
Figure 3.6: Wages and Benefits - Poland



to population growth by increasing the number of newborns, which, in turn, augments the size of the future labor force. Both effects result into an improvement of the old age support ratio in Germany, and into a respective worsening in the sending regions. The relatively mild reactions of wages, on the other side, can be explained by the mobility of capital demanding an equalization of interest rate any point in time. When labor migrates from either Poland or Southern Europe, it increases the marginal productivity of capital in Germany and lowers the marginal productivity in the sending regions. The no-arbitrage condition then forces capital to follow labor which counteracts the downward pressure on wages in Germany and the upward pressure in the sending regions. Note that without a fixed factor in the production function, an increase in $L_{ger,t}$ would trigger an immediate reallocation of capital large enough to keep relative wages unchanged. The fixed factor, however, already absorbs a fraction of the increase in the marginal productivity of $K_{ger,t}$ due to a larger $L_{ger,t}$, such that less capital has to be reallocated to Germany. The quantitative implications of the endogenous migration flows are larger in Poland due to a size effect: Since Poland has the smaller population, the migration flows matter more. Additionally, the reallocation of labor has an asymmetric effect in the sending regions and in Germany due to the productivity loss of θ.

In the case of Southern Europe, the reaction of benefits to emigration is qualitatively equivalent to that in Poland. Since emigration rates are lower, however, the change in benefits is less pronounced (-1% in 2050). Interestingly, wages in Southern Europe are slightly lower in the benchmark scenario for the first half of the century, even though the relative change is very weak. The fact that emigration can actually cause a fall in wages can be motivated by a particular dynamic in this three-country world: Due to the significantly larger labor movements between Poland and Germany, the no-arbitrage condition demands a greater outflow of capital from Southern Europe

Figure 3.7: Net Foreign Assets



Note: The solid lines indicate the benchmark scenario (migration) and the marked lines the counterfactual (no migration).

compared to what would be necessary to compensate for its own migration flows. In total, the reduction in capital dominates the reduction in labor supply so that wages (marginally) fall.

Furthermore, migration flows affect the evolution of the interest rate in the following way: In the first decades of the forecast period there is almost no difference between both model variants. In later decades, however, one observes a higher interest rate in the migration scenario. To illustrate this point, I focus on the effects in Germany: The increase in labor supply rises the interest rate, whereas the inflow of additional capital induces a downward pressure on r. Due to the fixed factor in production, relatively less capital than labor has to be allocated to Germany to ensure the equalization of interest rates. Since the inflow of workers is thus stronger, interest rates are higher in the benchmark variant. A graphical comparison between both model variants can be found in appendix 3.C.

Lastly, it remains to take a closer look at the impact of migration flows on the asset allocation across regions. In this respect, figure 3.7 plots the net foreign asset positions for both the benchmark and the counterfactual scenario. The common features of both model variants are a constantly positive NFA position of Germany, a constantly negative one of Southern Europe, as well as increasing net foreign asset holdings of Poland. The first two observations can be explained by the much greater generosity of the PAYG system in Southern Europe providing a strong disincentive for saving and ultimately resulting into a capital import. On the other hand, the increase in the Polish

NFA reflects the strong decline in the wapr, which in turn reduces the Polish investment rate and leads to a greater capital export. The striking result displayed in figure 3.7 is that the moderate per-period migration flows trigger large asset reallocations resulting into significant differences between the NFA positions of both model scenarios. At its peak, the Polish net foreign asset holdings are about 9.3 percentage points larger in the migration variant. To explain this large difference, one needs to disentangle the effects of emigration on the different components of the ratio $\frac{NFA_{pol,t}}{Y_{pol,t}}$. Note that net foreign assets in this model economy are given by the difference between domestic assets and the sum of the domestic capital stock and the value of domestic land:

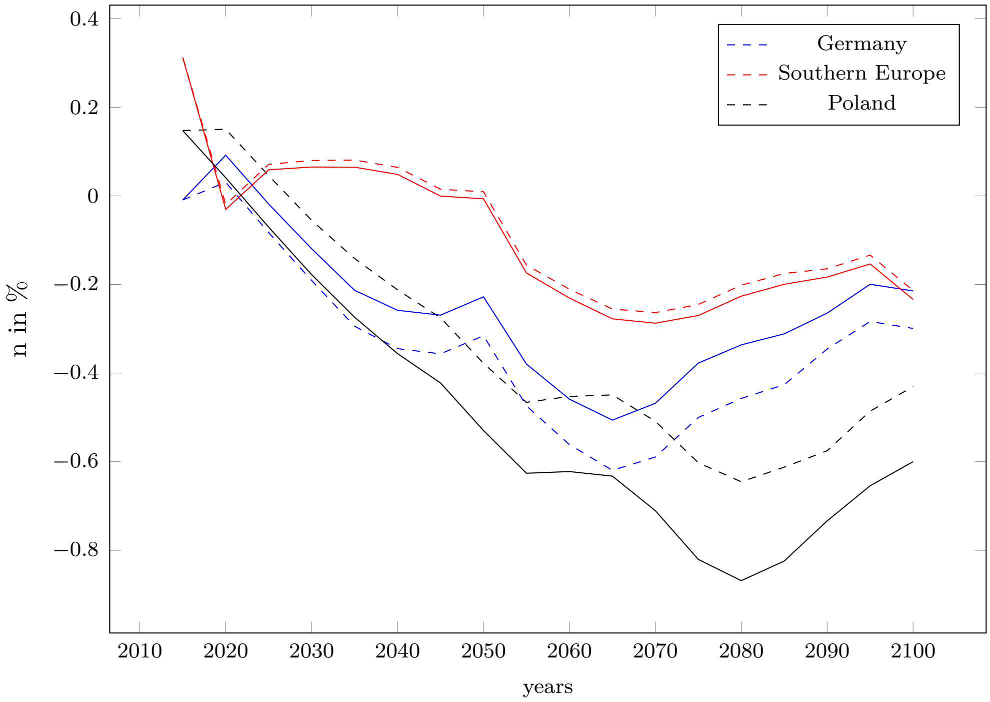
$$\frac{NFA_{pol,t}}{Y_{pol,t}} = \frac{A_{pol,t} - K_{pol,t} - p_{pol,t-1}F_{pol}}{Y_{pol,t}}. \tag{3.25}$$

Even though all components of $\frac{NFA_{pol,t}}{Y_{pol,t}}$ fall in response to emigration, the total effect on this ratio is positive. While the reduction in capital and output is quantitatively similar, the price of land decreases more strongly. Hence, the greater decline in the value of land implies that a larger share of Polish aggregate savings is allocated to international assets so that - ceteris paribus- its NFA position rises. Additionally, total Polish asset holdings fall by less than capital and output. This weaker reaction is due to the fact that emigration induces both a rise in wages and interest rates which has positive effect on savings of the non-migrants. The opposite reasoning of course holds true for Germany.

3.4.4 Endogenous Demographic Transition

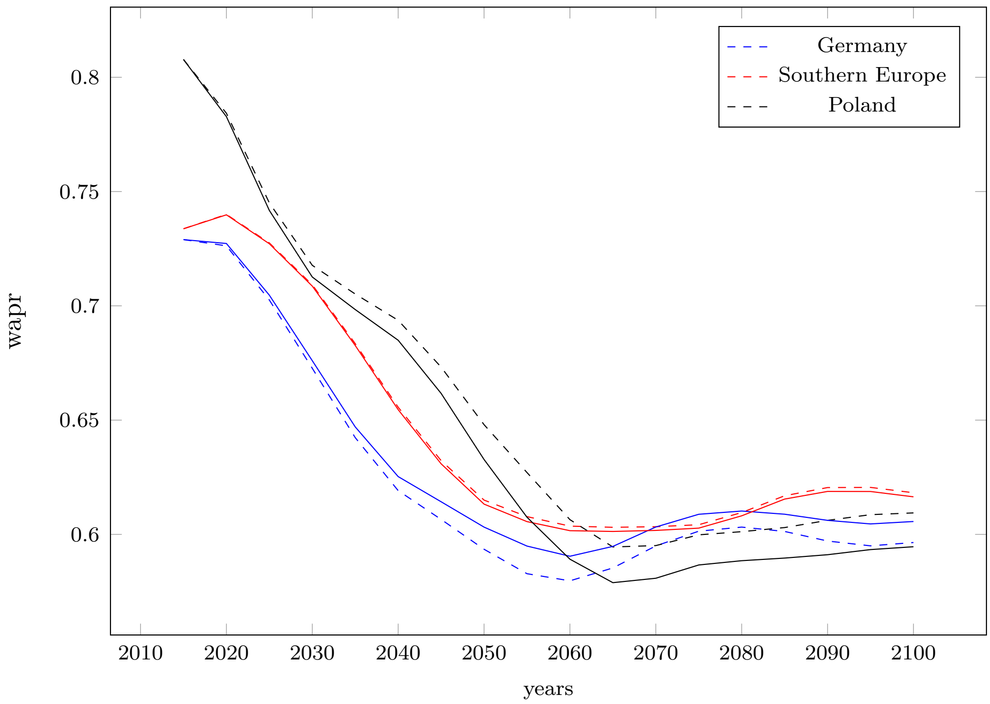
The counterfactual analysis can not only be used to examine the macroeconomic effects of migration flows, but also to uncover how they shape the demographic transition itself. In this respect, figure 3.8 plots the region-specific population growth rates for the benchmark and the counterfactual scenario. Emigration reduces population growth (n) in Poland and Southern Europe, whereas it leads to a smaller population decline in Germany. The largest difference between both growth rates amounts to 0.12 percentage points in the case of Germany. Likewise, endogenous migration also impacts the working age to population ratio as depicted in figure 3.9. Here, the absence of immigration from the sending regions pushes the German wapr down, whereas the Polish one significantly increases. In conclusion, both figures demonstrate that any analysis on the impacts of demographic change that treats migration as purely exogenous ignores important feedback mechanisms between the evolution of macroeconomic variables and the demographic transition itself.

Figure 3.8: Population Growth Rates



The solid lines indicate the benchmark scenario and the dashed lines the counterfactual. Numbers refer to annual values.

Figure 3.9: Working Age to Population Ratio



Note: The solid lines indicate the benchmark scenario and the dashed lines the counterfactual.

3.4.5 Net Migration or In- and Outflows

A possible caveat to the modeling and calibration strategy employed is that one should account for endogenous return migration and target both in- and outflows instead of net migration flows. While this would in principle allow for more complex migration dynamics, it presents great challenges for the model solution. Firstly, it requires at least a two-dimensional household heterogeneity: Inflows can be matched by assuming differing, but time-invariant disutility costs as in section 3.2.4. With respect to outflows, however, it then needs a further dimension of heterogeneity that induces a return to the home country for some agents, but not for all (e.g. an increase the disutility costs for a constant fraction per preference type).[15] Further, introducing return migration implies that individuals can make more discrete choices over the life-cycle. As discussed in appendix 3.D.2, this might result into larger non-concave regions of the value functions thereby significantly increasing the computational burden. What are the implications of restricting the model to only produce one-directional migration? Since gross inflows are larger then net inflows, the calibration puts a too high barrier on entering Germany. Accordingly, inflows are larger with two-directional migration dynamics so that the direct effect of immigration on $L_{ger,t}$ increases. On the other hand, by forcing migrants to remain in Germany, their impact on population growth is maximized since they do not return during their fertile periods (see the demographic law of motion in (3.2)). Lastly, it needs to be emphasized that allowing for return migration during retirement would increase the incentives to migrate to Germany: Retirees could move back to their home country and avoid the disutility costs of living abroad while still receiving the same pension benefits.

3.5 Constant Replacement Rate

So far, it was assumed that contribution rates remain constant throughout the demographic transition so that benefits have to decrease to ensure a fiscal equilibrium. In the following section, I investigate a further possible policy response to the demographic change by assuming that the burden of adjustment also lies on the tax rate, whereas the ratio of old age provision and net wages remains stable. The policy change is implemented as a symmetric reform in all countries. I repeat the analysis outlined in the section before and present the most central insights.

In the alternative policy scenario, I follow the approach of Krueger and Ludwig

[15] An empirical analysis of the living conditions of the migrant population in Germany by Statistisches Bundesamt (2016b) documents that 80 % of the survey participants plan to stay in Germany for the rest of their life. Stratified by region, this value amounts to 77 % for Eastern Europeans and 72 % for South-Western Europeans.

(2007) and assume that the (instantaneous) net replacement rate[16] (ξ) stays constant at its 2015 level. Hence, taxes are allowed to vary such that (3.13) and the following equation are fulfilled:

$$\xi_{x,t} = \frac{b_{x,t}}{(1-\tau_{x,t})w_{x,t}} = \frac{b_{x,2015}}{(1-\tau_{x,2015})w_{x,2015}} \quad \forall t \geq 2015 \tag{3.26}$$

Allowing for a rise in the tax rate has strong macroeconomic implications through various channels. Firstly, since the generosity of the old age provision (relative to current wages) does not further decline with population aging, agents need to save less for their retirement period. Secondly, the higher contributions taxes directly reduce net labor income and thereby also the scope for savings. In total, the decline in aggregate savings prevents the capital to labor ratio from increasing as strongly as in the case of constant tax rate. Focusing on Germany, the rise in the tax rate lowers the capital stock by 7%, increases the interest rate by 10 basis points and leads to a 0.5% drop in the wage in the year 2050 (relative to the constant tax scenario). Likewise, the contribution rate is predicted to increase by 8 percentage points over the same time period.

Besides its general macroeconomic implications, a rising tax rate also influences migration incentives. As argued in section 3.4.2, relative wages have a stronger impact on lifetime utility than relative benefits. While under the former policy response the burden of adjustment to population aging was on benefits, this burden is now shifted to the contribution rate and thus on net wages. Hence, the greater distortion from social security is transmitted to earlier periods of the life-cycle thereby increasing its effect on migration decisions.

Figure 3.10 and 3.11 show the evolution of migration flows when the replacement rate is kept constant. Regarding Poland, the model predicts a similar trend as in the constant tax scenario: Net immigration rates decrease over the century. However, the curve is shifted upwards. For the case of Southern Europe, one observes a different pattern: The net immigration shows a much clearer positive trend than in the constant tax scenario and lies above the calibration target for the majority of transitional periods. Under this alternative scenario, Germany therefore experiences a greater inflow of workers from the sending regions, even though total immigration still remains below the calibration period average. Again, one can use the concept of the *threshold disutility* as a measure for the evolution of migration incentives as in section 3.4.2. Under a constant replacement rate, $\mu_{s_i,t}$ shows a clear positive trend for both sending regions along the demographic transition. The upward drift of μ_{pol} can be traced

[16] Note that this notion of a replacement rate differs from the definition of the OECD (2015) which defines a net replacement as the ratio between benefits and individual past lifetime earnings.

back to the strong increase in relative net wages in Germany (up to 10% until the year 2050 compared to their level in 2015). Regarding Southern Europe, the course of μ_{south} can be explained by a combination of increasing net wages from 2040 on and the fact that the overall size of the distortions from social security is significantly larger in Southern Europe ($\tau_{south,2015} > \tau_{ger,2015}$). In this context, it is important to recall that welfare losses increase non-linearly in the tax rate. Hence, an increase in τ_{south} results into higher welfare losses than a similar increase in τ_{ger}. To translate the value of the *threshold disutility* into an economically interpretable measure, I again compute the CEV Θ as in section 3.4.2. For both regions Θ is significantly more negative under the constant replacement rate scenario implying that the marginal migrants are willing to suffer even higher utility costs compared to the zero-costs type for moving to Germany. At its peak, the absolute difference between both policy scenarios amounts to slightly more than 2% of lifetime consumption in Southern Europe and to 3.7% in Poland, respectively. The corresponding graphical illustration is found in appendix 3.B. Summing up, one can state that placing the fiscal burden of the pension system on workers will increase the migration pressure in Southern Europe and Poland thereby accelerating the population aging in the sending regions.

Before turning to the discussion of welfare effects, it needs to be pointed out that by abstracting from an earnings-benefits linkage, labor supply distortions from social security are in general overstated in the model which might lead to the conjecture that incentives to emigrate are in fact weaker than the model predicts. However, a comparison of the structure of the different pension schemes (OECD (2015)) reveals that the German system is completely earnings-related whereas all other systems feature some type of earnings-independent component, so that relative distortions are lower in Germany. Hence, if these institutional differences were taken into account, the more complex model environment might give rise to even stronger migration incentives.

3.6 Welfare

In the following section I outline the welfare effects of the migration flows in both the constant tax and the constant replacement rate scenario. In general, individual welfare is affected by labor movements through the accompanying changes in factor prices and pension benefits. Figure 3.12 displays the welfare change between the counterfactual (no migration) and the benchmark (migration) variant for both policy scenarios. In particular, it displays the consumption equivalent measure (Δ), i.e. the percentage change in consumption necessary to make an individual in the counterfactual variant indifferent between her current state and living in the benchmark scenario. Hence, a positive value implies that agents are better off with migration. Changes in welfare

Figure 3.10: Immigration from Poland

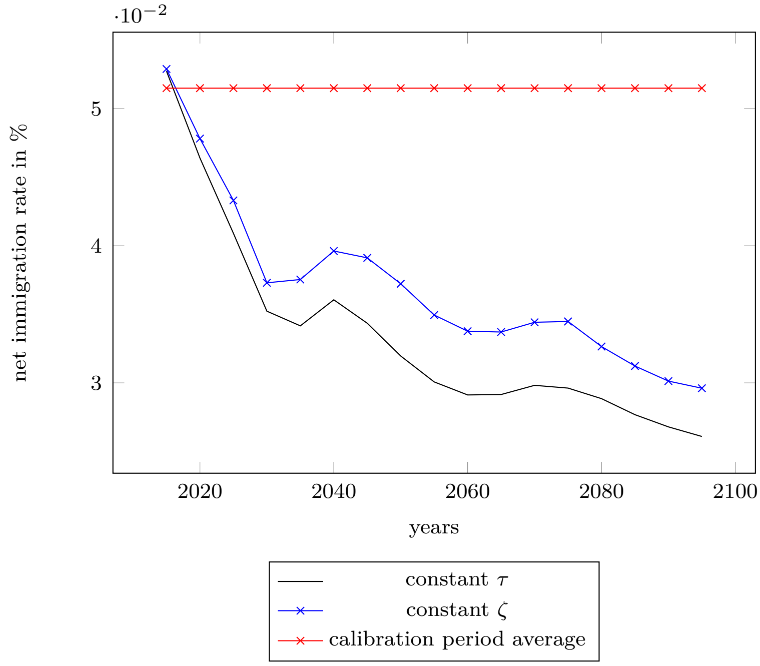
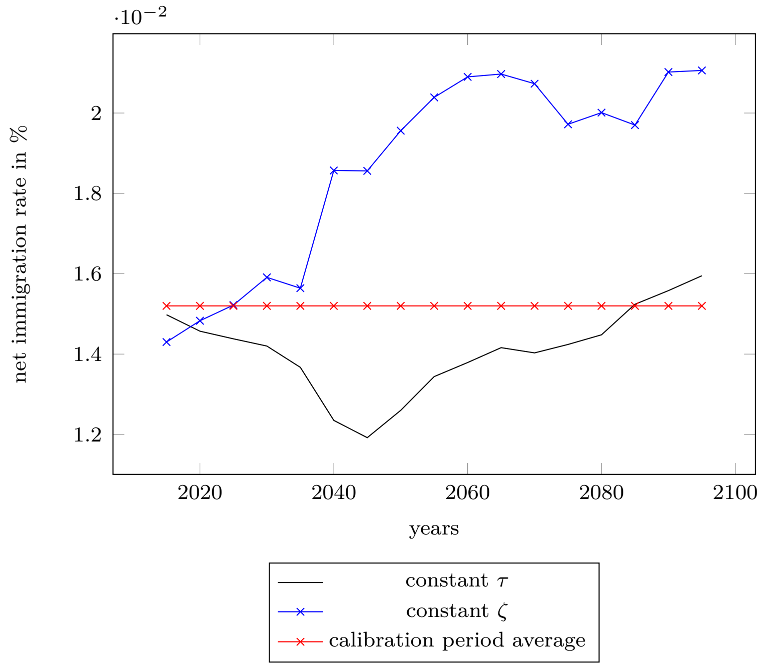


Figure 3.11: Immigration from Southern Europe



are shown for the cohorts[17] between 1990 and 2050. Further, results are reported for *stayers* only.

Starting with the constant tax scenario, one observes positive, but moderate welfare effects in Germany that decrease over time without turning negative. The shape of the curve can be motivated as following: Differences between both model variants are less strong in earlier periods and begin to materialize later.[18] Consequently, younger cohorts are subject to the positive effect on benefits (which they receive at later stages of the life-cycle) while the negative effect of lower wages is limited. Future cohorts, on the other hand, experience a stronger decline in wages which reduces welfare. For Poland, the opposite holds true, whereby the corresponding Δ is larger in absolute terms. The generation of 2010 experiences a loss of 0.6% of lifetime consumption. The fact that welfare of agents in Poland is affected more strongly is again due to a size effect since migration flows represent a larger share of the total population in Poland than in Germany. Individuals in Southern Europe are continuously negatively affected by emigration due to lower wages and benefits.[19]

Having described the welfare consequences in the constant tax scenario, it remains to uncover the welfare effects when the tax rate is allowed to adjust. As argued before, agents in Germany experience larger welfare gains from immigration as long as they profit from higher benefits while only having to suffer from a small wage reduction. Following that logic, one must expect different welfare implications under the constant replacement rate scenario because the fiscal pressure on social security now directly affects net wages. The curves in figure 3.12 confirm this conjecture. As migration immediately raises net wages, all German cohorts under investigation experience welfare gains. In fact, these gains are increasing over time and are significantly larger than in the constant tax scenario. This is firstly due to the aforementioned greater importance of net wages in terms of welfare (compared to benefits), and secondly due to the overall larger size of migration flows. Welfare changes in the sending regions exhibit just the reversed pattern since emigration enhances population aging and likewise the financial burden for workers. Welfare losses are especially severe in Poland where they reach a level of 3% of lifetime consumption.

3.7 Conclusion

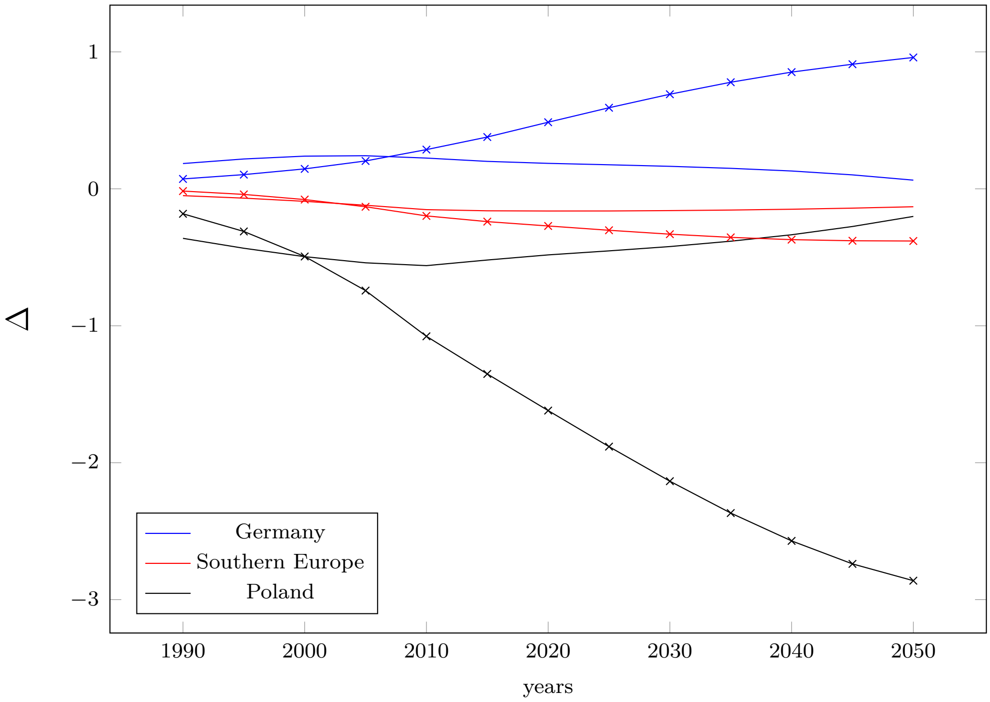
This paper studies endogenous intra-European migration along the demographic transition between Germany as the receiving region, and Southern Europe and Poland as sending regions. I distinguish between two different policy responses to popula-

[17]The terms *cohort* or *generation* refer to the point of time when individuals become economically active.

[18]See figure 3.5.

[19]See the discussion about the effects of emigration on prices in Southern Europe in section 3.4.3.

Figure 3.12: Welfare



Note: The solid lines indicate the constant tax scenario and the x-marked lines the constant replacement rate scenario.

tion aging: In the first scenario, the contribution rates remain constant and pension benefits decrease. In the second scenario, I fix the replacement rate at its level of 2015 and let contribution rates increase to support the implied level of benefits. In both policy scenarios, migration flows are predicted to fall relative to current levels. However, incentives to migrate to Germany are stronger in the second scenario since workers in the sending regions are more strongly affected by the large distortions from social security. Even though the migration flows arising remain small relative to total population, they are shown to have significant macroeconomic implications. This is caused by the *dual* effect of migration on population dynamics. Firstly, the current workforce is directly affected by migration movements. Secondly, migration entails an amplification effect by influencing population growth thereby altering the size of the future workforce. As a result of immigration from the sending regions, Germany experiences a decline in the gross wage on the one hand and higher returns to social security on the other, while the quantitative effect on the social security variables is significantly larger. The ensuing welfare effects of migration hinge upon the considered policy scenario. If tax rates are assumed to remain constant, the distortions from social security are less strong and immigration leads to moderate welfare gains in Germany accompanied by welfare losses in the sending regions. Since the share of emigrants with respect to total population is larger in Poland than in Southern Europe, welfare effects in Poland are more pronounced. If tax rates have to adjust, the distortions from social security significantly grow such that their alleviation through immigration causes higher welfare gains in Germany which continuously increase up to a maximum of 1 % of lifetime consumption. Likewise, the sending regions experience even larger welfare losses due to emigration. For the case of Poland, the reduction in welfare is at its peak equivalent to 3% of lifetime consumption. This result points to a fundamental problem arising within the common European market. While all European countries are confronted with strong population aging, migration flows can serve to mitigate its consequences in some countries, however, only at the expense of worsening the demographic problem in others. Further, the dependence of migration flows on the policy scenario implies that governments have to take migration responses into account when reforming their social security systems. In particular, if regions which already exhibit significant emigration cannot contain the fiscal burden of young workers along the demographic transition, an increase in migration pressure might accelerate the speed of population aging. Ultimately, from a methodological point of view, the endogeneity of migration flows introduces a feedback between demographics and changes in the economic environment. In this respect, the paper can be seen as a step towards developing a greater understanding of the endogenous nature of the demographic transition.

Appendix 3.A Cross-Sectional Measure

In the following, I present the evolution of the cross-sectional measure for both the destination and the sending regions. Firstly, newborns arrive according to:[20]

$$\Phi_{t+1}(\mathcal{A},\mathcal{K};1,1,x,x)=\begin{cases}\mathcal{N}_{t+1,1,x}\int_{\mathcal{K}} f_{\lambda_x}(\kappa)d\kappa \;\; if \;\; 0\in\mathcal{A}\\ 0 \;\; \text{else.}\end{cases}$$

For stayers with $j < R$, it holds:

$$\Phi_{t+1}(\mathcal{A},\mathcal{K};j+1,j+1,d,d)=\int_{\mathcal{A}\times\mathcal{K}}\mathbb{1}\{a'_t(a,\kappa;j,j,d,d)\in\mathcal{A}\}d\Phi_t(a,\kappa;j,j,d,d)\psi_{d,t,j}$$

$$\Phi_{t+1}(\mathcal{A},\mathcal{K};j+1,j+1,s_i,s_i)=\int_{\mathcal{A}\times\mathcal{K}}(1-\varphi_t(a,\kappa;j,j,s_i,s_i))\mathbb{1}\{a'_t(a,\kappa;j,j,s_i,s_i)\in\mathcal{A}\}$$
$$d\Phi_t(a,\kappa;j,j,s_i,s_i)\psi_{s_i,t,j}$$

Stayers with $R\leq j<J$, move across time as following:

$$\Phi_{t+1}(\mathcal{A},\mathcal{K};j+1,R,d,d)=\int_{\mathcal{A}\times\mathcal{K}}\mathbb{1}\{a'_t(a,\kappa;j,R,d,d)\in\mathcal{A}\}d\Phi_t(a,\kappa;j,R,d,d)\psi_{d,t,j}$$

And in the sending regions equivalently.
For new arrivals with $j\in[1,R-1]$:

$$\Phi_{t+1}(\mathcal{A},\mathcal{K};j+1,j,d,s_i)=\int_{\mathcal{A}\times\mathcal{K}}\varphi_t(a,\kappa;j,j,s_i,s_i)\mathbb{1}\{a'_t(a,\kappa;j,j,s_i,s_i)\in\mathcal{A}\}$$
$$d\Phi_t(a,\kappa;j,j,s_i,s_i)\psi_{s_i,t,j}$$

In relation to the demographic model from 3.2.2, it holds:

$$\tilde{m}_{t,j,s_i}=\frac{\int_{\mathcal{A}\times\mathcal{K}}\varphi_t(a,\kappa;j,j,s_i,s_i)\mathbb{1}\{a'_t(a,\kappa;j,j,s_i,s_i)\in\mathcal{A}\}d\Phi_t(a,\kappa;j,j,s_i,s_i)}{\mathcal{N}_{t,j,s_i}}$$

Lastly, for past migrants with $j\in[2,J-1]$ and for all $j_m\in[1,\min\{j-1,R-1\}]$:

[20] Note that the distributional parameter λ_{ger} can be set arbitrarily to any positive real number.

$$\Phi_{t+1}(\mathcal{A},\mathcal{K};j+1,j_m,d,s_i) = \int_{\mathcal{A}\times\mathcal{K}} \mathbb{1}\{a'_t(a,\kappa,j,j_m,d,s_i) \in \mathcal{A}\} d\Phi_t(a,\kappa;j,j_m,d,s_i)\psi_{s_i,t,j}.$$

Appendix 3.B Evolution of Migration Incentives

This section contains the graphs depicting the evolution of the CEV (Θ), referred to in sections 3.4.2 and 3.5. Figures 3.13 and 3.14 refer to the constant tax scenario, whereas figures 3.15 and 3.16 contrast both policy experiments. Note that Θ follows just the reversed pattern of the *threshold disutlity* discussed in section 3.4.2. Further, it is important to note that the evolution of $\Theta_{s_i,t}$ is not smooth since the space of preference types needs to be discretized in order to solve the model numerically as further discussed in section 3.D.2.

Figure 3.13: Threshold Disutility (constant tax) - Poland

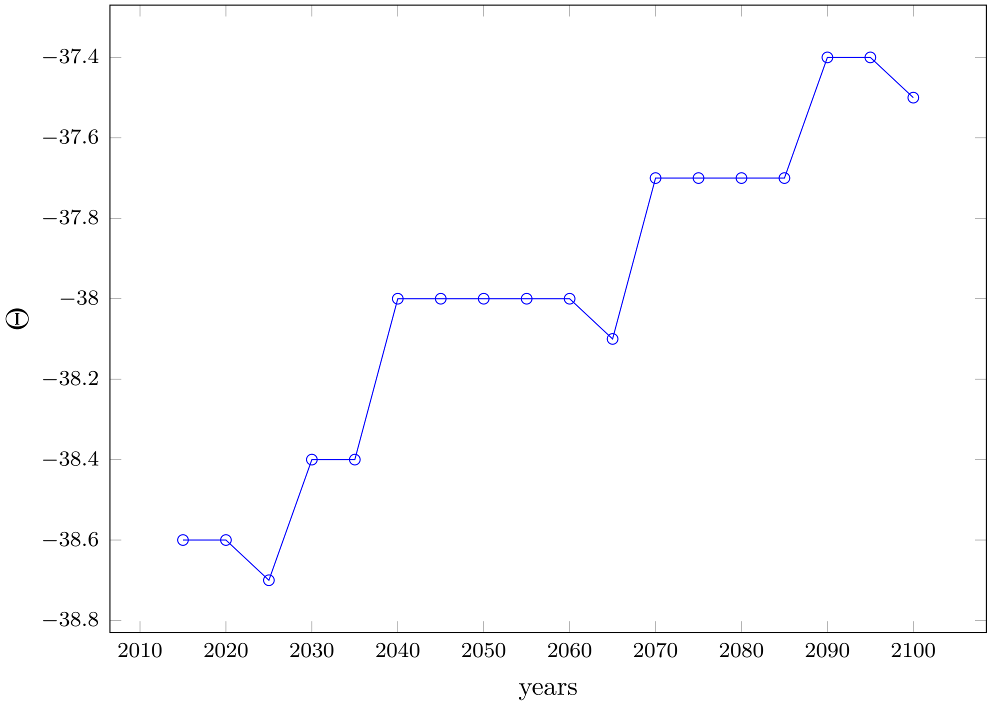


Figure 3.14: Threshold Disutility (constant tax) - Southern Europe

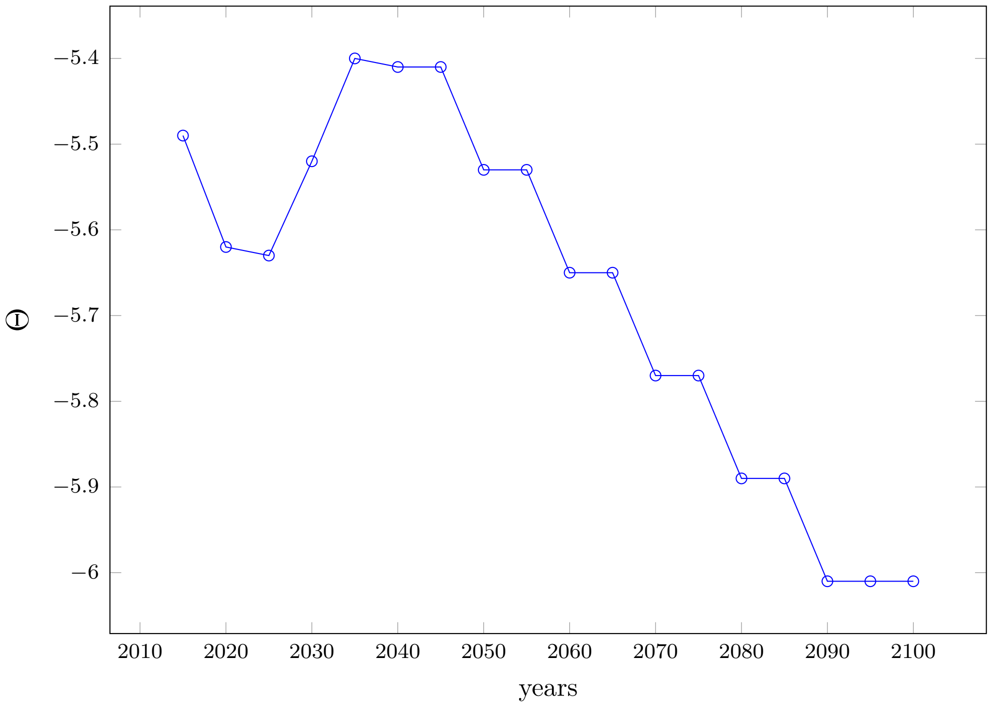


Figure 3.15: Threshold Disutility (both scenarios) - Poland

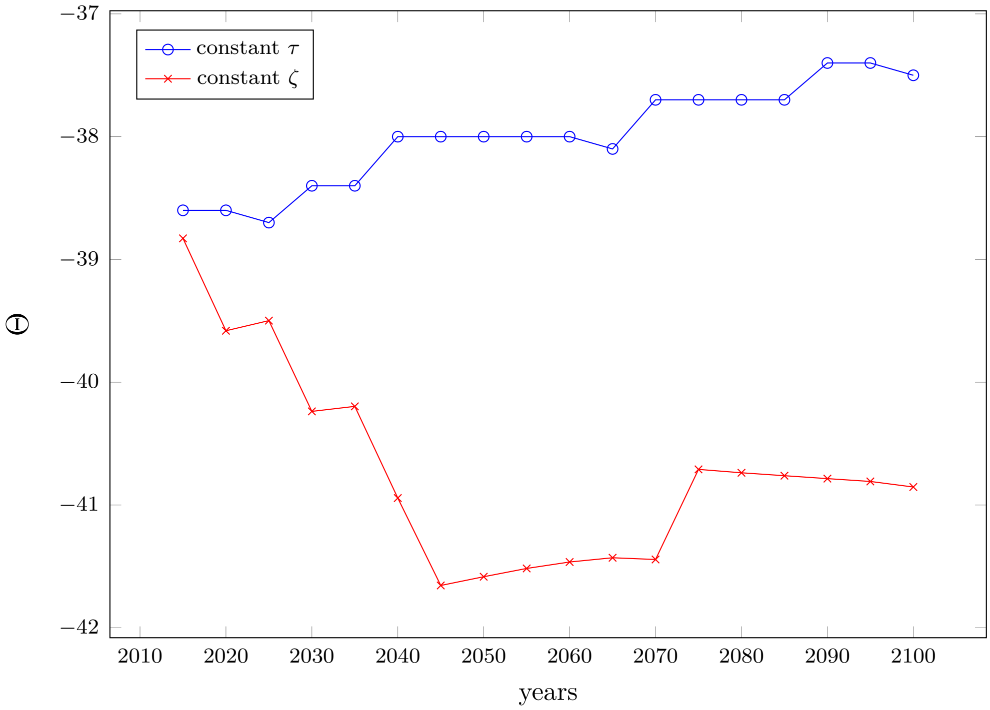
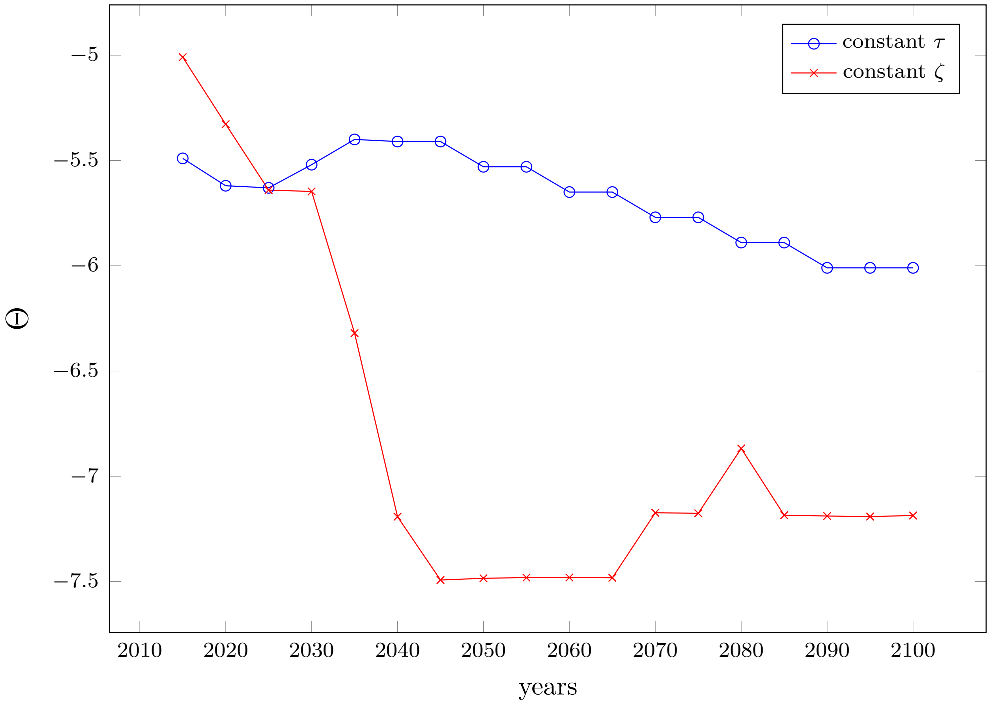


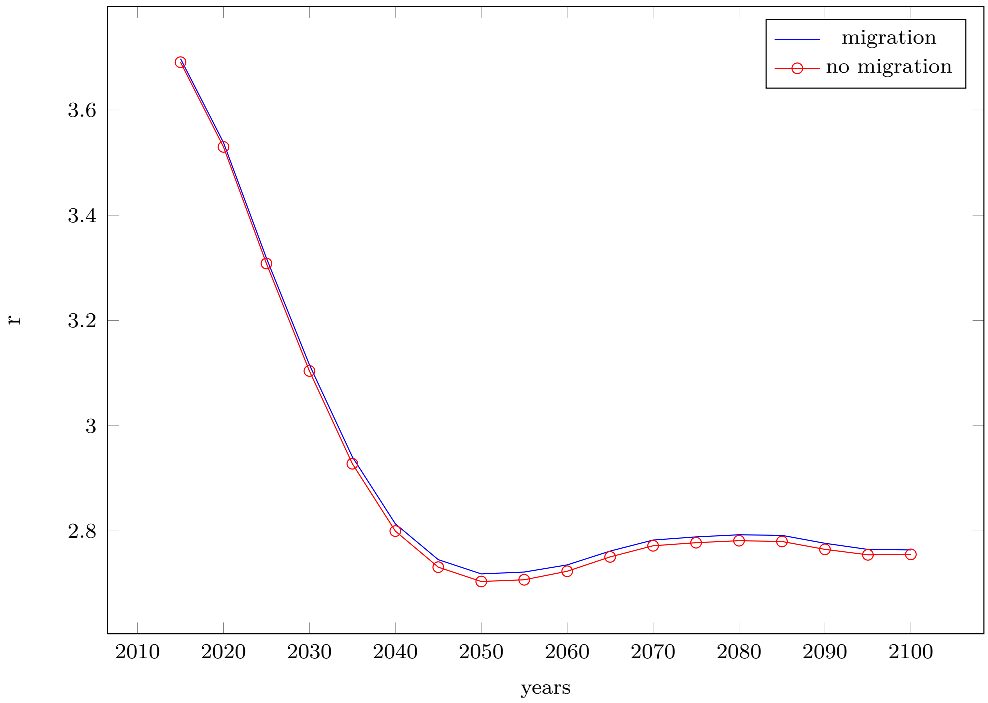
Figure 3.16: Threshold Disutility (both scenarios) - Southern Europe



Appendix 3.C Interest Rate

Figure 3.17 shows the evolution of the interest rate in both the benchmark and the counterfactual scenario.

Figure 3.17: Interest rate



Appendix 3.D Computation

3.D.1 Aggregate Model

Given the vector of structural parameters displayed in table 3.1, I solve for an artificial steady (SS^{ini}) in $t = 0$ by iterating on the steady sate vector of macroeconomic aggregates $\vec{\Psi}^{SS} = [K, L]$, where K denotes total capital, and L is a 3×1 vectors containing region-specific labor supply. Agents born in the initial steady state expect prices to stay constant until infinity. The demographic transition starting in 1950 as well the simultaneous introduction of labor mobility is then introduced to them as unforeseen event that requires a re-optimization of all generations already alive.

Note that the model's final steady state is unknown ex ante since demographics evolve endogenously such that the final population distribution in 2300 results from solving the entire transition path. However, computing the transition requires a guess for the final steady state (SS^{final}_{guess}) . Therefore, I solve for a steady state with a stationary population distribution to which the model would converge until 2300 if there was no endogenous migration. In particular, this distribution can be calculated using the demographic law of motion in (3.1) and (3.2), whereby I assume $\tilde{m}_{t,j,s_i} = 0$ $\forall t, j, s_i$ and I let m_{t,j,s_i} be equal to the migration rates projected by United Nations (2015).

Given SS^{ini} and SS^{final}_{guess}, I construct a transition vector of macroeconomic aggregates ($\vec{\Psi}^T$) by linearly interpolating between both steady states. $\vec{\Psi}^T$ has more elements than $\vec{\Psi}^{SS}$ since it additionally includes the mass of retirees in each region adjusted for their pension entitlements[21] as well as total population. Hence, $\vec{\Psi}^T = [K, L, Ret, Pop]$. Adding the measure of retirees is necessary to compute the endogenous social security variables. Further, keeping track of total population allows to calculate population growth rates used for the stationarization as in İmrohoroğlu et al. (1999). I iterate over $\vec{\Psi}^T$ using a linear updating scheme until initial guesses and model outcomes are sufficiently close to each other.

3.D.2 Household Problem

Endogenous Grid Method and Non-Concave Problems

I solve the household problem by backward induction applying the endogenous grid method (EGM) proposed by Carroll (2006). However, due to the discrete choice involved in the migration decision, the individual budget set is non-convex, which might lead to a non-concave value function. The standard EGM procedure is not equipped to handle non-concave problems. Therefore, I rely on a generalization of the EGM

[21] Equal to the terms in brackets on the r.h.s of (3.14) and (3.15).

method developed by Fella (2014) tailored at dealing with such non-convexities. The fundamental idea of this extension is to partition the value function into a *concave region* where the Euler equation is both necessary and sufficient and *non-concave region* where the Euler equation still holds at a local maximum. To check whether the local maximum detected by the EGM is indeed a global one, I use a derivate-free method to verify all solutions obtained in the *non-concave region*.

Preference Heterogeneity

The household problem for German newborns can be solved for a representative agent since Germans do not migrate. In contrast, the life-cycle optimization problem for newborns in the sending regions has to be solved for various preference types. In particular, I discretize the continuous state space $\mathcal{K}$ into 15 different grid points $[\kappa_1, \ldots, \kappa_{15}]$. Accounting for a relatively high number of preference types is important for two reasons. Firstly, a fine grid supports convergence of the algorithm outlined in section 3.D.1. Secondly, it enables the detection of variations in the *marginal migrant* as in figures 3.13 to 3.16. Having obtained the type-specific policy functions, aggregation requires numerical integration between preference types.

Pseudo Code

The presentation of the pseudo code is restricted to an individual in the sending region. I set up two different asset grids, one for the end-of-period assets $\mathcal{G}_{a'} = a'_1, \ldots, a'_{n-1}$ and one for the beginning-of-period assets $\mathcal{G}_a = [a_1, \ldots, a_n]$. Note that $\mathcal{G}_{a'}$ contains only $n-1$ grid points. This will be useful for dealing with the borrowing constraint as explained below.

1. In period J: For all $j_m \in [1, R]$, all $x \in \{d, s_i\}$ and all $a_i \in \mathcal{G}_a$ obtain

$$\begin{aligned}
c(a_i, \kappa, J, j_m, x, s_i) &= (1+r)a_i + \pi(j_m) \\
a'(a_i, \kappa, J, j_m, x, s_i) &= 0 \\
l(a_i, \kappa, J, j_m, x, s_i) &= 0 \\
V(a_i, \kappa, J, j_m, x, s_i) &= u(c(a_i, \kappa, J, j_m, x, s_i), 0) \\
V_a(a_i, \kappa, J, j_m, x, s_i) &= u_c(c(a_i, \kappa, J, j_m, x, s_i), 0)(1+r)
\end{aligned}$$

2. In period $j = J-1, \ldots, R+1$: The function $V_{a'}(a', \kappa, j+1, j_m, x, s_i)$ is known from the previous step. Since it is defined on $\mathcal{G}_a$, it needs to be interpolated on

$\mathcal{G}_{a'}$. For all $j_m \in [1, R]$, all $x \in \{d, s_i\}$ and all $a'_i \in \mathcal{G}_{a'}$, one can use the Euler equation to solve for current period consumption:

$$u_c = \beta\psi_j V_{a'}(a'_i, \kappa, j+1, j_m, x, s_i), \tag{3.27}$$

where

$$u_c = \gamma \frac{[c^{\gamma}(1-l)^{1-\gamma}]^{(1-\eta)}}{c}. \tag{3.28}$$

Since $l = 0$ during retirement, this reduces to:

$$u_c = \gamma c^{\gamma(1-\eta)-1},$$

so that one can directly solve for c. With the help of the budget constraint, one can then back out a_i giving rise to the endogenous beginning-of-period asset grid. To obtain policy and value functions, it again requires interpolation of consumption and savings on $\mathcal{G}_a$. Hence, for each $a_i \in \mathcal{G}_a$ update:

$$\begin{aligned}
c(a_i, \kappa, j, j_m, x, s_i) &= c_i \\
l(a_i, \kappa, j, j_m, x, s_i) &= 0 \\
a'(a_i, \kappa, j, j_m, x, s_i) &= a'_i \\
V(a_i, \kappa, j, j_m, x, s_i) &= u(c(a_i, \kappa, j, j_m, x, s_i), 0) + \beta\psi_j V(a'_i, \kappa, j+1, j_m, x, s_i) \\
V_a(a_i, \kappa, j, j_m, x, s_i) &= u_c(c(a_i, \kappa, j, j_m, x, s_i), 0)(1+r)
\end{aligned}$$

Before interpolation on $\mathcal{G}_a$, however, I test whether the agent might have entered the borrowing constrained region. This is the case if the endogenous beginning-of-period asset for $a'_i = 0$ is greater than zero. If a borrowing constrained region has been detected, I follow Kindermann and Krueger (2014) and extend the pre-interpolation vectors by one element to left: I set $a_1 = 0$ and $a'_1 = 0$, so that I obtain $c_1 = \pi(j_m)$.

3. In period $j = R, \ldots, 1$: During the working period, labor supply in (3.28) is positive. In order to solve for consumption via the Euler equation, I eliminate $(1-l)$ by using the MRS:

$$(1 - l(j)) = \frac{1-\gamma}{\gamma} \frac{1}{w(1-\tau)\epsilon(j)} c(j).$$

Plugging this into (3.28), one gets:

$$u_c = c(j)^{-\eta} \gamma \Big[\frac{1-\gamma}{\gamma} \frac{1}{w(1-\tau)\epsilon(j)} \Big]^{(1-\gamma)(1-\eta)}.$$

Individuals can migrate throughout their working life, except for the last period. After an agent has migrated, the optimization problem is strictly concave due to the absence of return migration. For an individual still residing in the sending region, I firstly compute the continuation value of a migrant and then the one of a stayer:

$$\begin{aligned}
v(a_i, \kappa, j, j, s_i, s_i)^{stay} &= U(c^{stay}(a_i, \kappa, j, j, s_i, s_i), l^{stay}(a_i, \kappa, j, j, s_i, s_i)) \\
&+ \beta \psi_j V(a_i', \kappa, j+1, j+1, s_i, s_i) \\
v(a_i, \kappa, j, j, s_i, s_i)^{migrate} &= U(c^{stay}(a_i, \kappa, j, j, s_i, s_i), l^{migrate}(a_i, \kappa, j, j, s_i, s_i)) \\
&+ \beta \psi_j V(a_i', \kappa, j+1, j, d, s_i).
\end{aligned}$$

Note that the EGM refinement explained in section 3.D.2 applies to $v(\cdot)^{stay}$ due to the discrete choice in future periods.

Lastly, the migration policy function is determined as:

$$\begin{cases} \varphi = 1 & \text{if} \quad v^{migrate}(\cdot) > v^{stay}(\cdot) \\ \varphi = 0 & \text{else.} \end{cases}$$

4. The Distributional Implications of Migration: An Open Economy Analysis of Germany and Poland

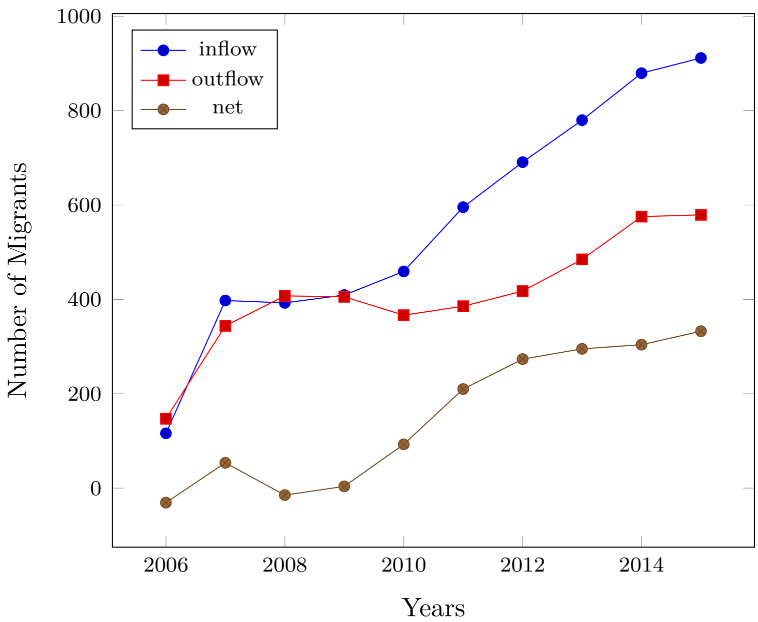
4.1 Introduction

Over the last ten years, Germany has received a steady increase in the inflow of migrants from European countries, peaking at 912.000 in 2015 (see figure (4.1)). Further, net migration turned from negative numbers in 2006 into a large migration surplus (333.000 in 2015) thereby making Germany the most important destination country for intra-European migration. Among all immigrants in Germany, Polish migrants represent the largest group. In 2016, 1.47 million Polish citizens with a personal migration experience lived in Germany (Statistisches Bundesamt (2016a)).[1] Further, net immigration from Poland showed a clear positive trend over the last ten years indicating that the stock of Polish migrants is likely to increase further in the near future (Destatis (2017)). The goal of this study is to uncover the macroeconomic and distributional implications of the migration flows between Poland and Germany. Therefore, I set up a large-scale open economy OLG model calibrated to match the skill composition of the total Polish and German workforces, as well as of the Polish migrant population in Germany. Within the model, migration affects the macroeconomy through changes in labor supply, differences in saving behavior between natives and migrants (in Germany), as well as between stayers and return migrants (in Poland). Additionally, I account for the effect of migration on public pensions by explicitly modeling the transferability of pension rights as practiced in the European Union. Incorporating pensions in the model is essential because the significantly younger age structure of the Polish migrant labor force improves the sustainability of the German PAYG system. Further, given the size of the pension systems in both Germany and Poland, pension benefits are an important determinant of life-cycle savings.

In the last decades, a large body of empirical literature has focused on estimating the impact of immigration on natives' employment status, in particular on wages. Over

[1] The second largest group were Turkish citizens with a total number of 1.32 million.

Figure 4.1: Migration: Germany - EU



Source: Destatis (2017). Numbers are in thousands.

time, this literature has not reached a consensus about the effects of immigration, but rather established a variety of results, ranging from negative (Borjas (2003)) to (at least on average) positive wage effects (Dustmann, Frattini, et al. (2012)). As argued in Dustmann and Preston (2012), one reason for this lack of consensus is that different studies follow different approaches and thus ultimately do not measure the same effect. Broadly summarized, there exist two general approaches to the estimation of the wage effects of immigration: The *spatial correlation* and the *national* approach. The former (e.g. Dustmann, Frattini, et al. (2012)) relies on variations in migration densities across regions to measure the response of native wages to changes in immigrant labor supply. This approach has been criticized by advocates of the *national* approach (e.g. Borjas (2003)) for neglecting the equilibrating forces between local labor markets induced by local immigration shocks. Thus, this strand of literature strongly emphasizes the need to estimate wage effects on a national level, so that possible adaption mechanisms, such as capital adjustments, are accounted for. Several studies following the *national* approach have used structural estimation procedures. As one example, Ottaviano and Peri (2012) use a multi-level CES production function as their structural framework. My study connects to this literature by also employing a CES production function that allows for imperfect substitutability between different skill types and thus is able to capture the distributional effects of migration between skill groups.

A related general equilibrium study addressing the effects of skill-specific immigration is the seminal paper by Storesletten (2000). In particular, the author asks for the age and skill composition of the migrant population necessary to alleviate the fiscal pressure in the US tax and transfer system caused by population aging. Further papers dealing with the macroeconomic and fiscal effects of immigration are Storesletten (2003) and Fehr et al. (2004). My paper extends this literature and contributes to the understanding of the macroeconomic and distributional effects of migration in the following way: Firstly, the papers mentioned beforehand assume perfect substitutability between different skill types. Building on the empirical literature, I allow for imperfect substitutability, such that immigration implies changes in relative wages between labor types, if the skill composition of the migrant population differs from that of non-migrants. Secondly, I emphasize the importance of analyzing the effects of migration in an open economy framework. When investigating the effects of immigration, it is important to account for differences between migrants and non-migrants with respect to their consumption, labor supply and savings behavior. I argue that only an open economy perspective can comprehensively uncover these differences. In particular, I assume that migrants living in Germany face a positive probability of returning to Poland in each period of their life. This creates a precautionary savings motive since they face a significant loss in labor income after returning inducing them to save considerably more than non-migrants in both countries.[2] Two important theoretical contributions to the literature on savings of return migrants discussing this mechanism are given by Galor and Stark (1990) and Dustmann (1997).

To uncover the implications of migration, I perform the following thought experiment. Starting from a steady state with two-directional migration flows between Poland and Germany, I set migration rates to zero and compute the corresponding new steady state. The counterfactual therefore corresponds to a scenario in which there is no migration between both countries. Comparing both model variants then discloses the distributional implications of the entire migration movements between Germany and Poland.[3] Individuals in the economy are affected by labor mobility through alterations in factor prices and pension benefits. Addressing the former, I qualitatively decompose wage effects into changes in relative labor supply and capital formation. Regarding labor supply, we observe that the Polish migrant population in Germany is characterized by a more than proportionally large share of low-skilled workers implying that wage effects are concentrated among this group in both countries. Further, changes in absolute wages depend on how the capital to labor ratio adjusts to migration. In this respect, it is important to understand the differences in savings behavior between

[2]Storesletten (2000) also models return migration. However, he assumes that after returning, agents face the same sequence of factor prices and net transfers as in the US. This assumption necessarily rules out that economic choices of a migrant are influenced by income differences between the host and her home country.

[3]I abstract from analyzing the transitional dynamics since the abolishment of labor mobility between member states of the EU is not a currently realistic policy scenario and therefore it does not require an analysis of the adjustment process to this policy change. In the context of this model, the studied policy experiment should merely be seen as a conceptually useful tool to study the macroeconomic effects of migration.

migrants and non-migrants. The model predicts that - while residing in Germany - migrants build up large stocks of assets that significantly exceed those of non-migrants. This has a particular positive effect on the Polish capital to labor ratio since return migrants bring their savings back to their home country. Overall, we see mild changes in wages for high-skilled and medium-skilled workers. In contrast, low-skilled workers in Germany experience 0.51% higher wages in the no-migration variant, while the respective group in Poland suffers from a large wage reduction equal to 3.53%. Whereas changes in wages strongly depend on the skill composition of migrants, the effect on pension benefits is determined by their age structure. Since the Polish migrant population is considerably younger than the German one, the absence of immigration leads to a lower working age to population ratio and thus decreases benefits. In Poland, the rejuvenation of the population induces an upward pressure on benefits, which is, however, partly counteracted by negative wage responses. Ultimately, welfare effects are weak for medium-skilled and high-skilled workers in the two economies. However, low-skilled workers in Germany experience a welfare loss due to immigration in the amount of 0.47% of lifetime consumption. On the other side, low-skilled workers in Poland are considerably better off due to emigration. Their welfare gain equals 3.42% of lifetime consumption. The results outlined beforehand rest on the assumption that migrants can only invest in Germany. In the context of a sensitivity analysis, I additionally allow migrants to invest in Poland. Due to these cross-border investments, the welfare improving role of the migrants' savings is weakened in Germany. In Poland, however, non-migrants benefit even more from migration due to the additional inflow of capital.

Lastly, an integral part of my study is to investigate whether the general equilibrium wage effects of migration substantially differ from those obtained in the structural empirical literature. I show that such differences exist because empirical studies necessarily have to make simplifying assumptions about adjustments of the capital to labor ratio that do not need to hold in general equilibrium models as considered here. Regarding the case of Germany and Poland, I find the following asymmetry: While the capital to labor ratio is only mildly affected by migration in Germany, labor movements induce a capital deepening in Poland caused by the beneficial role of migrants' savings for the Polish economy. As a consequence, ignoring this mechanism would cause a significant upward bias in estimated wage effects of emigration for Polish workers.

4.2 Model

4.2.1 Regions and Demographics

The model economy comprises two regions which are called *home* (h) and *foreign* (f). They are inhabited by J overlapping generations facing a country-specific idiosyncratic risk to survive from one period to the other denoted by $\psi_{x,j}$. It holds that $\psi_{x,0} = 1$ and $\psi_{x,J} = 0$. Both regions grow at a constant rate n. An exogenously determined share of agents born in f migrates to h, whereas all agents born in h are immobile by assumption. Migration takes place during the first period of life, such that migrants arrive in h in $j = 2$.[4] I further account for the possibility of return migration by assuming that migrants return to f each period with a probability of λ. Agents cannot re-enter h after being sent back to f.

4.2.2 Production

Each region $x \in \{h, f\}$ produces a homogeneous good with a CES production function which is a modification of Glitz and Wissmann (2017). The modified version in (4.1) abstracts from imperfect substitutability between age groups[5], but additionally includes capital as an input factor, as well as skill-neutral labor productivity growth:

$$\begin{aligned} Y_{x,t} &= A_x K_{x,t}^{\alpha} [\mu_x (Z_t L_{high,x,t})^{\gamma} + (Z_t U_{x,t})^{\frac{\gamma}{\rho}}]^{\frac{1-\alpha}{\gamma}} \\ U_{x,t} &= [\sigma_x L_{med,x,t}^{\rho} + L_{low,x,t}^{\rho}] \end{aligned} \tag{4.1}$$

Besides capital ($K_{x,t}$), production inputs consist of high-skilled ($L_{high,x,t}$), medium-skilled ($L_{med,x,t}$) and low-skilled labor ($L_{low,x,t}$). Further, Z_t denotes labor-augmenting technological progress growing at a constant rate g. The model assumes some parameters to be identical in both countries, whereas others are allowed to differ. Regarding the former, α defines the share of capital. $\frac{1}{1-\gamma}$ denotes the elasticity of substitution (eos) between high-skilled and non-high-skilled labor, whereas $\frac{1}{1-\rho}$ specifies the eos between medium-skilled and low-skilled labor ($\gamma, \rho < 1$). Further, δ is the depreciation rate. The weights of type-specific labor inputs in production are allowed to be location-dependent: μ_x refers to the weight of high-skilled labor and σ_x to that of medium-skilled. Perfect competition among firms demands an equalization of factor prices and marginal products:

[4] Note that this assumption is well in line with the data since immigrants from Poland are on average below 25 (Statistisches Bundesamt, 2016a).

[5] This simplification is necessary due to computational limitations. The solution algorithm iterates over 14 variables, including interest rates, wages, and pension benefits. Just allowing for imperfect substitutability between young and old workers would already increase the number of variables to 20.

$$w_{high,x,t} = A_x K_{t,x}^{\alpha}(1-\alpha)\Upsilon_{x,t}^{\frac{1-\alpha}{\gamma}-1}\mu_x(Z_t L_{high,x,t})^{\gamma-1}Z_t \tag{4.2}$$

$$w_{med,x,t} = A_x K_{t,x}^{\alpha}(1-\alpha)\Upsilon_{x,t}^{\frac{1-\alpha}{\gamma}-1}(Z_t U_t)^{\frac{\gamma}{\rho}-1}\sigma_x L_{med,x,t}^{\rho-1}Z_t \tag{4.3}$$

$$w_{low,x,t} = A_x K_{t,x}^{\alpha}(1-\alpha)\Upsilon_{x,t}^{\frac{1-\alpha}{\gamma}-1}(Z_t U_t)^{\frac{\gamma}{\rho}-1}L_{low,x,t}^{\rho-1}Z_t \tag{4.4}$$

$$r_{x,t} = A_x \alpha K_{t,x}^{\alpha-1}\Upsilon_{x,t}^{\frac{1-\alpha}{\gamma}} - \delta, \tag{4.5}$$

where

$$\Upsilon_{x,t} = [\mu(Z_t L_{high,x,t})^{\gamma} + (Z_t U_t)^{\frac{\gamma}{\rho}}] \tag{4.6}$$

4.2.3 Households

Decision Problem in Foreign

In the following section I illustrate the decision problem of an individual born in f. Agents exhibit a two-dimensional type heterogeneity: They differ with respect to their skill type $s \in \{1,2,3\}$ (high, med, low) and their migration type $\kappa \in \{1,2\}$ (stayer, mover). A combination of both skill and migration type is assigned to an agent at the beginning of the life-cycle and invariant from then on. The lifetime utility of an individual is given by:

$$\sum_{j=1}^{J}\beta^{j-1}(\prod_{k=1}^{j}\psi_{f,k-1})\left[\frac{(c^{\xi}(j)(1-l(j))^{1-\xi})^{1-\eta}}{1-\eta}\right] \tag{4.7}$$

Each individual lives up to a maximum age J. Future periods are discounted with a constant discount factor β and a period-to-period survival probability of ψ. Agents obtain utility from consumption (c) and leisure $(1-l)$. ξ determines the relative weight of consumption and $\frac{1}{\eta}$ describes the intertemporal elasticity of substitution.

In the following, we turn to the budget constraint stated in (4.8). We need to distinguish between two different states of residence: Either the individual still lives in the place of birth ($x_t(j) = f$) or she has migrated ($x_t(j) = h$).

$$\begin{cases}(1+r_{f,t})a_t(j) + e_{f,t}(j) = a_{t+1}(j+1) + c_t(j) & \text{if } \ x_t(j) = f \\ (1+r_{h,t})a_t(j) + e_{h,t}(j) = a_{t+1}(j+1) + c_t(j) & \text{if } \ x_t(j) = h\end{cases} \tag{4.8}$$

A part of the income is derived from individual returns on savings in the capital good ($a_t(j)$). As long as the agent lives in country f, she receives the interest rate

$r_{f,t}$ as returns on her assets. Further, it is assumed that individual asset holdings are attached to the migrant. Hence, when the agent moves to h, she brings her individual capital stock to the *home* economy and consequently earns the *home* interest rate. Likewise, return migrants carry their asset holdings back to country f.

The other component of personal income is given by the following state-dependent function $e_{x,t}(j)$ comprising both labor earnings and pension benefits.

$$\begin{cases} w^s_{f,t}(1-\tau_{f,t})l_t(j)\epsilon(j) & \text{if} \quad j < R \;\;\&\;\; x_t(j) = f \\ w^s_{h,t}(1-\theta)(1-\tau_{h,t})l_t(j)\epsilon(j) & \text{if} \quad j < R \;\;\&\;\; x_t(j) = h \\ \pi_t(.) & \text{else.} \end{cases} \tag{4.9}$$

We have to distinguish individual states both along the age and location dimension. With R denoting the exogenous retirement age, $j < R$ defines the state of workers. If an agent resides in foreign, earnings are determined by the skill-specific wage paid in f ($w^s_{f,t}$) net of the foreign contribution rate to the PAYG system ($\tau_{f,t}$) , as well as individual labor supply ($l_t(j)$) and an age-dependent productivity ($\epsilon(j)$). On the other hand, if the worker has migrated, individual labor earnings are determined by the home wage net of the home social security tax. Further, migrants are assumed to be less productive than natives, hence, wages are subject to a productivity loss (θ). The age-dependent productivity profile is assumed to be identical between both regions. Finally, retirees receive pension benefits according to the pension formula π as explained in the next section. Total personal income is spent on future individual assets ($a_{t+1}(j+1)$) and consumption ($c_t(j)$).

Pension Benefits

The two regions run national PAYG pension systems. Both are organized according to a *place of residence principle* as practiced in the European Union. This principle implies that individuals acquire pension claims in each region they work. Hence, migrants will be entitled to pension benefits from both f and h. I capture this scheme of pension entitlements through the following formula:

$$\begin{cases} \pi_t(j) = \frac{n^f_t(j)b^s_{f,t}+n^h_t(j)b^s_{h,t}(1-\theta)}{R} & \text{if} \quad j > R \\ 0 & \text{else,} \end{cases} \tag{4.10}$$

where $n^f(j)$ and $n^h(j)$[6] denote the number of periods spent working in either f or h at age j. The type-specific pension benefits in home and foreign are given by $b^s_{h,t}$ and $b^s_{f,t}$. The pension formula therefore forms a weighted average of home and foreign benefits, whereby the weights depend on the length of the working spell in h and f. Note that I assume that a migrant's entitlements to the German pension system are discounted by (1-θ), and thus proportional to the wage gap.

We further have to specify a law of motion for $n^f(j)$ describing its evolution along the life-cycle:

$$\begin{cases} n^f(j+1) = n^f(j) + 1 & \text{if} \quad j < R \;\;\&\;\; x(j+1) = f \\ n^f(j+1) = n^f(j) & \text{if} \quad j < R \;\;\&\;\; x(j+1) = h \\ n^f(j+1) = n^f(j) & \text{if} \quad j \geq R \end{cases} \tag{4.11}$$

The first case refers to an working agent who is not in the last period of her working life and will reside in *foreign* in $j+1$. This comprises both *stayers* and return migrants living in f as well as next-period return migrants who still live in h at age j. The second case relates either to an individual currently residing in h who is not forced to return at the end of the period or to an emigrant. The ultimate case states that after the last period of working life has been reached, $n^f(j)$ remains constant. Note that $n^f(j) + n^h(j) = j$ has to hold in each period of the working life, so that pension entitlements are uniquely determined by $n^f(j)$.

Lastly, it remains to specify the relation between the type-specific benefits. I assume that benefits are proportional to the ratio between type-specific labor income and total labor income:

$$b^s_{x,t} = \frac{w^s_{x,t} L^s_{x,t}}{Y^L_{x,t}} \frac{Pen_{x,t}}{Ret^s_{x,t}}, \tag{4.12}$$

where $Pen_{x,t}$ captures total pension payments, $Ret^s_{x,t}$ denotes the mass of skill-specific retirees and $Y^L_{x,t}$ is total labor income.[7] Note that this pension formula implies that total payments to retirees of one skill-type exactly match the contributions of working agents of the same type. Hence, this stylized representation of a pension scheme resembles the pension systems in Germany and Poland in the sense that both schemes exhibit a strong earnings linkage. In fact, the German point system is completely earnings related. The Polish notional-account system[8] features some small de-

[6]The time index t is dropped for notational convenience.

[7]In particular, $Ret^s_{x,t}$ denotes the skill-specific population mass of retirees weighted by their individual claims to the pension system.

[8]Notional-account schemes assign contributions to an individual account and calculate a respective

gree of redistribution due to minimum pensions and unemployment regulations (OECD (2015)). However, this outlined modeling approach neglects that agents take the effects on their individual pension benefits into account when making decisions about labor supply. Modeling this mechanism would require a replacement of the discrete state variable n^f by a continuous one.

4.2.4 Government

Besides running a PAYG pension system, the government uses accidental bequests to finance government consumption equal to $G_{x,t}$.

4.2.5 Recursive Formulation

I present the recursive formulation of the household problem for an individual born in the sending region. I define the vector of state variables as $z = (a, \kappa, s, j, n^y, x, y)$, whereby y denotes the place of birth, and x the current location. Let us begin with the Bellmann equation for a stayer ($\kappa = 1$):

$$
\begin{aligned}
&V_t(a, \kappa, s, j, n^f, f, f) = \max_{c,l,a'} \Big[U(c, l) + \beta \psi_{f,j} V_{t+1}(a', \kappa, s, j+1, n^{f'}, f, f) \Big] \qquad (4.13)\\
&s.t. \;\; c + a' = (1 + r_{f,t}) + e_{f,t}\\
&c, a' > 0, l \in [0, 1],
\end{aligned}
$$

where $n^{f'}$ evolves according to (4.11). Now, let us focus on a migrant. For $\kappa = 2$ in $j = 1$:

$$
\begin{aligned}
&V_t(a, \kappa, s, j, n^f, f, f) = \max_{c,l,a'} \Big[U(c, l) + \beta \psi_{f,j} V_{t+1}(a', \kappa, s, j+1, n^{f'}, h, f) \Big] \qquad (4.14)\\
&s.t. \;\; c + a' = (1 + r_{f,t}) + e_{f,t}\\
&c, a' > 0, l \in [0, 1],
\end{aligned}
$$

If the agent has migrated in the past and currently resides in h, she has to plan with a possible return at the end of the period ($\lambda > 0$):

---

return. Since these balances are only book values, the system is labeled with the term *notional* (see OECD (2015)).

$$V_t(a,\kappa,s,j,n^f,h,f) = \max_{c,l,a'}\Big[U(c,l) + \beta\psi_{f,j}\Big\{\lambda V_{t+1}(a',\kappa,s,j+1,n^{f'},f,f) \tag{4.15}$$
$$+ (1-\lambda)V_{t+1}(a',\kappa,s,j+1,n^{f'},h,f)\Big\}\Big]$$
$$s.t.\;\; c + a' = (1+r_{h,t}) + e_{h,t}$$
$$c, a' > 0, l \in [0,1].$$

For a return migrant, the recursive problem is identical to the one in (4.13).

4.2.6 Decision Problem in Home

All agents born in h are immobile by assumption, so that they face the same life-cycle optimization problem as *stayers* in *foreign*. Hence, in the equilibrium characterization in the following section, the entire distribution mass for home agents lies on type $\kappa = 1$.

4.2.7 Equilibrium

I define $\Phi_t(a;\kappa,s,j,n^y,x,y)$ as the mass of people with asset stock $a \in \mathcal{A}$, migration type $\kappa \in \{1,2\}$, skill type $s \in \{1,2,3\}$, age $j \in [1,J]$, number of periods spent working in country of birth $n^y \in [1,R]$, place of residence $x \in \{h,f\}$ and place of birth $y \in \{h,f\}$ in period t.

Definition A competitive equilibrium consists of sequences of individual functions for the household, $\{V_t(\cdot), c_t(\cdot), l_t(\cdot), a'_t(\cdot)\}_{t=0}^{\infty}$, sequences of production plans for the firms $\{K_{x,t}, L_{x,t}^{high}, L_{x,t}^{med}, L_{x,t}^{low}\}_{t=0,x\in\{h,f\}}^{\infty}$, prices $\{w_{x,t}^{high}, w_{x,t}^{med}, w_{x,t}^{low}, r_{x,t}\}_{t=0,x\in\{h,f\}}^{\infty}$, policies $\{\tau_{x,t}, b_{x,t}, G_{x,t}\}_{t=0,x\in\{h,f\}}^{\infty}$ and measures $\{\Phi_t\}_{t=0}^{\infty}$ such that

1. Given prices and transfers, $c_t(\cdot), l_t(\cdot), a'_t(\cdot)$ solve the individuals' dynamic problem and $V_t(\cdot)$ are the associated value functions.

2. Factor prices satisfy (4.2),(4.3),(4.4),(4.5).

3. Accidental bequests are given by (stayers, past migrants, new migrants):

$$
\begin{aligned}
Beq_{h,t+1} = & \sum_{\kappa}\sum_{s}\sum_{j=1}^{J-1}\int_{\mathcal{A}} a_t'(a;\kappa,s,j,\min\{j,R\},h,h)(1-\psi_{h,j})(1+r_{h,t+1}) \\
& d\Phi_t(a;\kappa,s,j,\min\{j,R\},h,h) \\
& +(1-\lambda)\sum_{s}\sum_{j=2}^{J-1}\int_{\mathcal{A}} a_t'(a;2,s,j,1,h,f)(1-\psi_{f,j})(1+r_{h,t+1}) \\
& d\Phi_t(a;2,s,j,1,h,f) \\
& +\sum_{s}\int_{\mathcal{A}} a_t'(a;2,s,1,1,f,f)(1-\psi_{f,1})(1+r_{h,t+1}) \\
& d\Phi_t(a;2,s,1,1,f,f)
\end{aligned} \tag{4.16}
$$

And in *foreign* (stayers, current return migrants, past return migrants):

$$
\begin{aligned}
Beq_{f,t+1} = & \sum_{s}\sum_{j=1}^{J-1}\int_{\mathcal{A}} a_t'(a;1,s,j,\min\{j,R\},f,f)(1-\psi_{f,j})(1+r_{f,t+1}) \\
& d\Phi_t(a;1,s,j,\min\{j,R\},f,f) \\
& +\lambda\sum_{s}\sum_{j=2}^{J-1}\int_{\mathcal{A}} a_t'(a;2,s,j,1,h,f)(1-\psi_{f,j})(1+r_{f,t+1}) \\
& d\Phi_t(a;2,s,j,1,h,f) \\
& +\sum_{s}\sum_{j=3}^{J-1}\sum_{n^f=1}^{\min\{j-1,R-1\}}\int_{\mathcal{A}} a_t'(a;2,s,j,n^f,f,f)(1-\psi_{f,j})(1+r_{f,t+1}) \\
& d\Phi_t(a;2,s,j,n^f,f,f)
\end{aligned} \tag{4.17}
$$

4. Accidental bequests are taxed at 100% and used for government consumption

$$G_{x,t} = Beq_{x,t+1}. \tag{4.18}$$

5. The social security budget clears in each country:

$$\tau_{x,t}\sum_{s} w_{x,t}^{s} L_{x,t}^{s} = Pen_{x,t}. \tag{4.19}$$

Total expenditures on pension benefits are divided between the skill types:

$$\sum_{s} Pen_{x,t}^{s} = Pen_{x,t} \tag{4.20}$$

Type-specific pension payments in country h are divided into payments to natives and past or current immigrants:

$$\begin{aligned} Pen_{h,t}^{s} = & \sum_{j=R+1}^{J} b_{h,t}^{s} \Phi_t(\mathcal{A}, \mathcal{K}, s, j, R, h, h) \\ & + \sum_{j=R+1}^{J} \sum_{n^f=1}^{R-1} \sum_{x} \frac{R-n^f}{R} b_{h,t}^{s} (1-\theta) \Phi_t(\mathcal{A}, 2, s, j, n^f, x, f). \end{aligned} \tag{4.21}$$

Likewise, type-specific pension payments in f comprise both stayers and migrants:

$$\begin{aligned} Pen_{f,t}^{s} = & \sum_{j=R+1}^{J} b_{f,t}^{s} \Phi_t(\mathcal{A}, 1, s, j, R, f, f) \\ & + \sum_{j=R+1}^{J} \sum_{n^f=1}^{R-1} \sum_{x} \frac{n^f}{R} b_{f,t}^{s} \Phi_t(\mathcal{A}, 2, s, j, n^f, x, f). \end{aligned} \tag{4.22}$$

6. In each country labor markets clear:[9]

$$\begin{aligned} L_{h,t}^{s} = & \sum_{\kappa} \sum_{j=1}^{R} \int_{\mathcal{A}} l_t(a; \kappa, s, j, j, h, h) \epsilon(j) d\Phi_t(a; \kappa, s, j, j, h, h) \\ & + \sum_{j=2}^{R} \int_{\mathcal{A}} l_t(a; 2, s, j, 1, h, f) \epsilon(j) (1-\theta) d\Phi_t(a; 2, s, j, 1, h, f). \end{aligned} \tag{4.23}$$

$$L_{f,t}^{s} = \sum_{\kappa} \sum_{j=1}^{R} \sum_{n^f=1}^{j} \int_{\mathcal{A}} l_t(a; \kappa, s, j, n^f, f, f) \epsilon(j) d\Phi_t(a; \kappa, s, j, n^f, f, f). \tag{4.24}$$

[9]For non-migrants in home, $n^y = j$ holds in each period of the working life.

7. Capital markets clear in each country:[10]

$$
\begin{aligned}
K_{h,t+1} = & \sum_{\kappa}\sum_{s}\sum_{j=1}^{J-1}\int_{\mathcal{A}} a_t'(a;\kappa,s,j,\min\{j,R\},h,h)\psi_{h,j} \\
& \qquad d\Phi_t(a;\kappa,s,j,\min\{j,R\},h,h) \\
& +(1-\lambda)\sum_{s}\sum_{j=2}^{J-1}\int_{\mathcal{A}} a_t'(a;2,s,j,1,h,f)\psi_{f,j} \\
& \qquad d\Phi_t(a;2,s,j,1,h,f) \\
& +\sum_{s}\int_{\mathcal{A}} a_t'(a;2,s,1,1,f,f)\psi_{f,1} \\
& \qquad d\Phi_t(a;2,s,1,1,f,f)
\end{aligned}
\tag{4.25}
$$

$$
\begin{aligned}
K_{f,t+1} = & \sum_{s}\sum_{j=1}^{J-1}\int_{\mathcal{A}} a_t'(a;1,s,j,\min\{j,R\},f,f)\psi_{f,j} \\
& \qquad d\Phi_t(a;1,s,j,\min\{j,R\},f,f) \\
& +\lambda\sum_{s}\sum_{j=2}^{J-1}\int_{\mathcal{A}} a_t'(a;2,s,j,1,h,f)\psi_{f,j} \\
& \qquad d\Phi_t(a;2,s,j,1,h,f) \\
& +\sum_{s}\sum_{j=3}^{J-1}\sum_{n^f=1}^{\min\{j-1,R-1\}}\int_{\mathcal{A}} a_t'(a;2,s,j,n^f,f,f)\psi_{f,j} \\
& \qquad d\Phi_t(a;2,s,j,n^f,f,f)
\end{aligned}
\tag{4.26}
$$

The national income identity in h is given by:

$$Y_{h,t} + (1-\delta)K_{h,t} + F^{pen}_{h,t} + F^{k}_{h,t} = K_{h,t+1} + C_{h,t} + G_{h,t}. \tag{4.27}$$

Accordingly, the national income identity in f reads:

$$Y_{f,t} + (1-\delta)K_{f,t} + F^{pen}_{f,t} + F^{k}_{f,t} = K_{f,t+1} + C_{f,t} + G_{f,t}, \tag{4.28}$$

whereby $F^{pen}_{x,t}$ denotes the net cross-country financial flow resulting out of pension payments for migrants. Likewise, $F^{k}_{x,t}$ refers to net capital flows caused by migration. See appendix 4.A.2 for the derivation.

8. The cross-sectional measure is generated as in appendix 4.A.1.

[10]The ordering of the different terms is the same as in the equation for bequests (4.16).

4.3 Calibration

4.3.1 Population

The benchmark steady state is calibrated to match the current joint population distribution of Germany and Poland. Data on shares of the specific skill groups within each country is taken from OECD (2017b) and summarized in table 4.1. The OECD relies on the ISCED classification to categorize educational attainments. I define high-skilled workers as those with *tertiary education* (ISCED 5-7). Medium-skilled workers comprise individuals with *upper secondary and post-secondary non-tertiary education* (ISCED 3-4). Lastly, low-skilled workers cover all of those with an educational attainment of *below upper secondary education*. The composition of the Polish migrant population can be characterized on the basis of Statistisches Bundesamt (2016a), which covers both individuals with a migration background and individuals with an own migration experience. To compute the calibration targets I only focus on the latter group. The data enables to differentiate types according to the degree obtained. In particular, three different main categories can be distinguished: *Academic degree*, *non-academic degree*, and *without professional degree*. It is rather straightforward to align the first category with the definition of high-skilled workers from above[11], however, a complication may arise with respect to medium-skilled and low-skilled workers. More precisely, the group of individuals without a professional degree in Statistisches Bundesamt (2016a) in principle also covers individuals with a general degree of secondary education. According to the classification above, those would belong to ISCED levels 3-4 and thus be counted as medium workers. This might imply that the calibration overestimates the share of low-skilled workers in the Polish migrant population. However, there are strong arguments objecting this conjecture. First of all, almost all medium-skilled tasks in Germany require a specific kind of vocational training. Hence, a migrant without a *professional degree* will most likely end up in a low-skilled job. Further, this specific argument is supported by a general finding by Dustmann, Frattini, et al. (2012), who argue that many immigrants experience a significant degree of *downgrading*, meaning that their place in the wage distribution does not match their expected place based on their qualifications. Accordingly, I count the group of individuals with a *non-academic degree*[12] as medium-skilled, and the ones *without professional degree* as low-skilled workers.

Finally, to obtain the skill shares, I firstly compute the ratio between the number of people within each category and the total number of Polish migrants. Subsequently, I

[11] I can match to the OECD definition of tertiary education (ISCED 5-7) with the data from Statistisches Bundesamt (2016a) by adding all individuals with the degree *Meister* to the group with a university degree.

[12] Excluding the ones holding a *Meister*, see above.

multiply these skill shares with the ratio between the total number of Polish migrants above 20 and the total population in Germany above 20.[13] Limiting the age span is appropriate since the model only includes the life stages of workers and retirees. Given this restriction, Polish migrants account for 2.04% of the (adult) population in Germany.

Comparing the first two columns of table 4.1, one observes that Germany and Poland exhibit a roughly equal share of high-skilled workers. Germany, however, has fewer medium-skilled and more low-skilled workers. The third column in table 4.1 displays the share of different skill types among total Polish migrants. In comparison with the total skill distribution in both countries, one sees that Polish migrants have a slightly lower share of high-skilled individuals. Moreover, the group of migrants consists of considerably more low-skilled and significantly less medium-skilled workers.

Table 4.1: Skill Shares

	Germany	Poland	Polish Migrants
high-skilled	0.283	0.287	0.258
medium-skilled	0.582	0.626	0.505
low-skilled	0.135	0.087	0.235

A further characteristic of Polish migrants is that they are considerably younger than the total population in Germany. The working age to population ratio (wapr) of Polish migrants is 87 % whereas the overall value in Germany is only 74 %.[14]

The calibration strategy aims at simultaneously matching the skill distribution of the total German and Polish population, as well as the skill and age composition of Polish migrants. Let $N(\kappa, s, j, x, y)$ denote the time-invariant population mass of agents with birthplace y, location x, age j, skill type s and migration type κ. Since population dynamics are fully exogenous (see section 4.2.1), the targets can be matched by choosing the type and country-specific number of newborns as well the return probability λ.[15] Newborns can be decomposed as following:

$$N_{\kappa,s,1,x,x} = \Omega_x \omega_{x,s} \phi_{x,s,\kappa}, \tag{4.29}$$

where Ω_x defines the relative size of the total population of country x. $\omega_{x,s}$ and $\phi_{x,s,\kappa}$ refer to the country-specific shares of newborns with skill type s and with migration

[13] I follow this two-step approach because the single skill classes are not differentiated by age.

[14] The wapr is here defined as the ratio between individuals in the age span between 20 and 65 and the total population above the age of 20.

[15] Note that I do not explicitly target the wapr of German natives. However, the model wapr is equal to 0.72 and thereby close to the actual one (0.74).

Table 4.2: Population Parameters

Parameter	Value	Population Measure	Target
$\omega_{h,1}$	0.2835	$\frac{\sum_\kappa \sum_{j=1}^J \sum_y N(\kappa,1,j,h,y)}{\sum_\kappa \sum_s \sum_{j=1}^J \sum_y N(\kappa,s,j,h,y)}$	Share of high-skilled in h
$\omega_{h,2}$	0.5836	$\frac{\sum_\kappa \sum_{j=1}^J \sum_y N(\kappa,2,j,h,y)}{\sum_\kappa \sum_s \sum_{j=1}^J \sum_y N(\kappa,s,j,h,y)}$	Share of medium-skilled in h
$\omega_{f,1}$	0.2856	$\frac{\sum_\kappa \sum_{j=1}^J N(\kappa,1,j,f,f)}{\sum_\kappa \sum_s \sum_{j=1}^J N(\kappa,s,j,f,f)}$	Share of high-skilled in f
$\omega_{f,2}$	0.6198	$\frac{\sum_\kappa \sum_{j=1}^J N(\kappa,2,j,f,f)}{\sum_\kappa \sum_s \sum_{j=1}^J N(\kappa,s,j,f,f)}$	Share of medium-skilled in f
$\phi_{f,1,2}$	0.0909	$\frac{\sum_{j=1}^J N(2,1,j,h,f)}{\sum_\kappa \sum_s \sum_{j=1}^J \sum_y N(\kappa,s,j,h,y)}$	Share of high-skilled migrants
$\phi_{f,2,2}$	0.0814	$\frac{\sum_{j=1}^J N(2,2,j,h,f)}{\sum_\kappa \sum_s \sum_{j=1}^J \sum_y N(\kappa,s,j,h,y)}$	Share of medium-skilled migrants
$\phi_{f,3,2}$	0.2485	$\frac{\sum_{j=1}^J N(2,3,j,h,f)}{\sum_\kappa \sum_s \sum_{j=1}^J \sum_y N(\kappa,s,j,h,y)}$	Share of low-skilled migrants
λ	0.025	$\frac{\sum_s \sum_{j=1}^R N(2,s,j,h,f)}{\sum_s \sum_{j=1}^J N(2,s,j,h,f)}$	Wapr migrants

type κ, respectively. Note that ϕ additionally depends on s, such that the share of migrants differs across skill-types. I pre-specify $\Omega_h = 0.7$ which corresponds the relative population size of Germany. Further, I set $\phi_{h,s,1} = 1$ for all s. Hence, the mass of migrants born in h is equal to zero. Table 4.2 summarizes the calibrated parameters, their values and the corresponding population moments.

Finally, it is necessary to specify the remaining pre-determined demographic parameters. I define $J = 99$, and set $\psi_{x,j}$ equal to the age-dependent mortality rates in Germany and Poland in 2015 as given by Eurostat (2017b). Lastly, both regions exhibit a population growth of zero ($n = 0$).

4.3.2 Production

In table 4.3, I summarize the parameters of the model's production side as described by (4.1). Those parameters which differ between the two countries exhibit the additional subscript x. The Cobb-Douglas parameter of the capital share (α) is set to 0.35 in order to match the observed mean labor share in the EU28 in the years 2005-2015 (0.65), as reported by Eurostat (2017a). Again, based on Eurostat (2017c) and the mean value from the EU28 in the same period, the depreciation rate δ is chosen to generate an overall investment share of about 0.2. Next, we turn to the weights of the skill-specific labor supply in the production. In this respect, I calibrate μ_x and σ_x to match the type-specific skill premiums in both countries as of 2015. The OECD (2017a) documents a high-skilled premium of 1.58 in Germany and 1.62 in Poland, as well as a medium-skilled premium of 1.24 in Germany and 1.19 in Poland, respectively.[16] The parameters governing the elasticity of substitution between the different skill-types are taken from Glitz and Wissmann (2017). According to OECD (2017c), the Polish GDP per capita amounted to 58% of the German one in 2016. I choose A_{pol} to match this productivity difference.

Table 4.3: Production Parameters

	Germany	Poland	Calibration Target / Explanation
α	0.35	"	Labor income share
δ	0.055	"	Investment share
μ_x	1.250	1.355	Skill premium high-skilled
σ_x	1.815	2.025	Skill premium medium-skilled
$\frac{1}{1-\gamma}$	1.6	"	EoS between high-skilled and non-high-skilled
$\frac{1}{1-\rho}$	3.8	"	EoS between medium-skilled and low-skilled
A_x	1	0.64	GDP per capita

EoS $\triangleq$ Elasticity of Substitution.

4.3.3 Households

The households' preference parameters are assumed to be identical in both regions. I calibrate the discount factor β to match an economy-wide capital to output ratio equal to 3. Further, the weight on consumption in the utility function (ξ) is chosen to lead to average hours worked of about 0.3 in both countries. The parameter of the intertemporal elasticity of substitution (η) is set equal to 2, as common in the literature. Concerning the age varying productivity, ϵ is taken from Lagakos et al. (2018), who estimate the life-cycle wage growth for several countries. ϵ is specified to equal the productivity profile estimated for Germany. Lastly, I account for the observed wage differences between natives and migrants in Germany and set θ to 0.1, corresponding to the average native-migrant wage gap reported by Brücker et al. (2014).

Table 4.4: Household Parameters

	Value	Calibration Target / Explanation
β	0.965	Capital to output ratio
ξ	0.3	Average hours worked
$\frac{1}{\eta}$	0.5	Intertemporal elasticity of substituion
θ	0.1	Skill loss of migrants

[16] The premiums refer to high-skilled versus medium-skilled as well as to medium-skilled versus low-skilled.

4.3.4 Pension System

Calibrating the social security parameters requires determining the country-specific contribution rates, as well as the exogenous retirement age. As documented by OECD (2015), the German contribution tax (τ_{ger}) is equal to 0.189 and the respective Polish one (τ_{pol}) equal to 0.195. Finally, agents in both economies retire at age 65 ($R = 65$).

4.4 Results

To uncover the distributional implications of Polish migration to Germany, I perform the following thought experiment: Starting from the model's initial steady state[17] with two-directional migration dynamics as described beforehand, I abolish labor mobility between the two regions and compute the associated counterfactual steady state.[18] Hence, I am interested in the marcoeconomic effects of the total migration from Poland to Germany. Comparing the outcomes of the two model versions then allows me to analyze the effects of labor movements on aggregates, factor prices, pension benefits and ultimately welfare.

Table 4.5: Steady State Comparison

	Germany	Poland		Germany	Poland
Aggregates			Prices and Benefits		
L_x^{total}	-2.13	6.61	w_x^{high}	-0.06	-0.15
L_x^{high}	-2.00	6.30	w_x^{med}	0.04	-0.08
L_x^{med}	-1.87	5.33	w_x^{low}	0.51	-3.53
L_x^{low}	-3.90	20.3	b_x^{high}	-0.33	0.38
Ret_x^{high}	-1.76	5.74	b_x^{med}	-0.25	0.12
Ret_x^{med}	-1.66	5.11	b_x^{low}	-0.07	-1.13
Ret_x^{low}	-3.34	17.4	sp^{high}	-0.01	0.06
K_x	-2.11	5.60	sp^{med}	-0.55	3.57
Y_x	-2.12	6.26	r	-0.01	0.07

The outcomes display percentage changes with respect to the benchmark steady state. L_x^{total} equals $\Upsilon_x^{\frac{1}{\gamma}}$ from (4.1).

Table 4.5 displays the percentage change in aggregates, prices and benefits between the counterfactual and benchmark scenario. In the absence of migration, labor supply decreases for all skill types in Germany and increases in Poland. The reported reductions in labor supply in Germany mirror the respective share of skill-dependent

[17]Note that the concept of a *steady state* here has to be understood as a *stationary equilibrium*, in which individual functions are constant over time and aggregate variables grow at a constant rate.

[18]Note that migration is consistent with a steady state since the population distribution is invariant (see section 4.3.1). The absence of migration in the counterfactual then implies a shift in the population mass from Germany to Poland, while maintaining the assumption of $n = 0$.

effective labor supply of migrants in the benchmark scenario.[19] In particular, low-skilled labor supply decreases most and medium-skilled labor decreases least. This is intuitive since table 4.1 reveals that migrants are more than proportionally low-skilled, whereas the share of medium-skilled migrants is comparatively lower. Further, the fact that changes in L^s_{ger} are solely driven by the population shift between both countries implies that natives do not significantly adjust their working hours in the counterfactual. Discussing the implications of immigration on total labor supply, it should be noted that the share of migrant labor supply is lower than the share of migrants in the total workforce. This is due to differences in hours profiles between migrants and natives and the productivity loss of Polish workers (θ). Turning to Poland, the increase in skill-specific labor supply is significantly larger than the corresponding reductions in Germany. While high and medium-skilled labor supply rises by 6% and 5%, the increase in L^{low}_{pol} amounts to even 20%. In this respect, two aspects of the model calibration have to be pointed out. First of all, the fact that Poland's population size is considerably smaller than Germany's (see section 4.3.1.) means that the migration flows have a much stronger impact on Poland. Secondly, the large increase in Polish low-skilled labor supply can be motivated as following: Compared to the total population in Germany, Polish migrants are more than proportionally low-skilled (see table 4.1). Further, the share of low-skilled workers in the total Polish population is relatively small (only 8.7%). Accordingly, the share of migrants among Polish low-skilled workers ($\phi_{f,3,2}$) has to be large in order to match the size of the group of low-skilled migrants. Assuming the absence of migration in the counterfactual then keeps this group in Poland and generates the large increase in L^{low}_{pol}. The change in the mass of retirees (Ret^s_x) works in the same direction as the change in labor supply, however, the effects are quantitatively smaller because migrants are younger on average, such that the shift in the population distribution is more pronounced among workers. Turning to wages, we see only marginal changes for high-skilled and medium-skilled workers in Germany, however wages of low-skilled workers rise more strongly (0.5%). For Poland we observe a similar picture: Wages are almost unaffected for the *high* and *medium* type, but fall by about 3.5 % for the *low* type. Lastly, it remains to analyze the differences in pension benefits between benchmark and counterfactual scenario. As explained in section 4.3.1, the migrant population is significantly younger than the total population, such that they positively contribute to the financial sustainability of the PAYG pension system. Indeed, benefits in Germany are lower for all skill types in the counterfactual. In this respect, the effect on b^{low}_{ger} is the weakest, since the decline in the working age to population ratio is compensated by a stronger wage increase. In Poland, the population is now younger. However, due to the more pronounced wage changes, benefits are only

[19]The effective labor supply accounts for the age-dependent productivity profile as well as for the productivity discount of migrants.

higher for high-skilled and medium-skilled workers, but fall for low-skilled types.

4.4.1 The Determinants of Wage Effects

In the following, I examine the determinants of the wage effects more closely. The motivation for this focus is twofold. Firstly, compared to pension benefits, changes in wages are more relevant in terms of welfare consequences, since benefits are lower and received at later stages of life, and thus subject to greater discounting (see section 4.5). Secondly, uncovering the driving forces behind wage changes is necessary to discuss whether the structural empirical migration literature is prone to produce biased estimates of wages effects by not taking general equilibrium responses into account (see section 4.4.3). The results on wages in table 4.5 can be decomposed into changes in the skill composition of total labor supply as well as into changes in capital formation. I am going to examine each component separately.

Skill Composition

Before discussing the effects of changes in the skill composition, it is important to address a few characteristics of the production function in (4.1). The chosen parameter values for the elasticity of substitution between the different labor types based on Glitz and Wissmann (2017) imply a greater substitutability between medium-skilled and low-skilled workers than between high-skilled and non-high-skilled workers ($\rho > \gamma$). How do wages of the respective labor types respond to a type-specific inflow of migrants? If we assume that capital remains constant and migrants are solely low-skilled, high-skilled wages increase, whereas low-skilled and medium-skilled wages decrease. Further, the decrease in w_{low} is stronger than in w_{med}. If all migrants are medium skilled, the same pattern holds, just that w_{med} decreases more strongly than w_{low}. Alternatively, assume that migrants are just of the high-skilled type. Then w_{high} falls, and w_{med} and w_{low} rise equally. This is caused by the fact that the chosen nesting structure restricts the elasticity of substitution between L_{high} and L_{med} to be identical to the one between L_{high} and L_{low}. Lastly, if the distribution of skills among migrants exactly matches the skill distribution of natives, then all wages fall equally. Summing up, we can conclude that - ceteris paribus - a workers' wage rises in response to an inflow of an additional migrant, if the migrant's skill type does not belong to the same nest in the CES aggregate, and falls otherwise. Table 4.6 shows how skill shares in the counterfactual compare to those in the benchmark scenario. While we observe a small increase among high-skilled and medium-skilled workers in Germany, there is a significant reduction in the share of low-skilled types. In Poland, we see the reversed pattern: The shares of high-skilled and medium-skilled workers decrease moderately, while the increase in low-skilled labor is much more pronounced. Overall, we can conclude that wage effects in table 4.5 are concentrated on low-skilled workers because the compositional shifts in the country-specific skill distributions are strongest among this particular group.

Table 4.6: Change in Skill Shares

	Germany	Poland
high-skilled	0.17	-0.49
medium-skilled	0.28	-0.99
low-skilled	-1.55	8.76

Numbers are in percent.

Furthermore, we can analyze the change in relative wages due to the undoing of migration flows. Based on equations (4.2) to (4.4), dropping time and country indexes and setting $Z_t = 1$, we can derive the skill premium for high-skilled versus medium-skilled, as well as for medium-skilled versus low-skilled worker:

$$sp^{high} = \frac{L_{high}^{\gamma-1}}{U^{\frac{\gamma}{\rho}-1}\sigma L_{low}^{\rho-1}} \tag{4.30}$$

$$sp^{med} = \frac{\sigma L_{med}^{\rho-1}}{L_{low}^{\rho-1}} \tag{4.31}$$

Next, define $l_s = \frac{L_s}{L^{total}}$, so that l_s gives the share of skill-specific labor supply in total labor supply. Then, we can take logs on both sides to obtain a linearized form of the skill premiums:

$$ln(sp^{high}) = (\gamma - 1)l_{high} - (\frac{\gamma}{\rho} - 1)ln(\sigma l_{med}^{\rho} + l_{low}^{\rho}) - ln(\sigma) - (\rho - 1)ln(l_{med}) \tag{4.32}$$

$$ln(sp^{med}) = ln(\sigma) + (\rho - 1)ln(l_{med}) - (\rho - 1)ln(l_{low}) \tag{4.33}$$

sp^{high} depends negatively on the share of high-skilled labor supply ($\gamma < 1$), and positively on l_{med} and l_{low} ($\frac{\gamma}{\rho} < 1$), whereas the effect of an increase in medium-skilled labor supply is stronger. Further, sp^{med} increases in l_{low} and decreases in l_{med} ($\rho < 1$). The medium-skilled premium is independent of l_{high} since the elasticity of substitution between high-skilled workers and the other labor types is identical. Since shares of high-skilled and medium-skilled labor change only slightly, sp^{high} decreases only marginally in Germany and increases a bit more strongly in Poland (see table 4.5). However, sp^{med} shows a more pronounced response. The medium-skilled premium falls by 0.55% in Germany and rises by 3.57% in Poland.

Capital Formation

Analyzing the effects of migration in general equilibrium allows uncovering the possible macroeconomic adjustment mechanisms to changes in labor supply. One important channel of adjustment is the response of the aggregate capital stock. Table 4.5 shows that K_{ger} decreases in the counterfactual by 2.11%, which is slightly less than total labor supply (L_{ger}^{total}). Recall that investment is assumed to be linked to the place of residence.[20] Hence, the reduction in K_{ger} is due to changes in the asset accumulation of natives as well as due to the absence of migrants' asset holdings. What role do the savings of migrants play for the aggregate capital stock? Compared to the skill-composition of the total German labor force, migrants are more than proportionally low-skilled, such that among all skill types the decrease in L_{ger}^{low} in the counterfactual is the most pronounced. However, since high-skilled and medium-skilled workers contribute more to aggregate savings, the reduction of the capital stock is considerably lower than the drop in L_{ger}^{low}. Further, it holds for all skill types that natives and migrants differ with respect to their savings behavior. In particular, assuming that migrants take the possibility of returning into account (see section 4.2.5) has important implications for their life-cycle savings profile. To make this point clear, consider the hypothetical case in which migrants enter the economy before they become economically active and stay in the foreign economy throughout their whole life. In this case, their savings, consumption and labor supply profile would be identical to the one of natives since they face the same sequence of factor prices and benefits. If, however, migrants have to plan with the possible event of returning to their home country, they face a positive probability that their labor income significantly drops from one period to the other. Given the calibrated differences in tfp, this reduction amounts to a difference of about 40%.[21] Integrating return migration into the household's life-cycle decision problem therefore creates a precautionary savings motive: Migrants have the incentive to save more than natives during their time in Germany, such that they can achieve a smooth life-cycle consumption and hours profile even in the case of experiencing a strong reduction in labor income after returning. Due to this savings motive, per capita asset holdings of migrants are 8% higher than those of natives. Note that this is partly a compositional effect since migrants differ from natives with respect to the age and skill composition. Regarding the distinction of skill types, we observe that high-skilled migrants save on average 9.5% more than high-skilled natives, whereby the respective figures are 13% and 10% for medium-skilled and low-skilled workers. Figure 4.2 plots the asset profile of German workers against two types of migrants. One type

[20] If capital was assumed to be fully mobile between the regions, the change in regional capital would work in the same direction. Capital would automatically follow labor, decreasing K_{ger} and increasing K_{pol}.

[21] Note that returning after retirement does not affect pension income since the amount of benefits paid to an individual is independent of its location.

returns at age 40 ($rp = 40$) and the other at age 65 ($rp = 65$). As can be seen, both migrant types exhibit an identical savings profile until age 39, the last period in which both reside in Germany. Further, both migrant types hold a higher individual asset position in the time before returning (and except the first years in which all types are credit constrained). After migrating back, agents then dissave faster than German natives. Note that migrants - given the calibrated productivity loss - save more even though they earn 10% less. In order to achieve their desired asset position, they work considerably more hours at younger ages and consume less throughout the life-cycle. The corresponding consumption and hours profiles can be found in appendix 4.B.1.

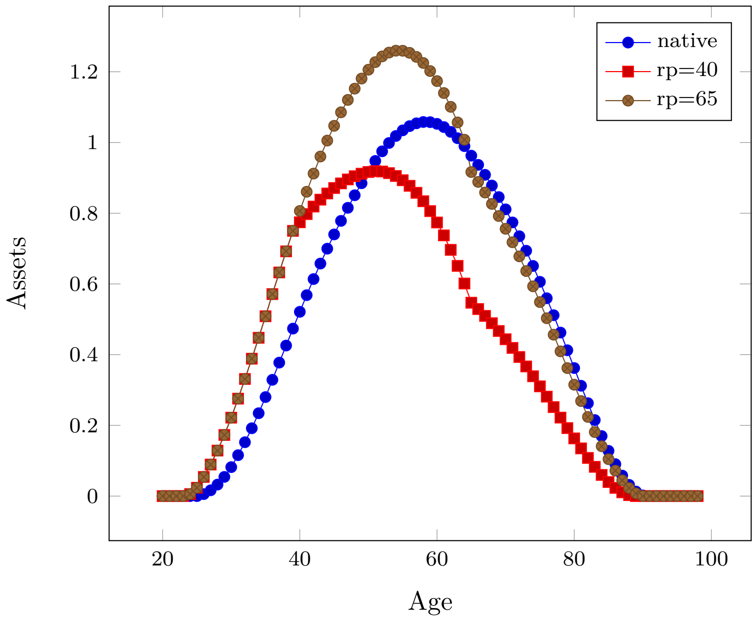
To evaluate how changes in asset accumulation affect wages, we need to compare the capital to labor input ratios in both model variants, which in this model equals $\frac{K_x}{\Upsilon_x^{\frac{1}{\gamma}}}$. Recall that the production function in (4.1) features a Cobb-Douglas structure between capital and total labor input, so that the elasticity of substitution between capital and labor is identical for all skill-types. Hence, a possible capital deepening would induce an symmetric upward pressure on German wages.[22] Ceteris paribus, the foregone higher savings of migrants exert a downward pressure on $\frac{K_{ger}}{\Upsilon_{ger}^{\frac{1}{\gamma}}}$. The overall impact of the absence of migration is additionally determined by the behavioral responses of natives in the counterfactual. It turns out, that due to changes in factor prices, German workers slightly increase per capita savings by 0.1%, which can be motivated the wage increase for low-skilled workers and the reduced benefits for all skill types (see section 4.4.1). In total, these two opposing effects cancel out, such that the capital to labor ratio remains almost unchanged.[23]

Turning to Poland, K_{pol} increases by 5.6% in the counterfactual which is about one percentage point less than L_{pol}^{total}. What does the absence of migration flows imply for the capital formation in Poland? First of all, we observe that the increase in labor supply is concentrated on low-skilled workers (see table 4.6). The degree of concentration is even stronger than in Germany since Poland has a significantly lower share of low-skilled agents. However, since medium-skilled and high-skilled workers hold much higher individual asset positions, the increase in K_{pol} is significantly lower than the increase in L_{pol}^{low}. Further, capital accumulation in Poland is affected through the missing capital inflow due to return migration. In particular, return migrants accumulate large savings while residing in Germany, such that their individual asset wealth exceeds the one of stayers by 56%. Figure 4.3 demonstrates this graphically:

[22]One might object that the chosen functional form ignores a possible capital-skill complementarity in the spirit of Krusell et al. (2000) who estimate a CES production function for US data. However, Duffy et al. (2004) find only weak support for the existence of such capital-skill complementarity relying on a large panel of 73 countries.

[23]In this respect, it should be noted that even though the increase in per capita savings of German workers is much smaller than the difference between per capita savings of natives and migrants, the small population share of the latter gives a greater weight to the effect working through the natives' saving response.

Figure 4.2: Asset Profiles



Asset profiles are displayed for high-skilled workers. *Native* denotes the asset profile of a non-migrant in Germany. The other two curves display the asset profile of migrants. *rp* denotes the period of return.

The later the period of return, the larger is the difference between the migrant's and the stayer's asset profile. Another measure displaying the beneficial role of the return migrants' savings for the Polish economy is the following: While returned migrants account for 5% of the total Polish population, their savings amount 8% of total wealth. Therefore, the absence of savings from return migrants in the counterfactual scenario has a negative impact on the capital to labor ratio. However, changes in factor prices and benefits induce Polish workers to increase their per capita savings by 3.1%. This latter effects counteracts the former one, so that the capital to labor ratio decreases by only 0.9%. Still, the decrease exerts a symmetric downward pressure on all Polish wages.

How do these model predictions relate to the empirical evidence on the savings behavior of migrants? A study that addresses differences in savings rates between migrants and natives in Germany is given by Bauer and Sinning (2011). Controlling for observable characteristics, they find that temporary migrants exhibit significantly larger per capita savings. In particular, the savings rate of temporary migrants is between 3.5 and 6.4 percentage points higher than that of permanent migrants and natives[24], depending on the exact specification. This results indicates that there is indeed an important connection between individual savings and the prospect of return migration. In this respect, however, it should be noted, that my model can only distinguish between temporary and permanent migrants *ex post*, i.e. after the return shocks have realized, whereas *ex ante* all migrants are potential temporary migrants.

[24] Bauer and Sinning (2011) identify temporary and permanent migrants through revealed intentions.

Further, the given study finds that employed migrant household heads save around 2 to 3 percentage points more than employed native households heads. Overall, while these findings qualitatively support the model predictions discussed beforehand, the design of the study does not enable a direct comparison in quantitative terms. Bauer and Sinning (2011) use data from the GSOEP comprising a representative sample of the total migrant population in Germany. Since the strength of the precautionary savings motive is determined by the income gap between sending and host country, a quantitative comparison would require an empirical study based on Polish migrants only.

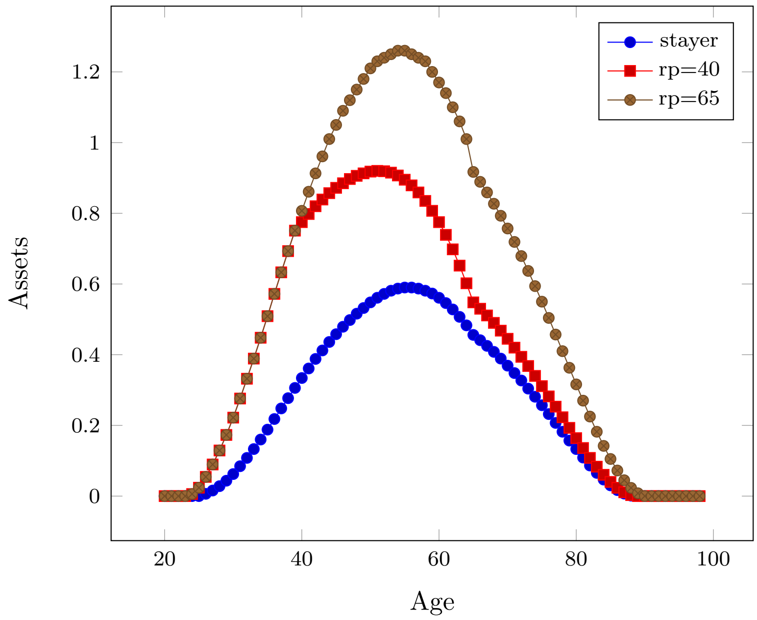
Lastly, it is necessary to discuss the role of uncertainty in the return process for the findings on differences in saving rates between migrants and non-migrants. In particular, it is intriguing to ask whether the mechanisms described beforehand were also at work in a model in which return migration is an endogenous choice. In this respect, consider the hypothetical case in which there is no uncertainty associated with the migration process and migrants could optimally choose whether (and when) to return to Poland.[25] In this case, the consumption smoothing motive would still exist such that return migrants would still have the incentive to build up large savings acting as a buffer against the drop in labor income after leaving the host country. Accordingly, the main mechanism generating the large and beneficial savings of return migrants for the Polish and German economy would still be present. The only difference between this hypothetical scenario and my model is in the group of permanent migrants in Germany. Since they could optimally choose to not return, they would not need to insure against a drop of income such that their saving rates would resemble those of German natives.

4.4.2 Cross-Border Investments

So far, it was assumed that migrants can only invest in the host country, as long as they reside in Germany. However, Bauer and Sinning (2011) show that the estimated differences in savings rates between migrants and natives are sensitive to the treatment of remittances, indicating that cross-border financial investments are potentially an important component of the savings behavior of migrants. Even though the underlying data set in Bauer and Sinning (2011) does not provide information on whether remittances embody altruistic transfers or personal savings, it is plausible to assume that a part of the migrants' savings is invested in their home country. The following section

[25] Whereas including an endogenous return migration decision would certainly give rise to a more comprehensive description of migration dynamics, completely neglecting an element of uncertainty would not. In fact, it is a broad consensus in the literature that migration is a risky process (e.g Jaeger et al. (2010)). Specifically, it is plausible to assume that migrants face a high labor income risk due to high search costs or a restricted access to social insurance (Chassamboulli and Palivos, 2014), and that some might react to a negative labor income shock with emigrating.

Figure 4.3: Asset Profiles



Asset profiles are displayed for high-skilled workers. *Stayer* denotes the asset profile of a non-migrant in Poland. The other two curves display the asset profile of return migrants. *rp* denotes the period of return.

revises the results obtained beforehand under the modified assumption that a share of total asset holdings by the migrant population is invested in Poland. In particular, I introduce a further dimension of type heterogeneity among Polish migrants: For each skill type s, I assume that a share of migrants equal to ω invests the entire savings in Germany.[26]

Departing from the benchmark steady state corresponding to $\omega = 1$, I lower ω gradually to a value of 0.5, implying that half of the Polish migrants in Germany invest their savings in their home country. The outflow of capital unambiguously lowers the capital stock in Germany, and increases capital in Poland. More precisely, cross-border investment of migrants may lead to a substantial increase in the Polish capital stock, if the share of foreign investment is large enough: If 50 % of the migrants' savings were invested abroad, this would push up k_{pol} by 1.5%. Note that the responses of k_{pol} is significantly larger due to two reasons: Firstly, the asset holdings of Polish migrants are considerably larger than those of non-migrants in Poland. Secondly, the result is driven by a *population size* effect. Whereas Polish migrants account 2.04 % of the total population in Germany, their population size equals 5.42 % of the non-migrant Polish population. As a result of the increase in capital supply in Poland, r_{pol} decreases with a falling ω, whereas the opposite is true for Germany. Turning to wages

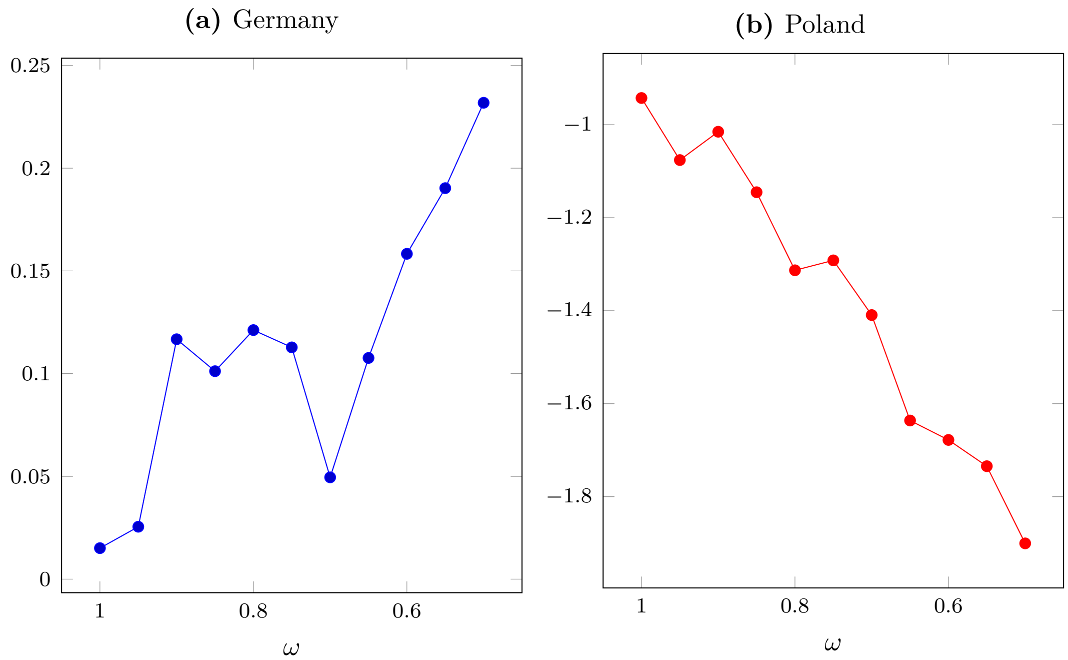
[26]Note that this exogenous classification of *investment types* is an ad-hoc version of modeling a portfolio optimization regarding the allocation between *home* and *foreign* assets explicitly. However, due to the absence of risk in the return on assets, this optimization would necessarily result into investing all assets in the country exhibiting the higher interest rate. Only the introduction of risk premiums on asset holdings or different asset classes could give rise to a meaningful investment choice problem.

and pensions, the capital deepening in Poland implies slightly higher wages and a bit more pronounced increase in pensions. Note that due to the upward pressure on wages and the falling interest rate, Polish non-migrants increase their labor supply, thereby effectively limiting a stronger reaction of wages. Further, the effects on pensions are quantitatively stronger, since a higher labor supply additionally increases the tax base and thereby benefits. Regarding Germany, the corresponding responses are negative, but very small. The respective figures can be found in appendix 4.B.2.

4.4.3 Migration and Wages: How Important are General Equilibrium Effects?

The results on changes in capital formation allow for an insightful perspective on the structural empirical migration literature. In particular, by relying on equilibrium wage conditions to estimate wage effects, these studies necessarily have to make assumptions about how the capital stock adjusts to changes in labor supply. While Borjas (2003) assumes that capital remains constant, Ottaviano and Peri (2012) suppose that the capital to labor ratio stays unchanged. The differences in assumption ultimately determine the nature of the estimated wage effect: Borjas (2003) estimates the *short term*, and Ottaviano and Peri (2012) the *long term* impact of immigration. Since my study concentrates on steady state comparisons, I am naturally interested in the long run consequences. In contrast to the assumption made in Ottaviano and Peri (2012), the supposed complete adjustment of the capital to labor ratio does not generally hold in OLG models as considered here, where savings behavior is influenced by a complex interplay of changes in prices and benefits. Although we have seen in section 4.4.1, that the German capital to labor ratio is only marginally affected by migration, this was due to opposing effects - foregone higher savings of migrants and an increase in per capita savings of non migrants - that roughly cancel out. Further, for lower values of ω, the changes in the capital to labor ratio get more pronounced. In this respect, figures 4.4a and 4.4b plot the changes in the capital to labor ratios between the no-migration and the migration steady state, whereby the latter is differentiated by varying levels of ω. As can be seen, extending the degree of cross-border investments implies that the effect of abolishing labor mobility on the capital to labor ratio becomes more pronounced. First, consider the case of Germany: While migrants still exhibit higher per capita savings, they are less beneficial for the German economy since a certain part is invested in Poland. Accordingly, without labor mobility, the capital to labor ratio increases. Regarding Poland, we observe the opposite: Since in the counterfactual, the Polish economy not only suffers from the missing savings of return migrants, but also from the absence of cross-border investments of current migrants, the decrease in $\frac{K_{pol}}{\Upsilon_{pol}^{\frac{1}{\gamma}}}$ gets stronger.

Figure 4.4: Changes in Capital to Labor Ratios



Results are reported as percentage changes relative to the migration scenario computed for different levels of ω.

Given these findings it is intriguing to ask how wage effects would differ if one followed the approach of Ottaviano and Peri (2012) and estimated wage effects solely from shifts in labor supply while keeping the capital to labor ratio constant. To this end, I construct the new counterfactual as follows: I decompose the total skill-specific labor supply in Germany in the migration steady state (L^s_{ger}) into a migrant and a native part ($L^s_{ger,nat}, L^s_{ger,mig}$). Labor supply in the no-migration variant ($\tilde{L}^s_x$) is then simply given by:

$$\tilde{L}^s_{ger} = L^s_{ger,nat} \tag{4.34}$$

$$\tilde{L}^s_{pol} = L^s_{pol} + L^s_{ger,mig} \tag{4.35}$$

Further, assuming an unchanged capital to labor ratio delivers $\tilde{K}^s_x$, so that I can simply compute wages ($\tilde{w}^s_x$) from equations 4.2 to 4.4. Lastly, I can calculate wage changes between this non-general-equilibrium counterfactual and the migration steady state. Contrasting these wage changes with the ones from table 4.5 then provides an insight into the direction and size of the bias resulting from neglecting general equilibrium responses. Tables 4.7 and 4.8 display the different wage responses, whereby they differentiate between the highest and lowest level of ω.

Regarding Germany, we see overall only minor differences between the scenario in which the capital to labor ratio is kept constant (*No GE*) and the one in which full

Table 4.7: Differences in Wage Effects - Germany

	$\omega = 1$		$\omega = 0.5$	
	GE	No GE	GE	No GE
high-skilled	-0.06	-0.07	0.05	-0.08
medium-skilled	-0.04	-0.03	0.00	-0.03
low-skilled	0.51	0.49	0.55	0.49

Numbers are in percent.

Table 4.8: Differences in Wage Effects - Poland

	$\omega = 1$		$\omega = 0.5$	
	GE	No GE	GE	No GE
high-skilled	-0.15	0.21	-0.45	0.21
medium-skilled	-0.08	0.16	-0.38	0.16
low-skilled	-3.53	-2.64	-3.79	-2.61

Numbers are in percent.

general equilibrium responses are accounted for (*GE*). This is not surprising since the effects in figure 4.7 are also rather mild. Deviations between both scenarios are, however, slightly larger for $\omega = 0.5$. On the contrary, we observe stronger differences in Poland. Specifically, for $\omega = 1$ one sees that the *No GE* scenario implies small wage increases for Polish high-skilled and medium-skilled workers and a strong wage decrease for low-skilled types. In contrast, allowing for general equilibrium responses in the counterfactual implies negative wage effects for all skill types, and an even stronger wage reduction for low-skilled workers.[27] Accordingly, the non-general-equilibrium counterfactual exhibits an upward bias in predicted wage effects, which is especially strong for low-skilled workers. This is caused by the fact that the assumed capital to labor ratio is too high: The non-general-equilibrium counterfactual ignores that the foregone savings of return migrants depress capital formation in Poland. Lowering ω to 0.5 even increases the size of the bias. Now, the *No GE* scenario additionally does not account for the negative effect of the missing cross-border investments of migrants living abroad. Likewise, the *No GE* exercise delivers weakly downward biased wage effects for Germany because the supposed capital to labor ratio is too low.[28] Summarizing, we can conclude that structural estimation approaches abstracting from changes in the capital to labor ratio may wrongly estimate the long-term effects of migration. In particular, the linkage between migration and capital formation results from a precau-

[27]Note that general equilibrium responses not only work through savings behavior, but also through adjustments of individual labor supply.

[28]Note that one reason for these weaker bias lies in the relatively small population share of Polish migrants. If one investigated the impact of total immigration in Germany, general equilibrium effects would naturally play a greater role.

tionary savings motive of migrants as well from capital movements between sending and host region driven by return migration and cross-border investments.[29]

4.5 Welfare

Having investigated the responses of factor prices and pension benefits, we can now ask how the welfare of natives in both Germany and Poland is affected by migration. In this respect, I calculate the consumption equivalent variation (CEV) that measures by how much percent you have to change lifetime consumption of an individual born in the counterfactual to make her indifferent between both model variants. This measure offers a convenient interpretation: If it is positive, agents benefit from migration and they lose in case the CEV turns out to be negative. Let us first focus on the benchmark model without cross-border investment. From a qualitative point of view, natives in Germany lose due to lower benefits, however low-skilled and medium-skilled still profit from higher wages (the latter only weakly). In Poland we observe that all skill types exhibit lower wages, whereas benefits only decrease for low-skilled workers. Changes in the interest rate are too small to significantly impact welfare. Table 4.9 displays the skill-specifics CEVs.

Table 4.9: CEV in Benchmark Model

	Germany	Poland
high-skilled	0.06	0.05
medium-skilled	0.06	-0.04
low-skilled	-0.47	3.42

Numbers are in percent.

Given the small reactions of factor prices and benefits, it is not surprising that we see only small welfare changes for high-skilled and medium-skilled workers in both counties. Again, the effects are more pronounced among low-skilled workers: German natives are worse off due to migration and it would take a reduction of 0.47 % of lifetime consumption to equalize welfare between the model variants. On the other hand, the low-skilled labor type in Poland benefits significantly from migration, with a welfare gain equal to 3.42 % of lifetime consumption in the counterfactual. So far, the discussed welfare effects hinge upon the assumption that migrants can solely invest in Germany. In section 4.4.1, we have seen that the higher per capita savings of migrants are beneficial to non-migrants in both countries. However, once we additionally allow

[29] An additional channel linking immigration and the capital to labor ratio would exist if skill types differed significantly in their saving rates. In this case, an influx of migrants not mirroring the skill composition of natives would directly alter per capita asset holdings. Such differences in saving rates would e.g. arise due to a redistributive tax and transfer system or skill-specific differences in mortality rates.

for cross-border investment, the per capita savings of immigrants in German domestic capital might actually be lower than that of natives, such that immigration could lead to a reduction of the German capital to labor ratio. On the other hand, the inflow of capital in Poland due to cross-border investment of migrants entails a positive effect on capital and hence on wages and pensions. To investigate how the welfare consequences of migration depend on the ability of migrants to invest in their home country, figures 4.5a to 4.5c display the evolution of the CEV as a function of ω. As can be seen, introducing cross-border investment has opposing effects on the welfare implications of migration in both countries. In particular, an increase in foreign investors (a decrease in ω) increases welfare losses for German low-skilled natives and reduces the small, but initially positive welfare effects for the other two labor types. In fact, at the right end of figure 4.5c, the CEV of German high-skilled workers even turns negative. On the contrary, the larger the share of foreign investors among Polish migrants becomes, the more positive are the welfare implications of migration in Poland. While the medium-skilled and the high-skilled type exhibit CEVs close to zero in the benchmark model, their welfare measures become significantly larger. Further, even for small shares of foreign investors, the CEV of medium-skilled Polish non-migrants is now positive, such that migration unambiguously improves welfare for all labor types.

Summarizing the findings on the welfare implications, the preceding analysis suggests that migration between Germany and Poland mainly entails a redistribution between low-skilled workers in each country, whereby welfare gains in Poland are considerably larger than welfare losses in Germany. However, welfare effects might also be significantly positive for medium-skilled and high-skilled workers in Poland, depending on the degree of cross-border investment of migrants residing in Germany.

4.6 Conclusion

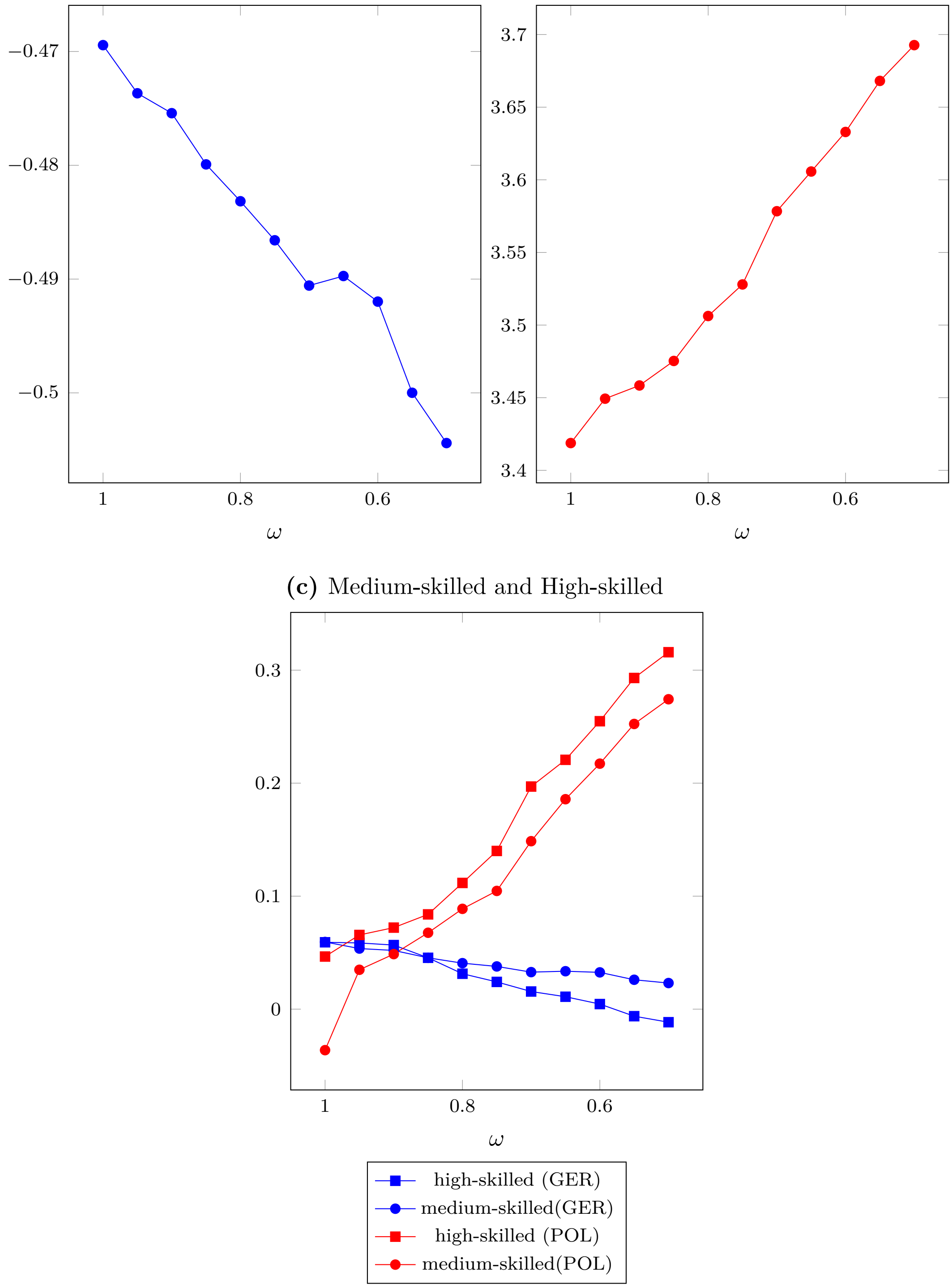
Studying the effects of migration has a long tradition in economic research. While the largest part of the literature consists of microeconometric studies, the given paper presents an open economy model able to uncover various general equilibrium effects associated with labor movements. The quantitative part of the paper applies the model to the case of Polish migration to Germany. The paper highlights several important channels through which migration affects the macroeconomy. Firstly, I allow for imperfect substitutability of skill types in the production function implying that differences in the skill compositions of migrants and natives induce changes in relative wages. Secondly, due to the possibility of returning to the home country, migrants and natives are shown to exhibit significant differences in their life-cycle hours, consumption and savings profiles. Thirdly, I demonstrate that the macroeconomic implications of labor movements are sensitive to whether (and to what degree) migrants invest in their

Figure 4.5: Welfare

(a) Germay: Low-skilled

(b) Poland: Low-skiled

(c) Medium-skilled and High-skilled



Results are reported relative to the benchmark scenario without cross-border investments ($\omega = 1$). Changes in interest rates are displayed in percentage points.

home country. Lastly, I account for differences in the age structure between migrants and natives to investigate their impact on the public pension system. One important advantage of this general equilibrium framework is that it establishes a relation between migration and capital formation. I show that the absence of this linkage in structural empirical studies might produce biased estimates of wages effects. Moreover, the structural framework allows me to employ a welfare analysis to investigate how non-migrants in both economies are affected by labor flows. I find that migration movements matching the current skill and age distribution of Polish migrants imply negligible welfare effects for high-skilled and medium-skilled workers in Germany, but moderate welfare losses for low-skilled types. Regarding Poland, migration also affects high-skilled and medium-skilled agents rather mildly, but entails large welfare gains for low-skilled individuals. Finally, I show that cross-border investments of migrants deepen the welfare losses in Germany, and enhance welfare gains in Poland.

Appendix 4.A Theoretical Appendix

4.A.1 Cross-Sectional Measure

The cross-sectional measure is generated as following:[30]

$$\Phi_{t+1}(\mathcal{A};\kappa,s,1,1,x,x)=\begin{cases}N_{\kappa,s,1,x,x} & if \;\; 0\in\mathcal{A}\\ 0 & \text{else.}\end{cases}$$

For agents with $y=h$ and $j<J$:

$$\Phi_{t+1}(\mathcal{A};\kappa,s,j+1,\min\{j+1,R\},h,h)=\int_{\mathcal{A}}\mathbb{1}\{a_t'(a;\kappa,s,j,\min\{j,R\},h,h)\in\mathcal{A}\} \\ d\Phi_t(a;\kappa,s,j,\min\{j,R\},h,h)\psi_{h,j}$$

Equivalently, for agents with $y=f$, $\kappa=1$ and $j<J$:

$$\Phi_{t+1}(\mathcal{A};\kappa,s,j+1,\min\{j+1,R\},f,f)=\int_{\mathcal{A}}\mathbb{1}\{a_t'(a;\kappa,s,j,\min\{j,R\},f,f)\in\mathcal{A}\} \\ d\Phi_t(a;\kappa,s,j,\min\{j,R\},f,f)\psi_{f,j}$$

For agents with $y=f$, $\kappa=2$ and $j=1$:

$$\Phi_{t+1}(\mathcal{A};\kappa,s,j+1,j,h,f)=\int_{\mathcal{A}}\mathbb{1}\{a_t'(a;\kappa,s,j,j,f,f)\in\mathcal{A}\}d\Phi_t(a;\kappa,s,j,j,f,f)\psi_{f,j}$$

For agents with $y=f$, $x=h$, $\kappa=2$, $2<j<J$ and $n^f=1$:

$$\Phi_{t+1}(\mathcal{A};\kappa,s,j+1,n^f,h,f)=(1-\lambda)\int_{\mathcal{A}}\mathbb{1}\{a_t'(a;\kappa,s,j,n^f,h,f)\in\mathcal{A}\}d\Phi_t(a;\kappa,s,j,n^f,h,f)\psi_{f,j}$$

$$\Phi_{t+1}(\mathcal{A};\kappa,s,j+1,n^{f'},f,f)=\lambda\int_{\mathcal{A}}\mathbb{1}\{a_t'(a;\kappa,s,j,n^f,h,f)\in\mathcal{A}\}d\Phi_t(a;\kappa,s,j,n^f,h,f)\psi_{f,j}$$

with

[30] With $N_{\kappa,s,1,x,x}$ denoting the number of newborns. See section 4.3.1 for further explanations.

$$\begin{cases} n^{f'} = 2 \;\; if \;\; j < R \\ n^{f'} = 1 \;\; \text{else.} \end{cases}$$

Lastly, for return migrants ($y = f$, $x = f$, $\kappa = 2$, $3 < j < J$ and $n^f \in \{1, R-1\}$):

$$\Phi_{t+1}(\mathcal{A}; \kappa, s, j+1, n^{f'}, f, f) = \int_{\mathcal{A}} \mathbb{1}\{a'_t(a; \kappa, s, j, n^f, f, f) \in \mathcal{A}\} d\Phi_t(a; \kappa, s, j, n^f, f, f)\psi_{f,j}$$

$$\begin{cases} n^{f'} = n^f + 1 \;\; if \;\; j < R \\ n^{f'} = n^f \;\; \text{else.} \end{cases}$$

4.A.2 Derivation of the National Income Identity

This section presents the derivation of the national income identity in *home* given by (4.27). To simplify notation, I consider the case without skill heterogeneity. Further, I drop the time index t and the state variables labeling the migration type (κ) and the pension claims (n^y)[31], thereby reducing the population measure defined in 4.3.1 to $N(j, x, y)$. The derivation of the national income identity in *foreign* follows the same steps.[32]

The individual budget constraint for any agent residing in h is given by:

$$e_{x,y}(j) + \pi_{x,y}(j) + (1 + r_h)a_{x,y}(j) = a_{x,y}(j+1) + c_{x,y}(j),$$

whereby policy and income functions are labeled with the indexes (x, y) denoting (destination, place of birth). Aggregating with the respective population weights, then delivers:

[31]For the derivation of (4.27), leaving aside κ is unproblematic, since all migrants are necessarily of type $\kappa = 2$. Further, it is also known that all migrants in h exhibit $n^f = 1$.

[32]Note, however, that the derivation of (4.28) does require a distinction between *stayers* and *return migrants* as well as between migrants with different pension claims.

$$w_h(1-\tau_h)\sum_{j=1}^{R}\epsilon(j)[N(j,h,h)l_{h,h}(j)+N(j,h,f)l_{h,f}(j)(1-\theta)] \tag{4.36}$$

$$+(1+r_h)\sum_{j=1}^{J}[N(j,h,h)a_{h,h}(j)+N(j,h,f)a_{h,f}(j)] \tag{4.37}$$

$$+b_h\sum_{j=R+1}^{J}\Big[N(j,h,h)+N(j,h,f)\frac{R-1}{R}(1-\theta)\Big] \tag{4.38}$$

$$+b_f\sum_{j=R+1}^{J}N(j,h,f)\frac{1}{R} \tag{4.39}$$

$$=\sum_{j=1}^{J-1}[N(j,h,h)a_{h,h}(j+1)+N(j,h,f)a_{h,f}(j+1)] \tag{4.40}$$

$$+\sum_{j=1}^{J}[N(j,h,h)c_{h,h}(j)+N(j,h,f)c_{h,f}(j)] \tag{4.41}$$

Let us now simplify the summands step by step. Firstly, (4.36) can be written as:

$$w_h(1-\tau_h)L_h \tag{4.42}$$

Taking into account that agents are born with zero assets, we obtain for beginning-of-period asset holdings (4.37):

$$(1+r_h)\Big[\underbrace{\sum_{j=2}^{J}N(j-1,h,h)a_{h,h}(j)}_{natives}+\underbrace{(1-\lambda)\sum_{j=3}^{J}N(j-1,h,f)a_{h,f}(j)}_{\text{non-return migrants}}+\underbrace{N(1,f,f)a_{h,f}(2)}_{\text{entering migrants}}\Big]$$

$$-(1+r_h)\Big[\sum_{j=2}^{J}(1-\psi_{h,j-1})N(j-1,h,h)a_{h,h}(j)+(1-\lambda)\sum_{j=3}^{J}(1-\psi_{f,j-1})N(j-1,h,f)a_{h,f}(j)$$
$$+(1-\psi_{f,1})N(1,f,f)a_{h,f}(2)\Big]$$

$$\Longleftrightarrow (1+r_h)(A_h+\tilde{A}_h)-Beq_h,$$

where A_h contains the savings by natives and non-return migrants in h, and $\tilde{A}_h$ captures the asset holdings by entering migrants.

The pension benefits in lines (4.38 and 4.39):

$$Pen_h+\widetilde{Pen}_h,$$

whereby Pen_h denotes the pension payments paid from the social security system in h to all agents residing in h and $\widetilde{Pen}_h$ refers to the amount of pension paid from country f to migrants in h.

Next-period assets in line (4.40):

$$\sum_{j=1}^{J-1}[N(j,h,h)a_{h,h}(j+1) + (1-\lambda)N(j,h,f)a_{h,f}(j+1) + \underbrace{\lambda N(j,h,f)a_{f,f}(j+1)}_{\text{return migrants}}]$$

$$\Longleftrightarrow A'_h + \tilde{A'}_f,$$

where $\tilde{A'}_f$ summarizes all savings made by return migrants.

Together with aggregate consumption from line (4.41), we can now summarize

$$w_h(1-\tau_h)L_h + (1+r_h)(A_h + \tilde{A}_h) - Beq_h + Pen_h + \widetilde{Pen}_h = A'_h + \tilde{A'}_f + C_h$$

Now, we can use the following equilibrium conditions:

1. $K_h = A_h + \tilde{A}_h$
2. $G_h = Beq_h$
3. $K'_h = A'_h + \tilde{A'}_h$
4. $Y_h = w_h L_h + (r_h + \delta)K_h$
5. $\tau_h w_h L_h = Pen_h + \widetilde{Pen}_f$

Substituting in, we obtain:

$$Y_h - \delta K_h + K_h + \widetilde{Pen}_h - \widetilde{Pen}_f = K'_h + \tilde{A'}_f - \tilde{A'}_h + C_h + G_h$$

Rearranging and defining $F_h^{pen} = \widetilde{Pen}_h - \widetilde{Pen}_f$ and $F_h^k = \tilde{A'}_h - \tilde{A'}_f$:

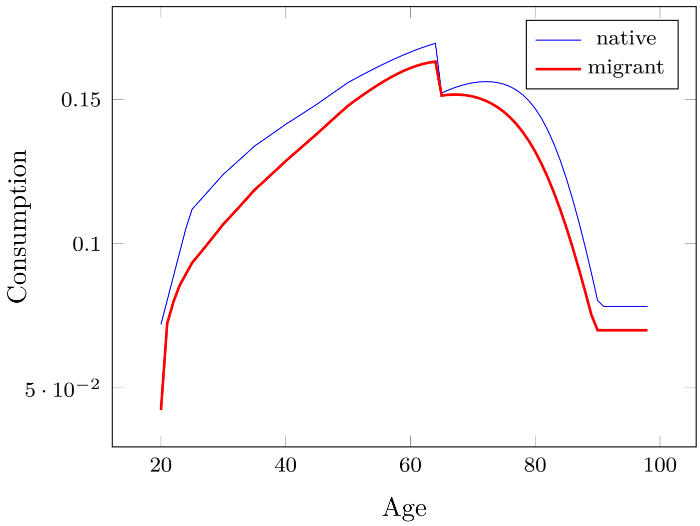
$$Y_h + (1-\delta)K_h + F_h^{pen} + F_h^k = K'_h + C_h + G_h$$

Appendix 4.B Quantitative Appendix

4.B.1 Life-Cycle Profiles

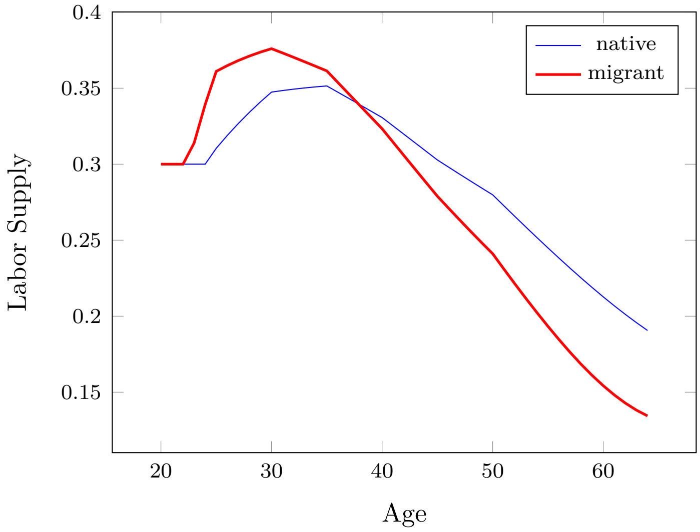
Figures 4.6 and 4.7 display consumption and labor supply profiles for migrants and natives separately.

Figure 4.6: Consumption Profiles



Consumption profiles are displayed for high-skilled workers.

Figure 4.7: Labor Supply Profiles



Labor supply profiles are displayed for high-skilled workers.

4.B.2 Cross-Border Investments

Figures 4.8 to 4.11 depict the country-specific steady state outcomes for capital, interest rates, wages and pensions as a function of the investment parameter. Results are

Figure 4.8: Capital

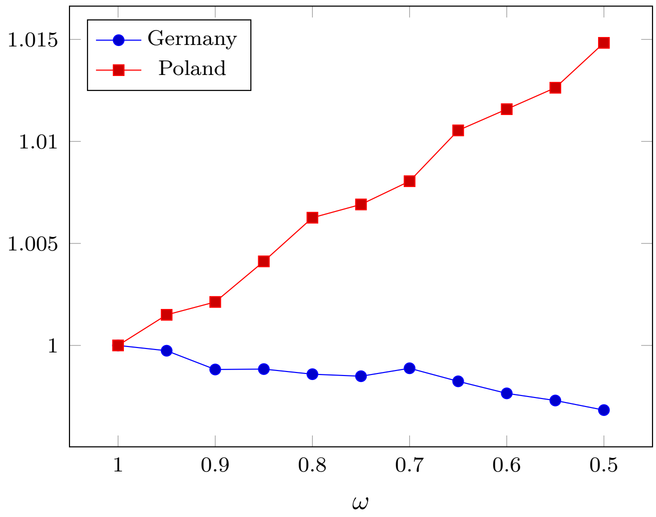
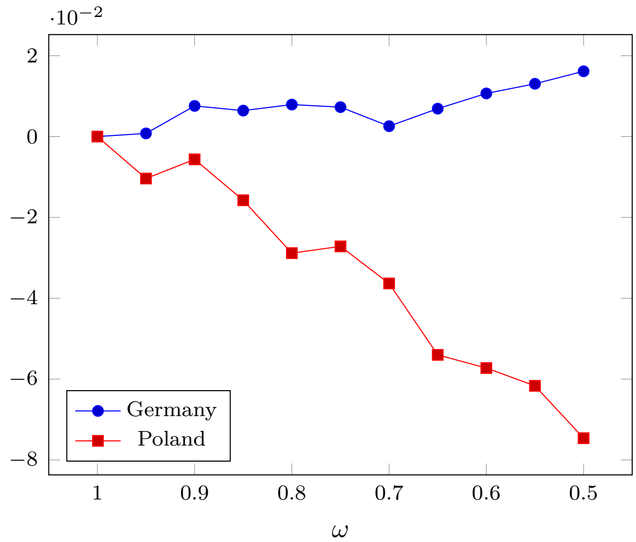


Figure 4.9: Interest Rates



reported relative to the benchmark scenario without cross-border investments ($\omega = 1$). Changes in interest rates are displayed in percentage points.

Figure 4.10: Wages

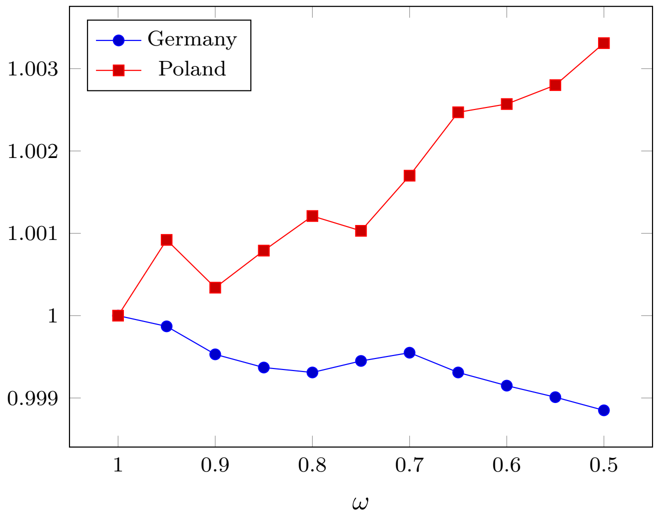
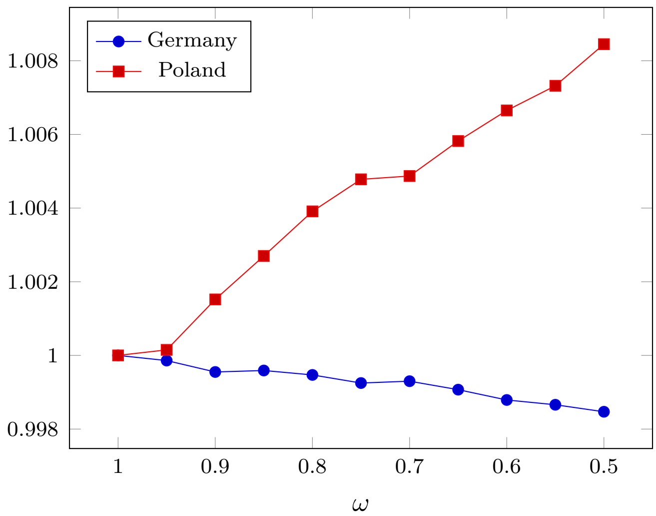


Figure 4.11: Pensions



5. Conclusion

This thesis contains three self-contained papers contributing to the literature on demographic change, migration and public pensions. While the nexus of these three topics is present in each chapter, the single papers all provide a different perspective on the topic area. Chapter 2 introduces the basic framework for analyzing endogenous migration flows in a open economy model where countries exhibit differences in the generosity of public pension systems. Chapter 3 expands the model setting along several dimensions. First of all, I extend the model from chapter 2 to a three-country set-up, in which Germany as the host region receives immigration from Poland and Southern Europe. Furthermore, I introduce a complex demographic structure enabling an explicit analysis of the demographic transition. In contrast to related quantitative macroeconomic studies of population aging such as Krueger and Ludwig (2007) or Attanasio et al. (2007), the endogeneity of migration flows introduces a feedback mechanism between demographic and economic variables. In particular, migration responds to changes in relative wages and relative returns to the public pension systems caused by population aging. The migration flows arising in general equilibrium alter country-specific population dynamics as well as macroeconomic aggregates, factor prices and social security variables. Finally, chapter 4 shifts the focus from the interconnection between migration and population aging to the distributional implications of current labor movements. In the context of a two-country model I study the case of Polish-German migration. I highlight two main channels through which migration entails distributional effects. Firstly, labor movements change relative wages as long as they amend a country's skill composition. Secondly, due to return migration, the savings behavior of migrants differs from that of non-migrants. Specifically, if income differences between sending and host region are significantly large and migrants expect to return to their home country with a positive probability, they accumulate high per capita savings to insure against a possible drop in income after returning. These higher assets of return migrants unambiguously increase the capital intensity in Poland (sending country). Whether Germany (host country) also benefits from the migrants' savings behavior depends on the degree of cross-border investments.

In all three papers I address the topic of intra-European migration. This is of particular relevance because EU-member states allow for a free movement of workers in between them despite the existing wide heterogeneity with respect to economic prosperity and social security arrangements. A fruitful path for future research consists of disentangling the driving forces behind migration flows. My thesis demonstrates that with ongoing population aging, distortions emerging from social security systems might become an important determinant of labor movements. Further, the thesis suggests that it requires a multi-dimensional analysis to understand the macroeconomic and distributional implications of migration. While an analysis mainly focusing on the effects of migration working through changes in labor supply and capital formation (see chapter 4) detects a redistribution of welfare from the host to the sending region, an analysis focusing on the long-run demographic effects (see chapter 3) rather indicates that the welfare redistribution works in the other direction.

Bibliography

Attanasio, Orazio, Sagiri Kitao, and Giovanni Violante (2007). “Global demographic trends and social security reform”. *Journal of Monetary Economics 54* (1), 144–198.

Auerbach, Alan J and Laurence J Kotlikoff (1987). “Evaluating Fiscal Policy with a Dynamic Simulation Model”. *American Economic Review 77* (2), 49–55.

Bauer, Thomas K and Mathias G Sinning (2011). “The savings behavior of temporary and permanent migrants in Germany”. *Journal of Population Economics 24* (2), 421–449.

Bayer, Christian and Falko Juessen (2012). “On the Dynamics of Interstate Migration: Migration Costs and Self-Selection”. *Review of Economic Dynamics 15* (3), 377–401.

Borjas, George J (2003). “The labor demand curve is downward sloping: Reexamining the impact of immigration on the labor market”. *The Quarterly Journal of Economics 118* (4), 1335–1374.

Börsch-Supan, Axel, Alexander Ludwig, and Joachim Winter (2006). “Ageing, Pension Reform and Capital Flows: A Multi-Country Simulation Model”. *Economica 73* (292), 625–658.

Breyer, Friedrich and Martin Kolmar (2002). “Are national pension systems efficient if labor is (im) perfectly mobile?” *Journal of Public Economics 83* (3), 347–374.

Brücker, Herbert, Andreas Hauptmann, Elke J Jahn, and Richard Upward (2014). “Migration and imperfect labor markets: Theory and cross-country evidence from Denmark, Germany and the UK”. *European Economic Review 66*, 205–225.

Carroll, Christopher D. (2006). “The method of endogenous gridpoints for solving dynamic stochastic optimization problems”. *Economics Letters 91* (3), 312–320.

Chassamboulli, Andri and Theodore Palivos (2014). “A Search-Equilibrium Approach to the Effects of Immigration on Labor Market Outcomes”. *International Economic Review 55* (1), 111–129.

Cooley, Thomas F and Edward C Prescott (1995). “Economic growth and business cycles”. *Frontiers of business cycle research 1*.

Destatis (2016). *National Accounts*. URL: `https://www.destatis.de/EN/FactsFigures/NationalEconomyEnvironment/NationalAccounts/`

NationalAccounts.html;jsessionid=C3F764E3C540B4743CB67E133D8EF538.InternetLive1 (visited on 12/09/2016).
Destatis (2017). *Migration statistics.* URL: https://www-genesis.destatis.de/genesis/online/data;jsessionid=82B5596B23540A1DE8BEF44EF1B81CD8.tomcat_GO_2_3?operation=abruftabelleAbrufen&selectionname=12711-0001&levelindex=1&levelid=1518191227198&index=1 (visited on 02/09/2017).
Duffy, John, Chris Papageorgiou, and Fidel Perez-Sebastian (2004). "Capital-skill complementarity? Evidence from a panel of countries". *Review of Economics and Statistics 86* (1), 327–344.
Dustmann, Christian (1997). "Return migration, uncertainty and precautionary savings". *Journal of Development Economics 52* (2), 295–316.
Dustmann, Christian, Tommaso Frattini, and Ian P Preston (2012). "The effect of immigration along the distribution of wages". *Review of Economic Studies 80* (1), 145–173.
Dustmann, Christian and Ian Preston (2012). "Comment: Estimating the effect of immigration on wages". *Journal of the European Economic Association 10* (1), 216–223.
Eurostat (2015a). *Death and life expectancy data.* URL: http://ec.europa.eu/eurostat/web/population-demography-migration-projections/deaths-life-expectancy-data/database (visited on 06/02/2015).
——— (2015b). *Poulation data.* URL: http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/database (visited on 04/15/2015).
——— (2017a). *Compensation of employees.* URL: http://ec.europa.eu/eurostat/en/web/products-datasets/-/TEC00013 (visited on 09/08/2017).
——— (2017b). *Death and life expectancy data.* URL: http://ec.europa.eu/eurostat/web/population-demography-migration-projections/deaths-life-expectancy-data/database (visited on 09/06/2017).
——— (2017c). *GDP and main components.* URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_gdp&lang=en (visited on 12/20/2017).
——— (2018). *Social Protection Expenditure.* URL: http://ec.europa.eu/eurostat/web/social-protection/data/database (visited on 05/16/2018).
Fehr, Hans, Sabine Jokisch, and Laurence J. Kotlikoff (2004). "The Role of Immigration in Dealing with the Developed World's Demographic Transition". *FinanzArchiv: Public Finance Analysis 60* (3), 296–296.
Fella, Giulio (2014). "A generalized endogenous grid method for non-smooth and non-concave problems". *Review of Economic Dynamics 17* (2), 329–344.

Galor, Oded and Oded Stark (1990). "Migrants' savings, the probability of return migration and migrants' performance". *International Economic Review*, 463–467.

Geppert, Christian (2015). "On the distributional implications of demographic change". *mimeo.*

Glitz, Albrecht and Daniel Wissmann (2017). "Skill Premiums and the Supply of Young Workers in Germany". IZA Discussion Paper Series.

Hansen, G D (1993). "The Cyclical and Secular Behaviour of the Labour Input: Comparing Efficiency Units and Hours Worked". *Journal of Applied Econometrics 8* (1), 71–80.

Hassler, John, José V Rodríguez Mora, Kjetil Storesletten, and Fabrizio Zilibotti (2005). "A positive theory of geographic mobility and social insurance". *International Economic Review 46* (1), 263–303.

Heer, Burkhard (2018). "Optimal pensions in aging economies". *The B.E. Journal of Macroeconomics 18* (1), 1–19.

Heer, Burkhard and Andreas Irmen (2014). "Population, pensions, and endogenous economic growth". *Journal of Economic Dynamics and Control 46* (C), 50–72.

Homburg, Stefan and Wolfram F Richter (1993). "Harmonizing public debt and public pension schemes in the European Community". *Journal of Economics 7*, 51–63.

İmrohoroğlu, Ayşe, Selahattin İmrohoroğlu, and Douglas H Joines (1995). "A life cycle analysis of social security". *Economic theory 6* (1), 83–114.

——— (1999). "Social security in an overlapping generations economy with land". *Review of Economic Dynamics 2* (3), 638–665.

Jaeger, David A, Thomas Dohmen, Armin Falk, David Huffman, Uwe Sunde, and Holger Bonin (2010). "Direct evidence on risk attitudes and migration". *The Review of Economics and Statistics 92* (3), 684–689.

Kindermann, Fabian and Dirk Krueger (2014). "High marginal tax rates on the top 1%? Lessons from a life cycle model with idiosyncratic income risk". Tech. rep. National Bureau of Economic Research.

Klein, Paul and Gustavo Ventura (2009). "Productivity differences and the dynamic effects of labor movements". *Journal of Monetary Economics 56* (8), 1059–1073.

Krueger, Dirk and Alexander Ludwig (2007). "On the consequences of demographic change for rates of returns to capital, and the distribution of wealth and welfare". *Journal of Monetary Economics 54* (1), 49–87.

Krusell, Per, Lee E Ohanian, José-Víctor Ríos-Rull, and Giovanni L Violante (2000). "Capital-skill complementarity and inequality: A macroeconomic analysis". *Econometrica 68* (5), 1029–1053.

Lagakos, David, Benjamin Moll, Tommaso Porzio, Nancy Qian, and Todd Schoellman (2018). "Life cycle wage growth across countries". *Journal of Political Economy 126* (2), 797–849.

Ludwig, Alexander, Thomas Schelkle, and Edgar Vogel (2012). "Demographic change, human capital and welfare". *Review of Economic Dynamics 15* (1), 94–107.

OECD (2013). "Pensions at a Glance 2013". *OECD Publishing.*

——— (2015). "Pensions at a Glance 2015". *OECD Publishing.*

——— (2016). *Level of GDP per capita and productivity.* URL: `http://stats.oecd.org/index.aspx?DataSetCode=PDB_LV` (visited on 06/22/2016).

——— (2017a). *Education and earnings.* URL: `https://stats.oecd.org/Index.aspx?DataSetCode=EAG_EARNINGS` (visited on 11/21/2017).

——— (2017b). *Educational attainment and labour-force status.* URL: `https://stats.oecd.org/Index.aspx?DataSetCode=EAG_NEAC` (visited on 10/09/2017).

——— (2017c). *Level of GDP per capita and productivity.* URL: `http://stats.oecd.org/index.aspx?DataSetCode=PDB_LV` (visited on 08/22/2017).

Ottaviano, Gianmarco IP and Giovanni Peri (2012). "Rethinking the effect of immigration on wages". *Journal of the European Economic Association 10* (1), 152–197.

Rupert, Peter and Giulio Zanella (2015). "Revisiting wage, earnings, and hours profiles". *Journal of Monetary Economics 72* (C), 114–130.

Statistisches Bundesamt (2015). *Vorläufige Wanderungsergebnisse.* Wiesbaden, Germany.

——— (2016a). "Bevölkerung mit Migrationshintergrund - Ergebnisse des Mikrozensus". Fachserie 1 Reihe 2.2 - 2016.

——— (2016b). "Datenreport 2016. Ein Sozialbericht für die Bundesrepublik Deutschland".

Storesletten, Kjetil (2000). "Sustaining fiscal policy through immigration". *Journal of Political Economy 108* (2), 300–323.

——— (2003). "Fiscal implications of immigration—A net present value calculation". *The Scandinavian Journal of Economics 105* (3), 487–506.

United Nations (2015). *World Population Prospects: The 2017 Revision.* Department of Economic and Social Affairs, Population Division. URL: `https://esa.un.org/unpd/wpp/DataQuery/` (visited on 06/14/2016).

——— (2018). *World Population Prospects: The 2017 Revision.* Department of Economic and Social Affairs, Population Division. URL: `https://esa.un.org/unpd/wpp/DataQuery/` (visited on 05/29/2018).