# Demographic Change and Labor Mobility

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**Abstract**

This paper provides a quantitative analysis of intra-European migration flows between Germany, Southern Europe and Poland along the demographic transition. Migration movements evolve endogenously as a reaction to changes in relative prices induced by population aging. Immigration from Southern Europe and Poland reduces gross wages in Germany slightly, but alleviates the distortions from social security significantly. This lower elasticity of wages is caused by a large inflow of capital accompanying immigration which counteracts the downward pressure on wages due to a higher labor supply. Welfare effects of endogenous migration flows depend crucially on the policy reaction to population aging. If contribution rates remain constant and the burden of adjustment lies on pension benefits, the negative wage effect of immigration limits the positive welfare gains from higher pensions in Germany. On the contrary, if contribution rates adjust, welfare effects are both larger and increasing over time since immigration serves to stabilize net wages. However, these positive welfare effects in Germany come at the expense of significant welfare losses in the sending regions.

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# 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 or by incorporating migration shocks. 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 system. 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 the consequences of the migration flows 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 flows.

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. While immigration unambiguously alleviates the pressure on the social security system, its negative effect 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 future generations, however, these welfare gains decrease over time since the negative effect on 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 effect net wages. Consequently, the mitigation of those distortions due to immigration induces significant welfare gains in Germany that grow along the demographic transition. These positive welfare effects for individuals in Germany are, however, mirrored by large welfare losses in the sending regions.

My paper connects to and extends a field of literature dealing with the quantitative 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, Ludwig, and Winter (2002) analyze, inter alia, intra-European capital flows, whereas Attanasio, Kitao, and Violante (2006) 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, Schelkle, and Vogel (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

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

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 demographics or social security. To sum up, my paper preserves the open economy nature of earlier studies and adds a further household adaptation mechanism to the existing literature.

The paper is organized as follows. In section 2, I describe the underlying theoretical model and define the equilibrium conditions. Subsequently, section 3 discusses the calibration stratgy. Section 4 covers the main positive results of the benchmark model, including the predicted pattern of migration movements and their impact on prices and aggregates. Based on this positive analysis, I further shed light on the welfare implication of intra-European migration flows. Lastly, the previous analysis is revisited for a different policy scenario in section 5.

# 2. Model

## 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.

## 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 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 the appendix.

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

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

And for the destination region:

$$
\begin{aligned}
\mathcal{P}_{t+1,j+1,d} &= \mathcal{P}_{t,j,d}\Big(\psi_{t,j,d} + m_{t,j,d}\Big) \\
\mathcal{P}_{t+1,j+1,s_1} &= \mathcal{P}_{t,j,s_1}\psi_{t,j,s_1} + \mathcal{N}_{t,j,s_1}\tilde{m}_{t,j,s_1} \\
\mathcal{P}_{t+1,j+1,s_2} &= \mathcal{P}_{t,j,s_2}\psi_{t,j,s_2} + \mathcal{N}_{t,j,s_2}\tilde{m}_{t,j,s_2} \\
\mathcal{N}_{t,j,d} &= \mathcal{P}_{t,j,d} + \mathcal{P}_{t,j,s_1} + \mathcal{P}_{t,j,s_2} \\
m_{t,j,d} &= 0 \;\; \textit{if} \;\; j > 20 \\
\mathcal{N}_{t+1,0,d} &= \sum_{j=15}^{50} f_{t,j,d}\mathcal{N}_{t,j,d}
\end{aligned} \tag{2}
$$

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 99. 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, 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. Secondly, it contains an endogenous part ($\tilde{m}_{t,j,s_i}$) covering the net migration rate of $d$ w.r.t sending region $s_i$. Both migration rates are age-dependent. 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 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

[2]The length of the time span is common in this literature as it is necessary to ensure a convergence to a final steady state.

$(\mathcal{P}^d_{t,j,s_1}, \mathcal{P}^d_{t,j,s_2})$. 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 $d$ includes agents with different mortality risk. Therefore, the recursions in (2) have to be stated for each group separately. The population distribution of the sending regions is captured in $\mathcal{N}_{t,j,s_i}$.

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.

## 2.3. Production

All regions produce one single good using a CRS production technology requiring land ($F$), labor ($L$) and capital ($K$) as input factors:

$$Y_{x,t} = A_{x,t} K^{\nu}_{x,t} L^{\sigma}_{x,t} F^{1-\nu-\sigma}_{x} \tag{3}$$

for $x \in \{d, s_1, s_2\}$. $A_{x,t}$ denotes the technology level in the respective region. Even though $A_{x,t}$ 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 $\nu$ and $\sigma$ are constant over time and across regions. Capital depreciates at a country independent rate $\delta$. Finally, perfect competition among firms requires an equalization of the input factors' marginal products and their prices:

$$r^k_{x,t} = \nu A_{x,t} K^{\nu-1}_{x,t} L^{\sigma}_{x,t} F^{1-\nu-\sigma}_{x} - \delta \tag{4}$$

$$w_{x,t} = \sigma A_{x,t} K^{\nu}_{x,t} L^{\sigma-1}_{x,t} F^{1-\nu-\sigma}_{x} \tag{5}$$

$$r^f_{x,t} = (1-\nu-\sigma) A_{x,t} K^{\nu}_{x,t} L^{\sigma}_{x,t} F^{-\nu-\sigma}_{x} \tag{6}$$

## 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.

### 2.4.1. Preference heterogeneity

I follow Klein and Ventura (2009) and allow for a preference heterogeneity among possible migrants in the sending regions. In particular, agents differ with respect to utility costs they have to bear when living abroad ($\mu_\kappa$), where $\kappa$ denotes the preference type which is realized at birth and fix 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.

### 2.4.2. 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. Denoting age with $j$ and period of time with $t$, lifetime utility of an agent in sending region $s_i$ with preference type $\kappa$ can then be written as:

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

$\eta$ governs the intertemporal elasticity of substitution and $\gamma$ 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 his place of birth ($x_j \neq s_i$). Depending on the current location, the budget constraint can be expressed as follows:

$$\begin{cases} (1+r_t)a_t(j) + e_{x,t}(j) + tr_{x,t} = a_{t+1}(j+1) + c_t(j) + \varphi_t(j) mc_{x,t} & \text{if} \quad x_t(j) = s_i \\ (1+r_t)a_t(j) + e_{x,t}(j) + tr_{x,t} = a_{t+1}(j+1) + c_t(j) & \text{if} \quad x_t(j) \neq s_i \end{cases} \tag{7}$$

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:

$$1 + r_{x,t} = \frac{p_{x,t} + r^f_{x,t}}{p_{x,t-1}} \tag{8}$$

$$r_t = r_{x,t} \quad \forall x \in \{d, s_1, s_2\}. \tag{9}$$

Equation (8) defines the intra-regional no-arbitrage condition between both asset types where $p_{x,t}$ denotes the price of land in region $x$ and in period $t$. Equation (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.

Additionally, agents receive a lump-sum transfer $tr_{x,t}$ resulting out of the collection and redistribution of accidental bequests by the government. Importantly, migrants do not receive transfers from the destination country, i.e. transfers do not directly influence the migration decision.

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

$$\begin{cases} w_{s_i,t}(1-\tau_{s_i,t}) l_t(j)\epsilon(j) & \text{if} \quad j < R \ \& \ x_t(j) = s_i \\ w_{d,t}(1-\tau_{d,t}) l_t(j)\epsilon(j) & \text{if} \quad j < R \ \& \ x_t(j) \neq s_i \\ \pi(.) & \text{else.} \end{cases} \tag{10}$$

Individuals work until they reach an exogenous retirement age $R$. If an agent has not migrated he earns the home wage $(w_{s_i,t})$ and pays the home contribution tax $(\tau_{s_i,t})$. Further, his earnings depend on the life-cycle efficiency profile $\epsilon$ which is identical in all regions. The policy function associated with migration is captured in

$\varphi(\cdot)$. It is equal to one if the individual decides to migrate in the current period and zero otherwise. Migration (potentially) requires a payment of moving costs ($mc_{x,t}$). After arriving in the destination region, individuals earn wages paid in $d$ and pay the corresponding contribution tax. Pension benefits are determined by the function $\pi(\cdot)$ as explained in the next section.

### 2.4.3. 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. Importantly, national pension systems are linked via a *place of residence* principle[3], 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:

$$\pi_t(j_m) = \frac{j_m b_{s_i,t} + (R - j_m) b_{d,t}}{R} \quad \text{for} \quad 0 < j_m \leq R, \tag{11}$$

$b_{s_i,t}$ refers to the benefits paid to stayers in sending region $i$ whereas $b_{d,t}$ are the 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 his 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, he receives a weighted average of benefits paid to non-migrants in both countries.

### 2.4.4. Recursive Formulation

Defining the vector of state variables as $z = (a, \kappa, j, j_m, x, s_i)$[4], the household problem for a working agent ($j \leq R$), who has not migrated yet, can be written in a recursive way:

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

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

$$V_t(a,\kappa,j,j,x,s_i) = \max_{c,a',\varphi}\Big[U(c) + \beta\psi_{x,t,j}\Big\{\varphi V_{t+1}(a',\kappa,j+1,j,d,s_i) \tag{12}$$
$$+ (1-\varphi)V_{t+1}(a',\kappa,j+1,j+1,s_i,s_i)\Big\}\Big]$$
$$s.t. \quad c + a' = (1+r_t)a + e_{x,t}(j) + tr_{x,t} - \varphi_t(j)mc_{x,t}$$
$$c, a' > 0, \varphi \in \{0,1\}.$$

## 2.5. 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, $\{V_t(\cdot), c_t(\cdot), a'_t(\cdot), \varphi(\cdot)\}_{t=0}^{\infty}$, sequences of production plans for the firms $\{K_{x,t}, L_{x,t}\}_{t=0,x\in\{d,s_1,s_2\}}^{\infty}$, policies $\{\tau_{x,t}, b_{x,t}\}_{t=0,x\in\{d,s_1,s_2\}}^{\infty}$, transfers $\{tr_{x,t}\}_{t=0,x\in\{d,s_1,s_2\}}^{\infty}$, 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, $c_t(\cdot), a'_t(\cdot), \varphi(\cdot)$ solve the individual's dynamic problem and $V_t(\cdot)$ are the associated value functions.
2. Factor prices satisfy (4),(5),(6).
3. Transfers in countries $d$ and $s_i$ are given by:

$$tr_{d,t+1} = \sum_{j=1}^{J-1}\sum_{j_m=1}^{R}\int_{\mathcal{A}\times\mathcal{K}} a'(a,\kappa;j,j_m,d,d)(1-\psi_{d,t,j})(1+r_{t+1}) \, d\Phi_t(a,\kappa;j,j_m,d,d) \tag{13}$$
$$tr_{s_i,t+1} = \sum_{x\in\{d,s_i\}}\sum_{j=1}^{J-1}\sum_{j_m=1}^{R}\int_{\mathcal{A}\times\mathcal{K}} a'(a,\kappa;j,j_m,x,s_i)(1-\psi_{s_i,t,j})(1+r_{t+1}) \, d\Phi_t(a,\kappa;j,j_m,x,s_i). \tag{14}$$

4. The social security budget clears in each country:

$$\tau_{x,t}w_{x,t}L_{x,t} = Pen_{x,t}, \tag{15}$$

whereas pension payments in country $d$ are given by:

$$
\begin{aligned}
Pen_{d,t} = &\sum_{j=R+1}^{J} b_{d,t}\Phi_t(\mathcal{A},\mathcal{K},j,R,d,d) \\
&+\sum_{i=1}^{2}\sum_{j=R+1}^{J}\sum_{j_m=1}^{R}\frac{R-j_m}{R} b_{d,t}\Phi_t(\mathcal{A},\mathcal{K},j,j_m,d,s_i).
\end{aligned}
\tag{16}
$$

and in country $s_i$:

$$
\begin{aligned}
Pen_{s_i,t} = &\sum_{j=R+1}^{J} b_{s_i,t}\Phi_t(\mathcal{A},\mathcal{K},j,R,s_i,s_i) \\
&+\sum_{j=R+1}^{J}\sum_{j_m=1}^{R}\frac{j_m}{R} b_{d,t}\Phi_t(\mathcal{A},\mathcal{K},j,j_m,d,s_i).
\end{aligned}
\tag{17}
$$

5. Markets clear in $d$ and $s_i$

$$
L_{d,t} = \sum_{j=1}^{R}\int_{\mathcal{A}\times\mathcal{K}} l(a,\kappa;j,j,d,d)\epsilon(j)d\Phi_t(a,\kappa,j,j,d,d) \tag{18}
$$

$$
+\sum_{i=1}^{2}\sum_{j=2}^{R}\sum_{j_m=1}^{j-1}\int_{\mathcal{A}\times\mathcal{K}} l(a,\kappa;j,j_m,d,s_i)\epsilon(j)d\Phi_t(a,\kappa,j,j_m,d,s_i). \tag{19}
$$

$$
L_{s_i,t} = \sum_{j=1}^{R}\int_{\mathcal{A}\times\mathcal{K}} l(a,\kappa;j,j,s_i,s_i)\epsilon(j)d\Phi_t(a,\kappa,j,j,s_i,s_i). \tag{20}
$$

$$
A_{t+1} = \sum_{y\in\{d,s_1,s_2\}}\sum_{x\in\{d,s_1,s_2\}}\sum_{j=1}^{J-1}\sum_{j_m=1}^{R}\int_{\mathcal{A}\times\mathcal{K}} a'(a,s;j,j_m,x,y)d\Phi_t(a,s;j,j_m,x,y), \tag{21}
$$

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

$$
A_{t+1} = K_{t+1} + \sum_{x\in\{d,s_1,s_2\}} p_{x,t}F_x. \tag{22}
$$

The aggregate resource constraint is given by:

$$\sum_{x\in\{d,s_1,s_2\}} Y_{x,t} + (1-\delta)K_t = \sum_{y\in\{d,s_1,s_2\}} \sum_{x\in\{d,s_1,s_2\}} \sum_{j=1}^{J} \sum_{j_m=1}^{R} \int_{\mathbb{A}\times\mathcal{K}} c(a,s;j,j_m,x,y) \tag{23}$$

$$d\Phi_t(a,s;j,j_m,x,y) + K_{t+1} + \sum_{i=1}^{2} \sum_{j=1}^{J} \sum_{j_m=1}^{R} \int_{\mathcal{A}\times\mathcal{K}} \varphi(a,s;j,j_m,s_i,s_i) m_{s_i,t}$$

$$d\Phi_t(a,s;j,j_m,x,x).$$

6. There are no arbitrage-opportunities as expressed by (8) and (9).

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

# 3. Calibration

## 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, whereas the weights depend on the relative population sizes at each point in time[5]. To be able to simulate 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.

## 3.2. Migration Rates

Accounting for a preference heterogeneity among potential migrants allows to match 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 his disutility of living abroad ($\mu_k$) from an exponential distribution $f(\lambda_{s_i})$. Given a life-cycle sequence of factor prices, benefits, taxes and migration costs, the distribution parameter $\lambda_{s_i}$ determines the share of agents within a specific cohort willing to emigrate from region $s_i$. Data on migration flows is taken from Statistisches Bundesamt (2015). I choose $\lambda_{s_{south}}$ to match the average net migration flow to

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

Germany over the period 1992-2015 ($\overline{mig}_{south}$).[6] 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, Germany postponed the introduction of free labor mobility until 2004. Since data on net migration flows is available from 2007 on, the calibration target w.r.t Poland ($\overline{mig}_{pl}$) refers to the period 2007-2015.[7]

Importantly, due to the coexistence of exogenous and endogenous migration within the model, one cannot directly use UN migration data for the simulation exercise without an appropriate adjustment. This is the case since $m_{t,j,x}$ only refers to migration vis-a-vis the rest of the world, excluding any model region. In particular, it is unclear which part of $mig^{UN}_{t,ger}$ can be attributed to the net migration flows w.r.t. to Southern Europe and Poland. Therefore, one needs to make an assumption about how $m_{t,j,x}$ relates to the UN data on net migration flows ($mig^{UN}_{t,x}$). To tackle the problem, I assume that the fraction of net migration to Germany stemming from Southern Europe and Poland is equal to the sum of the calibration targets $\bar{mig}_{south}$ and $\bar{mig}_{pl}$ at any point in time. Hence, I obtain the exogenous migration rates by:

$$\begin{aligned} m_{t,ger} =& [mig^{UN}_{t,ger} - \overline{mig}_{south} - \overline{mig}_{south}] \\ m_{t,south} =& [mig^{UN}_{t,south} + \overline{mig}_{south}] \\ m_{t,pol} =& [mig^{UN}_{t,pol} + \overline{mig}_{pol}] \\ & \forall t, j \end{aligned} \tag{24}$$

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 2.2.[8]

## 3.3. Households

The discount factor $\beta$ is set to 1.011 in accordance with Hurd (1989) resulting into a wealth to annual output ratio of 4.47. The parameter $\eta$ governing the intertemporal

[6]Note that even though the the endogenous migration rates in 2.2 are age-dependent, the calibration target $\overline{mig}_{s_i}$ refers to the total net immigration rate. Targeting age-dependent migration flows is not feasible due to the lack of data. Further, it would require additional assumptions on the model itself, e.g. an age-varying disutility of living abroad.

[7]The periods for the calibration target are not consistent with the length of a model period equal to 5 years. Hence, I assume that w.r.t Southern Europe, net immigration rates in 1990 and 1991 are equal to the average of the years 1992 to 1995. Likewise, w.r.t. Poland, I assume that net immigration years in 2005 and 2006 are equal to the average of the years 2007 to 2010.

[8]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 $\bar{mig}_{south}$ and $\bar{mig}_{pl}$ adjust accordingly.

elasticity of substitution is set to 2 as common in the literature. Further, $\gamma$ defining the importance of consumption relative to leisure is chosen to be 0.35 thereby inducing an average of hours worked equal to 0.3. The age-dependent efficiency profile is taken from Lagakos et al. (2015) who document life-cycle wage growth in several countries. I specify $\epsilon$ to be equal to the reported wage profile of Germany. Due to the absence of a reliable estimate for migration costs in Europe, I let the physical migration costs ($mc$) be equal to zero in the benchmark calibration. I report a sensitivity analysis w.r.t. to positive values of $mc$ in the appendix.

## 3.4. 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).[9] Hence, I do the following: I use German data to find the labor income share $\sigma$, which is about 0.67. 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 0.284 and a land share of 0.046. Additionally, I assume that the stock of land per worker in each region is equal to one in the initial stationary equilibrium. This ensures that initial wage differences are solely due to difference in $A_{x,0}$ which, in turn, are chosen to match cross-country differences in gdp per capita. Further, I calibrate $\delta$ to match an investment share in Germany equal to 0.2. Finally, the tfp growth rate $g$ is chosen to result into an per capita output growth rate of 1%.[10] Table summarizes the production side parameters.

## 3.5. Social Security

I use data provided by OECD (2015) to calibrate the public pension system in each region. More precisely, I set contribution taxes equal to the reported values in 2015 and let benefits adjust to ensure budget clearing. Regarding Southern Europe, the region-wide contribution tax consists of a weighted average of the country-specific rates. The weights are determined by the relative population sizes in 2015. In the

[9]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 w.r.t. 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.

[10]All parameters are chosen to match calibration targets and model outcomes in the initial steady state.

**Table 1:** Production Parameters

| Parameters | Value |
|---|---|
| $\sigma$ | 0.67 |
| $\nu$ | 0.284 |
| $F_x$ | $L_{x,0}$ |
| $A_{ger,0}$ | 1 |
| $A_{south,0}$ | 0.76 |
| $A_{pl,0}$ | 0.43 |
| $\delta$ | 0.07 |
| $g$ | 0.08 |

Note: The values for $\delta$ and $g$ are annualized.

benchmark calibration, I let the exogenous retirement age $R$ be equal to 65 in each region.

**Table 2:** Contribution rates

| Parameters | Value |
|---|---|
| $\tau_{ger}$ | 0.189 |
| $\tau_{south}$ | 0.274 |
| $\tau_{pol}$ | 0.195 |

# 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 whereas the latter marks the end of the demographic transition. 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 conduct a normative analysis with the aim of uncovering the welfare implications of intra-European migrations flows for generations living through the demographic transition.

## 4.1. Comparative Statics

For the initial steady state I assume an identical population growth rate of 1.5% in each region and the immobility of labor[11] Table 3 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 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 haver 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 250 basis points. Further, capital deepening leads to an increase in German detrended wages by 12.7% and to a similar rise in the sending regions. As a reaction to lower returns to savings and higher returns to labor, individuals increase average labor supply ($\bar{l}$) by around 30%. Despite the strong rise of wages, detrended benefits fall by 60% in the model regions which displays the enormous effect of population aging on public pension systems. Finally, due to the sharp increase in individual labor supply, per capita output increases in all model regions.

**Table 3:** Steady State Comparison

| Variable | Germany | Southern Europe | Poland |
|---|---|---|---|
| $r$ | -2.5 | -2.5 | -2.5 |
| $w$ | 12.7 | 11.6 | 14.3 |
| $b$ | -55.9 | -58.2 | -63.0 |
| $Y/N$ | 7.2 | 4.8 | 10.3 |
| $\bar{l}$ | 32.0 | 30.1 | 34.4 |

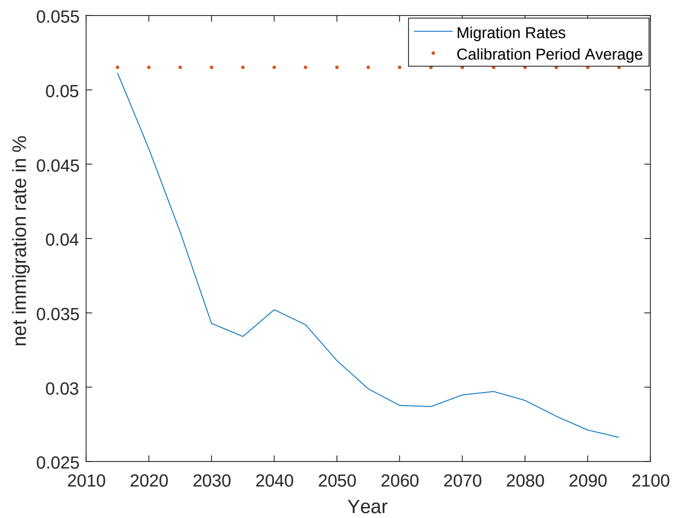
Note: Numbers refer to the percentage change between final and initial steady state.

[11] 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 relying on a representative agent.

## 4.2. Migration Flows

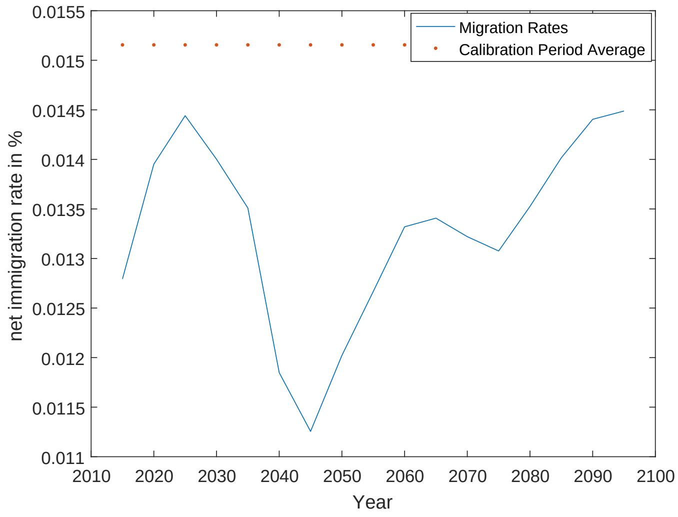
In the following section I present and analyze the migration flows between the model regions in the main period of interest, 2015-2100. In the respective calibration periods, migration data documents an average yearly inflow of about 10.000 net migrants from Southern Europe and about 40.000 from Poland implying yearly net immigration rates in Germany of around 0.052% (Poland) and 0.015% (Southern Europe). Figure 1 and 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, whereas 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 w.r.t Southern Europe. The respective immigration rate directly drops below the calibration period average and then fluctuates on a lower level without converging back.

**Figure 1:** Immigration from Poland




What drives the course of the net immigration rate? First of all it is determined by demographic factors. The aging process 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 9.5% of the entire population in 2010, but only for 6.7% in 2030. Since migration takes place at early stages of the life-cycle, the decline in the relative share of the young reduces the immigration rate. The second determinant is the alteration of migration incentives due to a changing economic environment. Individuals in the sending regions base their location choice both on

**Figure 2:** Immigration from Southern Europe




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 variables is directly affected by the pattern of the demographic transition. Figure 3 displays the working age to population ratio (wapr) in each of 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.

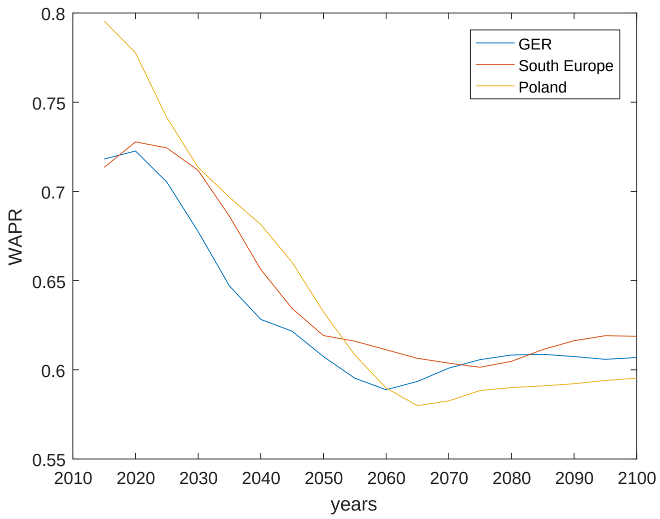
In contrast to Krueger and Ludwig (2007), the production function in (3) includes a fixed factor which has important implications for the evolution of wages. Not accounting for a fixed factor would imply that capital mobility equalizes interest rates, the capital intensities and thus also wages up to a ratio of tfp differences. Using (4),(5) and (9), relative wages are given by:

$$\frac{w_{d,t}}{w_{s_i,t}} = \left(\frac{A_{d,t}}{A_{s_i,t}}\right)^{\frac{1}{1-\nu}} \left(\frac{L_{s_i,t}/F_{s_i}}{L_{d,t}/F_d}\right)^{\frac{1-\sigma-\nu}{1-\nu}} \tag{25}$$

Hence, relative wages do not only depend on TFP differences, but also on the relative number of workers per land endowment implying that differences in aging processes feed back onto relative wages. More precisely, if one region ages more strongly, $L_{x,t}/F_x$ falls such that its relative wage rises.

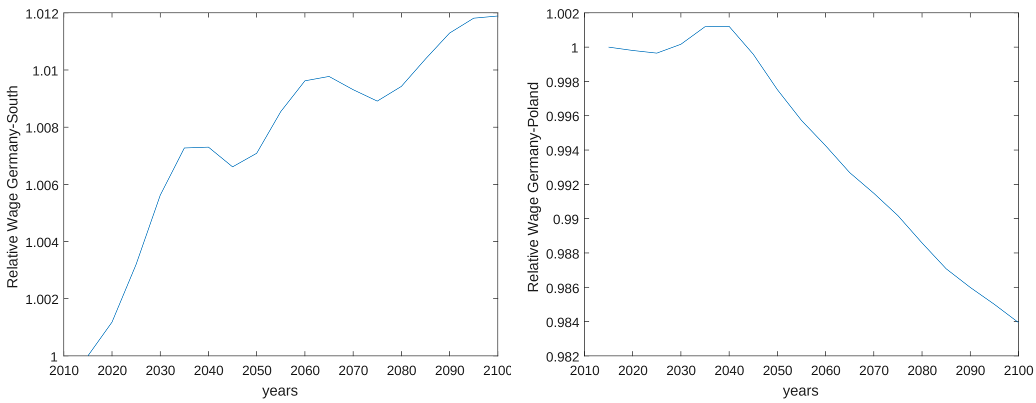
Figures 4 and 5 depict the evolution of relative wages and benefits over the course of the century. All variables are normalized to their level of 2015. Since the labor to

**Figure 3:** WAPR




Note: The wapr is itself a model outcome since it depends partly on the endogenous migration flows.

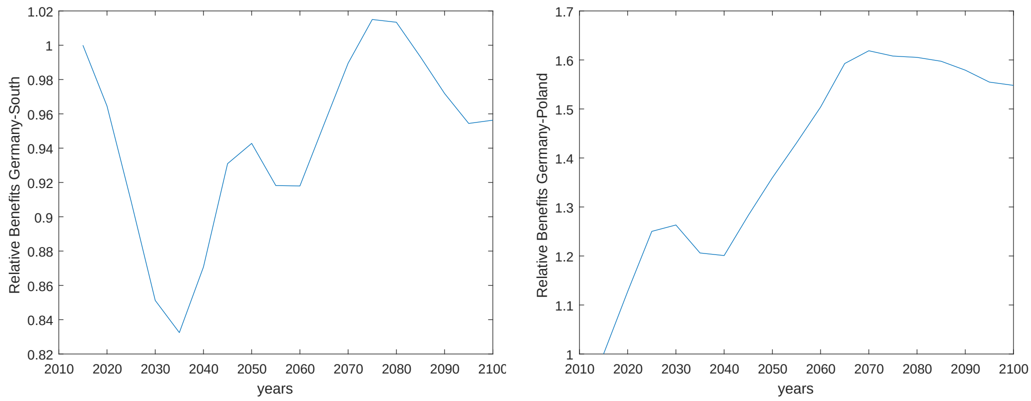
**Figure 4:** Relative Wages - Index




**(a)** Relative Wage Germany-South **(b)** Relative Wage Germany-Poland

Note: Relative wages are normalized w.r.t. the value in 2015.

**Figure 5:** Relative Benefits - Index




**(a)** Relative Benefits Germany-South **(b)** Relative Benefits Germany-Poland

Note: Relative benefits are normalized w.r.t. the value in 2015.

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 2030 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 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 $(\frac{L_{d,t}/Ret_{d,t}}{L_{s_i,t}/Ret_{s_i,t}})$.[12] Concerning the importance of each component for the migration decisions, it holds that - in general - wages have a stronger impact on migration incentives than relative benefits 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 the fluctuation in $\frac{b_{ger,t}}{b_{s_i,t}}$ is much larger than it is in $\frac{w_{ger,t}}{w_{s_i,t}}$.

In order to analyze how migration incentives change over the demographic transition along with wages and benefits, it requires a measure that isolates the variation in the net immigration rate that is due to economic forces from the variation that results out of demographic factors. Such a measure is given by the *threshold disutility* ($\bar{\mu}_{i_s,t}$), i.e. the highest disutility of living abroad suffered by one of the migrants. If prices in Germany develop more favorably, individuals are willing to accept higher utility costs such that the *threshold disutility* increases. For the case of Poland, $\bar{\mu}_{pol,t}$ follows the path of the relative wage in the first decades and falls until the mid of the century.

[12]Note that in each country the paths of $\frac{L_{x,t}}{Ret_{x,t}}$ and $\frac{L_{x,t}}{F_x}$ show the same trend. However, this relation does not necessarily hold for the relative terms $\frac{L_{d,t}/Ret_{d,t}}{L_{s_i,t}/Ret_{s_i,t}}$ and $\frac{L_{d,t}/F_d}{L_{s_i,t}/F_{s_i}}$. Hence, relative benefits and relative wages do not necessarily move into opposite directions.

From then on, it remains on this lower level, with a small temporary increase that can be motivated by a simultaneous rise in relative benefits[13]. Regarding Southern Europe, $\bar{\mu}_{south,t}$ firstly remains stable but then decreases which coincides with a decline in relative benefits. Starting in 2050, $\bar{\mu}_{south,t}$ moves upward since relative wages and relative benefits both exhibit a positive trend. The graphical illustration of the development of the *threshold disutility* can be found in the appendix.

## 4.3. Counterfacutal Analysis

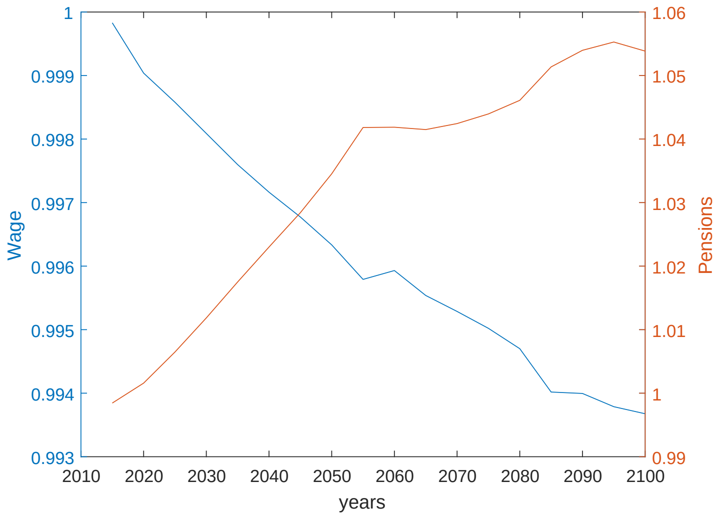
While in the previous section I focused on the analysis of the pattern of migration flows, I now shed light on their ensuing macroeconomic effects. In this regard, I compute a counterfactual model scenario in which labor mobility is abolished at the beginning of the forecast period. This regime change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

The quantitative exercise in the previous section revealed that demographic and economic forces reduce the net immigration rate in Germany. Nevertheless, the endogenous migration flows still have significant macroeconomic implications. Figures 6 and 7 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 influence 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 more than 4% until 2050. The wage reduction is caused by the relatively larger labor force which decreases marginal productivity. The rise in benefits, on the other hand, stems from the broadening of the tax base. Vice versa, emigration in 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 8 % towards the mid of the century.

Which mechanisms cause the low elasticity of wages and the high elasticity of benefits with respect to migration flows? First of all, it is important to note that the large increases in benefits are generated by migration flows of a moderate size.

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

**Figure 6:** Germany



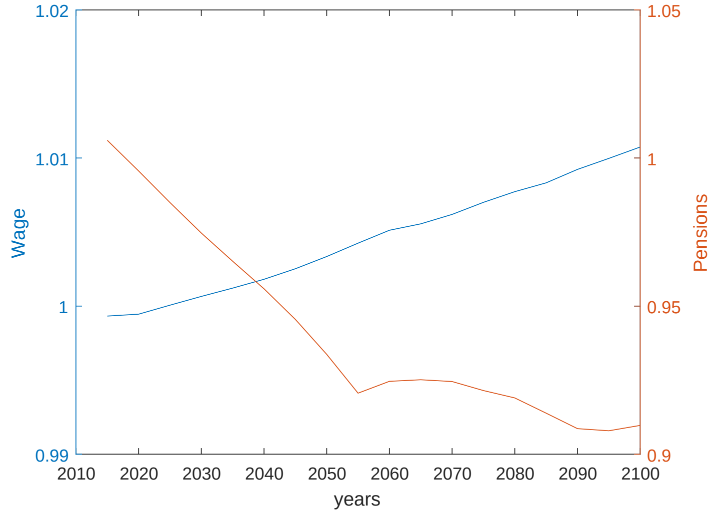

Note: Wages and benefits are expressed as relative values w.r.t to the counterfactual scenario.

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 to population growth by increasing the number of newborns, which, in turn, augments the size of the future labor force. 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.

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, 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 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.

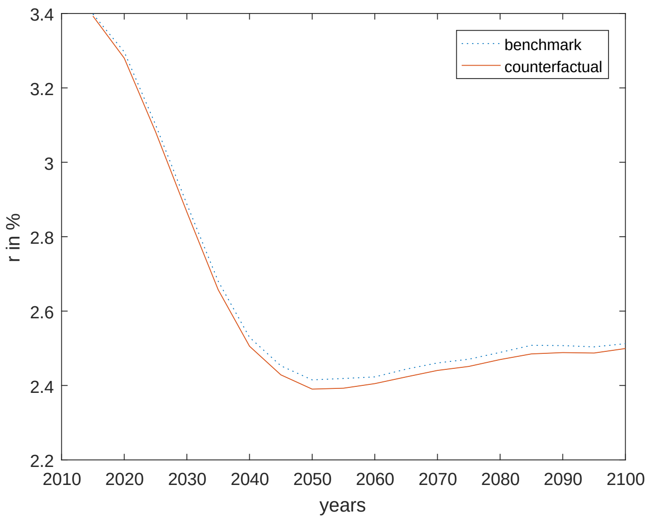
Furthermore, figure 8 shows the evolution of the interest rate in both the benchmark

**Figure 7:** Poland



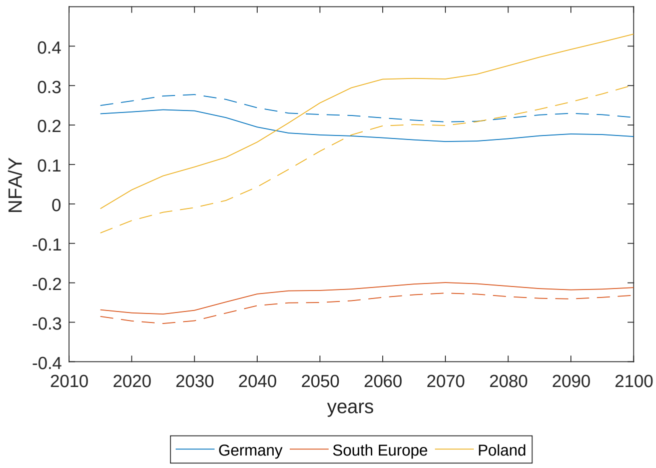

Note: Wages and benefits are expressed as relative values w.r.t to the counterfactual scenario.

**Figure 8**



and the counterfactual scenario. 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 on the German interest rate: The increase in labor supply rises the interest rates, 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.

**Figure 9:** Net Foreign Assets



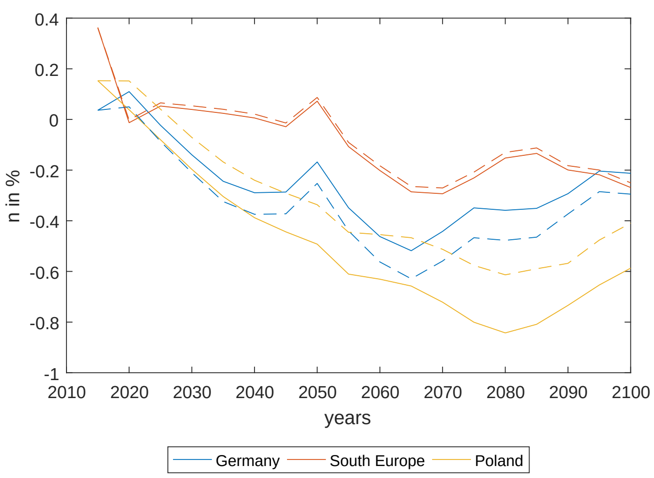

Note: The solid lines indicate the benchmark scenario and the dashed lines the counterfactual.

Lastly, it remains to take a closer look at the impact of migration flows on the asset allocation across regions. In this respect, figure 9 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 9 is that the moderate per-period migration flows trigger larger asset reallocations resulting into significant differences between the NFA positions of both model scenarios. At its peak, the Polish net foreign asset holdings are more than 13 percentage points larger in the migration variant. A part of this effect can be explained by the aforementioned capital outflows accompanying emigration. The second effect leads back to the impact of migration flows on land prices. The more workers leave Poland, the less productive each unit of land becomes and hence the lower is the land price. This decline in the value of land implies that a larger share of Polish aggregate savings is allocated to international assets so that its NFA position rises.

## 4.4. Endogenous Demographic Transition

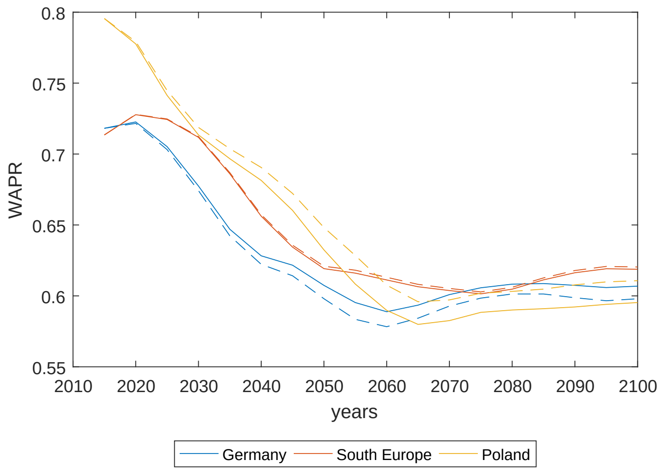
The counterfactual analysis can not only be used to examine the macroeconomic effects of migration flows, but also to uncover how they shape the demographic transition itself. In this respect, figure 10 plots the region-specific population growth rates for the benchmark and the counterfactual scenario. 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% in the case of Germany. Likewise, endogenous migration also impacts the wapr as depicted in figure 11. 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 10:** Population Growth Rates




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

**Figure 11:** WAPR




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

# 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 responses 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. I repeat the analysis outlined in the section before and the present the most central insights.

In the alternative policy scenario, I follow the approach of Krueger and Ludwig (2007) and assume that the (instantaneous) net replacement rate ($\xi$) stays constant at its 2015 level. Hence, taxes are allowed to vary such that (15) and the following equation are fulfilled[14]:

$$\xi_{x,t} = \frac{b_{x,t}}{(1-\tau_{x,t})w_{x,t}} = \frac{b_{x,2015}}{(1-\tau_{x,2015})w_{x,2015}} \quad \forall t \geq 2015 \tag{26}$$

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

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

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 8%, increases the interest rate by 20 basis points and leads to a 0.7% drop in the wage in the year 2050 (relative to the constant tax scenario). Likewise, the contribution rate is predicted to increase by 10 percentage points over the same time period.

Besides its general macroeconomic implications, a rising tax rate also influences migration incentives. As argued in section 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 12 and 13 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 similar pattern. Under this alternative scenario, Germany therefore experiences higher immigration from the sending regions. The larger inflow of migrants from Poland can be traced back to the strong increase in relative net wages in Germany (up to 13% until the year 2050). Regarding Southern Europe, higher immigration 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 $\tau_{south}$ results into higher welfare losses than a similar increase in $\tau_{ger}$. Again, a graphical illustration of the evolution of migration incentives is found in the appendix.

# 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 14 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 ($\Delta$), i.e. the percentage change in consumption necessary to make an individual

**Figure 12:** Immigration from Poland

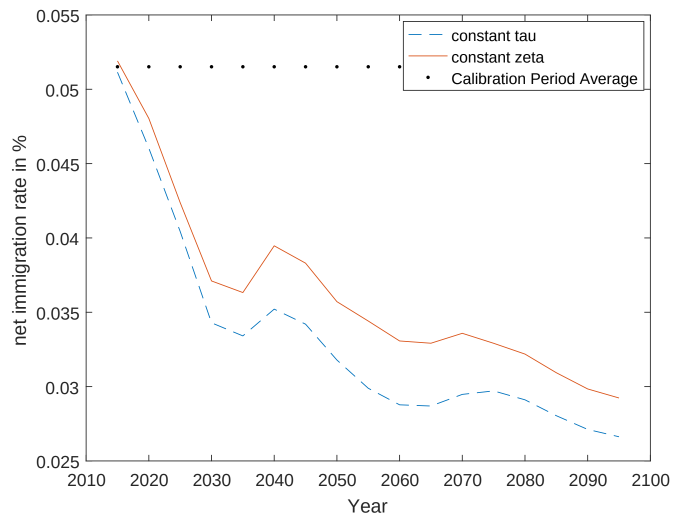
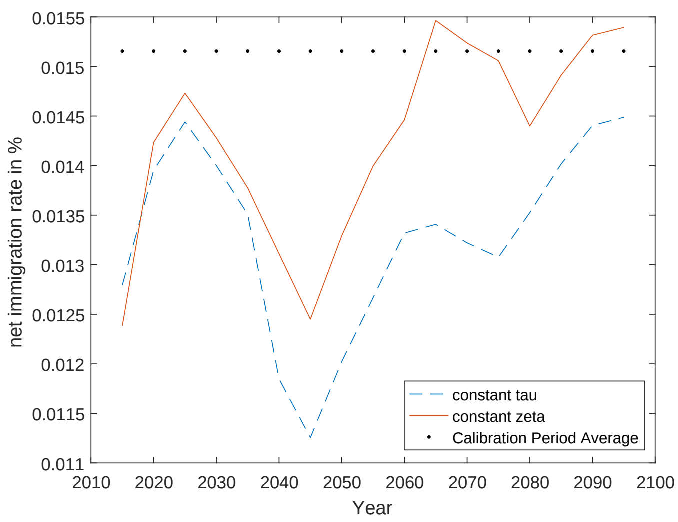



**Figure 13:** Immigration from South Europe



in the counterfactual variant indifferent between his current state and living in the benchmark scenario. Hence, a positive value implies that agents are better off with migration. Changes in welfare are shown for the cohorts[15] between 1990 and 2050. Further, results are reported for *stayers* only. Starting with the constant tax scenario, one observes positive but slightly decreasing welfare effects in Germany. The cohort of 2050 even experiences small welfare losses. 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[16]. 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. Note, however, that welfare effects in Poland turn positive already in 2020 and rise to a maximum of 1% in 2050. Individuals in Southern Europe are continuously negatively affected by emigration due to lower wages and benefits.[17]

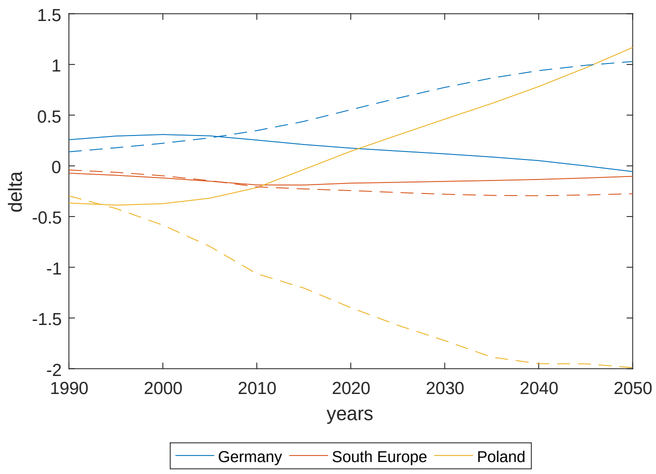
Having described the welfare consequences in the constant tax scenario, it remains to uncover the welfare effects when the tax rate is allowed to adjust. As argued before, agents in Germany experience larger welfare gains from immigration as long as they profit from higher benefits while only having 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 14 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. 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. Again, welfare changes in the sending regions exhibit just the reversed pattern since emigration enhances population aging and likewise the financial burden for workers. In Poland, welfare losses amount to even 2% of lifetime consumption for cohorts between 2040 to 2050.

[15]The term *generation* refers to the point of time when individuals become economically active, not to when they are born.

[16]See figure 6.

[17]See the discussion about the effects of emigration on prices in Southern Europe in section 4.3.

**Figure 14:** Welfare




Note: The solid lines indicate the constant tax scenario and the dashed lines the constant replacement rate scenario.

# 7. Conclusion

Macroeconomic studies on the impact of population aging have so far considered the demographic development as purely exogenous. In contrast, this paper allows for endogenous migration flows thereby (partly) endogenizing the demographic transition itself. In particular, workers can emigrate in response to changes in relative prices and in relative returns to social security induced by differences in regional aging processes. The analysis focuses on intra-European migration between Germany as the receiving region, and Southern Europe and Poland as sending regions. Even though the migration flows 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 and benefits have to adjust to ensure a fiscal equilibrium, the distortions from social security are less strong and immigration leads to moderate welfare gains in Germany that are decreasing over time. However, if tax rates have to adjust, these distortions significantly grow such that their alleviation through immigration causes larger welfare gains in Germany which continuously increase up to a maximum of 1% of lifetime consumption. Likewise, the sending regions experience high welfare losses due to emigration. For the case of Poland, the welfare losses are at its peak equivalent to 2% 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. Hence, the free movement of labor might give rise to important distributional effects between European economies.

# Appendix 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:

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

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

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

$$\Phi_{t+1}(\mathcal{A},\mathcal{K},j+1,j+1,d,d) = \int_{\mathcal{A}\times\mathcal{K}} d\Phi_t(a,\kappa,j,j,d,d)\psi_{d,t,j}$$

$$\Phi_{t+1}(\mathcal{A},\mathcal{K},j+1,j+1,s_i,s_i) = \int_{\mathcal{A}\times\mathcal{K}} (1-\varphi(a,\kappa,j,j,s_i,s_i))d\Phi_t(a,\kappa,j,j,s_i,s_i)\psi_{s_i,t,j}$$

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

$$\Phi_{t+1}(\mathcal{A},\mathcal{K},j+1,R,d,d) = \int_{\mathcal{A}\times\mathcal{K}} d\Phi_t(a,\kappa,j,R,d,d)\psi_{d,t,j}$$

And in the sending regions equivalently.

Lastly, it remains to keep track of migrants in the destination region. For new arrivals with $j \in [2, R]$:

$$\Phi_{t+1}(\mathcal{A},\mathcal{K},j+1,j,d,s_i) = \int_{\mathcal{A}\times\mathcal{K}} \varphi(a,\kappa,j,j,s_i,s_i)d\Phi_t(a,\kappa,j,j,s_i,s_i)\psi_{s_i,t,j}$$

In relation to the demographic model from 2.2, it holds:

$$\tilde{m}_{t,j,s_i} = \frac{\int_{\mathcal{A}\times\mathcal{K}} \varphi(a,\kappa,j,j,s_i,s_i) d\Phi_t(a,\kappa,j,j,s_i,s_i)\psi_{s_i,t,j}}{\int_{\mathcal{A}\times\mathcal{K}} d\Phi_t(a,\kappa,j,j,s_i,s_i)}$$

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

$$\Phi_{t+1}(\mathcal{A},\mathcal{K},j+1,j_m,d,s_i) = \int_{\mathcal{A}\times\mathcal{K}} d\Phi_t(a,\kappa,j,j_m,d,s_i)\psi_{s_i,t,j}.$$

# Appendix B Prices and Migration Incentives

In the figures below I plot the evolution of relative net wages $\left(\frac{w_{ger,t}(1-\tau_{ger,t})}{w_{s_i,t}(1-\tau_{s_i,t})}\right)$ against $\bar{\mu}_{s_i,t}$ starting from 1990 for the two policy scenarios. The relative net wage and $\bar{\mu}_{s_i,t}$ exhibit related pattern in all figures. It is important to note that the evolution of $\bar{\mu}_{s_i,t}$ is not smooth since the space of preference types needs to be discretized to solve the model numerically. I allow for 15 different preference types.

Moreover, the concept of the *threshold disutility* can be used to investigate the differences in migration incentives between the two policy scenarios. As it can be seen in figures 19 and 20, $\bar{\mu}_{s_i,t}$ significantly increases under the constant replacement rate scenario indicating that the greater distortions from social security enhance migration pressure.[18]

# Appendix C Migration Costs

To be added.

# Appendix D Computation

To be added.

[18]Note that the net immigration rate from Southern Europe under the constant replacement rate scenario in figure 13 is already higher in the years 2015 to 2030 even though $\bar{\mu}_{south,t}$ is not. This is due to the fact that the policy change in 2015 is not modeled as a shock and hence already influences demographics before its implementation. Slightly different demographics then translate into this observed increase in the net immigration rate.

**Figure 15:** Poland - constant tax

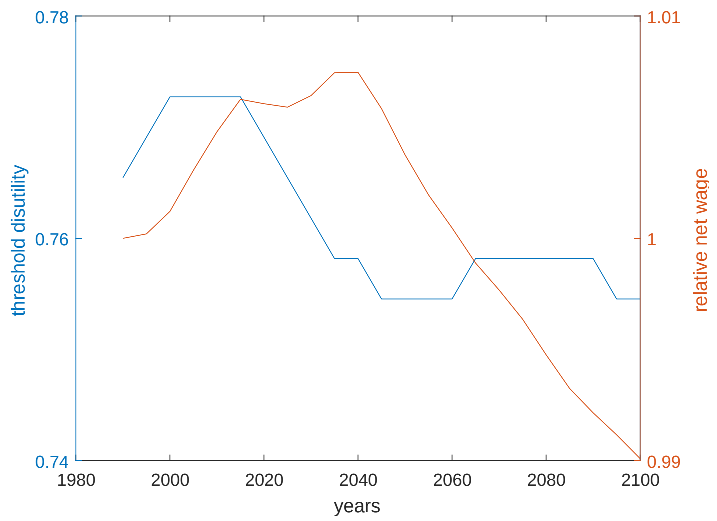



**Figure 16:** Southern Europe - constant tax

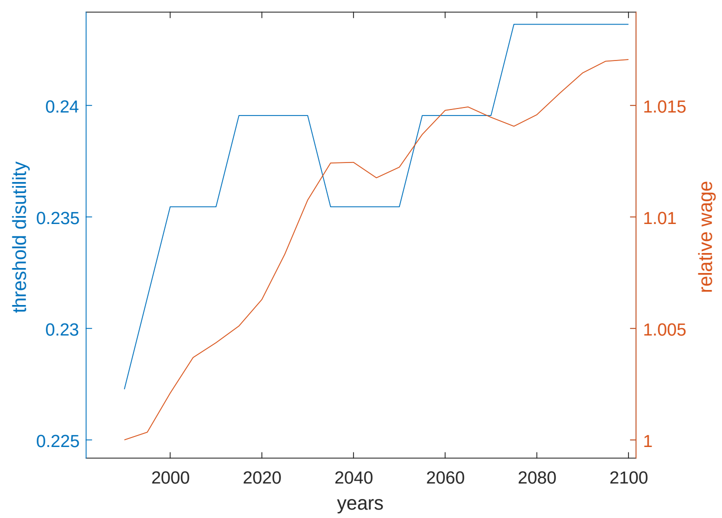


**Figure 17:** Poland - constant replacement rate

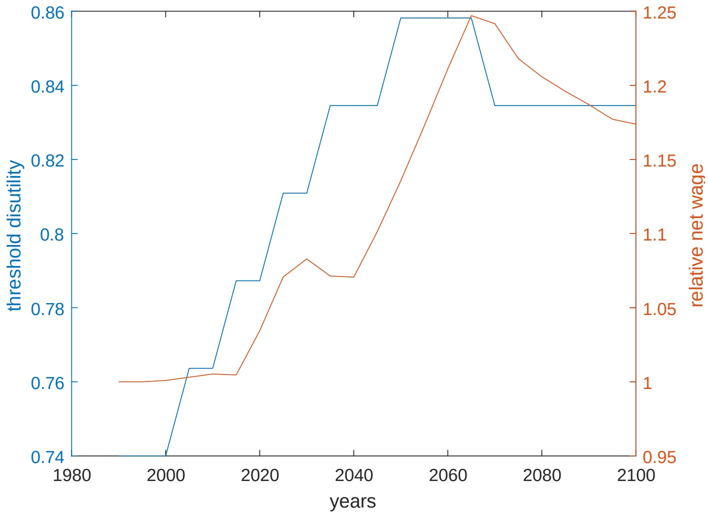



**Figure 18:** Southern Europe - constant replacement rate

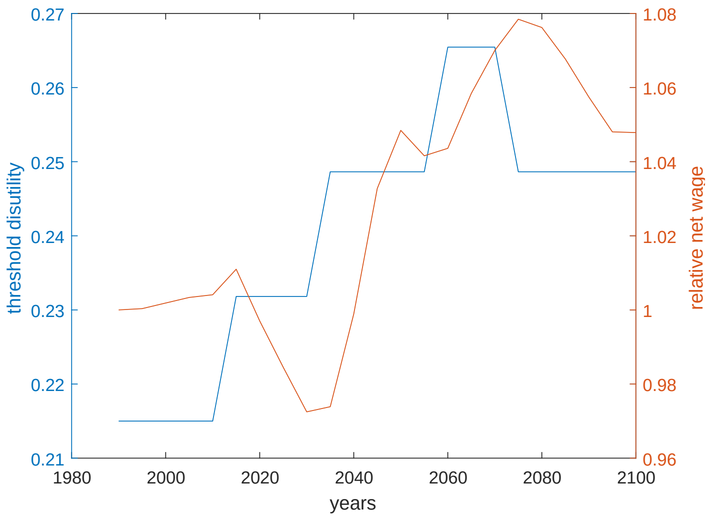


**Figure 19:** Southern Europe - comparison between policy scenarios

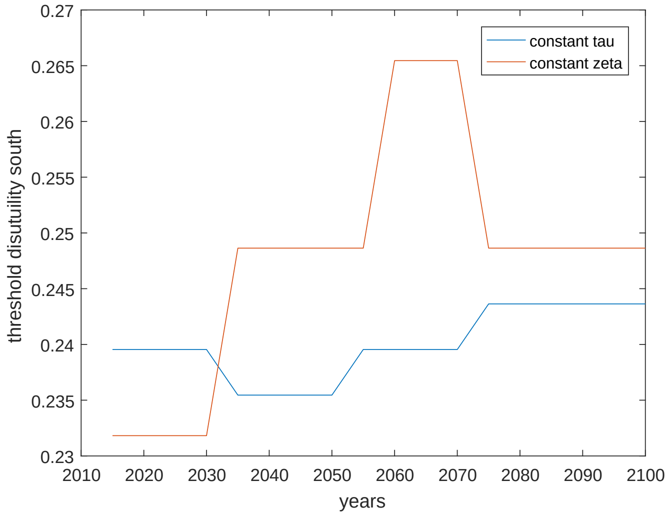
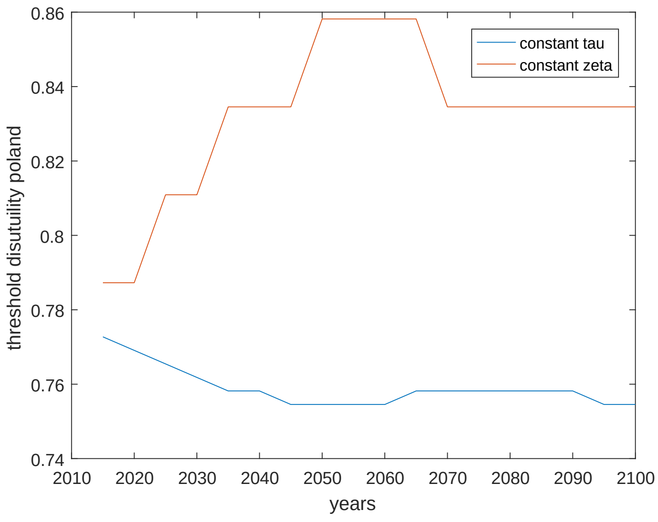



**Figure 20:** Poland - comparison between policy scenarios



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