Demography, capital flows and unemployment

L. Marchiori, O. Pierrard and H.R. Sneessens

Discussion Paper 2011-40

Institut de Recherches Économiques et Sociales
de l'Université catholique de Louvain

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Demography, capital flows and unemployment*

Luca Marchiori † Olivier Pierrard ‡ Henri R. Sneessens §

October 2011

Abstract

This paper contributes to the already vast literature on demography-induced international capital flows by examining the role of labor market imperfections and institutions. We setup a two-country overlapping generations model with search unemployment, which we calibrate on EU15 and US data. Labor market imperfections are found to significantly increase the volume of capital flows, because of stronger employment adjustments in comparison with a competitive economy. We next exploit the model to investigate how demographic asymmetries may have contributed to unemployment and welfare changes in the recent past (1950-2010). We show that a policy reform in one country also has an impact on labor markets in other countries when capital is mobile.

Keywords: demographics; capital flows; overlapping generations; general equilibrium; unemployment
JEL Classification: C68; D91; E24; F21; J11

*Henri Sneessens acknowledges the financial support of the Belgian French speaking community (ARC conventions 09-14/019 on "Geographical mobility of factors", and 09-14/018 on "Sustainability"). The views expressed in this paper are personal views of the authors and do not necessarily reflect those of the Banque centrale du Luxembourg or the Eurosystem.

†Central Bank of Luxembourg; and IRES, Université catholique de Louvain. *E-mail:* luca.marchiori@bcl.lu.

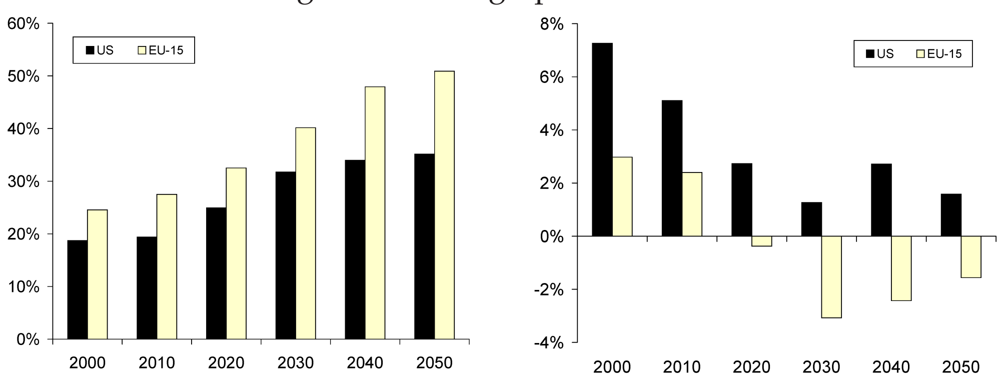
‡Central Bank of Luxembourg; and IRES, Université catholique de Louvain. *E-mail:* olivier.pierrard@bcl.lu.

§CREA, Université du Luxembourg; IRES, Université catholique de Louvain; and IZA, Bonn. *E-mail:* henri.sneessens@uni.lu.

1 Introduction

Population aging is a phenomenon common to all the regions of the world (United Nations, 2010). Its intensity and pace however differ greatly across countries. There are stark differences not only between the North and the South, but also among advanced countries (see Figure 1). Several studies have stressed that cross-country demographic differences generate international capital flows (see, for instance, Higgins, 1998). In countries where the labor force is shrinking, the increased life expectancy raises total savings above domestic investment needs (at the prevailing interest rates), whereas countries where the labor force continues to grow have insufficient domestic savings. Capital is thus expected to flow from rapidly aging countries to countries with positive population growth rates. Many papers analyzed the determinants and consequences of these capital flows. Our paper contributes to this literature by examining the role of labor market imperfections and institutions. More specifically, we investigate how demographic trends, through their effects on capital movements, affect unemployment and participation rates, and interact with labor market institutions.

Figure 1: Demographic indicators



a. Old-age dependency ratio (+65 / 15-64) b. Labor Force (5-year growth rate)

Source: United Nations (2010).

General equilibrium models with overlapping generation dynamics have proven to be a most appropriate tool to examine the implications of population aging. Most models have been developed in a closed-economy setting (e.g. De Nardi et al., 1999). More recent contributions extend these models to multiple countries, to incorporate the effects of capital flows between countries and thereby quantify the international implications of demographic changes (Börsch-Supan et al., 2006; Attanasio et al., 2007). Indeed, many papers show that demographic differences explain a large fraction of historical capital flows between advanced countries (Feroli, 2003; Henriksen, 2002; Domeij and Floden, 2006). Brooks (2003) uses projected demographic changes to forecast international capital movements across eight world regions. Other works focus on the impact of aging on the viability of pension systems, when capital is mobile across countries (Fehr et al., 2003; Börsch-Supan et al., 2006; Attanasio et al., 2007; Aglietta et al., 2007; Krueger and Ludwig, 2007). One of the main findings of these studies is that, although capital mobility (largely induced by demographic differences) does not quantitatively change the evolution of the fiscal variables compared with a closed-economy setting, it does matter from a quantitative point of view for factor prices, macroeconomic aggregates and the distribution of wealth. In the receiving country, capital inflows boost labor income (which enhances the welfare of young workers) and reduce capital returns (which harms the elderly). Existing studies however assume competitive labor markets and do not account for the effects of labor market imperfections and institutions. The cross-country differences (especially between the EU15 and the US) in labor market imperfections and institutions may considerably influence the macroeconomic effects of aging and of induced capital flows. For instance, we observe that the EU unemployment rate has remained higher than that in the US for 2-3 decades, which coincides with the rise in international capital flows, including capital flows from Europe to the US.[1] Nevertheless, few papers in the literature incorporate labor market frictions and focus on labor market outcomes. One exception is de la Croix et al. (2010) but their model works in a closed-economy setting and, therefore, does not investigate the interaction between capital flows and labor market frictions.

Our contribution aims to fill this gap by setting up a general equilibrium model with overlapping generation dynamics *à la* Auerbach and Kotlikoff (1987) that combines imperfect labor markets, endogenous retirement decisions and international capital mobility[2]. The focus is on the consequences of demography-induced capital flows when there are search frictions and early retirement possibilities. The model includes two exogenous driving forces: the (usual) demographic variables and the variables that shape labor market institutions (replacement ratios), which have considerably changed over time in the US and EU15.

Our main findings can be summarized as follows. *First*, the existence of labor market imperfections reinforces the effects of demographic asymmetries on capital flows. Like other authors, we find that capital flows from a country that is aging more quickly (the EU15) to the one that is aging more slowly (the US). In our setup, though, this flow has a positive impact on EU unemployment (and a negative effect on US unemployment) and strengthens the European net creditor position. More precisely, because, in a frictional economy, the employment rate reacts strongly

[1] See section 5 for empirical evidence and Head and Smits (2004) for a similar observation.

[2] Diaz-Gimenez and Diaz-Saavedra (2009), Sánchez Martín (2010) and Fehr et al. (2011) investigate the consequences of the demographic transition using models with endogenous retirement, albeit in closed-economy environments with competitive labor markets. See Hairault et al. (2010) for a model with endogenous retirement decisions and labor market frictions, but without demographic changes and capital mobility.

and positively (resp. negatively) to capital inflows (resp. outflows), the amount of capital flow needed to arbitrage out cross-country differences in capital returns becomes substantially larger than in a competitive economy. These mechanisms and effects change the welfare implications of demography-induced capital flows. *Second*, when examining the implications of our model for the developments of the past few decades, we find that demography-induced capital flows may have contributed up to 2-3 percentage points to the rise in the unemployment gap between the EU and the US. Of course, most of the rise in unemployment comes from asymmetrical changes in labor market institutions. The importance of these latter variables is not surprising and is in line with previous findings (see, for instance, Nickell (1997) and Nickell et al. (2005)). The impact of demographic asymmetries and of capital flows is not negligible, however, and has been changing over time. A high proportion of prime-age workers (as in the US between 1975 and 1995) means, ceteris paribus, lower savings, higher capital costs and unemployment rate. With capital flows, part of this unemployment rise is "exported" and contributed to the EU-US unemployment gap of the late 20th century. *Third*, we show that a policy reform implemented in one country also has an impact on labor markets in other countries when capital is mobile. In particular, we find that a pension reform in one region also improves labor market conditions in the other. In fact, savings and investment are stimulated in the region where a pension reform is undertaken, leading to improvements in labor market outcomes. In addition, part of the newly accumulated capital will flow to the other region, inducing positive effects on (un-)employment rates.

The remainder of this paper is organized as follows. Section 2 describes the model. Section 3 details the calibration. Section 4 presents the key simulation results and illustrates the role of capital flows and labor market frictions. Section 5 further discusses the roles of demographic variables and capital flows in explaining unemployment and welfare changes after 1950. We also examine the international effects of pension reforms and check the robustness of our results to the introduction of a third, capital-exporting country (meant to capture the effect of rising capital inflows from China). Section 6 concludes.

2 The Model

This study develops a two-region general equilibrium model featuring overlapping-generations (OLG) dynamics and calibrated to real data. Capital markets are integrated between the two regions, the EU15 and the US. Each region i (=A, B) is characterized by frictions à la Diamond-Mortensen-Pissarides, with (exogenous) job destruction and a matching function. There is perfect substitutability between all workers, although labor productivity is age dependent. Perfect substitutability means that there is a single matching function (all vacancies can be filled by any worker of any age). Age-directed search is not a credible strategy in our setup. Because the value of an unfilled vacancy is zero at equilibrium (free entry condition), a firm that would open a vacancy targeted at young workers, for example, would eventually hire the first worker she meets, provided the surplus to be shared is positive. Bargained wages will reflect differences in work efficiency. For the time being, the regional index i is hidden for notational convenience.

2.1 Demography

We do not model education and human capital accumulation and focus on behaviors of people between 25 and 104 (the maximum life duration). One period of time lasts five years. Each member of a given generation can thus live for up to sixteen five-year periods (from age 25 till 104), indexed from 0 to 15. Let $Z_{a,t}$ denote the size of the generation reaching age a at period t. The size of new generations changes over time at an exogenous rate x_t:

$$Z_{0,t} = (1 + x_t)\, Z_{0,t-1}, \quad \forall t > 0, \tag{1}$$

where x_t includes both fertility and migration shocks at age zero. Abstracting from later migration shocks, the size of a given generation t declines deterministically through time. This size is determined by a cumulative survival probability $\beta_{a,t+a}$ so that:

$$Z_{a,t+a} = \beta_{a,t+a}\, Z_{0,t} + X_{a,t+a}, \quad \forall a \in (0, 15], \tag{2}$$

where $0 \leq \beta_{a,t+a} \leq 1$ is decreasing in a, with $\beta_{0,t} = 1$. Migration flows after age 0 are taken into account through $X_{a,t+a}$. Total (adult) population at time t is equal to $Z_t = \sum_{a=0}^{15} Z_{a,t}$. The demographic growth and survival probability vector can vary over time. These changes are assumed to be exogenous.

We use the dummy variable $z_{a,t+a}$ to define the population of working age:

$$P_{a,t+a} = z_{a,t+a}\, Z_{a,t+a} \tag{3}$$

where $z_{a,t+a} = 1$ for $0 \leq a \leq 7$, $z_{a,t+a} = 0$ otherwise. We assume a mandatory retirement age of 65 so that all people older than 64 ($8 \leq a \leq 15$) are inactive. We further assume that the participation rate between 25 and 54 is exogenous and normalized to unity. Between ages 55 and 64, workers can choose to retire early. People of working age are thus either employed (N), unemployed (U), or on an early retirement scheme (E):

$$\begin{aligned} P_{a,t} &= N_{a,t} + U_{a,t} + E_{a,t}\,, \\ &= \left[n_{a,t} + u_{a,t} + e_{a,t}\right] P_{a,t}\,, \qquad 0 \leq a \leq 7 \\ \Leftrightarrow \quad 1 &= n_{a,t} + u_{a,t} + e_{a,t}\,, \end{aligned} \tag{4}$$

where lower-case letters denote the proportion of individuals in each status. The early retirement rate before 55 is zero ($e_{a,t} = 0$ for $a < 6$). Let $\lambda_{6,t}$ denote the fraction of people who choose to retire early and leave the labor market at age $a = 6$ (between 55 and 60) so that the number of early retired workers of that age group is $E_{6,t} = \lambda_{6,t}\, P_{6,t}$. Similarly, let $\lambda_{7,t}$ denote the fraction of active workers who decide to leave the labor market at age $a = 7$ (between 60 and 64). The total number of workers on early retirement at time t is then equal to:

$$
\begin{aligned}
E_{6,t} + E_{7,t} &= e_{6,t}\, P_{6,t} + e_{7,t}\, P_{7,t}\,, \\
\text{with:} \quad & e_{6,t} = \lambda_{6,t}\,, \\
& e_{7,t} = \lambda_{6,t-1} + \lambda_{7,t}\,(1 - \lambda_{6,t-1})\,.
\end{aligned} \tag{5}
$$

2.2 Labor Market Flows

We assume a constant returns to scale matching function:

$$M_t = M(V_t, \Omega_t) \tag{6}$$

where V_t and Ω_t stand respectively for the total number of vacancies and job seekers at the beginning of period t. Ω_t is the sum across all age categories:

$$
\begin{aligned}
\Omega_t &= \sum_{a=0}^{7} \Omega_{a,t}\,, \\
&= P_{0,t} + \sum_{a=1}^{5} \left[1 - (1-\chi)\, n_{a-1,t-1}\right] P_{a,t} \\
&\quad + \left[1 - (1-\chi)\, n_{5,t-1}\right] (1 - \lambda_{6,t})\, P_{6,t} \\
&\quad + \left[(1 - \lambda_{6,t-1}) - (1-\chi)\, n_{6,t-1}\right] \, (1 - \lambda_{7,t})\, P_{7,t}
\end{aligned} \tag{7}
$$

At the beginning of time t, all new entrants $P_{0,t}$ are job seekers. Except for early retirement decisions, job separations are determined by an exogenous job destruction rate χ. Parameters $\lambda_{6,t}$ and $\lambda_{7,t}$ introduce the effects of early retirement.

The probabilities of finding a job and of filling a vacancy are defined as follows:

$$p_t = \frac{M_t}{\Omega_t} \qquad \text{and} \qquad q_t = \frac{M_t}{V_t}\,. \tag{8}$$

The number of employed workers in age group a is determined by the sum of non-destroyed jobs (when $a > 0$) and of new hires:

$$\begin{aligned} n_{a,t} &= p_t \frac{\Omega_{a,t}}{P_{a,t}}, && \text{for } a = 0\,; \\ &= (1-\chi)\, n_{a-1,t-1} + p_t \frac{\Omega_{a,t}}{P_{a,t}}, && \text{for } 1 \le a \le 5\,; \\ &= (1-\lambda_{a,t})\,(1-\chi)\, n_{a-1,t-1} + p_t \frac{\Omega_{a,t}}{P_{a,t}}, && \text{for } 6 \le a \le 7\,. \end{aligned}$$

After substituting for $\Omega_{a,t}$, this equation becomes:

$$\begin{aligned} n_{a,t} &= p_t\,, && \text{for } a = 0\,; \\ &= (1-p_t)(1-\chi)\, n_{a-1,t-1} + p_t\,, && \text{for } 1 \le a \le 5\,; \\ &= (1-p_t)(1-\lambda_{a,t})\,(1-\chi)\, n_{a-1,t-1} + p_t(1-\lambda_{a,t})\,, && \text{for } a = 6\,; \\ &= (1-p_t)(1-\lambda_{a,t})\,(1-\chi)\, n_{a-1,t-1} + p_t(1-\lambda_{a,t})(1-\lambda_{a-1,t-1})\,, && \text{for } a = 7\,. \end{aligned} \tag{9}$$

The same equation can be written in terms of the probability of filling a vacancy q_t by using $p_t = q_t\, V_t/\Omega_t$. Total employment will then be equal to:

$$N_t = \sum_{a=0}^{7} N_{a,t}\,, \qquad \text{with } N_{a,t} = n_{a,t}\, P_{a,t}\,.$$

2.3 Households

Each individual is assumed to belong to a representative household, one for each age category. There is no aggregate uncertainty, and all households have perfect foresight. There is perfect insurance against the adverse effects of individual lifetime uncertainty. There are no intended bequests. Participation rates of workers below age 55 are assumed to be exogenous and normalized to unity. The household's decision variables are consumption, savings and early retirement rates, subject to the lifetime budget constraint.

Optimization Program of the Representative Household

We write the objective function of the household (effectively one cohort) as follows:

$$W_t^H = \max_{c_{a,t+a},\, \lambda_{6,t+6},\, \lambda_{7,t+7}} \sum_{a=0}^{15} \beta^a\, \beta_{a,t+a} \left\{ \mathcal{U}(c_{a,t+a}) - d^n\, n_{a,t+a}\, z_{a,t+a} + d_a^e\, \frac{(e_{a,t+a})^{1-\kappa}}{1-\kappa}\, z_{a,t+a} \right\} Z_{0,t}\,, \tag{10}$$

where β is a subjective discount factor[3], $\beta_{a,t+a}$ is a cumulative survival probability, $z_{a,t+a}$ is the working age dummy variable ($z_{a,t+a} = 1$ for $0 \le a \le 7$, 0 otherwise), and $Z_{0,t}$ is the initial size

[3] As stressed by Ríos-Rull (2001), β can represent both pure time preference and the effect of family size changes (implying that consumption is enjoyed differently at different ages).

of the cohort. Instantaneous utility is assumed to be separable in c, n and e. The utility of per capita consumption is represented by a standard concave function (we shall use a logarithmic function). The marginal disutility of working is assumed to be constant[4] and equal to d^n. The extra utility derived from early retirement is represented by a concave function of the early retirement rate ($0 < \kappa < 1$). The decision variables are c, λ_6 and λ_7. These last two variables refer to the fraction of agents in the corresponding age groups who decide to go on early retirement and leave the labor market at ages 55 and 60, respectively. Employment rates $n_{a,t+a}$ and early retirement rates $e_{a,t+a}$ (and their connection to the λs) are given by (5) and (9).

The household's flow budget constraint at time $t+a$ takes the form:

$$I_{t+a} + \frac{\beta_{a-1,t+a-1}}{\beta_{a,t+a}} \left[1 + r^*_{t+a}(1-\tau^k_{t+a})\right] \cdot s_{a-1,t+a-1} = (1+\tau^c_{t+a}) c_{a,t+a} + s_{a,t+a}, \tag{11}$$

where $I_{a,t+a}$ comprises labor income and various transfers:

$$I_{a,t+a} = z_{a,t+a} \cdot \left[(1-\tau^w_{t+a}) w_{a,t+a} \cdot n_{a,t+a} + b^u_{a,t+a} \cdot u_{a,t+a} + b^e_{a,t+a} \cdot e_{a,t+a}\right] + (1 - z_{a,t+a}) b^j_{a,t+a}.$$

Wage and consumption tax rates are given by τ^w and τ^c, respectively; $b^u_{a,t+a}, b^e_{a,t+a}, b^j_{a,t+a}$ are the replacement benefits received, respectively, by the unemployed worker, the early retiree and the pensioner; $s_{a,t+a}$ is the financial wealth accumulated at time $t+a$, in per-capita terms. This financial wealth is held in the form of either shares or physical capital. Because there is perfect insurance against individual lifetime uncertainty (as if there were a perfect annuity market), the total return to savings is equal to one plus the risk-free international interest rate r^*_{t+a}, net of capital taxes τ^k, divided by the survival probability $\beta_{a,t}/\beta_{a-1,t-1}$.

The optimal consumption plan must satisfy the usual Euler equation:

$$\frac{u'_{c_{a,t+a}}}{1+\tau^c_{t+a}} = \beta \left[1 + r^*_{t+a+1}(1-\tau^k_{t+a+1})\right] \frac{u'_{c_{a+1,t+a+1}}}{1+\tau^c_{t+a+1}}.$$

After substitution and rearrangements, the condition determining the optimal proportion of early retirees of age 60 can be shown to be:

$$\begin{aligned} \frac{b^e_{7,t+7}}{(1+\tau^c_{t+7})\, c_{7,t+7}} + d^e_7 \, (e_{7,t+7})^{-\phi} = \pi_{7,t+7} & \left[\frac{(1-\tau^w_{t+7})\, w_{7,t+7}}{(1+\tau^c_{t+7})\, c_{7,t+7}} - d^n\right] \\ & + (1-\pi_{7,t+7}) \left[\frac{b^u_{7,t+7}}{(1+\tau^c_{t+7})\, c_{7,t+7}}\right], \end{aligned} \tag{12}$$

where π is the unconditional probability of being employed (i.e., the probability that an active worker chosen at random is actually employed). A similar condition holds for early retirement at age 55 Equation (12) says that the household's optimal early retirement rate is such that

[4]Our formulation normalizes the disutility of search activities of the unemployed to zero. Setting $d^n \geq 0$ amounts to assuming that the disutility of working can be larger than that of searching.

the marginal utility of early retirement (early retirement income plus leisure utility) is equal to the expected marginal utility of remaining active on the job market (wage income net of labor disutility and unemployment benefit, each weighted by their respective probabilities). Which member of the household will actually go on early retirement does not depend on the initial employment status. It follows from our specification of labor market flows (equation (9)) that both employed and unemployed workers may become early retirees. Imposing the restriction that only previously unemployed workers can shift to early retirement would be much too restrictive and unrealistic. Firms do take advantage of the generosity of early retirement schemes to adjust the number of their employees, and elderly workers agree to retire earlier if the early retirement compensation is appropriate.

For later use, we also note that the value of an additional job for a household of age a is given by:

$$\begin{aligned}\frac{1}{u'_{c_{a,t}}}\,\frac{\partial W^H_t}{\partial N_{a,t}} &= \frac{1}{u'_{c_{a,t}}}\;\frac{1}{z_{a,t}\,Z_{a,t}}\,\frac{\partial W^H_t}{\partial n_{a,t}} \\ &= \sum_{j=0}^{7-a}\frac{\beta_{a+j,t+j}}{\beta_{a,t}}\,\beta^j\,\frac{u'_{c_{a+j,t+j}}}{u'_{c_{a,t}}}\left\{\frac{(1-\tau^w_{t+j})\,w_{a+j,t+j}-b^u_{a+j,t+j}}{(1+\tau^c_{t+j})}-\frac{d^n}{u'_{c_{a+j,t+j}}}\right\}\frac{\partial n_{a+j,t+j}}{\partial n_{a,t}}\end{aligned} \tag{13}$$

where $\partial n_{a+j,t+j}/\partial n_{a,t}$ can be obtained from (9).

2.4 Firms

There are two productive factors, labor and capital. Labor is measured in efficiency units. Efficiency may vary across age (because of experience) and across generations (because of education). We define the total labor input as follows:

$$H_t = \sum_{a=0}^{7} h_{a,t}.N_{a,t}\,.$$

We assume a constant return to scale production function in labor and capital:

$$Y_t = A_t\,F(K_t, H_t)\,, \tag{14}$$

where A_t stands for total factor productivity. Firms rent capital at cost $v_t = R^*_t + \delta - 1$, with $R^*_t \equiv 1 + r^*_t$, and pay a gross wage $w_{a,t}$ to workers of age a. We denote by ζ the employer wage tax. The representative firm maximizes the discounted value of all the dividends (profits) that will be distributed to its shareholders. Profits at time t are given by:

$$\Pi_t = Y_t - v_t\,K_t - \sum_{a=0}^{7}(1+\zeta_t)\,w_{a,t}\,N_{a,t} - \mathsf{a}\,V_t \tag{15}$$

where "a" stands for the cost of posting a vacancy. The value of the firm can thus be written as follows[5]:

$$W_t^F = \max_{K_t, V_t} \left\{ Y_t - v_t\, K_t - \sum_{a=0}^{7} (1+\zeta_t)\, w_{a,t}\, N_{a,t} - \mathsf{a}\, V_t \right\} + (R^*_{t+1})^{-1}\, W^F_{t+1} \tag{16}$$

subject to (9) and $p_t = q_t\, V_t / \Omega_t$. The first-order optimality conditions are:

$$v_t = A_t F_{K_t}\,, \tag{17}$$

$$\mathsf{a} = q_t \sum_{a=0}^{7} \frac{\Omega_{a,t}}{\Omega_t} \frac{\partial W_t^F}{\partial N_{a,t}}\,, \tag{18}$$

where $\frac{\partial W_t^F}{\partial N_{a,t}}$ is the value at time t of an additional worker of age a. With a job destruction rate χ, this value is equal to:

$$\begin{aligned} \frac{\partial W_t^F}{\partial N_{a,t}} =& \frac{1}{z_{a,t}\, Z_{a,t}} \frac{\partial W_t^F}{\partial n_{a,t}} \\ =& \sum_{j=0}^{7-a} \frac{\beta_{a+j,t+j}}{\beta_{a,t}} \, (R^*_{t,t+j})^{-1} (1-\lambda_{a+j-1,t+j-1})\,(1-\lambda_{a+j,t+j})\,(1-\chi)^j \\ & \cdot \left\{ h_{a+j,t+j}\, A_t F_{H_{t+j}} - (1+\zeta_{t+j})\, w_{a+j,t+j} \right\}, \end{aligned} \tag{19}$$

where $\lambda_{a+i,t+i} \equiv 0$ for $a+i<6$.

2.5 Government

We assume that unemployment and (early or legal) retirement benefits are determined by an exogenous fraction of the relevant gross wage, so that

$$\begin{aligned} b^u_{a,t} &= \rho^u_t\, w_{a,t} && \text{for} \quad 0 \le a \le 7\,; \\ b^e_{a,t} &= \rho^e_{a,t}\, w_{a,t} && \text{for} \quad 6 \le a \le 7\,; \\ b^j_{a,t} &= \rho^j_t \sum_{i=0}^{3} \frac{w_{a-i,t-i}}{4} && \text{for} \quad 8 \le a \le 15\,. \end{aligned} \tag{20}$$

The retirement benefit is computed on the average wage of the last four periods. Total transfer expenditures are then equal to:

$$T_t = \rho^u_t \sum_{a=0}^{7} w_{a,t}\, u_{a,t}\, Z_{a,t} + \sum_{a=6}^{7} \rho^e_{a,t}\, w_{a,t}\, e_{a,t}\, Z_{a,t} + \rho^j_t \sum_{i=0}^{3} \frac{w_{a-i,t-i}}{4} \sum_{a=8}^{15} Z_{a,t}. \tag{21}$$

[5]Shareholders may belong to different age groups and have different consumption level. Still, they all have the same discount factor given by $\tilde{\beta}_{t+1} = \beta\, \frac{u'_{c_{a+1,t+1}}}{u'_{c_{a,t}}} = (R^*_{t+1})^{-1}\,,\ \forall a \,\epsilon\, \{0,14\}$.

Public consumption is assumed to be a fraction of output, net of vacancy costs, i.e.

$$G_t = \bar{g}\,(Y_t - \mathsf{a}\,V_t). \tag{22}$$

We further assume that the "government" balances its budget in every (five-year) period by adjusting consumption taxes (ie, τ_t^c is the adjusting variable)[6]:

$$\tau_t^c C_t + (\tau_t^w + \xi_t)\left(\sum_a \omega_{a,t} n_{a,t} P_{a,t}\right) + \tau^k\left(\sum_a r_t^*\ s_{a-1,t+a-1}\ Z_{a-1,t+a-1}\right) = G_t + T_t, \tag{23}$$

where aggregate consumption $C_t = \sum_a c_{a,t}\, Z_{a,t}$. For convenience, we assume no public debt. Public debt could be introduced by postulating an exogenous path of the debt, and assuming that the deficit adjusts (via τ^c) to match that path.

2.6 Wages

Wages are renegotiated in every period. They are determined by a standard Nash bargaining rule:

$$\max_{w_{a,t}} \left(\frac{\partial W_t^F}{\partial N_{a,t}}\right)^{1-\eta} \left(\frac{1}{u'_{c_{a,t}}}\,\frac{\partial W_t^H}{\partial N_{a,t}}\right)^{\eta}. \tag{24}$$

The first-order optimality condition can then be written:

$$(1-\eta)\,\frac{1}{u'_{c_{a,t}}}\,\frac{\partial W_t^H}{\partial N_{a,t}} = \eta\,\frac{1-\tau_t^w}{(1+\zeta_t)(1+\tau_t^c)}\,\frac{\partial W_t^F}{\partial N_{a,t}}. \tag{25}$$

2.7 International Capital Market

Let Q_t denote the total financial value of firms at time t. In our deterministic setup, the return on equities must be equal to the market interest rate. In other words, the value of equities must be such that, for all $t \geq 0$:

$$\frac{Q_{t+1} + \Pi_{t+1}}{Q_t} = R_{t+1}^*. \tag{26}$$

The left-hand side is the return of one unit of savings investment in equities while the right-hand side is the return if invested in firms' bonds.

The aggregate stocks of capital in the two regions satisfy

$$K_{t+1}^A + Q_t^A + FA_t = \sum_{a=0}^{14} s_{a,t}^A\, Z_{a,t}^A. \tag{27}$$

[6]Changes in τ_t^c affect all incomes in the same way, whereas changes in τ_t^w for instance would change net replacement rates.

$$K_{t+1}^B + Q_t^B - FA_t = \sum_{a=0}^{14} s_{a,t}^B\, Z_{a,t}^B\,. \tag{28}$$

where $FA_t (\equiv FA_t^A)$ denotes the net foreign assets position of region A, and region B's external wealth is $FA_t^B = -FA_t$.

The current account surplus of region A (or the net capital outflow from region A to region B) is given by the change in the net foreign asset position of region A,

$$CA_t^A \equiv CA_t = FA_{t+1} - FA_t. \tag{29}$$

Consequently, region B's current account is $CA_t^B = -CA_t$.

2.8 Intertemporal General Equilibrium

The intertemporal general equilibrium is formally defined as follows.

Definition 1 *Given the following exogenous processes and initial conditions:*

- *demographic variables* $\{x_t\}_{t=0..+\infty}$ *(fertility),* $\{\beta_{a,t}\}_{t=0..+\infty}^{a=0..15}$ *(mortality),* $\{X_{a,t}\}_{t=0..+\infty}^{a=0..15}$ *(migration),*
- *policy variables* $\{\rho_t^u, \rho_{a,t}^e, \rho_t^j\}_{t=0..+\infty}$ *(replacement rates) and* $\{\tau_t^k, \tau_t^w, \zeta_t\}_{t=0..+\infty}$ *(tax rates),*
- *initial population* $\{Z_{a,-1}\}^{a=0..15}$*, assets* $\{s_{a,-1}\}^{a=0..14}$ *and capital stock* $\bar{K}_0 < \sum_{a=0}^{14} s_{a,-1} Z_{a,-1}$*,*

an inter-temporal equilibrium with perfect foresight and labor market frictions is such that:

1. *saving* $\{s_{a,t}\}_{t=0..+\infty}^{a=0..14}$*, consumption* $\{c_{a,t}\}_{t=0..+\infty}^{a=0..15}$ *and retirement* $\{e_{a,t}, \lambda_{a,t}\}_{t=0..+\infty}^{a=6,7}$ *maximize households'utility (10) subject to budget constraint (11) and to (5),*
2. *capital input* $\{K_t\}_{t=0..+\infty}$*, posted vacancies* $\{V_t\}_{t=0..+\infty}$ *and output* $\{Y_t\}_{t=0..+\infty}$ *maximize firms'profits (16) subject to (8), (9), (14), and* $K_0 = \bar{K}_0$*,*
3. *the number of new hires* $\{M_t\}_{t=0..+\infty}$*, the probabilities of finding a job* $\{p_t\}_{t=0..+\infty}$ *and of filling a vacancy* $\{q_t\}_{t=0..+\infty}$*, and the employment rates* $\{n_{a,t}\}_{t=0..+\infty}^{a=0..7}$ *satisfy the matching technology (6), (8) and (9),*
4. *total population and population of working age* $\{Z_{a,t},\ P_{a,t}\}_{t=0..+\infty}^{a=0..7}$*, and number of job seekers* $\{\Omega_t\}_{t=0..+\infty}$ *satisfy the population dynamics (1), (2), (3) and (7).*
5. *unemployment* $\{u_{a,t}\}_{t=0..+\infty}^{a=0..7}$ *is such that the time constraint (4) holds.*

6. *wages* $\{w_{a,t}\}_{t=0..+\infty}^{a=0..7}$ *are negotiated following the Nash bargaining rule (24),*

7. *government benefits* $\{b_t^u, b_t^e, b_t^j\}_{t=0..+\infty}$ *follow the rules defined by (20), and government spending* $\{G_t\}_{t=0..+\infty}$ *follows (22),*

8. *consumption taxes* $\{\tau_t^c\}_{t=0..+\infty}$ *are set by the government to balance its budget (23),*

9. *stock market prices* $\{Q_t\}_{t=0..+\infty}$ *satisfy the arbitrage condition (26),*

10. *the international interest rate* $\{r_t^*\}_{t=0..+\infty}$ *clears the world capital market, i.e.,* (27) *and* (28).

3 Calibration

This section describes the calibration of the model's parameters and exogenous variables. The model starts from an initial steady state in 1900 and is calibrated to reflect the economic conditions of both regions in 2005. After 2125, all exogenous variables are kept constant. The population distribution stabilizes at the beginning of the 23^{rd} century, and the economy progressively reaches a new steady state in the following decades. Our analysis focuses on the subperiod from 1950 to 2100 within the transitional path.[7]

Technology and human capital. We assume a constant returns-to-scale Cobb-Douglas production function. The elasticity of output with respect to capital is set to α = 0.33. To focus on the effects of demographic changes, we leave aside technological progress and assume constant values of the TFP and age-specific human capital parameters (A_t and $h_{a,t}$ respectively). TFP is set to 20 in the EU15 and 24.054 in the US to match the ratio of GDP per capita between the EU15 and the US at 72.64% over the period 2003-2007 (see Table 2, data from the IMF, 2009). Moreover, to reproduce the life-cycle profile of wages, we assume that a worker's productivity increases with age until he or she turns 50, and then slowly decreases, as suggested by empirical findings (see, for instance, Kotlikoff and Gokhale, 1992; Johnson and Neumark, 1996; Aubert and Crépon, 2003). The efficiency parameters h_0 to h_7 are set at the following values: 3.4, 3.68, 4, 4.32, 4.4, 4.4, 4.2 and 4.2. Finally, the depreciation rate of capital is set at 2.5% per quarter.

Preferences. We assume identical preferences in both regions. Utility is logarithmic in consumption, so the wealth and substitution effects of a change in the interest rate cancel each other. There is no bequest motive and the labor disutility parameter d_n is set equal to 0.25, which represents 9 to 12% of wage income in both regions. Parameter κ is set to 0.80, implying a Frisch elasticity of about 0.6, in line with estimated values (Den Haan and Kaltenbrunner, 2009). The leisure (early

[7]Starting the simulations in 1900 and ending them in 2300 allows us to isolate the period in which we are interested from the initial and final conditions.

Table 1: Parameter values

Variable	EU-15	US	Variable	EU-15	US
Production function			**Preferences**		
A	20	24.054	β (quarterly)	0.9924	0.9924
δ (quarterly)	0.025	0.025	κ	0.80	0.80
α	0.33	0.33	d^n	0.25	0.25
			d^e_6	0.153	0.153
Policy variables (in %)			d^e_7	0.164	0.164
$\bar{g}$	19.37	14.49			
τ^w	12.27	7.65	**Labor market variables**		
τ^f	25.64	7.65	a	38.28	73.78
τ^k	24.45	34.70	ν	6.50	6.50
ρ^u	43.45	23.27	η	0.50	0.50
ρ^j	58.24	38.60	χ (quarterly)	0.02	0.03
ρ^e_6	17.45	0.00			
ρ^e_7	34.90	28.95			

Most parameters are time invariant and calibrated to reproduce 2005 data. Only the four ρ's change over time, as a result of important historical institutional shifts. We reproduce their 2005 values here. See Figure 12 in Appendix C for the full historical values.

retirement) parameters are set at $d^e_6 = 0.153$ and $d^e_7 = 0.164$, and contribute to reproducing senior activity and exit rates (see below). As in Attanasio et al. (2007), we fix the subjective rate of time preference at 0.77% per quarter to obtain a capital-output ratio in 2005 of 2.50 annually in the United States. With these values, individual consumption rises over the life cycle and savings are negative during the first two periods of life. Our calibration yields a real interest rate of 5.93% per annum in 2005 (4.55% in the final steady state), in line with the equilibrium interest rates in similar models (e.g. 6.6% in 2005 in Attanasio et al. (2007) and 7.4% in Krueger and Ludwig (2007)). Although these interest rate levels may seem high at first sight, Attanasio et al. (2007, p.165) notice that they are still lower than the postwar real return on US equity (about 8%).

Taxes. Government consumption is a constant fraction of GDP $\bar{g} = 19.37\%$ in the EU15 and $\bar{g} = 14.49\%$ in the US on average over the 2000-2005 period (WDI, 2006). Data on capital taxation are taken from Bosca et al. (2005). The capital tax rate τ^k equals 24.45% in the EU15 (population-weighted average) and 34.7% in the US.[8] Data on employer's and employee's wage taxes (τ^f

[8]See *Cuadro 1* (p.128) of Bosca et al. (2005). Their study belongs to the research line initiated by Men-

and τ^w, respectively) originate from the OECD Tax Database (OECD, 2010b). More precisely, we use averages over the 2000-2009 period of the "Employer SSC" item to compute τ^f and of the "Employee SSC" item for τ^w. The employer's wage tax is 7.65% in the US and 25.64% in the EU15 (population-weighted), whereas the employee's wage tax is 7.65% in the US and 12.27% in the EU15.

Transfers. The generosity of transfers, i.e., the replacement rates for unemployment and for mandatory and early retirement, increased greatly during the 20^{th} century, and we must use the full set of historical values in the simulation exercises. Appendix C details the computation of these historical values from available data (Martin, 1996; Cornelisse and Goudswaard, 2001) and displays them in Figure 12 (where the 2005 values correspond to those shown in Table 1). The following paragraphs briefly present the calculation of replacement rates for 2005, and a more complete description is provided in Appendix B.

Gross replacement rates over a five-year unemployment spell in both regions are calculated from OECD (2009, Table 1.6, population-weighted averages). They are set to a value corresponding to 90% of the gross replacement rate in the first year of an unemployment spell and are displayed in Table 1. The reference wage used to compute pension benefits is typically an average over the best years of activity. We set the reference wage at the average wage of workers aged 45-64. At a given replacement rate, our formulation implies that pensions are indexed on current wages. The values for the gross replacement rate ρ_t^j correspond to 38.6% for the US and 58.24% for the EU15 in 2005 (OECD, 2009).

In the US, there is no public pension scheme before age 62 and the replacement rate for early retirement for workers aged 55-59, ρ_6^e, is therefore set to 0 (see e.g. Gruber and Wise, 2004, p.15). Workers retiring between 62 (the early retirement age) and the normal retirement age (NRA) obtain limited pension benefits, implying a (gross) replacement rate for early retirement at age 60-64, ρ_7^e, of 75% of the benefit a person receives at NRA, ρ^j. In contrast to the US, workers retiring before early retirement age in the EU15 may be compensated through unemployment and disability programs or by large severance packages if they are laid off (Gruber and Wise, 1999). However, as not every EU country provides old-age benefits to people retiring before age 60 and not every senior worker qualifies for such programs, ρ_6^e is set at a lower value than ρ_7^e (50% of ρ_7^e). The value for the (gross) replacement rate at age 60-64, ρ_7^e, in the EU15 is based on OECD computations (see Duval, 2003, Figure 1).

These values allow us to reproduce the different senior activity and exit rates in the EU15 and the US, despite identical values for the leisure parameters d_6^e and d_7^e. Table 2 shows that early retirement and activity rates for the groups aged 55-59, 60-64 and 55-64 years in 2005, resulting from these parameter values, are in line with those calculated from the OECD (2010a) data (see

doza et al. (1994), but improves on the latter by providing data for a larger set of OECD countries.

Appendix B on the computation of target activity rate values).

Labor market parameters. Following den Haan et al. (2000), we adopt the following constant returns-to-scale matching function:

$$M(V_t, \Omega_t) = \frac{V_t \, \Omega_t}{(V_t^{\nu} + \Omega_t^{\nu})^{\frac{1}{\nu}}}. \tag{30}$$

The major advantage of this approach, compared with the standard Cobb-Douglas specification used in the literature is that it guarantees matching probabilities between zero and one for all Ω_t and V_t $(0 < p_t, q_t < 1)$.[9] In contrast, RBC models, which study the effects of (smaller) shocks in the short term, tend to use the Cobb-Douglas specification. However, function (30) is more appropriate in our case, where labor markets are subject to large shocks over a longer period.

Several sources report that job destruction rates differ between the US and the EU15. Bassanini and Marianna (2009, Figure 4) use inter-industry data that are comparable across eleven OECD countries to suggest an average *annual* job destruction rate of about 13% in the US. This number is close to the one in Klein et al. (2003, p.244), who report 10.2 jobs destroyed each year per 100 positions in U.S. manufacturing over the 1974-1993 period. Moreover, *quarterly* job destruction rates over the 1990-2005 period range between 5 and 8 per cent across US industries (excluding the construction sector which is characterized by a 14 per cent rate of job destruction per quarter, Davis et al., 2010). For the EU15, Bassanini and Marianna (2009, Figure 4) report an average job destruction rate of about 8% *per annum* in some European countries (Germany, Finland and Sweden). In their model applied to the euro area, Christoffel et al. (2009) use a *quarterly* rate of 6 per cent. We fix the quarterly job destruction rate χ at 3% for the US and 2% for the EU15.

The values for our *quarterly* χ's may seem low compared with the above-mentioned magnitudes, but they imply high χ's over the five-year period (45.62% in the US and 33.24% in the EU15) and are, therefore, reasonable. The bargaining power of workers η is set to the conventional value of 0.5 (see, e.g., Mortensen and Pissarides, 1994). Vacancy costs a and the parameter of the matching function ν are used to reproduce unemployment rates of workers ages 25-54 in 2005 (own calculations based on data from the OECD, 2010a), under the condition that the matching efficiency parameter, ν, is the same in the EU15 and the US. A similar ν in both regions implies that the *matching process* is the same in the US and the EU15 (although this does not exclude the possibility that other labor market parameters, like the cost of posting a vacancy, the job destruction rate and the generosity of unemployment benefits, may differ across regions). These parameter values yield a steady-state probability of filling a vacancy (over a five-year period) of

[9] Function (30) reflects the following matching procedure. Its denominator ($\equiv J_t$) represents the number of channels through which matches occur at each period. A firm and a worker assigned (randomly) to the same channel are successfully matched, otherwise agents remain unmatched. A worker locates a firm with probability V_t/J_t, a firm locates a worker with probability Ω_t/J_t, and the total mass of matches is $V_t\Omega_t/J_t$ (den Haan et al., 2000, p.485).

85.2% in the EU15 and 77.1% in the US and a probability of finding a job of 93.5% in the EU15 and 96.9% in the US.

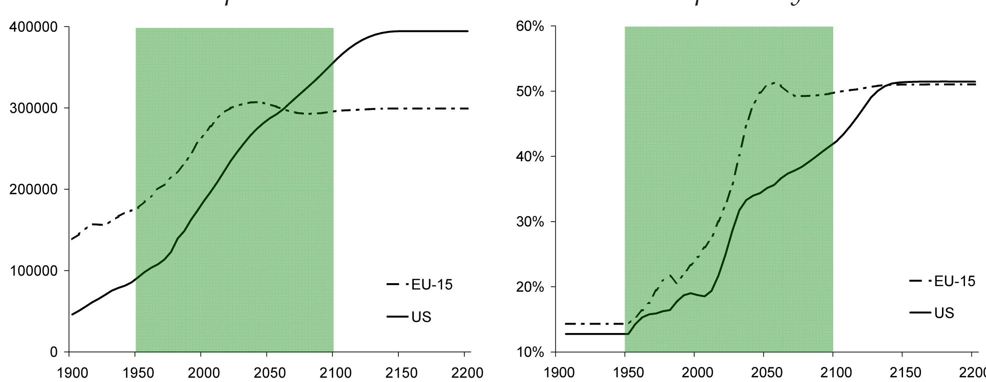
Table 2: Data match given parameter settings

	EU-15		**US**	
Variable	**Data**	**Model**	**Data**	**Model**
λ_{55-59}	22.85	22.96	13.29	13.26
λ_{60-64}	46.24	44.26	25.23	26.30
$ActRate_{55-59}$	77.15	77.04	86.71	86.74
$ActRate_{60-64}$	41.48	42.62	64.84	63.69
$ActRate_{55-64}$	60.97	61.26	77.39	76.75
u_{25-54}	6.90	6.90	4.24	4.24
Ypc/Ypc^{US}	72.64	72.64	100	100

Data refer to 2005 and numbers are in percentages. Ypc stands for GDP per capita net of vacancy costs and is normalized to 100 in the US.

Figure 2: Population (+25) and Dependency ratio (65+ over 25-64)

a. Population *b. Dependency ratio*



Demographic variables. Survival probabilities from 1900 to 2100 are taken from the US Social Security Administration (Bell and Miller, 2005) for the United States and from French data (Vallin and Meslé, 2001) for the EU15. Population by age classes over the 1950-2050 period are taken from the United Nations (2010). The UN series are extended for the United States until 2100 through projections by the US Census (2000) over the 2050-2100 period. No such data are available for the EU15, where the migration shocks ($X_{a,t}$) are held constant from 2050 onwards whereas fertility (x_t) still varies beyond 2050 according to the information on population aged

0-24. Further details on the calibration of the demography are provided in Appendix A.[10] According to these estimates, the population of the United States is on an increasing track over the whole 21^{st} century and will overtake Europe's in the middle of the century (Figure 2.a). In the EU15, the dependency ratio (population above 64 divided by population aged 25-64) increased by less than 10 percentage points from 1950 till 2000; it will more than double between 2000 and 2050 to reach a level of about 50% (Figure 2.b). Over the whole 21^{st} century, the dependency ratio of the United States will not exceed the European one, remaining below 40%.

Pension expenditures and future pension reforms. Our baseline leads to a cost of public pensions equal to 6.16% of GDP in the US and 12.72% in the EU15 in 2005. These values are remarkably close to those reported by the OECD for 2005 (OECD, 2009, p.139) and to the official estimate by the European Commission (2009a) for the EU15. To limit the rise in pension expenditures, several countries have undertaken significant reforms of their pay-as-you-go pension systems (see IMF, 2010a, Appendices IV and V). Our baseline scenario incorporates such reforms via progressive decreases in the replacement rate over the coming years by assuming, in both regions, a 20-per cent decrease of the replacement rate defined above by 2030 (and a 30-per cent decrease by 2055). With these changes in pension replacement rates, the ratio of public pension expenditures to GDP increases by similar magnitudes in our baseline as projected in official studies (IMF, 2010b; European Commission, 2009a). Our model yields similar results as estimates considering only the demographic effect on public pension expenditures, i.e., without future changes in replacement rates (Bongaarts, 2004; European Commission, 2009a). See Appendix D for details.

4 Baseline Results

The baseline scenario illustrates the effects of aging in the EU15 and the US. The focus is on transitional dynamics. Our simulations start in the year 1900, which is assumed to be a steady state. The dynamics are driven by the exogenous changes in the demographic variables between 1900 and 2100 and by the changes in the values of the institutional variables (replacement rates) decided before 2010. All exogenous variables remain constant after the year 2100, and the model progressively converges towards a new steady state. The focus will be on the 1950-2050 subperiod, which lies sufficiently far away from the initial and the final steady states to avoid a significant impact of these initial and terminal constraints.

We first present the results of the benchmark specification, which includes both capital mobility and labor market imperfections. We next study the role of capital flows and economic integra-

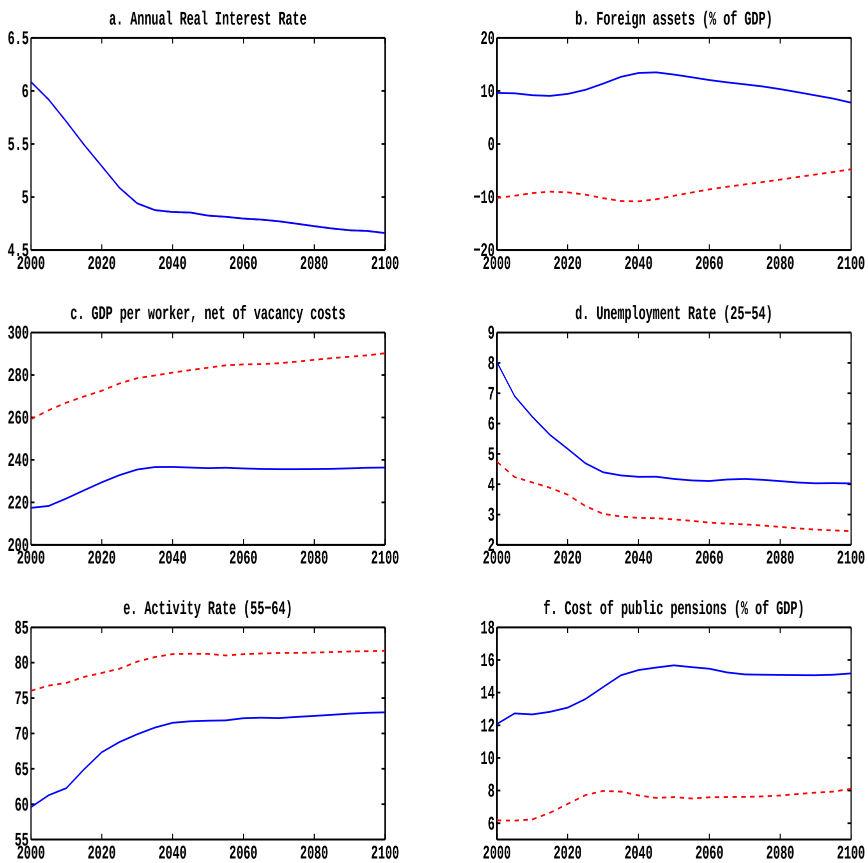
[10] Moreover in Appendix E, we also check for the robustness of our results when we do not use of the US Census data for the 2050-2100 period (Figure 14).

tion by comparing open and closed economy results, and we examine the role of labor market imperfections by comparing our results with those obtained in a perfect competition setup.

4.1 Benchmark model

Our simulation results are broadly in line with the findings of the literature and various official reports. In what follows, we focus on some key variables, especially those related to capital flows and labor market imperfections and reproduced in Figure 3. We briefly comment on the implications of aging for aggregate employment, the cost of public pensions and international capital flows.

Figure 3: Effects of aging in the benchmark case



Europe-15 (—) and United States (---)

Benchmark case: frictional labor markets and integrated capital markets

Population aging stimulates savings and capital accumulation, depressing the worldwide interest rate. Figure 3 shows that the real annual interest rate is predicted to fall by 1.42 percentage points (pp) between 2000 and 2100 (from 6.08% to 4.66%).[11]

Capital accumulation also affects employment by enhancing average labor productivity and wages. The former effect makes labor more profitable and raises employment probabilities (reduces unemployment) for all age groups, while higher wages encourage senior workers to remain active (see Figure 3, panels d and e). The participation rate of workers aged 55-64 increases by 11.71 pp, from 61.26 pp in 2005 to 72.98 pp in 2060. This rise is similar to the one projected by the European Commission (11 pp for males and 21 pp for females between 2007 and 2060, European Commission, 2009b, p.61, Graph 26). Lower unemployment and higher participation increase the aggregate employment rate by 6.83 percentage points in the EU15 and 3.13 pp in the US between 2000 and 2100. The cost of public pensions in percentage of GDP rises by 3.10 pp between 2000 and 2100 in the EU (3.30 pp between 2000 and 2040). A smaller increase is expected in the US (1.93 pp between 2000 and 2100; 1.53 pp between 2000 and 2040). Like other authors, we find that capital flows from the more quickly aging country (the EU15) to the country that is aging more slowly (the US). Over the whole 21st century, the US will have a higher working-age population ratio than the EU15, which implies a greater demand for capital in the US. The evolution of net foreign asset holdings (in percentage of GDP) is depicted in panel b of Figure 3. The EU15 remains a net creditor to the US throughout the century, which corroborates the findings of Krueger and Ludwig (2007). The negative US (positive European) net foreign asset position results from cumulated current account deficits (surpluses) in previous periods (not shown here). As in Krueger and Ludwig (2007), the US foreign assets position improves after 2040, when the US current account turns positive (not shown here)[12].

[11] As a comparison, the interest rate falls by 1 percentage point (pp) over the in Krueger and Ludwig (2007) period 2000-2060 and by more than 3 pp over the 2005-2070 period in Attanasio et al. (2007). In our model, the decline in the interest rate is especially marked between 2000 and 2040 during the dramatic aging of the population (1.22 pp, from 6.08% to 4.86%). In Krueger and Ludwig (2007) and Attanasio et al. (2007), the interest rate falls by 0.80 pp and 2 pp, respectively, over the same period.

[12] In Krueger and Ludwig (2007), the US foreign assets position is about -18% of GDP in the beginning of the 21st century (-10% in our model's baseline), decreases to -36% in 2040 (-11% in our baseline) and improves from 2040 onwards to reach -22% in 2100 (-5% in our baseline). Moreover, the evolution of the current account in both regions is very similar to the one obtained by Krueger and Ludwig (2007). This latter study yields a deterioration of the US current account of up to 2% of GDP by 2040 (up to 1% in our model over the same period).

4.2 Open versus closed economy

International capital flows explain why interest rates remain so similar across countries[13]. We evaluate their impact on other economic variables by comparing the benchmark open-economy model to its closed-economy counterpart. The main results are illustrated in Figure 4. The solid lines repeat the open-economy results already discussed; the dashed lines correspond to the closed-economy models without capital mobility. In the latter setting, the European interest rate is about 25-30 basis points lower, and 25-30 basis points higher for the US. Absent capital mobility, there is more capital available for investment in Europe, which lowers the interest rate (by about 25-30 basis points) and stimulates labor productivity, job creation (the unemployment rate is 0.5-1.0 percentage points lower) and senior participation (up by 2-3pp). As a consequence, the employment rate would be 1.25 pp higher in 2000 (0.55 in 2100) than in the open economy. The opposite occurs in the US, where capital would become scarcer and the employment rate would decrease by 1.14 pp in 2000 (0.30 in 2100).

Finally, the degree of capital mobility plays a smaller role in the cost of public pensions (not shown in Figure 4). This finding corroborates results of Börsch-Supan et al. (2006) and Attanasio et al. (2007)[14]. The explanation is the same: the fiscal gains/losses associated with higher/lower capital income are almost exactly compensated by the fiscal losses/gains associated with lower/higher labor incomes.

4.3 Frictional versus competitive labor markets

To better understand the role and the quantitative impact of labor market imperfections, we now compare the benchmark model to the same open-economy model with perfectly competitive labor markets. The main results are illustrated in Figure 5. The solid lines repeat the results already discussed in section 4.1; the starred-dotted lines correspond to the case with perfectly competitive labor markets.

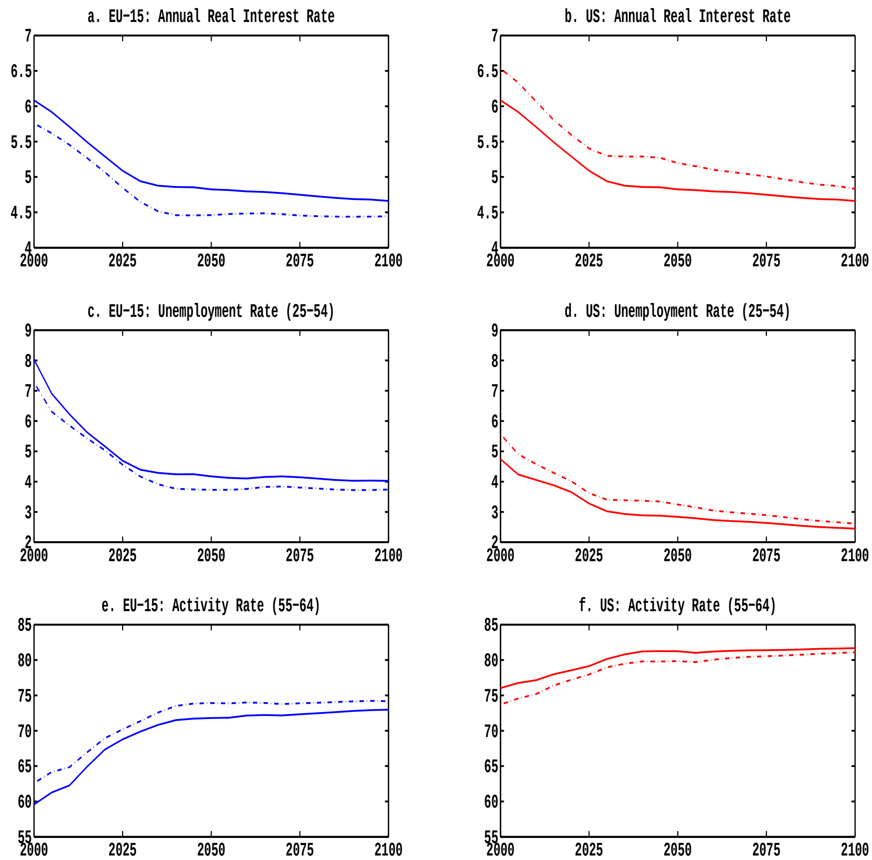
In the latter case, there is no unemployment, and changes in the aggregate employment rate result solely from changes in senior participation rates[15]. Senior participation rates are quite

[13] The monthly return on equity (ROE) of the S&P 500 between 1960 and 2005 is 0.58%, whereas the ROE of the DAX is 0.62%. These ROEs also have similar volatility and have a correlation of 51%. The correlation obviously increases further when considering quarterly returns.

[14] In the closed economy, the cost of public pensions is between 0.29 percentage points in 2000 and 0.17 in 2100 *lower* for the EU15 and from 0.13 pp (2000) to 0.06 pp (2100) *higher* for the US than in the benchmark.

[15] We have assumed exogenous individual hours. Previous studies have shown that the elasticity of individual hours to wages is weak, so this channel plays little role. It would affect the frictional and competitive economies in similar ways.

Figure 4: Global Economy and Closed Economy



Capital market integration (—) and closed economy (-·-).

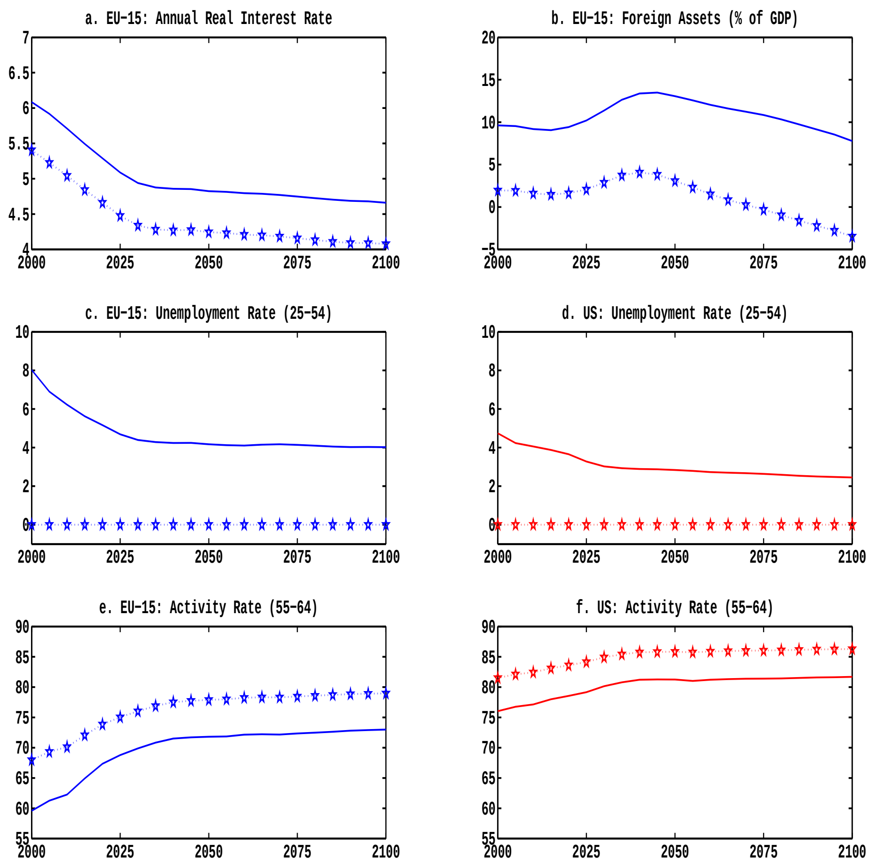
Europe-15 (left panel) and United States (right panel).

high in the frictionless economy (as a result of higher wages and the absence of unemployment) and are affected little by demographic changes. In turn, the aggregate employment is hardly changed. In contrast, in the frictional economy, job creation leads to higher employment probabilities, which stimulates senior participation. Both effects contribute to explaining the significant impact of demographic changes on the aggregate employment rate. Differences in employment rates are reflected in GDP, which increases less when labor markets are competitive (although GDP remains higher than in the benchmark case). The cost of public pensions as a percentage of GDP increases more in the competitive case (not shown in Figure 5)[16].

[16] At the beginning of the twenty-first century, the difference in the cost of public pensions is relatively small. For the EU, it is even smaller in the competitive economy than in the frictional one. In the frictional economy, there are relatively more early retirees at the beginning than at the end of the century.

Panel b of Figure 5 shows that capital flows are much more important in frictional economies. Foreign asset holdings in the EU (in percentage of GDP) are almost 10 pp higher in the case with frictions. This is because the employment rate reacts much more strongly to capital flows in a frictional economy than in a competitive one. Because capital inflows (outflows) have a stronger positive (negative) impact on the employment rate, the volume of capital flows needed to arbitrage out initial cross-country differences in capital returns is substantially larger in the frictional economy.

Figure 5: Frictional and competitive labor markets



Frictional (—) and competitive labor markets (··⋆··).
Europe-15 (left panel) and United States (right panel).

5 Further Results

The above findings raise further questions. How does the model's unemployment rate compare to the one observed over the last decades? What are the welfare implications of demographic changes and capital flows? What could be the effect of emerging economies on capital flows and labor market outcomes? What is the impact of pension reform on labor market outcomes? These questions are addressed in the following paragraphs.

5.1 Unemployment, 1950-2010

One way to test the robustness and reliability of our model is to check its implications for the period before 2000, especially for unemployment rates. The contrast between the EU and US unemployment rates over the last few decades is well known. European unemployment was low during the 1960s and started to increase in the 1970s, eventually exceeding the US rate in the early 1980s and remaining systematically higher ever since, except for a short period following the financial crisis of 2008. Cyclical fluctuations are of course not part of our model, and we should not expect it to reproduce the unemployment surges associated with the oil shocks or financial crises, for example. Still, we want to check whether our model yields reasonable values, in particular whether it can reproduce long-term (structural) changes over the 1950-2010 period.

Unemployment rates generated by the model are compared with the actual rates in panel a of Figure 6. The model tracks quite well the observed values and trends over the 1950-2010 period, although it includes only two exogenous driving forces (demography and labor market institutions). The main discrepancies between the model and the data coincide with the two oil shocks (1975, 1980) and the current recession (2008).

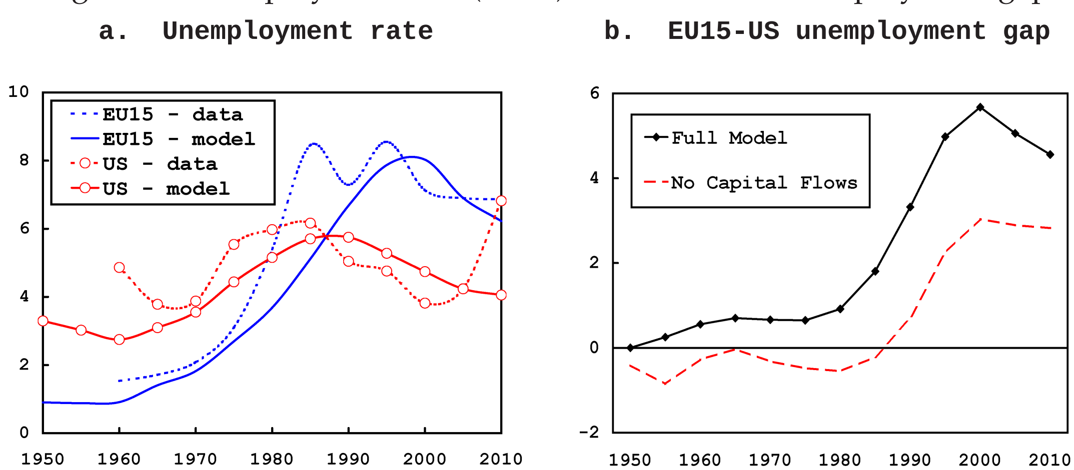
Panel b of Figure 6 illustrates the contribution of capital flows to these changes. The results are summarized in terms of the EU-US unemployment gap, normalized to zero in 1950. The total gap (reflecting both demographic and institutional changes as well as induced capital flows) is represented by the solid line with dots. It remains fairly stable at 0-1 percentage point until the early eighties. It then progressively increases and reaches a maximum of 5.5 percentage points in 2000, when it starts falling. Not surprisingly, most of the rise comes from the asymmetric changes in labor market institutions (see Figure 12 in the Appendix). The importance of these variables is well known (see, for instance, Nickell (1997) and Nickell et al. (2005))[17].

[17] Other factors have been mentioned in the literature. Blanchard and Wolfers (2000) and Ljungqvist and Sargent (2008), for instance, argue that the rise in the EU-US unemployment gap may not result from changes in the institutions themselves, but rather reflect the asymmetric effects of common shocks when the institutional setup is different. This argument is more related to cyclical fluctuations and the effects of oil shocks.

The impacts of demographic asymmetries and of capital flows are less understood. The dashed line represents the unemployment gap that would be observed without capital flows. The profile is similar to the one obtained with capital flows, although the unemployment gap is systematically lower, which again shows that capital flows from the EU to the US contributed to increasing (decreasing) the unemployment rate in the EU (US) (see Figure 4). A high proportion of prime-age workers (as in the US between 1975 and 1995) means, ceteris paribus, lower savings, higher capital costs and a higher unemployment rate. With capital flows, part of this unemployment rise is "exported" and contributed to the EU-US unemployment gap of the late 20th century. This capital flow effect explains why our model produces an almost unchanged US unemployment rate between 1950 and 2005 (as observed in the data, apart from cyclical fluctuation effects), although replacement rates have increased in the US as well.

The difference between the solid line with dots and the dashed line measures the contribution of demography-induced capital flows to the EU-US unemployment gap. This contribution remains roughly constant at about 1 percentage point until the late 1970s. It next increases and reaches a maximum of about 3 percentage points in the late 1990s, when it starts falling again. Demography-induced capital flows may thus have non-negligible (albeit time-varying) effects on unemployment gaps.

Figure 6: Unemployment rate (25-54) and EU15-US unemployment gap



Panel b shows the US-EU15 unemployment gap (normalized to its baseline 1950 value) in the baseline model (“Full model”) and in a simulation without capital flows (“No Capital Flows”).

5.2 Welfare

We examine in this section whether accounting for labor market frictions has a significant effect on welfare evaluation. We focus on the welfare effects of demographic changes and of capital flows. Such effects have already been examined in the literature in the context of competitive economies (Krueger and Ludwig, 2007; Attanasio et al., 2007).

To examine demographic effects, we consider a scenario where all replacement rates remain constant at their 2100 values over the entire simulation period. Demographic changes combine both longevity and fertility/migration shocks. To eliminate the mechanical effect of longer lifetime duration on welfare at constant consumption and labor supply levels, we rescale lifetime utilities as follows:

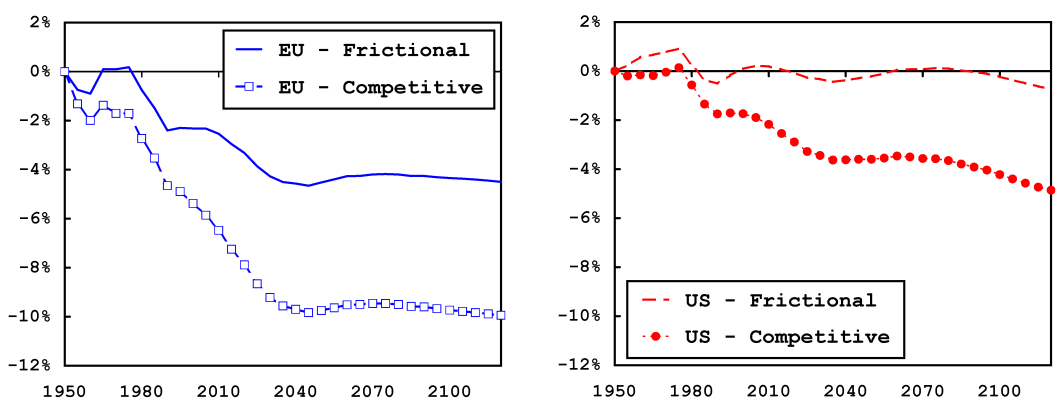
$$\widetilde{W}_t^H = \frac{W_t^H}{\sum_{a=0}^{15} \beta^a \, \beta_{a,t+a}} \tag{31}$$

where W_t^H is defined by equation (10). In other words, we focus on average welfare per period. The welfare gain (or loss) of a cohort born at time t relative to the cohort born in 1950 is measured by the percentage change in consumption needed in each period of life to compensate for lifetime utility differences, with a fixed labor supply. More formally:

$$g_t = \exp\{\widetilde{W}_t^H - \widetilde{W}_{1950}^H\} - 1 \tag{32}$$

is positive (negative) when there is a welfare gain (loss). The results are reproduced in Figure 7 for the EU (left panel) and the US (right panel) under the assumption of frictional (continuous line) or competitive (dashed line) labor markets.

Figure 7: Welfare Impact of Demographic Changes



Welfare is measured relative to the 1950 generation. The left (right) panel is for the EU (US); simple lines are for the case with frictions; lines with markers are for the case without frictions.

Under the competitive labor market assumption, ongoing demographic changes imply sizeable welfare losses for the generations entering the labor market after 1950, both in the EU and in the US. This result may not be surprising as population aging implies a longer retirement lifetime, to be financed by the savings accumulated over an (almost) fixed period of work. The rise in wages induced by population aging (see previous sections) is not large enough and is counteracted by the lower returns to savings[18]. The losses appear substantially larger in the EU economy (about 5 percentage points larger after 2010). This difference is substantially reduced (about 2 percentage points) when the EU public pension replacement rate is set at the same value as in the US (because of larger capital accumulation and output; not shown)[19]. The most striking and interesting result, though, is the comparison between the frictional and the competitive cases. In the frictional model, population aging implies both higher wages and higher employment rates. As a result, the welfare of successive generations remains roughly constant in the US; welfare losses are 6 percentage points lower in the EU (they would become as low as 1% if the pension replacement rate were the same as in the US).

Figure 8 illustrates the effects of capital flows on the welfare of EU and US cohorts (the US economy is shown with squared lines) in both the frictional and competitive labor market cases (continuous and dashed lines, respectively). The values reported are calculated as follows for each cohort:

$$g_t = \exp\{\widetilde{W}_t^H[\text{integrated economies}] - \widetilde{W}_t^H[\text{closed economies}]\} - 1 \tag{33}$$

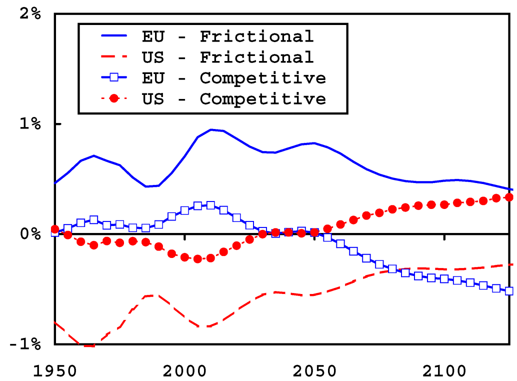
The underlying simulations incorporate both the demographic and the social security transfer changes of the benchmark model[20]. In the competitive case, capital flows have quite small welfare effects. In the frictional case, capital flows have a sizable and systematic positive welfare effect for the EU (negative for the US). The effect is about 1% in 2000 (compared with almost zero in the competitive case). The asymmetric welfare effects of capital flows for the EU and the US reflect the asymmetric effects of capital flows on domestic factor incomes. With capital flowing from the EU to the US, the interest rate rises (decreases) in the EU (US), and conversely for wages. In the competitive economy, the two effects compensate each other. In the frictional economy, because capital flows are much more important (see previous discussion), the capital income effect dominates. It is worth stressing that capital flows increase European welfare, despite their positive effect on European unemployment.

[18] Krueger and Ludwig (2007) look at a different scenario. They compare the welfare of a given cohort to the welfare that the same cohort would obtain if factor prices were to retain over their entire lifetime the value observed when they were born. From this analysis arises the apparently different conclusion that population aging benefits a newborn cohort, which will enjoy larger wages than otherwise.

[19] This comparison does not take into account the positive welfare effects that public pension schemes may have in incomplete market economies. See, for instance, Nishiyama and Smetters (2007).

[20] Keeping all replacement rates constant –as in figure 7– would give a similar picture.

Figure 8: Welfare Effects of Capital Flows



Welfare changes are measured for each generation relative to the closed-economy case. Simple lines refer to the case with labor market frictions (continuous line for the EU15, dashed line for the US). Lines with markers refer to the case without labor market frictions (squares for EU15, bullets for the US).

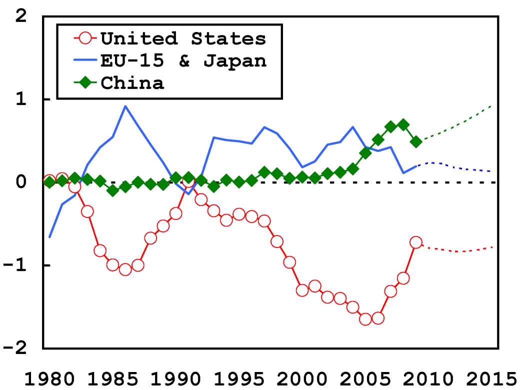
5.3 Emerging markets

The aim of our analysis is not to reproduce capital flows between the US and Europe exactly, but to highlight the labor market effects of bilateral capital flows generated by differences in EU-US demography. In other words, other elements affecting international capital flows, like business cycle fluctuations and long-term growth trends, are ignored. Our results are nevertheless relevant as several studies show that demographic differences explain a substantial fraction of *historical* international capital flows (Feroli, 2003; Henriksen, 2002; Domeij and Floden, 2006).

Another criticism could arise from the fact that capital flows between the US and Europe are also influenced by demographic changes in other countries. The US current account was mainly explained by the capital flows from other industrialized countries (the EU15 and Japan) until the end of the 20th century, perhaps even the mid-2000s. However, Figure 9 indicates that the importance of emerging economies, and foremost of China, in determining capital mobility worldwide will increase in coming years.

The following analysis provides an overview of the effects of capital flows from emerging countries from 2005 onwards on labor market outcomes in the US and the EU15. It would be inaccurate to posit the same working assumptions for the Chinese labor market as for the US and Europe (e.g., concerning wage bargaining). Moreover, recent studies show that Chinese demographic trends would imply a capital flow from the US to China, at least in the first decades of the 21^{st} century (Fehr et al., 2006; Attanasio et al., 2007). This finding is difficult to reconcile with the evidence from Figure 9. Capital flows from China to the US hinge on the particular saving

Figure 9: Current Accounts (as a percentage of world GDP)



Based on data (1980-2008) and forecasts (2009-2015) by the IMF (2010c).

behavior of the Chinese population and require a specific modelling of the Chinese economy (see, e.g., Song et al., 2011). To avoid issues raised by these particular features, we do not explicitly introduce the Chinese economy into the model as a third region. Instead, we simply assume that there is an unanticipated inflow of capital from China to the US. This assumption implies that, in equation (28):

$$FA_t^{US} = -FA_t^{EU15} - FA_t^{CHI}\,.$$

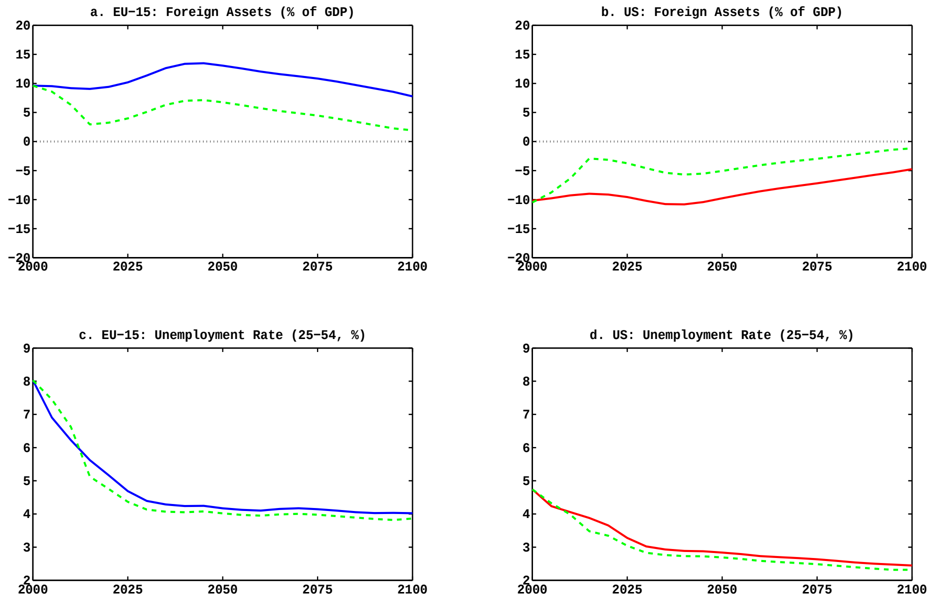
The foreign assets position of China, FA_t^{CHI}, is exogenous. FA_t^{CHI} is assumed to be positive from 2005 onwards (and zero before). In particular, using the IMF's current account numbers (Figure 9), we obtain that $FA^{CHI}/GDP_{2000}^{EU15}$ is equal to 2.28% in 2005, 6.31% in 2010 and 13.2% in 2015. We hold the latter value fixed from 2015 onwards.[21]

Figure 10 depicts the effects of capital flows from China to the US. The US foreign asset position turns even more negative and the EU15 one decreases as well. The reason for the latter result is that Chinese capital flows to the US partly substitute those from the EU15. In the medium and the long runs, the consequence of a larger supply of capital is a small reduction in the unemployment rate both in the US and in the EU15 through lower interest rates.[22] Moreover, the EU15-US unemployment gap is only negligibly affected when accounting for Chinese capital inflows to the US.

[21] Quantitatively similar results are obtained with a larger permanent foreign asset shock when extrapolating the IMF numbers until 2020.

[22] In the short run, from 2005 to 2015, the unemployment rate rises in both regions. The reason is that the increase in capital stock increases wage growth, raising the cost of labor and reducing the number of newly opened vacancies. After 2015, wage growth stabilizes.

Figure 10: Frictional and competitive labor markets



Baseline (—) and capital inflows from China (···).

Europe-15 on the left panel and the United States on the right panel.

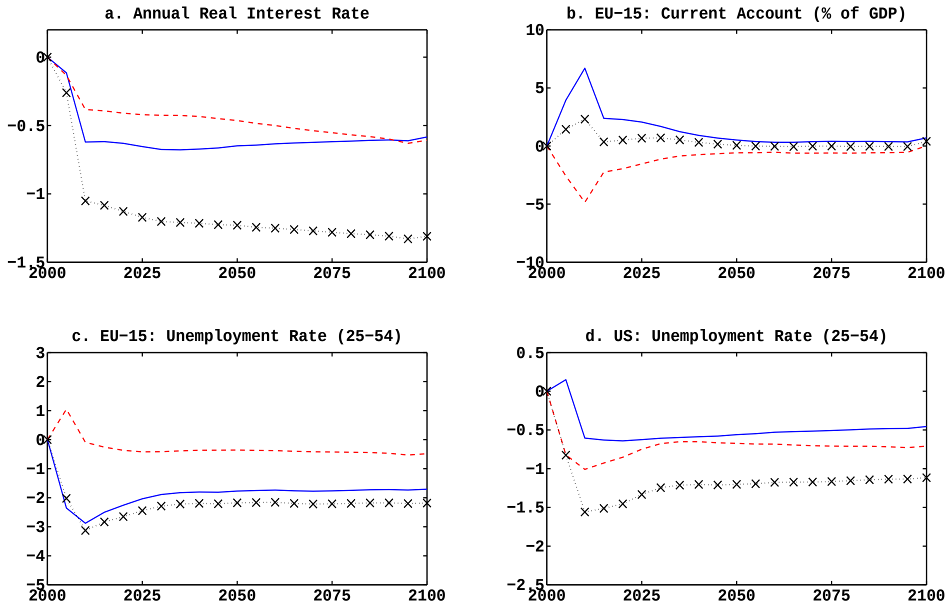
5.4 Pension reform

As mentioned in Section 3, many countries enacted policy reforms to address the fiscal challenges posed by pension finance. One frequently suggested reform is a shift from pay-as-you-go to a fully funded pension system. In this section, we look at the consequences of announcing in 2005 a shift to a fully-funded system in 2015. A more realistic scenario would be to gradually move to funded pensions, as in the UK in recent decades (Barr, 2006). The pension reform analyzed here is certainly too radical but suffices for illustrative purposes.

In Figure 11, we focus on the implications of implementing the fully funded scheme *in the EU15* (solid line). Similar results are obtained when the same reform is implemented *in the US* (dashed line) or *in both regions* simultaneously (dotted line with x). Figure 11 shows the impact of these scenarios for *both* the EU15 and the US. The results suggest that a pension reform in one region also improves labor market conditions in the other.

In the EU15, when the policy change is announced, aggregate consumption falls and savings rise. This change enlarges the stock of capital and induces a decrease in the interest rate. Capital accumulation has positive effects on labor productivity and on labor demand. These positive effects, in turn, stimulate wages and increase the activity rate of workers aged 55-64 years by

Figure 11: Pension reform in the EU15, the US and in both regions



Shift to a fully-funded system in the EU15 (—), in the US (- -) and in both regions (··x··).

Values in percentage point differences with respect to the baseline.

more than 5 percentage points in the long run. Under integrated capital markets, policy changes in one region also affect the economies of other regions. Indeed, the US benefits from part of the new European capital, as illustrated by the improvement in the European current account. The US capital stock is enhanced and labor demand is stimulated. The long-run employment rate increases by 2.61 percentage points in the EU15 and by 0.66 pp in the US.[23]

Finally, a pension reform initiated in the US (dashed line) and one initiated in both regions at the same time (dotted line with x) have qualitatively similar implications.[24]

[23] However, in the very short run, the US unemployment rate increases because capital inflow raises wage growth and depresses labor demand.

[24] Various other pension reforms could obviously be analyzed within our framework. For instance, it is well known that EU15 countries are characterized by low senior employment rates and generous early retirement schemes, which are found to considerably affect retirement decisions (Gruber and Wise, 2004). Hence, a relevant exercise would be to investigate the effects of a decrease in early retirement benefits. In short, a cut in early retirement benefits favors the activity of senior workers and increases employment overall. As a consequence, the marginal productivity of capital is improved and the interest rate rises (but only initially). Overall, the early retirement reform would bring about a long term increase in the aggregate employment rate (by 3.23 percentage points in case all early retirement benefits are removed) and only negligibly affect the unemployment rate. Finally, the reform slightly relieves the pressure on

6 Conclusion

The aim of this paper is to examine the impact of demographic changes on labor market outcomes when capital is mobile across countries. To address this question, a quantitative two-country overlapping-generations model is developed and calibrated to the EU15 and the US. The particularity of the framework is that it features labor market frictions and early retirement decisions.

It is found that the more favorable US demographic trends induce capital flows from the EU15 to the US, which lowers the unemployment rate in Europe and raises it in the US. In addition, the existence of labor market imperfections intensifies capital flows between the two regions. Our findings highlight the need to incorporate both international capital mobility and labor market institutions/frictions in quantitative general equilibrium models. The first is crucial to account for limited interest rate differentials across countries, while the second helps to generate positive unemployment. Moreover, the combination of both elements is necessary to reproduce differences in unemployment rates between the US and the EU15. Finally, a transition from a pay-as-you-go to a fully funded pension system in the EU15 stimulates savings and investment and improves labor market conditions. As part of the newly accumulated European capital is invested in the US, the EU15 pension reform will also be beneficial for US employment.

References

Aglietta, M., Chateau, J., Fayolle, J., Juillard, M., Cacheux, J. L., Garrec, G. L., and Touzé, V. (2007). Pension reforms in Europe: An investigation with a computable OLG world model. *Economic Modelling*, 24(3):481–505.

Angelini, V., Brugiavini, A., and Weber, G. (2009). Ageing and unused capacity in europe: is there an early retirement trap? *Economic Policy*, 24:463–508.

Attanasio, O., Kitao, S., and Violante, G. L. (2007). Global demographic trends and social security reform. *Journal of Monetary Economics*, 54(1):144–198.

Aubert, P. and Crépon, B. (2003). La productivité des salariés âgés : une tentative d'estimation. *Économie et Statistique*, 368(1):95–119.

Auerbach, A. and Kotlikoff, L. (1987). Dynamic Fiscal Policy. Cambridge University Press, Cambridge.

the cost of public pensions in the long run (-1.58 percentage points when early retirement benefits are completely removed).

Barr, N. (2006). Pensions: Overview of the issues. *Oxford Review of Economic Policy*, 22(1):1–14.

Bassanini, A. and Marianna, P. (2009). Looking inside the perpetual-motion machine: Job and worker flows in the OECD countries. OECD Social, Employment and migration working papers no. 95, Organisation for Economic Co-operation and Development, Paris.

Bell, F. C. and Miller, M. L. (2005). Life Tables for the United States Social Security Area 1900-2100. Actuarial Study No. 120, U.S. Department of Health and Human Services, SSA Pub. No. 11-11536. Social Security Administration, Office of the Chief Actuary.

Blanchard, O. and Wolfers, J. (2000). The role of shocks and institutions in the rise of european unemployment: The aggregate evidence. *The Economic Journal*, 110(462):C1–C33.

Blöndal, S. and Scarpetta, S. (1998). *The retirement decision in OECD countries*. OECD Economics Department Working Paper, No. 202, Paris.

Bongaarts, J. (2004). Population Aging and the Rising Cost of Public Pensions. *Population and Development Review*, 30(1):1–23.

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

Bosca, J. E., Garcia, J. R., and Taguas, D. (2005). Effective tax rates and fiscal convergence in the oecd: 1965-2001. *Hacienda Publica Espanola / Rivista de Economia Publica*, 174(3):119–141.

Brooks, R. (2003). Population Aging and Global Capital Flows in a Parallel Universe. *IMF Staff Papers*, 50(2):3.

Capretta, J. C. (2007). *Global Aging and the Sustainability of Public Pension Systems: An Assessment of Reform Efforts in Twelve Developed Countries*. A Report of the Aging Vulnerability Index Project, Center for Strategic and International Studies.

Christoffel, K., Costain, J., de Walque, G., Kuester, K., Linzert, T., Millard, S., and Pierrard, O. (2009). Inflation dynamics with labour market matching: assessing alternative specifications. Working paper 09-6, Federal Reserve Bank of Philadelphia.

Cornelisse, P. A. and Goudswaard, K. P. (2001). *On the Convergence of Social Protection Systems in the European Union?* MPRA Paper No. 21297.

Davis, S. J., Faberman, R. J., Haltiwanger, J., Jarmin, R., and Miranda, J. (2010). Business volatility, job destruction, and unemployment. *American Economic Journal: Macroeconomics*, 2(2):259–87.

de la Croix, D., Pierrard, O., and Sneessens, H. R. (2010). Ageing and Pensions in General Equilibrium: Labour Market Imperfections Matter. mimeo, CREA, University of Luxembourg and IRES, Université catholique de Louvain and Banque Centrale du Luxembourg.

De Nardi, M., Imrohoroglu, S., and Sargent, T. J. (1999). Projected U.S. Demographics and Social Security. *Review of Economic Dynamics*, 2(3):575–615.

den Haan, W., Ramey, G., and Watson, J. (2000). Job destruction and propagation of shocks. *American Economic Review*, 90(3):482–498.

Den Haan, W. J. and Kaltenbrunner, G. (2009). Anticipated growth and business cycles in matching models. *Journal of Monetary Economics*, 56(3):309–327.

Diaz-Gimenez, J. and Diaz-Saavedra, J. (2009). Delaying retirement in spain. *Review of Economic Dynamics*, 12(1):147–167.

Domeij, D. and Floden, M. (2006). Population Aging And International Capital Flows. *International Economic Review*, 47(3):1013–1032.

Duval, R. (2003). The Retirement Effects of Old-Age Pension and Early Retirement Schemes in OECD Countries. OECD Economics Department Working Papers, No. 370, OECD Publishing.

Ebbinghaus, B. and Gronwald, M. (2010). *International Policy Diffusion or Path Dependent Adaptation? The Changing Public Private Pension Mix in Europe*. Adapted paper from the Chapter to be published in Bernhard Ebbinghaus (Ed.): Varieties of Pension Governance. The Privatization of Pensions in Europe, Oxford: Oxford University Press, in preparation, 2010.

European Commission (2009a). "European Economy - Pension schemes and pension projections in the EU-27 Member States - 2008-2060, Volume I". Occasional Papers 56, Oxford, Economic Policy Committee (AWG) and Directorate-General for Economic and Financial Affairs.

European Commission (2009b). "The 2009 Ageing Report - Economic and budgetary projections for the EU-27 Member States (2008-2060)". Joint Report prepared by the European Commission (DG ECFIN) and the Economic Policy Committee (AWG), Economic and Financial Affairs.

Fehr, H., Jokisch, S., and Kotlikoff, L. (2003). The Developed World's Demographic Transition - The Roles of Capital Flows, Immigration and Policy. National Bureau of Economic Research, NBER Working Papers, 10096.

Fehr, H., Jokisch, S., and Kotlikoff, L. J. (2006). Will China Eat Our Lunch or Take Us to Dinner? Simulating the Transition Paths of the US, EU, Japan and China. In Kent, C., Park, A., and

Rees, D., editors, *Demography and Financial Markets*, RBA Annual Conference Volume. Reserve Bank of Australia.

Fehr, H., Kallweit, M., and Kindermann, F. (2011). Pension Reform with Variable Retirement Age - A Simulation Analysis for Germany. *Journal of Pension Economics and Finance, forthcoming*.

Feroli, M. (2003). Capital flows among the G-7 nations: a demographic perspective. Board of Governors of the Federal Reserve System (U.S.), Finance and Economics Discussion Series.

Friedman, G. R. (1937). *Unemployment Compensation: What and Why?* Social Security Board, Washington DC, March 1937. *Source:* webpage of Larry De Witte, Historian of the Social Security Administration, www.larrydewitte.net.

Gruber, J. and Wise, D. (1999). Social Security Programs and Retirement Around the World. University of Chicago Press, Chicago.

Gruber, J. and Wise, D. (2004). Social Security Programs and Retirement around the World: Microestimation. University of Chicago Press, Chicago.

Hairault, J., Langot, F., and Sopraseuth, T. (2010). Distance to retirement and older workers' employment: The case for delaying the retirement age, *forthcoming*. *Journal of the European Economic Association*.

Head, A. and Smits, K. (2004). Capital flows, incomplete markets, and the u.s. european unemployment gap. Society for Economic Dynamics, 2004 Meeting Papers.

Henriksen, E. R. (2002). A Demographic Explanation of U.S. and Japanese Current Account Behavior. Mimeo, Carnegie Mellon University, 2002.

Higgins, M. (1998). Demography, National Savings, and International Capital Flows. *International Economic Review*, 39(2):343–369.

IMF (2009). "World Economic Outlook Database". International Monetary Fund, October 2009, Washington DC.

IMF (2010a). From Stimulus to Consolidation: Revenue and Expenditure Policies in Advanced and Emerging Economies. Prepared by the Fiscal Affairs Department, International Monetary Fund.

IMF (2010b). Macroeconomic Effects of Public Pension Reforms. Prepared by Philippe Karam, Dirk Muir, Joana Pereira, and Anita Tuladhar, IMF Working Paper, International Monetary Fund.

IMF (2010c). *World Economic Outlook Database*. International Monetary Fund, October 2010, Washington DC.

Johnson, R. W. and Neumark, D. (1996). Wage Declines among Older Men. *The Review of Economics and Statistics*, 78(4):740–48.

Klein, M. W., Schuh, S., and Triest, R. K. (2003). Job creation, job destruction, and the real exchange rate. *Journal of International Economics*, 59.

Kotlikoff, L. J. and Gokhale, J. (1992). Estimating a firm's age-productivity profile using the present value of workers' earnings. *The Quarterly Journal of Economics*, 107(4):1215–42.

Kotlikoff, L. J., Smetters, K., and Walliser, J. (2007). Mitigating america's demographic dilemma by pre-funding social security. *Journal of Monetary Economics*, 54(2):247–266.

Krueger, D. and Ludwig, A. (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.

Ljungqvist, L. and Sargent, T. J. (2008). Two questions on european unemployment. *Econometrica*, 76(1):1–29.

Maddison, A. (2003). "The World Economy: Historical Statistics". OECD.

Martin, J. (1996). *Measures of Replacement Rates for the Purpose of International Comparisons: A Note*. OECD Economic Studies, No. 26, pp. 99-116.

Mendoza, E. G., Razin, A., and Tesar, L. L. (1994). Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption. *Journal of Monetary Economics*, 34(3):297–323.

Mortensen, D. and Pissarides, C. (1994). Job creation and job destruction in the theory of unemployment. *Review of Economic Studies*, 61.

Nickell, S. (1997). Unemployment and labor market rigidities: Europe versus north america. *Journal of Economic Perspectives*, 11(3):5574.

Nickell, S., Nunziata, L., and Ochel, W. (2005). Unemployment in the oecd since the 1960s. what do we know? *The Economic Journal*, 115.

Nishiyama, S. and Smetters, K. (2007). Does Social Security Privatization Produce Efficiency Gains? *The Quarterly Journal of Economics*, 122(4):1677–1719.

OECD (2009). Pensions at a Glance: Public Policies across OECD Countries. Organization for Economic Co-operation and Development, Paris.

OECD (2010a). OECD Employment Outlook 2010: Moving Beyond the Jobs Crisis. Organisation for Economic Co-operation and Development, Paris.

OECD (2010b). OECD Tax Database: Taxation on wage income, Part I. Organisation for Economic Co-operation and Development, Paris. (See also www.oecd.org/ctp/taxdatabase).

Ríos-Rull, J.-V. (2001). Population changes and capital accumulation: the aging of the baby boom. *Advances in Macroeconomics, The B.E. Journals in Macroeconomics*, 1(1).

Sánchez Martín, A. R. (2010). Endogenous retirement and public pension system reform in Spain. *Economic Modelling*, 27(1):336–349.

Song, Z. M., Storesletten, K., and Zilibotti, F. (2011). Growing like China. *American Economic Review*, 101(1):196–233.

United Nations (2010). World Population Prospects: The 2008 Revision. Department of Economic and Social Affairs, United Nations.

US Census (2000). "Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100 (Middle Series)". Population Projections Program, Population Division, Issued January 13, 2000, Washington: U.S. Census Bureau.

Vallin, J. and Meslé, F. (2001). Tables de mortalité françaises pour les XIXe et XXe siècles et projections pour le XXIe siècle. Données statistiques no 4, INED, Paris.

WDI (2006). World Development Indicators. World Bank, Washington DC.

Whitehouse, E., D'Addio, A., Chomik, R., and Reilly, A. (2009). Two Decades of Pension Reform: What has been Achieved and What Remains to be Done? *The Geneva Papers*, 34.

Appendix A: Calibration details on demography

Our demographic processes are based on several sources. Like Attanasio et al. (2007) and Krueger and Ludwig (2007), we use the United Nations' world population projections (United Nations, 2010), which provide data on the population by age class ($Z_{a,t}$) on a five-year basis for the United States and the countries of the EU15 between 1950 and 2050. Fertility and migration shocks at age 0, represented by x_t, reproduce the growth rate of the first age class. Moreover, in contrast to the two aforementioned studies, we use additional data to build the other demographic variables. To construct the survival probabilities, $\beta_{a,t+a}$, for the United States, we follow De Nardi et al. (1999) and Kotlikoff et al. (2007) and use the projections of the survival probabilities made by the US Social Security Administration from 1900 till 2100 (Bell and Miller, 2005). Survival probabilities from 1900 until 2100 for the EU15 are based on French data and borrowed from Vallin and Meslé (2001). Migration shocks at ages $a > 0$, $X_{a,t+a}$, are calibrated as differences between the population (by age group) generated by the $\beta_{a,t+a}$ and the population by age class of the United Nations. The population by age class before 1950 is constructed by keeping the population structure as it was in 1950 and using a scaling factor to reproduce the evolution of the total population over the 1900-1950 period, as in Maddison (2003). We further forecast demography beyond the UN forecasting horizon until 2200. For the US, we use the projections for the population by age class of the US Census (US Census, 2000), which reach the year 2100.[25] For later periods, probabilities to survive and fertility and migration in the year 2100 are held constant. For the EU15, the migration shocks experienced in 2050 are reported to successive periods. Because the survival probabilities vary until 2100, we can compute the population by age class between 2050 and 2100. After 2100, the survival probabilities and the fertility migration shocks of 2100 are held constant. This implies that the generation aged 25-29, the first age cohort in our model, becomes constant in size in 2125.[26] As a consequence, in both economies, the demographic steady state is reached in 2205. Afterwards, the demography is held constant, and the economy progressively reaches a steady state in successive periods. This strategy to calibrate the population dynamics is comparable to Krueger and Ludwig (2007) and Börsch-Supan et al. (2006), who assume a linearly increasing life expectancy beyond 2050 to forecast the population by age class over the 2050-2100 period. Our strategy also features an increasing life expectancy until 2100 and a stabilization of the population structure after 2200. However, in contrast to those studies, we make use of existing data and projections on survival probabilities.

[25]We use the growth rates by age class for the 2050-2100 period of the US Census (2000) data to extend the population by age class of the UN by using the scaling factor of the growth rate of the population by age class between 2045 and 2050. (For periods before 1950, the same could be done because we collected the recomposed historical population data by age class of the US Census rather than using the Maddison data.)

[26]In fact, in our demographic exercise we exploit the population data of all available age classes from 0-4 to 100-104. In the EU15, the 0-4 age class remains unchanged, i.e., demonstrates zero growth, from 2050 onwards in the EU15 and from 2100 onwards in the US. After 2100, the survival probabilities are held constant, and the 25-29 age class, i.e., the first age class in our model, stabilizes in 2125.

Appendix B: Replacement rates values in 2005

Transfers. Net replacement rates for unemployed workers vary a lot across countries and unemployment durations (OECD, 2009, Table 1.6.). They generally decrease after the first year of an unemployment spell. In the EU15, the net replacement rate decreases during the unemployment spell from 55.02% in the first year to 22.88% in the fifth year (OECD, 2009, Table 1.6, population-weighted averages). In the US, these values are 28% in the first year of unemployment and 0 afterwards. Given the values for tax rates described above, the *gross* replacement rate for the first year of unemployment is 48.27% in the EU15 and 25.86% in the US. The *gross* replacement rate over a five-year unemployment spell in both regions is set to a value corresponding to 90% of the respective gross replacement rates in the first year of an unemployment spell (see Table 1). These values imply *net* replacement rates of 49.5% for the EU15 and 25.2% for the US.[27]

The reference wage used to compute pension benefits is typically an average over the best years of activity. We set the reference wage at the average wage of workers aged 45-64 years. At a given replacement rate, our formulation implies that pensions are indexed on current wages. The values for the replacement rate ρ_t^j correspond to gross replacement rates by individual earnings level (mandatory pension programmes) reported by the OECD (2009). Hence, ρ^j equals 58.24% for the EU15 (population-weighted country average) and 38.6% for the US in 2005.

Gruber and Wise (2004, p.15) note that, in the US, the hazard rates outside of the labor force are close to 0 before age 54, increase gradually between 54 and 61 and then jump sharply at the first year of early retirement age (62). The low departure rates at ages 54-61 are due to the eligibility for early retirement under employer-provided pension plans rather than public pension schemes. Therefore, we set the replacement rate for early retirement for workers aged 55-59, ρ_6^e, to 0. Moreover, workers retiring between age 62 and the normal retirement age (NRA) face a reduction in their pension benefits (varying with the time to NRA and limited to each month before normal retirement age). For the US, the gross replacement rate for early retirement at ages 60-64, ρ_7^e, is set to 75% of the benefit a person receives at normal retirement age, ρ^j.[28] In contrast to the US, workers retiring before early retirement age in the EU15 may be compensated

[27] These values may seem large as they are closer to the net replacement rate for the first year of unemployment than they are to the average net replacement rate over five years of unemployment. This is especially true for the US, where the average net replacement rate over a five-year unemployment spell is only 5%. However, this choice is justified by the fact that, average unemployment duration in the US lies between 3 and 4.5 months over the 2003-2007 period, implying that the "effective" unemployment replacement rate is closer to the replacement rate for the first year of unemployment than it is to the average replacement rate. Moreover, the US proposed an Extended Benefits program, which provides 13 to 28 additional weeks of unemployment benefits (depending on the state).

[28] Normal (or full) retirement age (NRA) lies between 65 and 67 depending on a person's birth date (http://www.ssa.gov/pubs/10035.html#retirement).

through unemployment and disability programs or by large severance packages if they are laid off. However, as not every EU country provides old-age benefits to people retiring before age 60 and not every senior worker qualifies for such programs, ρ_6^e is set at a lower value than ρ_7^e (50% of ρ_7^e).[29] The value for the (gross) replacement rate at age 60-64, ρ_7^e, in the EU15 is based on OECD computations (see Duval, 2003, Figure 1).[30]

A last note concerns the target values for early retirement and activity rates for the age classes 55-59, 60-64 and 55-64 in Table 2. Because our analysis abstracts from people who are neither active nor early retired, senior activity rates are computed from the data (OECD, 2010a) by subtracting the fraction of people aged 55-64 who are neither contributors nor pensioners. This fraction is approximated by the proportion of non-active men aged 45-49 years over the 2003-2007 period. (Similar senior activity rates would be obtained from the data if the fraction of non-active and not early retired people corresponded to that of non-active people aged 25-54 or 40-44.) Finally, the early retirement rate of individuals aged 55-59 or 60-64, respectively, for the year 2005 are computed from OECD (2010a) data as the difference between the labor force participation rate of the 55-59 or 60-64 age classes, respectively, during the 2003-2007 period (yearly average) and that of the 50-54 or 55-59 age classes, respectively, during the 2000-2002 period (yearly average).

Appendix C: Historical values for replacement rates

Over the first half of the 20^{th} century, the evolution of the three replacement rates (unemployment and mandatory and early retirement) is calibrated using evidence concerning the estab-

[29]Computing early retirement replacement rates for a European country and, additionally, setting a unique value to represent the early retirement benefits for the whole EU15 region is not straightforward. In most countries, age 60 is the first opportunity of early retirement is 60. However, the effective early retirement age is ambiguous, as some countries provide unemployment and disability programs allowing for early retirement when a worker is younger than 60 (Gruber and Wise, 1999). For instance, in countries where such programs exist (e.g. Belgium, France, the Netherlands, Germany), departure rates from the labor force before the social security early retirement age are above 20 percent. This is, for example, the case for employees who are laid off and eligible for large benefits before age 60. In contrast, hazard rates before the first year of early retirement are much smaller in the United States (below 5%) and are instead due to private pension programs, as mentioned above (Gruber and Wise, 1999; Angelini et al., 2009). Additional complexity arises from the status classification system. In France, unemployed senior workers (above age 60) receive social security benefits and are classified as retired. In the Netherlands, the UK, Germany and Sweden, senior workers receiving disability benefits start to receive social security benefits at age 65 and are only then classified as retired (Gruber and Wise, 1999, p.28).

[30]Duval computes the average expected gross replacement rates at ages 60 and 65 for different earnings levels and marital statuses. We then use the ratio of replacement rates between ages 60 and 65 (based on Duval's estimates) and our value for replacement rate of pension benefits to fix ρ_7^e.

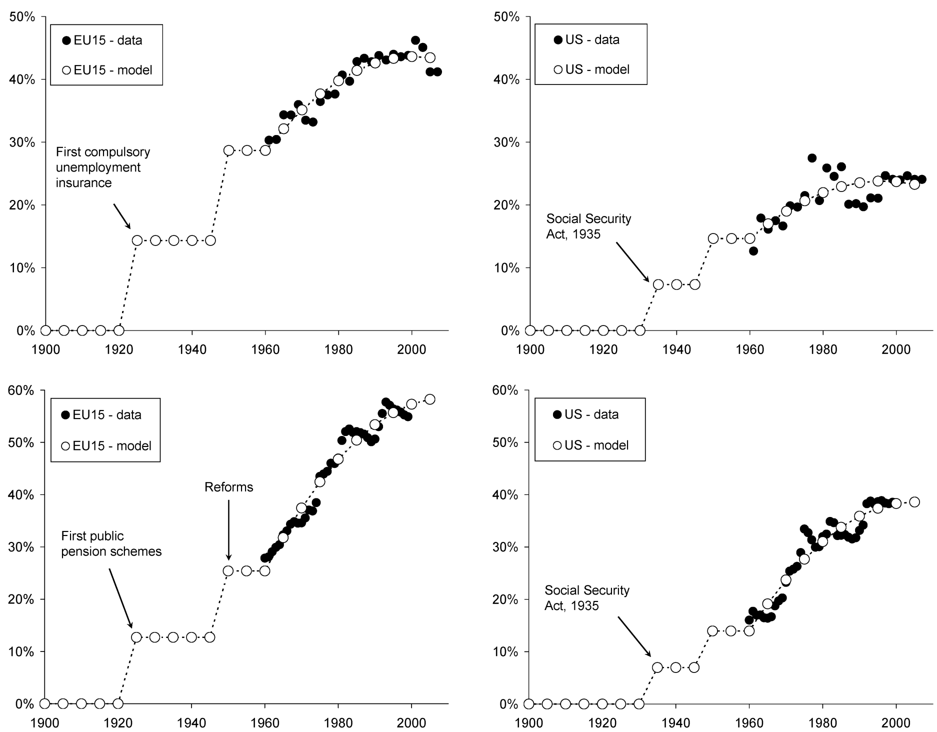
lishment of the various social insurance schemes in both regions. Over the second half of the 20^{th} century, the three replacement rates are calculated from available data.

Unemployment benefits: In the United States, before 1935, few states provided unemployment benefits on their own initiative, and only a few workers were covered by such schemes (Friedman, 1937). For this reason, the US replacement rate is set to zero from 1900 to 1930. The federal government established the first nationwide structure for unemployment compensation with the approval of the Social Security Act on August 14, 1935. By the end of 1936, 35 states had passed unemployment compensation laws covering about 18 million people. From 1935 to 1945, the replacement rate was constant and equalled half the value in 1960. According to the observation that social welfare transfers experienced a rapid rise in the 1960s and 1970s (see below), the replacement rate is held constant from 1950 to 1960, and it starts to rise continuously from 1960 onwards. The evolution of the (gross) unemployment replacement rate over the 1960-2005 period is calculated from the OECD's "summary measure of benefit entitlements", a bi-annual dataset collected over the 1961-2007 period (see also Martin, 1996). The OECD summary measure is defined as the average of the gross unemployment benefit replacement rates for two earnings levels, three family situations and three durations of unemployment. The data are plotted in the top panels of Figure 12 and normalized to the model's value for unemployment replacement rates in 2005 (see Table 1). From these data, a second-order polynomial trend for the unemployment replacement rate is specified. In the EU15, (only) voluntary unemployment benefit plans were established in several continental European cities between 1890 and World War I. The first national compulsory unemployment insurance system in any country was established by Great Britain in 1911, followed by Italy 8 years later. Over the next decade, other European countries established such schemes, covering 35 million people by 1937 (Friedman, 1937). Therefore, the EU15 replacement rate is set to zero from 1900 to 1920 and constant at half of the value in 1960 from 1925 to 1945. In 1950 and 1955, the replacement rate is equal to the rate in 1960, and from 1960 to 2005 it rises according to the trend calculated from the OECD data described above.[31]

Mandatory (normal) retirement benefits: The introduction of public pension systems largely occurred in the first half of the 20^{th} century, and most countries introduced pay-as-you-go pension schemes in the aftermath of World War II. In the United States, before 1935, old age support was left to state initiative and most elderly relied on support from their extended family (Capretta, 2007). The Social Security Act in 1935 established the first national system of old-age benefits, which was designed to pay benefits to retired workers aged 65 and older (Friedman, 1937).

[31] Note that the EU15 trend calculation does not make use of the Luxembourg (available only for few years) and Italian data. The reason for excluding Italy is that the OECD values for Italy are very low until the 1990s because the OECD accounts only for the "ordinary" unemployment benefits and excludes various other benefits provided by the Italian system, like those for short-time work (Martin, 1996, Annex).

Figure 12: Replacement rates: unemployment (top) and mandatory pensions (bottom)



Coverage remained limited, however, and the pension benefit was modest (Capretta, 2007). According to this evidence, the replacement rate is set to zero from 1900 to 1930. From 1935 to 1945, the replacement rate is set to half of the rate in 1960, and between 1950 and 1960 it is constant.According to Whitehouse et al. (2009), there was a rapid, real growth in pensions during the 1960s and 1970s (see also Blöndal and Scarpetta, 1998, Table III.3). Between 1960 and 2005, the change in the replacement rates for normal retirement is approximated by the change in social benefits as a percentage of GDP, which originates from OECD data over the 1960-1999 period (Cornelisse and Goudswaard, 2001, Annex 1). The data are plotted in the bottom panels of Figure 12 for the EU15 (left panel) and the US (right panel) and normalized to the model's value for pension replacement rates in 2005 (see Table 1). Again, a second-order polynomial trend shapes the evolution of mandatory retirement replacement rates over the 1950-2005 period. In the EU15, most countries introduced a first public pension scheme before or around World War I: Germany in 1889, France in 1910, Italy in 1919, Belgium in 1924 and Finland in 1937 (Ebbinghaus and Gronwald, 2010, Table 1). The EU15's average year of the first pension scheme was 1920, and accordingly, the replacement rate is set to zero from 1900 to 1915. The coverage of these first schemes was often limited to a certain type of worker (e.g. blue-collar workers in Germany). Thus, from 1920 to 1945, the pension replacement rate is assumed to be constant (as a result of the insecure interwar and World War II periods) and to be half of the value in 1950. The pension schemes evolved after World War II (being either reinforced or reformed). These changes occurred between 1945 (France, Belgium) and 1956 (Denmark, Finland, Netherlands), thus, on average, around 1950 (Ebbinghaus and Gronwald, 2010, Table 1). The replacement rate is therefore higher from 1950 onwards. It is constant between 1950 and 1960, and from then on, the replacement rate follows the trend computed from the above-mentioned OECD data in Cornelisse and Goudswaard (2001).

Early retirement benefits: In the United States, early eligibility for retirement benefits was introduced in 1961 (Gruber and Wise, 1999). As a consequence, the replacement rate for early retirement is set to zero before 1960. From 1960 onwards, it evolves like the replacement rate for normal pension benefits. Early retirement was implemented in Germany in 1972 and in France in the early 1970s (Gruber and Wise, 1999). Accordingly, the replacement rate equals zero before 1970 and follows the same path as that of normal pension benefits from 1970 onwards.

Appendix D: Future pension reforms

Pension expenditures and future pension reforms. Our baseline leads to a cost of public pensions equal to 6.16% of GDP in the US and to 12.72% in the EU15 in 2005. These values are reasonably close to those reported by the OECD for 2005 (OECD, 2009, p.139) and to the official estimate by the European Commission (2009a) for the EU15. The former study presents pension expenditures that amount to 6.0% of GDP in the US and 10.5% in the EU15 (or 12.5% when considering only the largest continental countries: Germany, France and Italy). Population aging is expected to lead to substantial increases in public pension spending in advanced countries. To limit the rise in pension expenditures, several countries have undertaken significant reforms of their pay-as-you-go pension systems (see IMF, 2010a, Appendices IV and V). In the United States, the 1983 reform included an increased payroll tax, taxes on social security benefits, the inclusion of federal employees in the base of participants and a postponement of the normal retirement age from 65 years to 67 years in 2027. Several EU15 countries have also adopted pension reforms. For instance, in France, the reforms of 1993 and 2003 expanded the calculation of the reference wage to consider a larger period, indexed it to prices rather than wages and increased the number of years of activity required to have full pension rights.

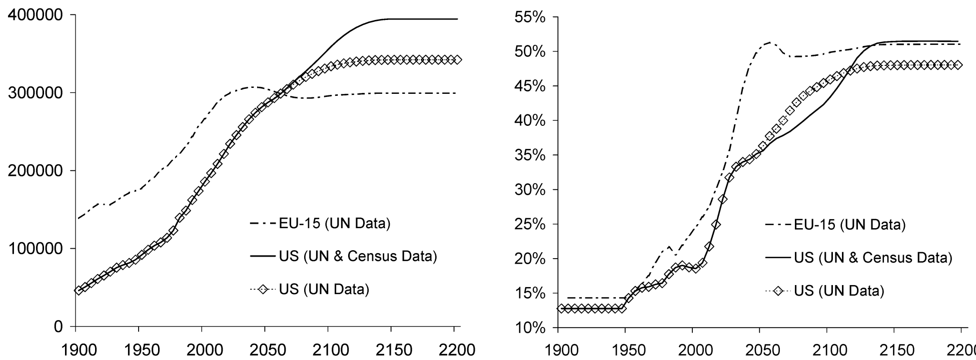
When accounting for the effects of legislated future policy reforms, pension expenditures should increase by 1 per cent of GDP in the US over the 2010-2030 period (IMF, 2010b, Figure 1). For the EU15, public pension spending is expected to increase by 7.7 per cent of GDP between 2007 and 2060 (relative increase of 75.5%) as a result of the demographic effect via the dependency ratio (European Commission, 2009a, p.39, Table 5). However, if the effects of policy reforms are taken into account, the expected increase is only 2.4 percentage points during the same period. Our baseline scenario incorporates such reforms via progressive decreases in the replacement rate over the coming years. It implies, in both regions, a 20 per cent decrease of the replacement rate defined above by 2030 (and a 30 per cent decrease by 2055). The replacement rate for early retirement is assumed to remain constant. With these assumed changes in pension replacement rates, public pension expenditures to GDP increase by similar magnitudes in our baseline as those projected in the aforementioned studies: over the 2005-2060 period, public pension spending rises by 1.43 per cent of GDP in the US (1.83% from 2005 to 2030) and by 2.74% in the EU15 (1.61% from 2005 to 2030).

Finally, when abstracting from future policy changes, the rise in public pensions predicted by our model is also remarkably close to changes in public pension expenditures forecasted by analyses that consider only the effects of demographic trends. For the United States, Bongaarts (2004) reports an expected rise in public pension expenditures from 8% to 14% of earnings between 2000 and 2050, with most of the change occurring between 2000 and 2030. Without considering any future pension reform, our model yields, for the US, an increase of 4.51 percentage points in the cost of public spending between 2000 and 2050 (5.38 between 2000 and 2100). In the EU15, public pension spending increases from 12.84% of GDP in 2005 to 22.36% in 2060 (relative increase of 74%). The EU15 would suffer an increment of 9.80% of GDP in public pension spending between 2000 and 2100, of which 8.96 per cent would occur between 2000 and 2040. Besides, the fact that most of this increase occurs before 2040 is also compatible with the European Commission's findings: the cost of public pensions is expected to increase by more than 2 percentage points during the periods of 2007-20, 2020-30 and 2030-40, but only by 1 pp between 2040 and 2050 and by less than 1 pp between 2050 and 2060 (European Commission, 2009a, projections for the EU-27, p.38, Graph 3).

Appendix E: Alternative US demography

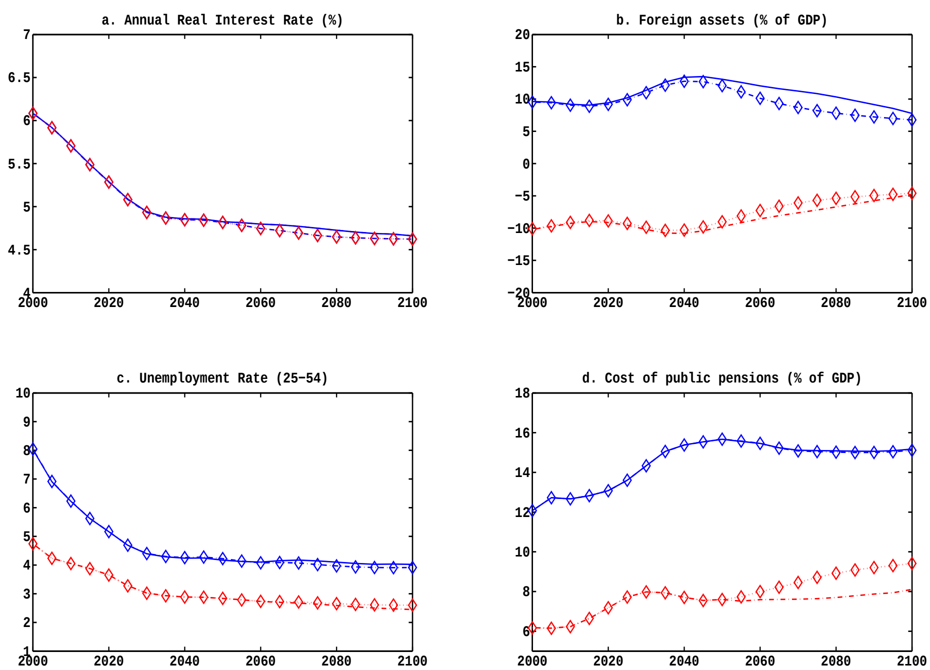
The EU15 demography is based on the United Nations' data over the 1950-2050 period, whereas the US demography also include additional data from the US Census for the 2050-2100 period. In this section, we check by how much our findings would change if we did not use this additional data for the US demography. Figure 13.a shows that the population of the US would increase by less if using only 'US (UN Data)' than when also using the additional data from the US Census, series 'US (UN & Census Data)'. This finding indicates that US Census projections assume that the US population is characterized by positive growth rates over the 2050-2100 period. Figure 13.b indicates that the dependency ratio would increase more steeply if we did not account for these additional information (series 'US (UN Data)'). However, the dependency ratio increases

Figure 13: Population (+25) and Dependency ratio (25-64 over 65+)



'EU15 (UN Data)' (·-·) and 'US (UN & Census Data)' are the projections data used in the benchmark case, whereas 'US (UN Data)' (·◇·) refers to the case where only UN data are used to calibrate the US demography.

Figure 14: Europe-15 and United States



Europe-15 (—) and United States (·-·),

EU15 with alternative US demography (—◇—) and US with alternative US demography (·◇·).

less in the long run (after 2100) because the decreasing fertility and mortality rates apply to the 'additional' people of the 'US (UN & Census Data)' series.

Figure 14 shows that the impact on the baseline (global economy) of using the alternative US demography (line with diamonds). Up to the year 2050, there is no difference compared with our preferred demographic calibration (lines without symbols). Small differences between the two demographic specifications appear after 2050. The international interest rate is decreased by an additional 0.1 percentage point with the alternative US demography. The cost of public pensions rises by an additional 2 percentage points with this alternative US demography (because it does not account for the positive population growth rates over the 2050-2100 period forecasted by the US Census).

Because the focus is on labor market outcomes, past generosity of unemployment benefits is calibrated to the available data. The evolution of unemployment replacement rates is calculated from the OECD "summary measure of benefit entitlements", a bi-annual dataset over the 1961-2007 period, based on Martin (1996). Replacement rates for normal and early retirement are supposed to follow the evolution of social benefits as a percentage of GDP, based on OECD data over the 1960-1999 period (Cornelisse and Goudswaard, 2001, Annex 1). Finally, the evolution of the three replacement rates (unemployment and mandatory and early retirement) over the first half of the 20^{th} century is based on additional references on the establishment of the various social insurance schemes in both regions (see Appendix B for further details).

Institut de Recherches Économiques et Sociales
Université catholique de Louvain

Place Montesquieu, 3
1348 Louvain-la-Neuve, Belgique

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ISSN 1379-244X D/2011/3082/040