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Aging, Pension Reform, and Capital Flows: A Multi-Country Simulation Model

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Abstract: We present a quantitative analysis of the effects of population aging and pension reform on international capital markets. First, demographic change alters the time path of aggregate savings within each country. Second, this process may be amplified when a pension reform shifts old-age provision towards more pre-funding. Third, while the patterns of population aging are similar in most countries, timing and initial conditions differ substantially. Hence, to the extent that capital is internationally mobile, population aging will induce capital flows between countries. All three effects influence the rate of return to capital and interact with the demand for capital in production and with labor supply. In order to quantify these effects, we develop a computational general equilibrium model. We feed this multi-country overlapping generations model with detailed long-term demographic projections for seven world regions. Our simulations indicate that capital flows from fast-aging regions to the rest of the world will initially be substantial but that trends are reversed when households decumulate savings. We also conclude that closed-economy models of pension reform miss quantitatively important effects of international capital mobility.

Keywords: aging; pension reform; capital mobility
JEL classification: E27; F21; G15; H55; J11

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1. Introduction

In the vast majority of countries, populations are aging, and demographic change will continue well into the 21st century. While the fact of population aging is common to most countries, extent and timing differ substantially, even within the industrialized countries. It is well known that within each country, demographic change alters the time path of aggregate savings. In a world of closed economies, differential aging will generate additional international differences in saving rates, investment, and rates of return. These differences are likely to be accentuated when some countries implement fundamental pension reforms – that is, shifts towards more pre-funding, induced by the effects of population aging on public pension budgets. In reality, we do not have closed economies but global capital markets. To the extent that capital is internationally mobile, population aging will therefore induce capital flows between countries, and these capital flows will modify the effects of population aging and pension reform in each county vis-à-vis a world of closed economies. This paper focuses on these effects of population aging and pension reform on international capital markets and other key macroeconomic variables.

We present a quantitative analysis of capital and labor market effects and, in particular, capital flows induced by differential aging processes across countries and by pension reforms. To this end, we develop a stylized multi-country overlapping generations (OLG) model, feed it with detailed demographic information, and then project macroeconomic aggregates such as international capital flows over a 70-year horizon using long-term demographic projections for different sets of countries and regions. Although all countries and regions are modeled symmetrically as large open economies, our presentation focuses on continental Europe as one of the world regions most severely affected by aging. At the same time, pension systems in continental Europe are dominated by still relatively generous pay-as-you-go (PAYG) financed public pensions.

The "triangular" relationship between population aging, pension reform and international capital markets receives increasing attention in the academic literature, see Börsch-Supan, Ludwig, and Winter (2002), Börsch-Supan, Köke, and Winter (2004), INGENUE (2002), and Fehr, Jokisch, and Kotlikoff (2003, 2004). We use a rich modeling framework which allows us to address different strands of the academic literature. First, our analysis is related to several recent papers that compare implications for capital flows predicted by OLG models with actual current account data (see, e.g., Brooks, 2003; Feroli, 2002; Henriksen, 2002; Dmoeij and Floden, 2004). Their as well as our analysis show that calibrated OLG models explain a good fraction of the low frequency movements of international capital flows as observed in the data. In addition, we show that the existence of PAYG pension systems in different world regions adds an additional indirect channel to the interaction between capital flows and demographic change. This channel is of particular importance if countries severely affected by the impact of population aging such as the continental European countries reform their pension systems.

Second, our paper adds to the discussion about the so-called “asset market meltdown hypothesis”. Several articles in the popular press have attributed recent turbulences in stock market prices to population aging and raised the fear that an asset market meltdown might occur when the baby boom generation decumulates its assets. In the academic literature, there is no consensus on the asset market meltdown hypothesis (see e.g. Poterba, 2001; Abel, 2001; and Brooks, 2002). According to our view, closed-economy models often used in the academic literature miss the important fact of international capital flows. We show that because of international diversification, the dynamics of capital accumulation and rates of return are different from what would be predicted by closed-economy models. One of the main goals of this paper is to analyze and quantify these mechanisms.

Third, our paper sheds light on the effects of international diversification on savings behavior and its interaction with pension reforms. This topic has received increasing attention as the pension reform debate progresses. Deardorff (1985) contains an early analysis, and Reisen (2000) provides a comprehensive overview of these issues. Reisen argues that there are pension-improving benefits of global asset diversification. In a theoretical paper, Pemberton (1999) highlights the importance of international externalities caused by the effects of national pension and savings policies on the world interest rate. Pemberton (2000) goes a step further and shows that an intergenerational Pareto improvement through coordinated pension reforms is possible. We will not tackle this policy issue; our welfare analysis is restricted to the direct welfare effects of population aging, pension reform, and capital mobility.

Finally, from an economic modeling perspective, this paper furthers our understanding of the various interactions among different features of calibrated OLG models. To this end, we present a sensitivity analysis that focuses on the role of including or excluding these features in our model. This approach allows us, for instance, to compare the effects of demographic change and of fundamental pension reforms in a model with and without endogenous labor supply. In addition, we present a standard sensitivity analysis concerning the role of the main elasticity parameters.

Our simulations predict substantial capital flows due to population aging. Population aging results in decreases of the capital-to-output ratio when the baby boomers decumulate their assets. International capital flows follow this trend. The countries most affected by aging such as the European Union will initially be capital exporters, while countries less affected by aging like the United States und other OECD regions will import capital. However, since households decumulate their assets, capital exports from these fast aging countries to the rest of the world decrease and therefore fast aging countries are projected to become capital import countries around the year 2020. Pension reforms with higher degrees of pre-funding are likely to induce more capital exports. They also increase labor supply considerably, while the effects on the rate of return to capital are small. While the rate of return is projected to decline in response to population aging, there is no devastating "asset meltdown".

The remainder of this paper is structured as follows. Section 2 presents empirical evidence on, and theoretical explanations for, the effects of population aging on international capital flows. In section 3, we present a multi-country OLG model that allows to evaluate these effects quantitatively. Section 4 describes the calibration of the model and displays indicators of *ex post* fit. Section 5 contains our *ex ante* simulation results for several pension policy and capital mobility scenarios. Section 6 presents an extensive sensitivity analysis. Section 7 concludes.

2. Some facts about population aging and international capital flows

Throughout the world, demographic processes are determined by the demographic transition which is characterized by falling mortality rates followed by a decline in birth rates, resulting in population aging and reducing the population growth rate (in some countries, even turning it negative). While patterns of demographic change are similar in most countries, extent and timing differ substantially. Europe and some Asian countries have almost passed the closing stages of the demographic transition process while Latin America is only at the beginning stages (Bloom and Williamson, 1998). North America is in between. So far, characteristics of a demographic transition process cannot be identified in Africa – fertility is at the highest level worldwide, and even though child mortality is declining, life expectancy is still very low (United Nations, 2001).[1]

[1] Only in part due to the enormous impact of AIDS.

In order to capture projected differences in demographic change across the world (particularly within the European Union) and differences in the generosity of public pension systems, we distinguish seven world regions in our benchmark scenario: (i) France, (ii) Germany , (iii) Italy as three European countries severely affected by population aging, (iv) the remainder of the European Union, (v) North America (the US and Canada), (vi) the remaining OECD countries, and (vii) all other countries in the world. While we treat France, Germany, and Italy as separate countries in our simulations, we simplify the presentation by aggregating them, except for Sections 5.4 and 5.5, where we present some results at the individual countries' level.

Figure 1, based on United Nations (2001), shows for these regions the effects of demographic change on two important demographic measures, the working age population ratio (the number of persons aged 15 to 65 as a percentage of total population) and the old-age dependency ratio (the number of persons older than 65 as a percentage of the working age population).

--- Figure 1 goes about here ---

A number of lessons can be learned from these graphs. First, all the world regions that we consider are affected by the consequences of demographic change – increasing life expectancies and falling fertility rates – resulting in decreasing working age population ratios and increasing old-age dependency ratios. Second, while working-age population ratios are more or less identical in 2000 for the OECD countries, the decrease in working age population ratio is strongest for the European Union countries, especially the three-country group of France, Germany, and Italy. Third, the latter group has the highest level of the old-age dependency ratio. Forth, there are significant differences in the timing and the pattern of demographic change across regions. As we will see, these different patterns have profound implications for the evolution of saving rates, rates of return, and international capital flows.

From a macroeconomic point of view, population aging will change the balance between capital and labor, in particular in industrialized countries. Labor supply will be scarce whereas capital will be relatively abundant. This will drive up wages relative to the rate of return on capital, reducing households' incentive to save (if the interest elasticity of saving is positive).

Differences in timing of demographic change across countries and regions induce international capital flows. Theoretical arguments that establish this link build on the well-known life-cycle theory of consumption and savings by Modigliani, Ando and Brumberg (Modigliani and Brumberg, 1954; Ando and Modigliani, 1963). The aggregation of individual, cohort-specific life-cycle savings profiles leads to a decrease of national saving rates in an aging economy. In a general equilibrium model of forward-looking individuals, it is not only the current demographic structure that alters the time path of aggregate savings, but also future demographic developments. There are two main channels for effects of demographic change on domestic capital formation. First, decreasing labor supply reduces demand for investment goods since less capital is needed. Second, in a closed economy, a decline in national savings leads to a decline in investment by definition. In an open economy, the link between these two aggregates is broken to the extent that capital is internationally mobile, see below.

Empirical evidence on how demographic change has affected saving behavior across countries in the past is reviewed by Poterba (2001). Following earlier work by Higgins (1998) and others, Lührmann (2003) investigates whether demographic factors have influenced international capital flows in the past. She uses a broad panel of 141 countries that covers the period 1960-1997 to investigate the effects of demographics on international capital flows. She confirms that cross-country capital flows are indeed influenced by demographic variables. Moreover, she shows that relative differences in the age structure across countries are the most important determinants of capital flows. In addition, Lührmann (2003) shows that future changes in the age structure of countries are important determinants of current saving and investment decisions, a finding that confirms forward-looking household behavior.

For quantitative projections of international capital flows induced by population aging, the degree of capital mobility is crucial. This is essentially an empirical question, and there has been no shortage of research on this issue since the famous puzzle of Feldstein and Horioka (1980).[2] In their original contribution, Feldstein and Horioka have shown that national saving and investment rates are highly correlated in virtually all OECD countries. While the coefficient has fallen over time, it is still remarkably high. These findings have been interpreted as an indication that capital is imperfectly mobile. However, there is no lack of alternative explanations for the observed correlation. For example, high correlations between saving and investment rates are consistent with perfect capital mobility in a growth model with demographic change and technological progress, as pointed out by Obstfeld (1986); see also Baxter and Crucini (1993), Taylor (1994), Obstfeld and Rogoff (1996), and Obstfeld and Rogoff (2000).

Even if capital is fully mobile, this does not necessarily imply that households do actually diversify their portfolios optimally. There is a large empirical literature on 'home bias' in inter-

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[2] See Obstfeld and Rogoff (1996) and Coakley, Kulasi, and Smith (1998) for surveys of the literature.

national portfolio choice (e.g., French and Poterba, 1991), and it is not yet fully understood why households do not optimally diversify their portfolios across countries. Portes and Rey (2004) suggest that information asymmetries across countries are a major source of home bias effects and that capital flows are affected by both geographic and informational proximity. Applied to pension reform policies, this literature suggests that households might be more willing to invest their retirement savings in 'similar' countries such as the EU or OECD countries than in, say, developing countries. For the lack of a better model of capital mobility, we do not construct a symmetric model but build several capital mobility scenarios from the point of view taken by the three largest economies in continental Europe (France, Germany, and Italy). We then model the polar cases of France, Germany, and Italy being a closed capital market and of perfect capital mobility within large regions. The regions we consider are the entire EU, the entire OECD, and the entire world. This approach allows us to understand the effects of capital mobility on savings, investment, and rates of return in the future even though the true effect might be smaller.

3. A dynamic, open-economy macroeconomic model

In this section, we present a dynamic macroeconomic model that allows us to analyze the effects of population aging and of a shift from a pay-as-you-go system to a (partially) funded pension system, induced by the pressure of population aging on public pension budgets. The model is based on a version of the overlapping generations model (Samuelson, 1958; Diamond, 1965) introduced by Auerbach and Kotlikoff (1987, chapter 3). Overlapping generations (OLG) models have been used extensively to study the effects of population aging on social security systems, a purpose for which they are well suited since they are based on households' and firms' optimal reactions to movements in the demographic structure and public policy measures.

Overlapping generations models have been used to analyze international capital flows since the seminal contribution by Buiter (1981). More recently, several authors have developed large-scale multi-country OLG models to study the effects of population aging and pension reform on international capital flows. While Attanasio and Violante (2000) focus on how the Latin American demographic transition affects international capital markets, Brooks (2003), Feroli (2002), Henriksen (2002) and Domeij and Floden (2004) examine capital flows in multi-regional OLG models.

Our paper improves in several dimensions on the existing literature. The above papers do not model PAYG pension systems and accordingly do not address the important issue of pension reform with its associated changes in saving patterns which in turn have implications on international capital flows.[3] Issues related to pension reform are also addressed by INGENUE (2001) and Fehr, Jokisch, and Kotlikoff (2003, 2004). We improve on these papers because we use more detailed demographic projections which model the various dimensions of demographic change, and we carefully distinguish between the effects of population aging and population shrinkage. Our work shows that the delicate effects of the differential timing of demographic change across countries on macroeconomic aggregates and capital flows can only be assessed with realistic demographic forecasts; they are largely ignored in the stylized demographic transition schemes used in other work. Unlike INGENUE (2001), we explicitly take three single European countries (France, Germany, and Italy) as examples for countries that are differently affected by population aging within Europe. France is aging much less than Germany and Italy. Accordingly, we do not only analyze capital flows from Europe to the rest of the world but also the resulting intra-European capital flows. They are of particular interest since they are not subject to exchange rate risks. Furthermore, we account for differences in the generosity of pension systems and simulate the impact of a stylized pension reform in the regions of our model.

An earlier version of the model used in this study was presented by Börsch-Supan, Ludwig, and Winter (2002). We modify and improve our earlier model along several dimensions. First, we extend the focus of our analysis to the entire European Union and no longer focus on Germany (exclusively). Second, we model endogenous labor supply decisions and hence implement important feedback effects due to differences in the relative returns on capital and labor which result from population aging. Third, we follow Abel (2001), Altig, et al. (2001) and Fehr, Jokisch, and Kotlikoff (2003, 2004) by including adjustment costs to capital in our analysis. Forth, we allow for life-time uncertainty in the household optimization problem, and we explicitly model age-specific productivity. Fifth, we start our calculations with a phase-in period of 150 years in order to relax the contrafactual assumption of a steady state in 2000. This is important for two reasons: it allows us to analyze how our model matches empirical counterparts of long time series of data, especially international capital flows and labor supply. We also avoid distortions due to adjustments of the model towards an equilibrium path which result from the arbitrary imposition of an initial steady state or other initial conditions.

[3] An exception is Domeij and Floden (2004) who model pension systems but do not address pension reforms.

The model has three building blocks: a demographic projection, a stylized pension system, and a macroeconomic overlapping generations model which generates the general equilibrium of the internationally linked economies.

3.1 The demographic projection model

Detailed demographic projections form the background of our analysis. Demography is taken as exogenous and represents the main driving force of our simulation model.[4] In each country i, the size of population of age j in period t, $N_{t,j,i}$, is given recursively by

(1) $$N_{t,j,i} = N_{t-1,j-1,i}(s_{t-1,j-1,i} + m_{t-1,j-1,i}) \quad \text{for} \quad j > 0 \quad \text{and} \quad N_{t,0,i} = \sum_{j=15}^{50} f_{t-1,j,i} N_{t-1,j,i}$$

where $s_{t,j,i}$ denotes the age-specific conditional survival rate, $m_{t,j,i}$ the net migration ratio, and $f_{t,j,i}$ the age-specific fertility rate.

Our demographic projections are based on the assumptions underlying the United Nations' demographic projections (United Nations, 2001). Population data are given at an annual frequency for the period 1950-2050 for age-groups of five. Further input data such as age-group specific mortality rates, life expectancy, and aggregate migration is only given at quinnquennial frequency. We interpolate between age groups and time intervals and "backfit" our population model to the UN population data for the time period 1950-2050. Furthermore, we forecast beyond the UN horizon of 2050 and assume that demographic processes stabilize after year 2200 by assuming constant mortality and fertility rates, see below.

The individuals in our model economies enter economic life at age 20 which we denote by a=1. The maximum age as implied by the demographic projections is 104 years. Accordingly the maximum economic age, denoted by Z, is 85. To simplify calculations in our economic model, we assume that all migration takes place at the initial age of 20. This simplifying assumption allows us to treat all "newborns" – immigrants and natives – in our economic model alike.[5]

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[4] We are aware that in the long run, neither fertility nor mortality is exogenous to economic growth. Migration reacts to international income differences also in the short-run. The literature, however, has so far not provided robust estimates of the elasticities of demographic movements to economic circumstances suitable for inclusion in this OLG model. This is an important area for further research.

[5] Both groups, newborns and immigrants, enter the economic model with zero assets. Furthermore, there are no skill differences between the two groups as, e.g., analyzed by Razin and Sadka (1999) and Storesletten (2000).

3.2 The stylized pension systems

Each region is assumed to have a two-tier pension system. The first tier represents a conventional public pay-as-you-go (PAYG) system characterized by a country-specific contribution and replacement rate. More precisely, for each region *i,* the exogenous policy variable is the time-specific gross replacement rate, $\gamma_{t,i}$, defined as the ratio of average gross pension to average gross wage income at time *t*. The budget of the PAYG pension system is balanced at any time *t* and determines the contribution rate, $\tau_{t,i}$, by

(2) $$\tau_{t,i}\sum_{a=1}^{Z} w^{g}_{t,a,i} l_{t,a,i} N_{t,a,i} = \sum_{a=1}^{Z} p_{c,a,i}(1-l_{t,a,i}) N_{t,a,i},$$

where the pension benefits $p_{c,a,i}$ for cohort *c=t-a* are computed as

(3) $$p_{c,a,i} = \gamma_{t,i}\sum_{a=1}^{Z}\lambda_{t,a,i} w^{g}_{t,a,i}$$

On the revenue side, $w^{g}_{t,a,i}$ denotes age-specific gross wages. Net wages are given by $w^{n}_{t,a,i} = w^{g}_{t,a,i}(1-\tau_{t,i}/2)$ where half of contributions are paid by the employee and the other half by the employer. This latter half will be taken into account when firms maximize profits. $l_{t,a,i}$ denotes labor supply resulting from optimal household decisions and $N_{t,a,i}$ the number of contributors of age *a* at time *t* in country *i*.

On the benefit side of the budget equation, pensions are defined by the general replacement rate $\gamma_{t,i}$ and by a "point system" that credits $\lambda_{t,a,i}$ times the gross wage earned at age *a*. This fits well the actual computation in France, Germany, and Italy. Benefits are not taxed and we ignore interactions with other social protection systems, such as health insurance. We assume that all persons in each region participate in the same pension system.

The second tier of our stylized pension system represents pre-funded private pensions.[6] We do not explicitly model this funded component of the pension system. Rather, it consists of voluntary private savings as it results from the households' optimal life-cycle decisions. Households react to their intertemporal budget constraints which include the benefit level of public pensions. Rational forward-looking behavior of households implies that households adjust their voluntary savings in response to the public pension replacement rates.

[6] In the language of the World Bank, this second tier corresponds to the "third pillar".

To separate the direct effects of population aging on capital markets and potential feedback effects from pension reform, we present our projections for two future counterfactual pension system scenarios which we apply to the first region consisting of the three large continental European countries:

(a) Under the "old system scenario", the 2006 replacement rates are maintained through our projection period, which, due to population aging, results in rising contribution rates.

(b) Under the "reform scenario", the 2006 contribution rates are frozen, which results in decreasing replacement rates.

These two pension system scenarios are extreme cases. While they are both counterfactual, they help us sharpen the effects of pension reform. The "old system scenario" projects the dominant and monolithic PAYG systems of the 1990s into the future. In fact, however, substantive reform steps are under way in France, Germany, and Italy. In turn, our "reform scenario" introduces faster and deeper transitions to partially funded multi-pillar pension systems than they are currently envisaged in the three countries. We assume that this pension reform is announced in 2004 and implemented in 2006. This leaves households with an adjustment period of two years prior to implementation of the reform.

3.3 The overlapping generations model

The two core elements of the macroeconomic general equilibrium model are the production and the household sector.

The production sector in each country consists of a representative firm that uses a CES production function given by

$$(4) \qquad Y_{t,i} = F(\Omega_i, K_{t,i}, L_{t,i}) = \Omega_i \cdot \left[\alpha_i K_{t,i}^{-\theta_i} + (1-\alpha_i) L_{t,i}^{-\theta_i}\right]^{-\frac{1}{\theta_i}} \cdot,$$

where $K_{t,i}$ denotes the capital stock and $L_{t,i}$ the labor supply of country i at time t. Labor supply $L_{t,i}$ is measured in efficiency units. α_i is the capital share. The elasticity of substitution between the factors of production, capital and labor, is given by $\beta_i = 1/(1+\theta_i)$.

Production efficiency of a household of age a at time t in country i has a factorial structure with three elements, relating to age, time and country. On the micro level, where households are distinguished by their age, labor productivity changes over the life-cycle according to age-specific productivity parameters ε_a. Hence, the age-specific gross wage is $w^g_{t,a,i} = w^g_{t,i} \cdot \varepsilon_a$ and the aggregate labor supply is $L_{t,i} = \sum_{a=1}^{Z} \varepsilon_a l_{t,a,i} N_{t,a,i}$ where $l_{t,a,i}$ denotes a single household's labor supply.

Second, aggregate and individual labor supply ($L_{t,i}$ and $l_{t,a,i}$) are measured in efficiency units relative to a time endowment E_t. The actual age specific labor supply which corresponds to what is observed in the data is therefore given by $L^{actual}_{t,a,i} = \frac{l_{t,a,i} N_{t,a,i}}{E_t}$. The time endowment increases over time according to $E_{t+1} = E_t(1+g_t)$. This "growth in time endowment" specification is equivalent to the standard labor augmenting technological change specification for the production sector and has useful properties for the specification of the household sector, see below.

Third, Ω_i is the technology level of country *i*. In order to isolate the effects of differential population aging from the effects of differential technological progress, we keep Ω_i constant over time in this version of the model. For the same reason, we do not index E_t by country. We calibrate Ω_i such that aggregate detrended GDP averaged over the calibration period is replicated in each country, see below.

We assume that investment is subject to convex adjustment costs (Hayashi, 1982) with a proportionality factor ψ_i. The dynamic problem of the firm is given by

(5) $$\max_{\{K_{i,t}\}_{t=1}^{T}, \{L_{i,t}\}_{t=1}^{T}, \{I_{i,t}\}_{t=1}^{T}} \sum_{t=0}^{\infty} d^f_{i,t} F\left(\Omega_i K_{t,i}, L_{t,i}\right) - I_{t,i} - C(I_{t,i}, K_{t,i}) - w^g_{t,i} L_{t,i}\left(1 + \tau_{t,i}/2\right)$$

subject to

(6) $$C(I_{t,i}, K_{t,i}) = \frac{\psi_i}{2} \frac{I^2_{t,i}}{K_{t,i}} \text{ and}$$

(7) $$I_{t,i} = K_{t+1,i} - K_{t,i}\left(1 - \delta_i\right),$$

where $d^f_{t,i}$ is the firm's discount factor defined by $d^f_{t,i} = \prod_{s=1}^{t} (1 + r_{s,i})^{-1}$ and δ_i is the rate of depreciation of capital. The adjustment cost formulation in equation 6 is the standard quadratic term, and the term $1/(1+\tau_{i,t}/2)$ in equation 5 reflects the fact that 50 percent of social security contributions are paid by the employer.

The first order conditions resulting from profit maximization give the following expressions for equilibrium wages and interest rates and for the equilibrium price of capital:

(8) $$w^g_{t,i} = \frac{1-\alpha_i}{\Omega_i^{\theta_i}} \frac{1}{1+\tau_{t,i}/2} \left(\frac{Y_{t,i}}{L_{t,i}} \right)^{1+\theta_i},$$

(9) $$q_{t,i} = 1 + \psi_i \frac{I_{t,i}}{K_{t,i}}, \text{ and}$$

(10) $$r_{t,i} = \frac{F_{K_{t,i}} + (1-\delta)\Delta q_{t,i} + \frac{\psi_i}{2}\left(\frac{I_{t,i}}{K_{t,i}}\right)^2}{q_{t-1,i}} - \delta_i,$$

where $q_{t,i}$ denotes the Lagrangian factor of the net investment equation 7, the total marginal costs of investment, which, in this formulation, also equals Tobin's q (Tobin 1969; Hayashi, 1982). F_K denotes the marginal product of capital. Equation 10 is the familiar arbitrage condition for the rate of return on financial and physical investment: The return on financial investment, $r_{t,i}$, must be equal to the return on one unit of physical investment at a price of $q_{t-1,i}$ in each country. The latter equals the marginal product of capital plus capital gains on non-depreciated capital plus the reduction in marginal adjustment costs minus depreciation. If $\psi_i=0$, i.e. if there are no adjustment costs to capital, then equation 10 reduces to the standard static condition $r=F_K-\delta$.

In order to determine aggregate consumption, we next consider optimal household behavior derived from intertemporal utility maximization. By choosing an optimal consumption path, each cohort c maximizes at any point in time t and age a the sum of discounted future utility. We use the identity $t=c+a$ to index some variables by cohort and time, others by age and time, as it is convenient.

The within-period utility function exhibits constant relative risk aversion, and preferences are additive and separable over time. Cohort c's maximization problem at $a=1$ is given by

(11) $$\max_{\{C_{c,a,i}\}_{a=1}^{Z}, \{l_{c,a,i}\}_{a=1}^{Z}} \sum_{a=1}^{Z} \frac{1}{(1+\rho_i)^{a-1}} \pi_{c,a,i} U\left(C_{c,a,i}, E_t - l_{c,a,i}\right),$$

where ρ_i is the pure time discount rate. In addition to pure discounting, households discount future utility with their unconditional survival probability $\pi_{c,a,i} = \prod_{j=1}^{a} s_{c,j-1,i}$. $C_{c,a,i}$ denotes consumption and $l_{c,a,i}$ labor supply of the household. Remember that the latter is measured in efficiency units relative to the time endowment E_t which increases over time. We assume that the period specific utility function is of the standard CES form given by

(12) $$U\left(C_{c,a,i},E_t-l_{c,a,i}\right)=\frac{1}{1-\sigma_i}\left\{\left(\left[\omega_{i,a}C_{c,a,i}^{-\gamma_i}+\left(1-\omega_{i,a}\right)\left(E_t-l_{c,a,i}\right)^{-\gamma_i}\right]^{-\frac{1}{\gamma_i}}\right)^{1-\sigma_i}-1\right\},$$

where σ_i is the coefficient of relative risk aversion. $\omega_{i,a}$ is the consumption share parameter, i.e. the weight of consumption relative to leisure in the household's utility which varies both across countries and across age. Finally, we denote by $\xi_i=1/(1+\gamma_i)$ the intra-temporal substitution elasticity between consumption and leisure.

A feature of our model is uncertainty about the time of death expressed in the term $\pi_{c,a,i}$ in equation 11. A complication arises because households face the risk of prematurely dying with positive wealth. We assume perfect annuity markets which implies that accidental bequests are distributed implicitly, as in the life-insurance framework by Yaari (1965); see also Rios-Rull (1996, 2001).[7] We do not include intended bequests in our model.

Denoting total wealth by $A_{c,a,i}$, maximization of the household's intertemporal utility is subject to a dynamic budget constraint given by

(13) $$A_{c,a+1,i}=\frac{1}{s_{c,a,i}}\left(A_{c,a,i}\left(1+r_{t+1,i}\right)+l_{c,a,i}w_{t,i,a}^{n}+\left(E_t-l_{c,a,i}\right)p_{c,a,i}-C_{c,a,i}\right).$$

The term $1/s_{c,a,i}$ reflects how the accidental bequests are dissipated through the annuity market. Income consists of asset income, net wages, and pensions.

The corresponding present value budget constraint is given by

(14) $$\sum_{a=1}^{Z}\pi_{c,a,i}y_{c,a,i}^{n}\prod_{j=1}^{a}\frac{1}{1+r_{t+j-1,i}}-\sum_{a=1}^{Z}\pi_{c,a,i}C_{c,a,i}\prod_{j=1}^{a}\frac{1}{1+r_{t+j-1,i}}\geq 0,$$

where we use the short hand $y_{c,a,i}^{n}=l_{c,a,i}w_{t,i,a}^{n}+\left(E_t-l_{c,a,i}\right)p_{c,a,i}$ to denote after-tax non-asset income.

Furthermore, maximization is subject to the constraint that leisure may not exceed time endowment (and may not be negative):

(15) $$0\leq l_{c,a,i}\leq E_{c+a}.$$

[7] One might object to the counterfactual assumption of perfect annuity markets and the absence of explicitly defined accidental bequests. As we show in our sensitivity analysis, allowing for accidental bequests and using alternative redistribution schemes turns out not to significantly alter our simulation results.

The solution to the intertemporal optimization problem can be characterized by two first-order conditions. First, the *inter-temporal Euler equation* describes the consumption growth rate of each household given by

$$(16) \qquad C_{c,a+1,i} = C_{c,a,i}\left(\frac{1+r_{t+1,i}}{1+\rho_i}\right)^{1/\sigma_i}\left(\frac{v_{c,a+1,i}}{v_{c,a,i}}\right)^{1/\sigma_i},$$

where $v_{c,a,i} = \left(\omega_a + (1-\omega_a)clr_{c,a,i}^{-\gamma_i}\right)^{\frac{1+\gamma_i-\sigma_i}{\gamma_i}}$. $clr_{c,a,i}$ is the consumption-leisure ratio defined in equation 17 below.

Second, the *intra-temporal Euler equation* relates current period consumption to current period leisure choice by

$$(17) \qquad E_t - l_{c,a,i} = \left(\frac{1-\omega_{i,a}}{\omega_{i,a}}\frac{1}{w_{c,a,i}+\mu_{c,a,i}-p_{c,a,i}}\right)^{\frac{1}{1+\gamma_i}} C_{c,a,i} = clr_{c,a,i}C_{c,a,i},$$

where $\mu_{c,a,i} \geq 0$ is the shadow value of leisure.

As Auerbach and Kotlikoff (1987, p. 35) point out, this specification results in a trending labor force participation if technological progress affects the technology level Ω_i and if the elasticity of substitution between consumption and leisure is not equal one, i.e. if $\gamma_i \neq 0$. Altig, et al. (2001) avoid this problem by assuming a "growth in time endowment" specification: technological change affects the time endowment of households rather than the technology level of the economy. In their specification, each cohort is endowed with more time than the previous one but time endowment is constant across the life-cycle of each individual cohort. Across the life-cycle, technological change is implemented by growth in life-cycle wages across age. Our specification differs in that we assume that E_t measures efficiency of all cohorts and increases according to $E_{t+1}= E_t(1+g_i)$ such that households get more efficient as time passes by. Instead, we assume the wage profile to be flat across the life-cycle (apart from the effect due to age-specific productivity). For the production sector, this specification is the standard labor augmenting technological change specification. For the household sector, it is not only labor that gets more efficient but also leisure, hence households get more efficient in using their time.

For given factor prices (i.e., wages and interest rates), shadow wage rates and the parameters of the public pension system (i.e., contribution and replacement rates), the life-time consumption paths of all generations can be computed using the Euler equations 16 and 17 and the constraints 13 to 15.

3.4 Equilibrium

We define the dynamic general equilibrium of the model economy sequentially.[8]

Definition 1. A competitive equilibrium of the economy is defined as a sequence of disaggregate variables, $\{C_{t,a,i}, l_{t,a,i}, A_{t,a,i}\}$, aggregate variables $\{C_{t,i}, L_{t,i}, K_{t,i}\}$, prices for capital and labor $\{q_{t,i}, w_{t,i}\}$ in each country *i*, and a common world interest rate $\{r_t\}$ such that

1. The allocations are feasible, i.e.

   $$Y_{t,i} + r_t F_{t,i} = S_{t,i}^n + C_{t,i} + D_{t,i} = S_{t,i}^g + C_{t,i} =$$
   $$\sum_{a=1}^{Z}\left(s_{t,a,i}A_{t+1,a+1,i} - A_{t,a,i}\right)N_{t,a,i} + \sum_{a=1}^{Z} C_{t,a,i}N_{t,a,i} + \left(\delta - (1-\delta)\frac{\Delta q_{t,i}}{q_{t-1,i}}\right)q_{t-1,i}K_{t,i}$$

   where $F_{t,i}$ is the amount of foreign assets, D_t is depreciation of capital valued in units of consumption and accounting for gains on non-depreciated capital and $S_{t,i}^n$ ($S_{t,i}^g$) is net (gross) savings.

2. Factor prices equal their marginal productivities as given in equations 8 through 10.
3. Firms and households behave optimally, i.e., firms maximize profits in equation 4 subject to the constraints in equation 5 and 6 and households maximize life-time utility given by equation 11 subject to the constraints in equations 13 through 15.
4. All markets clear. Market clearing on national markets requires that

   $$S_{t,i}^n = \sum_{a=1}^{Z} S_{t,a,i}^n N_{t,a,i} \qquad C_{t,i} = \sum_{a=1}^{Z} C_{t,a,i}N_{t,a,i} \qquad A_{t,i} = \sum_{a=1}^{Z} A_{t,a,i}N_{t,a,i} \qquad L_{t,i}^{e} = \sum_{a=1}^{Z} l_{t,a,i}^{e} N_{t,a,i}$$

   Market clearing on the international capital market and the assumption of perfect capital mobility across regions requires that the rate of return on financial investment is equalized across all countries,

   $r_{t,i} = r_t$,

   and that the sum of all foreign assets across all world regions equals zero, i.e.

   $$\sum_{i=1}^{R} F_{t,i} = 0 .$$

[8] Our definition of equilibrium as sequentially is consistent with our computational method. It can be numerically computed since the model economy converges to a steady state and becomes a well-behaved system with a small number of equations.

Hence, in equilibrium world output is equal to

$$(18)\qquad Y_t = \sum_{i=1}^{R} Y_{t,i} = \sum_{i=1}^{R} \left(S_{t,i}^{n} + C_{t,i} + D_{t,i}\right).$$

Foreign assets are defined as the difference between total and home assets that are equal to the value of the home capital stock

$$(19)\qquad F_{t,i} = A_{t,i} - H_{t,i} = A_{t,i} - q_{t-1,i}K_{t-1,i}$$

and international capital flows are defined by the difference between foreign assets in two successive periods and are equal to

$$(20)\qquad CA_{t,i} = F_{t+1,i} - F_{t,i} = A_{t+1,i} - A_{t,i} + q_{t,i}K_{t,i} - q_{t-1,i}K_{t-1,i} = S_{t,i}^{g} - q_{t,i}I_{t,i},$$

where $q_{t,i}I_{t,i}$ is physical investment valued in terms of consumption units which is equal to

$$(21)\qquad q_{t,i}I_{t,i} = q_{t,i}\left(K_{t+1,i} - (1-\delta)K_{t,i}\right) = q_{t,i}K_{t+1,i} - q_{t-1,i}K_{t,i} + \left(\delta - (1-\delta)\frac{\Delta q_{t,i}}{q_{t,i}}\right)q_{t-1,i}K_{t,i}.$$ [9]

Finally and for further reference it is useful to define the household saving rate as total savings net of depreciation divided by disposable income from domestic and foreign sources:

$$(22)\qquad savrate_{t,i} = \frac{S_{t,i}^{n}}{Y_{t,i} + r_t F_{t,i}}.$$

3.5 Solution method

We determine the equilibrium path of this overlapping generations model by using the recursive block Gauss-Seidel algorithm (see Auerbach and Kotlikoff, 1987) in an improved version (Ludwig, 2004). The algorithm searches for equilibrium paths of capital to output ratios and labor supply in each country. We start with initial guesses of theses variables and of the shadow wage rates and determine interest and wage rates. We plug these variables into the household model, solve the household model and aggregate across all households to obtain new guesses for labor supply and capital to output ratios as well as shadow wage rates. We then update the initial guesses by a modification of the standard Gauss-Seidel iterations re-

[9] Throughout these accounting definitions we made use of our simplifying assumption that all migration is concentrated at age *a=1*. Since initial wealth is zero, we therefore do not have to account for transfers of assets due to migration.

cently developed by Ludwig (2004), referred to as the "Gauss-Seidel-Quasi-Newton Algorithm".

4. Calibration of the model

We calibrate the model for the seven benchmark regions mentioned earlier: (i) France, (ii) Germany, (iii) Italy, (iv) the remainder of the European Union, (v) North America, (vi) the remaining OECD countries, and (vii) all other countries in the world. In our benchmark model, capital mobility is restricted to the OECD area but capital flows freely within this area.[10]

Our time line has four periods: a phase-in period, a calibration period (1960-2001), a projection period (2002-2100), and a phase-out period. First, we start calculations 110 years before our calibration period begins. At the start of this phase-in period we assume an initial steady state. The time between 1960 and 2001 is used as calibration period. Our projections run from 2002 through 2100. However, we display only results through the year 2070 to show the main period of population aging. The phase-out period after 2100 has two parts: a transition to a steady population, and an additional 100-year period towards a steady state of the economic model. We assume that mortality rates are constant beyond 2100. Furthermore, fertility rates are assumed to adjust during the period from 2100 until 2200 such that the total number of newborns is constant each year which implies that stable populations are reached in about 2200. We compute 100 more years until the model reaches a final steady state in 2300.

Our demographic model is calibrated with the assumptions underlying the United Nations (2001). These projections end in 2050. Our demographic projections beyond 2050 assume linear increases of life-expectancies with increments taken from the UN data until 2100 and constant fertility rates at levels reached in 2050 until we adjust them as just described.

In order to solve the pension system equations 1 and 2 for each country, we assume that *net* replacement rates are constant over time at current levels. We then solve for the associated time path of the contribution rate. We calibrate the pension systems with data on *gross* replacement rates taken from Palacios and Pallarès-Miralles (2000) which – to the best of our

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[10] There are two good reasons for choosing this rather modest capital mobility scenario. First, as already noted in section 2, there is a broad consensus that capital is quite mobile among OECD countries while this is much less clear for developing countries. Second, adding the additional countries of the region "Rest of the World" does not affect patterns of aggregate variables much. The relatively small sensitivity of results with respect to adding additional countries beyond the OECD countries is due to the fact that roughly 80 percent of world GDP is produced in the OECD and hence the additional weight of all other world regions is small in relative terms.

knowledge – provides the best currently available comparably computed measure of gross replacement rates for a large cross-section of countries. We then calculate *net* replacement rates as gross replacement divided by 1 minus taxes and employee's social security contributions taken from OECD (2001). We hereby treat pension income as tax-free. The theoretical counterpart of the relationship between gross and net replacement rates in our economic model is given by $\gamma^g_{t,i} = \gamma^n_{t,i}(1-0.5\tau_{t,i})$. We further normalize the net replacement rate as to match the average net replacement rates of a standard pensioner of roughly 70 percent in Germany.[11] We then solve for equilibrium contribution rates using the budget constraint in equation 1.

Further parameters of the model are the households' preference parameters, the parameters of the production function, and values of the age-specific productivity profile. For the latter, we use the cohort-corrected non-linear regression estimates by Fitzenberger, et al. (2001). This provides us with a representative age-wage profile that peaks at the age of 52 and then decreases slightly.

With two exceptions, technological and preference parameters are assumed to be constant and equal across all countries. More precisely, we assume that

$$g_i = g,\ \alpha_i = \alpha, \beta_i = \beta,\ \delta_i = \delta,\ \psi_i = \psi,\ \rho_i = \rho,\ \sigma_i = \sigma,\ \xi_i = \xi,\ \forall\, i = 1,\ldots,R\,.$$

Parameter values of these parameters are standard in the literature and summarized in table 1. The growth rate of productivity, g, is set to 1.5 percentage points which is slightly higher than the value of 1.4 percentage points suggested by Cutler, et al. (1990) and closer to the long-run projections suggested by the OECD. The capital share parameter, α, is usually set to 0.3-0.4. We set it to the intermediate value of 0.35. The annual depreciation rate, δ is assumed to be 5 percentage points per year.

--- Table 1 goes about here ---

The adjustment cost parameter, ψ, deserves more discussion. In a model without depreciation but with capital taxation, and with a lower growth rate, g, of 1 percentage point, the value for ψ equal to 10 as chosen by Altig, et al. (2001) results in a steady state q-value of 1.04. The empirical study by Oliner, et al. (1995) results in an equilibrium q-value of 1.13. In our model, with a productivity growth rate of 1.5 percentage points and a depreciation rate of 5 percentage points, the value of ψ=1.5 that we chose results in a steady state q-value of 1.0975

[11] A standard pensioner is a person who worked for 45 years and who received average labor income during that period.

which is just in between these two values used in the literature. As we show in our sensitivity analysis, adjustment costs do not affect our results much.

The discount rate in all countries, ρ, is set to 0.1 which is close to the estimate 0.011 of Hurd (1989). With this choice – and given all the other parameter values – our model produces an average capital to output ratio for the region "European Union" of about 2.9 for the calibration period 1960-2001. While comparable capital-output ratios for a large cross-section of countries are not available, a value of 2.9 is reasonable for many countries (OECD, 2003). The coefficient of relative risk aversion is set to 2 which is within the standard range of 1 to 4. We follow Altig, et al. (2001) in choosing the value for the intra-temporal substitution elasticity $\xi = 0.8$.

Levels of total factor productivity, Ω_i, vary across countries and are calibrated such that the model replicates output data in each country for the period 1960-2001. Since there is no government consumption in our theoretical model, we define output as the difference between actual GDP and government consumption. Consumption share parameters, $\omega_{i,a}$, vary across country and age. We define the functional form of $\omega_{i,a}$ in each country as

$$\omega_{i,a} = \overline{\omega_{a,i}}, \forall\, a \leq \underline{\mathrm{A}}, \quad \omega_{i,a} = \overline{\omega_{a,i}} - \Delta\omega_i, \forall\, \mathrm{A} < \mathrm{a} \leq \overline{\mathrm{A}}, \quad \omega_{i,a} = \omega_{i,\overline{A}} = \underline{\omega}_i,\ \forall\, a > \overline{A},$$

i.e., the consumption share parameter is assumed to be constant for ages $a \leq \underline{\mathrm{A}}$, then linearly decreases and is assumed to be constant again for ages $a > \overline{A}$. $\underline{\mathrm{A}}$ is set to 54 beyond which empirically observed labor supply starts to decrease and $\overline{A}$ is set to 80 since labor supply is essentially zero in all countries beyond the age of 80. While we hold the age boundaries constant across all countries, we calibrate $\overline{\omega_{a,i}}$ and $\Delta\omega_i$ such that our simulation model approximately replicates both aggregate labor supply as well as labor supply profiles across ages on average in each country for the period 1960-2001.

--- Figure 2 goes about here ---

Our parsimonious parameterization of $\omega_{i,a}$ results in a decent fit of empirically observed labor supply profiles across age, see Figure 2. Panels (a) and (b) of the figure show aggregate labor supply, measured as the share of employed persons as a percentage of total population over the period 1960 to 2001 for France, Germany, and Italy as well as the three other OECD regions, Rest of EU, USA and Canada, and all other OECD countries, respectively. The observed increases in actual (and predicted) labor supply shares across world regions are mainly due to increases in female labor force participation. As Panels (a) and (b) show, our model does well in matching the time path of labor supply shares for the countries of the European Union. While average labor supply shares in North America are also replicated, the model underestimates the increase of labor supply shares across time. For the remaining OECD countries, our model overestimates slightly the increase of labor supply shares across time.

Furthermore, Panel (c) depicts predicted and actual average age-specific labor supply shares – the latter in age-groups of five – for the group of countries France, Germany, and Italy (results for other regions are similar). The graph highlights the effects of our restriction on preferences regarding the consumption share parameter, $\omega_{i,a}$. Our model overestimates actual labor supply shares for young age-groups (below age 30). This is not surprising since motives to accumulate human capital – a learning-by-doing effect as suggested by Lucas (1988) – are absent in our model. After age 35, our predicted labor supply shares match the empirical average quite well. They decrease over the life cycle and fall sharply beyond age $\underline{A}$ = 54 since the preference for leisure, 1- $\omega_{i,a}$, is assumed to increase. Overall, our labor supply model results in a decent fit of age-specific labor supply shares.

Finally, we look at how well capital flows are replicated in the calibration period. This is much harder than replicating labor supply shares since capital flows have fluctuated heavily during this time obfuscating the long-run trends which we are interested in. Moreover, and at least as importantly, the benchmark assumption of free capital mobility within the OECD did not hold for the beginning of the benchmark period when stiff capital flow controls were imposed even among France, Germany, and Italy. To illustrate the ex-post predicted international capital flows, Figure 3 displays predicted and actual current-account to GDP ratios. In line with our theoretical model, we define the current account as the difference between gross national savings and gross fixed capital formation (domestic investment). For lack of data reasons, we cannot correct for government savings and investment and therefore our actual current account figures do not fully correspond to their theoretical counterparts.

--- Figure 3 goes about here ---

Results on patterns of international capital flows for the period 1970-2001 are encouraging, especially for the three large continental European countries and the rest of the OECD, while we over-predict capital flows of the rest of the EU until the mid 1980s, and under-predict thereafter. First, even though any capital market frictions are absent from our theoretical model, magnitudes of international capital flows are within reasonable ranges. Second, our model correctly replicates the facts that core European countries have been net capital export countries for most of the post-war period and that the rest of the OECD countries (in particular, North America) is a net capital import region. While our model replicates the broad trends of international capital flows, it cannot capture high-frequency variations. This should not come as a surprise given that our model is non-stochastic and has a clear long-run focus.

A final remark concerns the initial values of our model for the year 2002 under the different capital mobility scenarios. Conceptually, it is problematic to simulate a calibrated macroeconomic model under policy scenarios other than the one under which it was calibrated. In our case, the world for which we calibrate the model changes with the number of regions considered in the capital mobility scenarios. On the one hand, it would make sense to adjust the calibration parameters each time we change the number of regions that we consider. On the other hand, this would change households' reactions to changes in policy and it would therefore be more difficult to interpret our results with respect to a reform of the public pension system. For that reason and since we are primarily interested in the reaction of households to demographic change and fundamental pension reform, we keep parameter values constant across all capital mobility scenarios. We calibrate the model under the assumption that the "OECD" capital mobility scenario correctly reflects the "true" world and therefore that all other capital mobility scenarios are "counterfactual" worlds. The reader will note that this procedure results in differences in the values of the simulated variables in 2002, the base year of our simulations.

5. Simulation results for alternative pension and capital mobility scenarios

In this section, we present the results of our macroeconomic simulation model. For tractability, we focus on the three-country continental European region consisting of France, Germany, and Italy as a region with a very severe aging problem and with pension systems in an ongoing reform process.

To separate the direct effects of population aging on capital markets and potential feedback effects from pension reform, we present our projections for the two counterfactual pension policy scenarios described above: (a) the "old system scenario" which maintains these countries' current generous public pension systems, and (b) the "reform scenario" which introduces a transition to a funded pension system by freezing contribution rates in these three countries. The other regions' pension systems remain unchanged. By comparing these polar scenarios, we can show that a good portion of the capital market effects of population aging arise even without a fundamental pension reform. Accordingly, the figures below have three panels. Panel (a) corresponds to the "old system scenario", Panel (b) shows the "reform scenario", and Panel (c) shows the differences between these two scenarios, i.e. the effect of a fundamental pension reform implemented simultaneously in the three large continental European countries.

Moreover, each figure displays four lines, representing our four capital mobility scenarios. The first scenario corresponds to a closed economy where all investment of France, Germany, and Italy takes place within these three countries. The other three capital mobility scenarios open this closed economy up sequentially: France, Germany, and Italy diversify their investments (i) across all countries of the European Union, (ii) across all OECD countries, and (iii) across the entire world. As noted earlier, our benchmark scenario assumes that capital mobility is restricted to the OECD area.

The presentation of our results proceeds in several steps. Throughout, we focus on the economic consequences of aging and of fundamental pension reform on the continental European region consisting of France, Germany, and Italy. We first analyze the two channels of reaction of households to both demographic change and pension reform. We show how labor supply and savings patterns are affected by demographic change and by pension reforms. We next turn to an analysis of the firm sector and analyze the evolution of wage rates and the return to capital as well as its price, Tobin's q. We then turn to the difference between national saving and investment that generates international capital flows and describe how they are affected by demographic change.

While our results show substantial differences of international capital flow patterns between countries of the European Union and other world regions, there are also significant differences between countries within the different world aggregates. To highlight this aspect, we further present results on saving patterns and international capital flows for the three European countries on which we focus (France, Germany, and Italy). We conclude our discussion with a brief welfare analysis for households living in Germany.

Before presenting the results of our simulation model, it is useful to briefly describe the main mechanisms that are at work simultaneously in such a complex general equilibrium model. Consider a two-region world were there is an old region (e.g. the France-Germany-Italy region) and a relatively younger region (e.g. all non-European OECD countries). Assume that the younger region also has a less generous PAYG pension system, i.e., lower PAYG contribution and replacement rates. Further assume that both economies are closed. What are the effects of demographic change on saving rates and rates of return in such a stylized world with PAYG financed pension systems?

First, there is a *direct level effect*. The younger region has a relatively larger work force, a lower capital-labor ratio, and hence a higher rate of return. Accordingly, the saving rate is higher in that region. Over time and as a result of demographic change, the work force shrinks in both economies. Hence, capital-output ratios increase and both the rates of return and the savings rates decrease. We refer to this effect as the *direct trend effect* of demographic change. This effect is stronger for the older economy.

Second, there are indirect effects due to the existence of PAYG financed pension systems. PAYG financed pension systems "crowd out" private savings by providing old-age pension income and by taxing labor income. Hence, this *indirect level effect* works in the opposite direction as the direct effect of demographic change. Relative to a situation without PAYG financed pension systems, the indirect effect decreases the differences in saving rates and rates of return between the two economies. However, as the simulation results presented below suggest, the direct level effect dominates. Moreover, over time, old-age dependency ratios increase and therefore contribution rates to the PAYG pension system increase as well (taking PAYG replacement rates as given as we do in our old system scenario). This *indirect trend effect* is stronger in the older region which is more severely affected by the impact of demographic change and has a more generous PAYG pension system. As a result, in the older region the decrease in savings rates is relatively stronger and hence the decrease in the rate of return is less strong.

Consider now a case in which capital is mobile between the two economies. Due to the dominance of the direct level effect, the rate of return is initially higher for the older region as it would be if it was a closed economy. This increases savings relative to the closed economy case. However, due to the indirect trend effect the decrease in the rate of return is stronger than under the closed economy scenario. The decrease in saving rates is therefore stronger as well. These interactions between demographic change and the PAYG pension system are important for the interpretation of our main results to which we turn next.

5.1 Labor supply, contribution and replacement rates

Population aging has immediate effects on labor supply and the balance of the pension system. During the entire observation period, labor supply shares in the three European countries France, Germany, and Italy decrease from current levels of slightly below 42 percent to below 36 percent in 2050. The economic dependency ratio, defined as the ratio of pensioners to workers, is projected to increase from roughly 50 percent in 2002 to about 80 percent in 2050.[12]

As a result of the decrease in labor supply shares and the resulting increase in the economic dependency ratio, the contribution rate to the PAYG pension system increases sharply under the “old system scenario”, i.e. if current generous pension systems were maintained. These contribution rates are equilibrium contribution rates such that the budget of the pension system of each country is balanced at every point in time(implicitly including tax subsidies to the pension system). The time patterns of net replacement and contribution rates for France, Germany, and Italy that result from our procedure are summarized in table 2.

--- Table 2 goes about here ---

If current generous replacement rates were maintained, our model predicts increases in the equilibrium contribution rate in Germany from its current levels of roughly 27 percent to 41 percent in 2050 – more than a 50 percent increase. Our stylized pension reform freezes contribution rates at the level reached in 2006, roughly at 29 percent. As a result of this reform, average pension levels decrease: the net pension replacement rate is projected to decrease from 70 percent in 2000 to about 50 percent in 2050. Hence, for Germany, our model predicts a one-third transition towards pre-funding until 2050. Results for the other countries are similar, compare table 2.

Households respond to these decreases in pension benefit levels not only by increasing savings, but also by increasing labor supply.[13] Despite our restriction on preferences – decreasing consumption shares and increasing preference for leisure as described in section 4 above – our stylized pension reform would lead to quite substantial increases in aggregate labor supply. Labor supply shares are predicted to increase by more than 6.5 percent or 2.5 percentage points until 2050. This increase is roughly the same for all capital mobility scenarios. For instance, labor supply shares in the France-Germany-Italy region increase from about 36 to 38.5 percent in the year 2050. As a consequence, the economic dependency ratio is projected to decrease by almost 6 percentage points. Endogenous labor supply reaction is therefore a helpful mechanism to dampen the effects of population aging. We show below that this effect holds over the entire range of the crucial elasticity parameters in the OLG model.

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[12] The total sum of pensioners (“effective pensioners”) as used in this section is defined as the sum of actual pensioners weighted by their age-specific pension entitlements.

[13] Labour supply is projected to increase also for other parameter constellations, see Section 6.5 below.

5.2 Savings and capital stock

Panel (a) of Figure 4 shows the aggregate average saving rate of France, Germany, and Italy in our four capital mobility scenarios. In the year 2000, savings rates are substantially higher in the open economy scenarios than in the closed France-Germany-Italy region. This is in line with the higher rates of return (see next subsection) generated in an open economy which diversifies a great deal of the demographic effects that create lower saving rates (and rates of return) in economies with a large share of older persons.

--- Figure 4 goes about here ---

This direct level effect is superseded by the demographic changes during the 2000 to 2070 prediction window. Saving rates decrease until 2050 across all capital mobility scenarios since the baby boom generation decumulates assets. Saving rates are projected to rebound after the year 2050. The decrease of the savings rate caused by population aging – the difference between the value in 2000 and the minimum reached just after 2040 – is roughly 4.5 percentage points if capital mobility is restricted at most to the EU region (scenarios "F+G+I" and "EU"). If we allow for capital mobility within the OECD or the entire world, this decrease is 6.5 or 8 percentage points, respectively. This larger decrease in the open economy scenarios is explained by the *indirect trend* effect described above. The diversification advantages of worldwide capital mobility thus decline, and saving rates respond accordingly.

Projected aggregate saving rates under a fundamental pension reform are substantially higher and the effect of a pension reform is stronger in the OECD / World open-economy scenarios (the saving rate is projected to increase by slightly more than one percentage point in the EU scenario as compared to 2 percentage points in the OECD / World scenarios). An increase in national savings leads to an increase in the capital stock and thereby to a decrease in the rate of return to capital which then crowds out further savings. In those scenarios with a larger international capital market, substantially more savings is generated since – as we show below – the rate of return decreases by much less. These projections show that optimal life-cycle behavior generates additional saving under a fundamental pension reform – in our model, it is not the case that additional retirement saving induced by a pension reform crowds out other saving totally, as has often been claimed.

We also accumulate aggregate savings to obtain the world region's asset holdings and capital stocks and the related capital-to-output ratios (figures not shown). As a consequence of decreasing labor supply, the capital-to-output ratio increases from its current level of about 3 until it reaches a level of about 3.25 around 2040 and then decreases slightly when baby boomers decumulate assets (capital mobility scenario “OECD”). This decrease is much more pronounced if we restrict the international capital market to the EU area only. The simultaneous fundamental pension reform of France, Germany, and Italy leads to substantial increases in the capital-to-output ratio if we restrict capital mobility to these countries or the EU area. The increase is much lower if we relax this constraint which suggests that the additional savings shown in Figure 4 are largely invested abroad.

5.3 The rate of return and the price of capital

Much of the political and academic debate on the capital market consequences of demographic change and of pension reforms is centered around the rate of return to capital to which we turn next. First, we observe the same level effects as already described in the previous section. It is noteworthy that the demographic effect is larger than a second level effect. Since the PAYG systems are slimmer in the aggregate rest-of-the-world region than in France, Germany, and Italy, the capital stock accumulated for retirement savings is larger which depresses rates of return.

Second, as a consequence of population aging and the resulting increase in capital-to-output ratios, our model predicts the rate of return of return to capital to decrease by a bit less than one percentage point if capital moves freely within the OECD, see Figure 5. This decrease is less than would be associated with a “meltdown of asset prices”. Third, while the rate of return decreases across all capital mobility scenarios, substantial gains would be possible by shifting investments to demographic younger countries since our model predicts higher returns if we allow for free capital mobility across all world regions. However, as demographic processes are highly correlated across countries (compare Figure 1), differences in demographic processes across countries more or less only affect the level of the rate of return. Furthermore, diversification advantages decrease across time since the above mentioned indirect trend effects are at work as well.

--- Figure 5 goes about here ---

As Panels (b) and (c) of Figure 5 suggest, there would be an additional decrease in the rate of return to capital if France, Germany, and Italy would simultaneously reform their pension systems in a fundamental way. This decrease would amount to about 0.25 percentage points until 2070 if capital was freely mobile within these countries only. Due to the increase in labor supply, this long-run decrease in the rate of return is lower than a model with exogenous labor supply would suggest, see section 6. Moreover, and in line with our earlier results, the decrease in the rate of return is negligibly small if capital moves freely across OECD countries (or the entire world). In contrast to a model of exogenous labor supply, the present model even predicts an increase in the rate of return until about 2030 or 2040 (as a result of the endogenous labor supply reaction). While saving rates immediately start to increase after the reform, labor supply increases as well. As a net effect, this initially leads to a decrease in the capital to output ratio and an associated initial increase in the rate of return to capital.

Tobin's *q*, the price of capital, also decreases as a consequence of population aging but its level is higher in the demographically younger regions. As a consequence of fundamental pension reforms, *q*-values are predicted to increase slightly since the investment to capital ratio increases.

5.4 International capital flows

International capital outflows from the France, Germany, and Italy to other OECD countries roughly follow the pattern of savings and decrease steadily until 2050, see Figure 6. In the OECD and World capital mobility scenarios, they are initially positive at about 2 and 3.2 percentage points and turn negative to -2 and -2.5 percentage points in 2050, respectively; see Figure 5(a). Hence, the model predicts reversals in current account positions for fast aging countries such as France, Germany, and Italy.

--- Figure 6 goes about here ---

So far, our analysis concentrated on France, Germany, and Italy as a country aggregate. However, there are substantial differences across countries, even within continental Europe. To highlight this aspect, we next analyze savings patterns and international capital flows within the region of EU countries if the international capital market is restricted to the OECD area.

Figure 7(a), shows saving rates for France, Germany, and Italy, the remaining EU countries and the EU average. The time pattern of German saving rates roughly equals the EU average and is projected to decrease from current levels of 7 percent to about 2 percent in 2050. In France, as the demographic youngest among the three regions, decreases in savings rate only last until 2030 and the overall decrease is smaller than in other EU countries. Italy, faced with the strongest population aging process within Europe, is at the other extreme: Italian household's saving rates are projected to become substantially negative in 2050.

--- Figure 7 goes about here ---

5.5 Welfare analysis

Figure 8 shows the effects of the fundamental pension reform on remaining lifetime utility for different cohorts. We follow Altig, et al. (2001) and measure the change in remaining lifetime utility as the equivalent variation of *full* lifetime income. The index measures the present value of remaining life-time resources relative to current full life-time resources a household would have to receive (pay) under the new system to make him indifferent between the old and the new system. Therefore, an index number greater (smaller) than one has to be interpreted as loss (gain) in remaining life-time utility.

--- Figure 8 goes about here ---

The results show that remaining life-time utility of a large number of generations decreases as a consequence of the fundamental pension reform. Cohorts born between the years 1928 and 1982 are those who experience losses in remaining lifetime utility. Welfare losses are slightly higher if we restrict capital to be mobile only within the EU. While substantial welfare gains are possible in the long run in all capital mobility scenarios, the figure also illustrates that fewer cohorts experience losses if the capital mobility regions is widened. However, the difference between the capital mobility scenarios is not large.

6. Sensitivity analysis

The existing literature has mostly concentrated on sensitivity analysis of simulation results with regard to values of structural (deep) model parameters, see, e.g., Altig, et al. (2002) and Börsch-Supan, Ludwig, Heiss, and Winter (2003). We will provide this "standard" sensitivity analysis in subsection 6.5 below. Our main focus, however, is on a sensitivity analysis with regard to model specification. What difference does it make whether labor supply is endogenous or exogenous? Whether investment incurs adjustment costs? Whether perfect annuity markets absorb all accidental bequests? Whether part of retirement income is provided by a PAYG pension system? In order to shed light on these questions, we re-compute our benchmark model and three alternative models by subsequently switching off features of our model. Table 3 provides an overview of the various alternative models we analyze below.

--- Table 3 goes about here ---

The benchmark model has the following features: (a) adjustment costs, (b) perfect annuity markets, (c) endogenous labor supply, and (d) existence of a PAYG pension system. First, we eliminate adjustment costs (Alternative Model I). As it turns out, the existence of adjustment costs has little influence on the results. Since models without adjustment costs are substantially easier to solve, we continue our sensitivity analyses with models that do not feature adjustment costs to capital. Model II then does away with the assumption of perfect annuity markets and allows for accidental bequests. As we will see, this assumption does not affect our results in any significant way either, and we proceed by using the simpler model which imposes perfect annuity markets and abstracts from adjustment costs throughout the remaining sensitivity analysis.

Model III makes labor supply exogenous. As opposed to the previous two assumptions, this is a serious restriction. We show that the results for the pension reform scenario are strongly affected by ignoring endogenous labor supply since now only the capital accumulation channel remains for households to adjust their behavior in reaction to the policy change. Finally, Model IV abstracts from the fact that PAYG pension systems exist in almost all countries of the world as it is done in the models by Brooks (2003), Feroli (2002), and Henriksen (2002). Comparing models III and IV allows us to disentangle the direct effects of population aging on macroeconomic aggregates from the indirect effects which are generated through the channel of PAYG pension system changes in response to population aging. These effects are confounded in the analyses by Brooks (2003), Feroli (2002), and Henriksen (2002), and we separate them here for didactical purposes.

For simplicity, we concentrate on a three-region rather than a seven-region model as in the previous section. To this end we summarize world regions as follows: (i) France, Germany, and Italy, (ii) all other EU countries, and (iii) all other OECD countries. Due to Jensen's inequality, results for region (i) might differ from those shown in the previous section: here, we first summarize input data across three countries, $\sum X_i$, and then calculate $f\left(\sum X_i\right)$ whereas before we presented the average outcome, $1/R\sum f_i\left(X_i\right)$. As we show below, this approximation is of minor importance for our simulation results. Moreover, unless simulation outcomes between the benchmark and the alternative models differ significantly between the two pension reform scenarios, we only present the "old system" scenario.

6.1 The role of adjustment costs

We start by analyzing adjustment costs. Their first role is to dampen the adjustment process of investment. Second, the presence of adjustment costs allows capital-output ratios to differ across countries even under a Cobb-Douglas technology. Hence, modeling adjustment costs allow us to study cross-national differences in the price of capital and their evolution over time.

--- Figure 9 goes about here ---

Figure 9 compares simulation results for saving rates, rates of return to capital and current account to output ratios in a model with and without adjustment costs. As the figures illustrate, the time path of these variables are virtually identical in the “old system” scenario. The same holds for the “freezing reform” scenario (not shown). We can therefore conclude that our simulation results are not affected much by the presence of adjustment costs.

6.2 The role of perfect annuity markets

Figure 10 compares our OLG model featuring perfect annuity markets with a model in which annuity markets cannot perfectly absorb the longevity risk. Households face the risk of prematurely dying with positive wealth. For simplicity, we model the dissipation of bequests by an equal distribution to all persons still living in each model region.

--- Figure 10 goes about here ---

We conclude from Figure 10 that there are no discernible differences between the projections apart from level effects. Since households face the risk of prematurely dying with a positive amount of wealth, their preference for early consumption increases. Hence households have a flatter life-cycle saving profile and accumulate less wealth over the life-cycle than they do in a world with perfect annuity markets. Therefore, predicted levels of saving rates (rates of return) are lower (higher). We conclude that modeling annuity markets and accidental bequests is not an important issue for the study of aggregate saving rates, rates of return and international capital flows.

6.3 The case of exogenous labor supply

Figure 11 compares the time paths for the rate of return, the saving rate and the current account between models of endogenous and exogenous labor supply. In our exogenous labor supply scenario, we hold age-specific labor supply shares constant at levels obtained in the endogenous labor supply scenario in the year 2000. As the figure illustrates, the time pattern is only slightly different under the old system (pure PAYG) scenario. With exogenous labor supply, the time path of the aggregate saving rate fluctuates a bit more since households do not endogenously adjust their labor supply to changes in demographic processes and resulting changes in interest rates and wage rates and hence cannot “smooth” their savings pattern as much.

--- Figure 11 goes about here ---

Differences are much larger when a pension reform occurs. The adjustment paths under the new policy are depicted in Figure 11(b). If labor supply is endogenous, households simultaneously adjust their labor supply and their saving behavior to the change in policy. If labor supply is assumed to be exogenously fixed, however, households can only react with their saving behavior but not with changing their labor supply. The saving rate therefore immediately jumps to the higher level after the announcement of the reform and does not adjust gradually, see Figure 11(b). Moreover, the overall increase in the saving rate is considerably higher under the fixed labor supply assumption.

--- Figure 12 goes about here ---

This difference in behavior directly translates into substantial differences in the time paths for rate of return to capital. As Figure 12(a) shows, the impact of aging on the rate of return to capital is higher if households are constrained and cannot adjust their labor supply. Figure 12(b) shows the substantial differences that result from the reaction of savings to the change in policy as described above. If labor supply is endogenous, the rate of return initially increases since households increase their labor supply as a reaction to the change in policy. This effect is absent in case labor supply is exogenous. Hence, the rate of return to capital immediately decreases. As a result, the overall decrease of the rate of return to capital is also much higher.

--- Figure 13 goes about here ---

Finally, this effect is also reflected in the relative size of international capital flows, see Figure 13. Opening capital markets around the world creates substantially higher flows if the adaptation channel of labor supply responses does not work.

6.4 The absence of a pension system

So far, we have analyzed the effects of demographic change in a world which is characterized by the existence of fairly large PAYG pension systems. As populations age, these PAYG systems require higher contribution rates and/or provide lower replacement rates. These changes in the pension systems create indirect effects on saving rates, the rates of return and international capital flows in addition to the direct effects that are generated through household and firm maximization even in the absence of mandatory PAYG pensions. This section shows how large these direct effects are.

We simulate these direct effects in a model with exogenous labor supply, because in this specification, the effects on saving rates, the rates of return and international capital flows are most clearly seen. Allowing households to react to demographic change also via labor supply adjustments will dampen the effects on the capital market variables. We also know from the comparisons between Panels (a) and (b) in Figures 11 through 13 that labor supply will increase if the generosity of PAYG pension systems is reduced. We show below that this result is not sensitive to the calibration of the elasticity parameters.

The exercise is of course a counterfactual one and serves only for illustration – it separates various effects, but does not provide realistic estimates of a world without PAYG systems. We do not recalibrate Model IV, as always in this section. The argument is less that there is little point in calibrating a highly counterfactual model to historical data. More important is the aspect that recalibration would introduce yet another confounding effect in this multidimensional sensitivity analysis.

Results on the time path of the saving rates, rates of return to capital, and international capital flows in this counterfactual world are shown in Figure 14. We focus on the rate of return effects. First, the level effect of the open economy scenario labeled Scenario OECD is much higher than in a model which models PAYG pension systems. Since in the absence of a PAYG system, all retirement income has to be generated by savings, capital stocks are higher, decreasing the returns to capital across all regions.

--- Figure 14 goes about here ---

Second, the long-run decrease in the rate of return to capital (i.e., between the years 2000 and 2070) is lower in the open economy scenario and if we ignore the existence of PAYG-financed pension systems. This is the pure (and intuitive) effect of demographic change: while virtually all OECD countries are affected by demographic change, countries outside the European Union are younger and hence the rate of return to capital is higher and decreases more slowly in these countries.

There is, however, the additional indirect effect already described above. In a world with PAYG systems (left panel), the rate of return in the open economy scenarios is lower than in the closed economy scenario after about 2030, while it is reversed if all retirement income has to be provided through own savings. The indirect trend effect therefore masks the pure demographic effect. Since PAYG pension systems are less generous in countries outside Europe, households have to save more for retirement which decreases the rate of return (indirect level effect). In addition, crowding out of private savings is stronger in the European countries than in the region labeled "Rest OECD". This indirect trend effect dominates the direct "pure demographic" trend effect. Therefore, the rate of return to capital decreases more in the demographically younger countries than it would in a world without PAYG pension systems which eventually leads to the reversal of the rate of return levels (around the year 2030).

6.5 Structural model parameters

As a last exercise, we analyze the role played by three central structural model parameters, using alternative model I (no adjustment costs) and the OECD capital mobility scenario. We vary the coefficient of relative risk aversion (the inverse of the intertemporal elasticity of substitution), denoted by σ, the coefficient of the intratemporal elasticity of substitution between consumption and leisure, denoted by ξ, and the coefficient of the elasticity of substitution between capital and labor in the CES production function, denoted by β. As before, we constrain these coefficients to be equal across countries. We consider three different values for each of these parameters (including the benchmark calibration, printed in bold), as follows:

σ = 1.0, **2.0**, 3.0,

ξ = **0.8**, 1.0, 1.2,

β = 0.9, **1.0**, 1.1.

We show the results for three important outcome variables: saving rates, labor supply and rates of return. We vary parameters only in one dimension, i.e., we do not recalibrate other model parameters. Hence, levels of simulated variables differ across these simulations. In our presentation, we therefore normalize results such that they are independent of levels and report indices only. Figures 15 to 17 summarize the results of our sensitivity analyses.

--- Figures 15, 16, and 17 go about here ---

A first observation is that results do not vary much across these parameter specifications. We can therefore conclude that our qualitative simulation results are not affected much by the exact value of structural model parameters. Yet some significant differences in both level and timing exist and are worth studying. Increases in saving rates as a reaction to the fundamental pension reform are especially pronounced for σ=1 while the opposite holds for σ=3, see Figure 15a. Using σ=3 results in an interesting parameter constellation: while increases of saving rates and labor supply (Figure 16(a), right panel) resulting from the fundamental pension reform are relatively small, labor supply effects dominate during the entire projection period. The rate of return to capital increases therefore in response to a fundamental pension reform throughout the entire projection period while it decreases in the parameter constellations with a lower relative risk aversion parameter; compare the level of the three lines in the right panel with those in the left panel of Figure 17(a). However, given that we here focus on the "OECD" scenario the overall rate of return effects are of course small.

Higher values for the intratemporal elasticity of substitution between consumption and leisure result in lower decreases of labor supply due to population aging (Figure 16(b), left panel). Furthermore, as Figures 16(a) to 16(c) illustrate, labor supply shares increase due to the fundamental pension reform across all sets of structural parameters which are considered. The right panel of Figure 16(b) shows that the labor supply reaction is smallest for our benchmark calibration (ξ=0.8) relative to the other (larger) values of ξ considered as alternatives. As a result, the decrease of the rate of return to capital is strongest in our parameter constellation. One of our results, which might be politically most contentious, namely the absence of a serious asset meltdown, is therefore robust with respect to the choice of these crucial elasticity parameters, even at very low levels of the relative risk aversion parameter σ. As Figure 17(c) suggests, this also holds for lower values of the substitution elasticity between capital and labor.

7. Conclusions

We presented a quantitative analysis of the effects of population aging and pension reform on international capital markets, using several modifications of a computational general equilibrium multi-country overlapping generations model, viewed from a perspective of the three large continental European countries with large pay-as-you-go pensions systems: France, Germany, and Italy.

The first part of the paper focused on substantive results. Population aging works through various mechanisms. First, demographic change alters the time path of aggregate savings within each country. Second, this process may be amplified when a (population-aging induced) pension reform shifts old-age provision from pure pay-as-you-go towards more prefunding. Even with no reform, the core parameters of pay-as-you-go pensions need to adapt, changing saving behavior. Third, while the patterns of population aging are similar in most countries, timing and initial conditions differ substantially. Hence, to the extent that capital is internationally mobile, population aging will induce capital flows between countries.

All three effects influence the rate of return to capital and interact with the demand for capital in production and with labor supply. Our simulations predict substantial capital flows due to population aging. Population aging results in decreases of the capital-to-output ratio when the baby boomers decumulate their assets. International capital flows follow this trend. The countries most affected by aging such as the European Union will initially be capital exporters, while countries less affected by aging like the United States und other OECD regions will import capital. This pattern is reversed in about the year 2020 when baby boomers decumulate assets and the fast aging economies therefore become capital import regions. Pension reforms with higher degrees of pre-funding are likely to induce more capital exports. They also increase labor supply considerably, while the effects on the rate of return to capital are small. While the rate of return to capital declines in response to population aging, there is no devastating “asset meltdown”.

The timing pattern of these adjustments is complex, and one has to carefully distinguish level effects from changes over time. In the initial year of our projections (2000), savings rates in the France-Germany-Italy region are substantially higher in the open economy scenarios than under a closed economy assumption. This is in line with higher rates of return in economies with a smaller share of older persons. Open economies are able to diversify a great deal of the demographic effects that depress savings and the rate of return to capital.

This level effect is superseded by the demographic changes during the 2000 to 2070 prediction window. Saving rates decrease until 2050 across all capital mobility scenarios since the baby boom generation decumulates assets. Saving rates are projected to rebound after the year 2050. Since PAYG pension systems partially crowd out private savings, decreases of saving rates are stronger in the older regions. As a result, the decrease in the rate of return would be lower in these regions than in regions with less generous pension systems if these regions were closed economies. Diversification advantages of worldwide capital mobility thus decline, and saving rates respond accordingly. We should stress that population projections are reliable one generation ahead, while the projection error increases substantially thereafter. Consequently, results for the post-2030 period should be interpreted with care.

The second part of the paper provides an extensive sensitivity analysis of our results. We do not confine this analysis to the usual range of elasticity parameters, but especially focus on the influence of modeling strategies – such as modeling adjustment costs, perfect annuity markets, endogenous labor supply and explicit pay-as-you-go systems in an overlapping generations context.

Whether adjustment costs and perfect annuity markets are included in the model or not has only second-order effects on the time paths of macroeconomic aggregates. Our results are robust with respect to these modeling choices. Assuming exogenous labor supply, however, is a serious restriction, as well as ignoring the existence of large pay-as-you-go pension systems.

We conclude that the channel of labor supply adjustments to the challenges of population aging is an important one, and that we need the complex overlapping generations structure necessary to model pay-as-you-go pensions in order to generate realistic projections of the macroeconomic effects of population aging. Finally, we show that our results do change very little when we vary some of the central elasticity parameters in the usual range. Our politically probably most contentious conclusion, the absence of a serious asset meltdown, is robust with respect to the choice of these elasticity parameters.

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Figure 1: Projections of working age population and old-age population ratios for different world regions

Figure 1a: Working-age population ratios

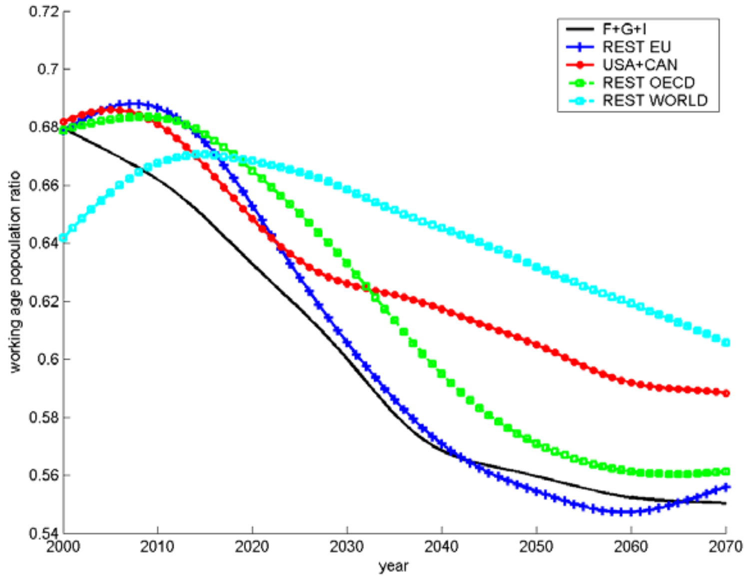
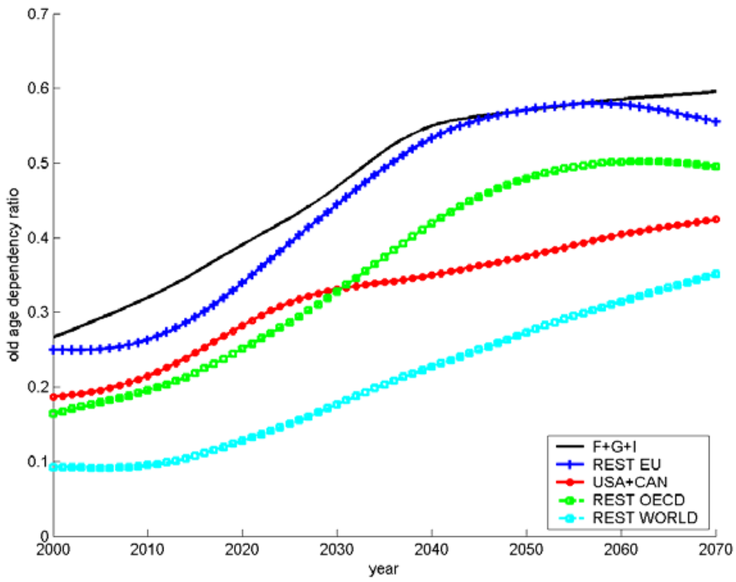


Figure 1b: Old-age dependency ratios



Notes: These figures show projections of the working-age population ratio (the number of people aged 15 to 65 as a percentage of total population) and the old-age dependency ratio (the number of people older than 65 as a percentage of the working age population) for five different world regions. F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries; REST WORLD: the remaining world countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 2: Actual and predicted aggregate labor supply shares

Figure 2a: France, Germany, and Italy

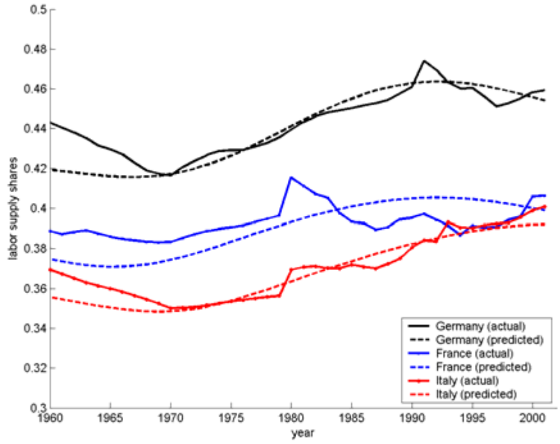


Figure 2b: Other world regions

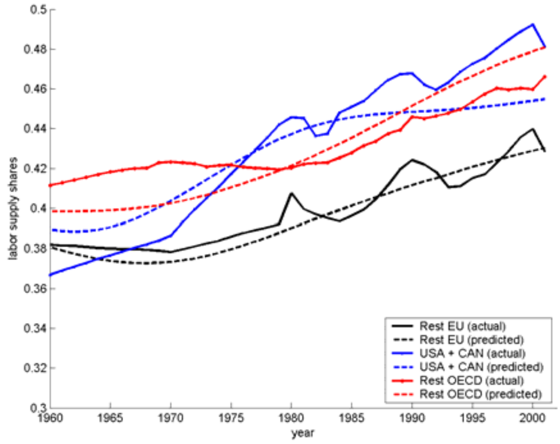
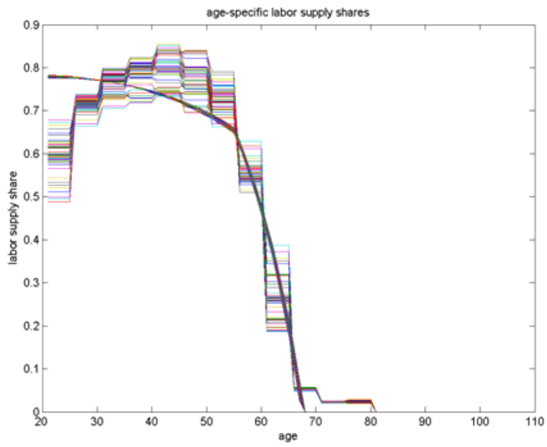


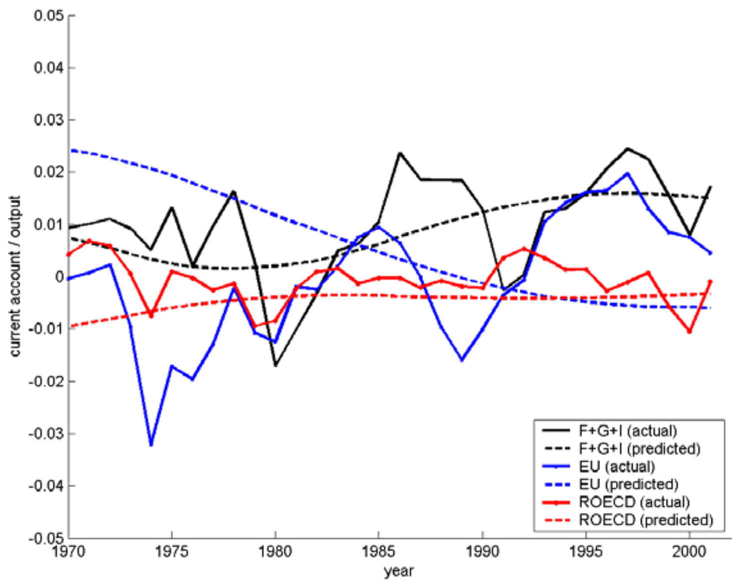
Figure 2c: Average age-specific labor supply shares in G+I+F



Notes: These figures show predicted and actual labor supply shares. Labor supply shares are the number of employed as a percentage of total population. REST EU: all countries of the European Union excluding France, Germany, and Italy; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 3: Actual and predicted current account to output ratios



Notes: This figure shows predicted and actual current account to total output ratios. Current account is defined as the difference between gross national savings and gross fixed capital formation (domestic investment). F+G+I: France, Germany, and Italy; EU: all countries of the European Union excluding France, Germany, and Italy; REST OECD: the remaining OECD countries.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 4: Saving rates

Figure 4a: Old system scenario

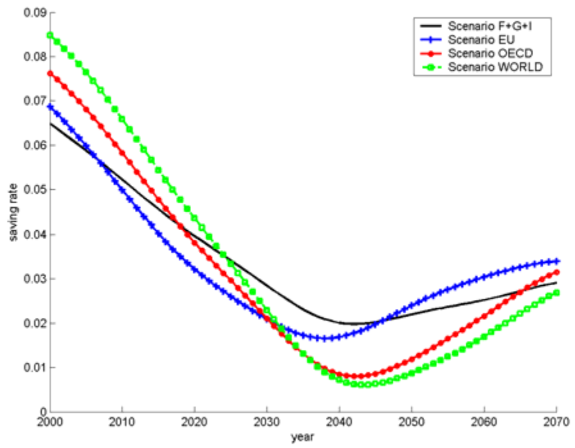


Figure 4b: Reform scenario

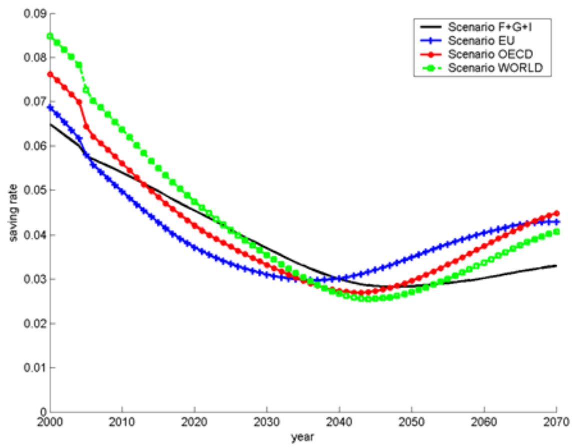
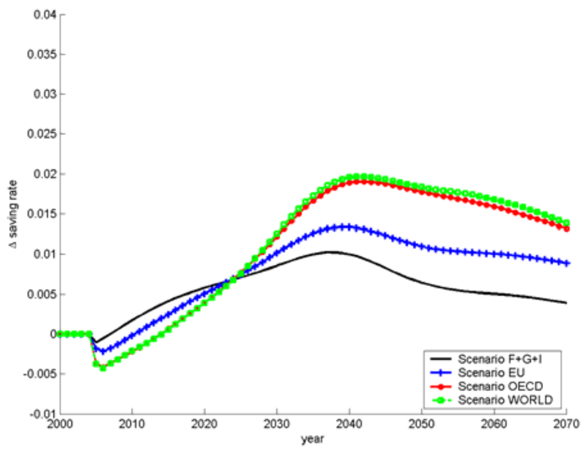


Figure 4c: Difference



Notes: These figures show the projected aggregate saving rate of households living in France, Germany, and Italy. Scenario F+G+I: perfect capital mobility within France, Germany, and Italy; Scenario EU: perfect capital mobility within the European Union; Scenario OECD: perfect capital mobility with the OECD; Scenario WORLD: perfect capital mobility across all world regions.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 5: Rate of return

Figure 5a: Old system scenario

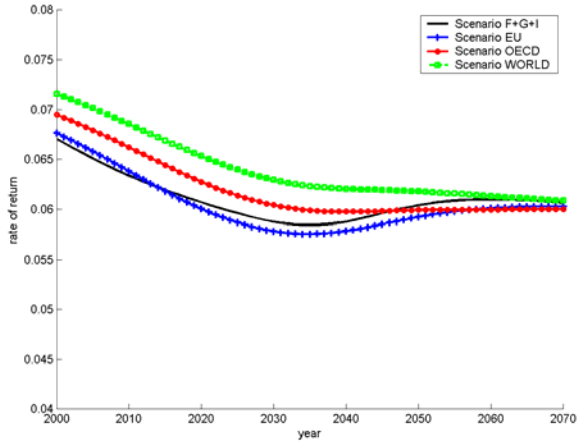


Figure 5b: Reform scenario

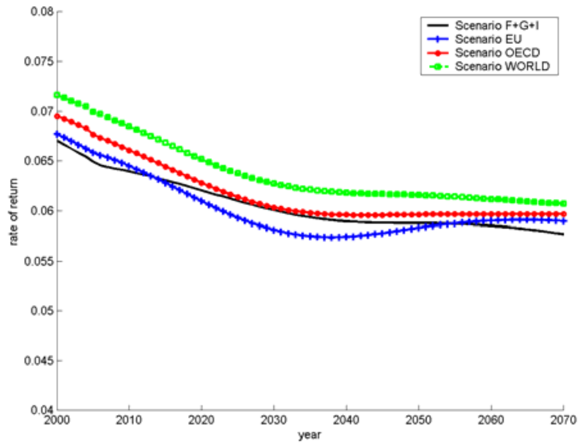
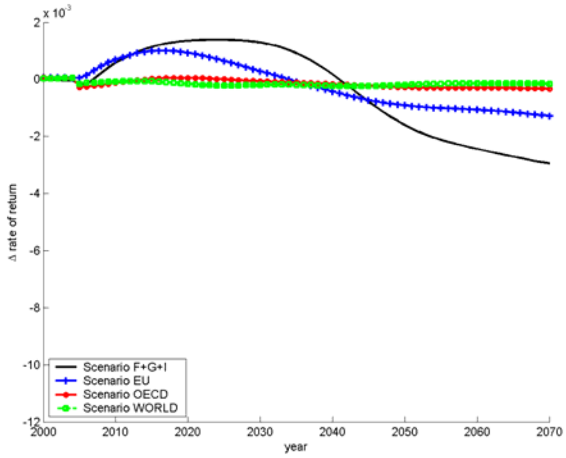


Figure 5c: Difference



Notes: These figures show the projected rate of return of the aggregate capital stock in France, Germany, and Italy. Scenario F+G+I: perfect capital mobility within France, Germany, and Italy; Scenario EU: perfect capital mobility within the European Union; Scenario OECD: perfect capital mobility with the OECD; Scenario WORLD: perfect capital mobility across all world regions.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 6: Current account to output ratios

Figure 6a: Old system scenario

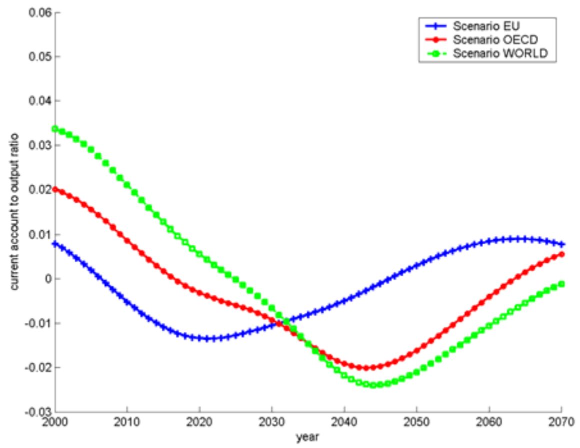


Figure 6b: Reform scenario

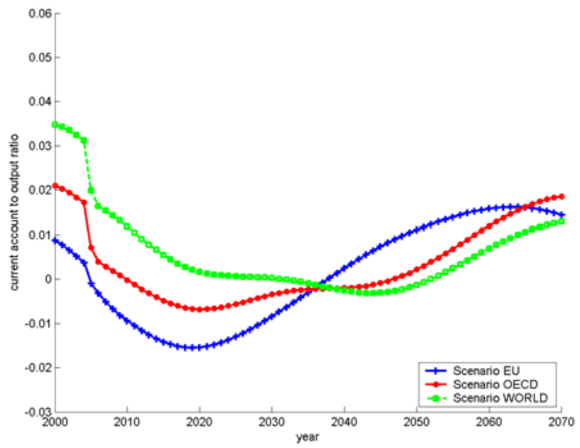
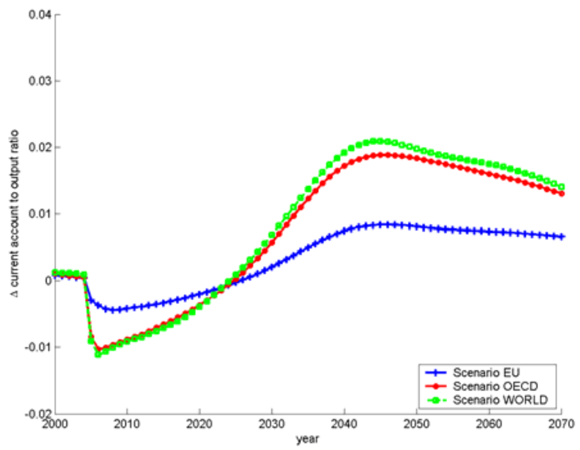


Figure 6c: Difference



Notes: These figures show the projected current account to output ratio in France, Germany, and Italy. Scenario EU: perfect capital mobility within the European Union; Scenario OECD: perfect capital mobility within the OECD; Scenario WORLD: perfect capital mobility across all world regions.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 7: Saving rates and capital flows in the European Union for the OECD scenario

Figure 7a: Saving rate

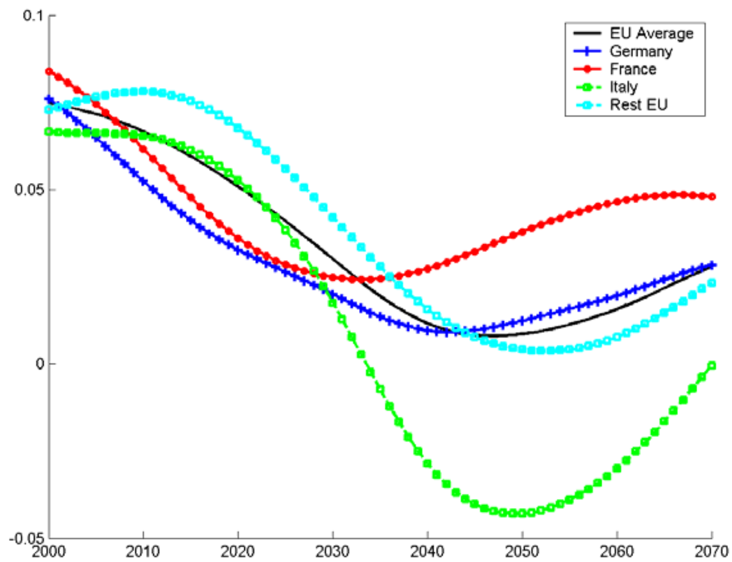
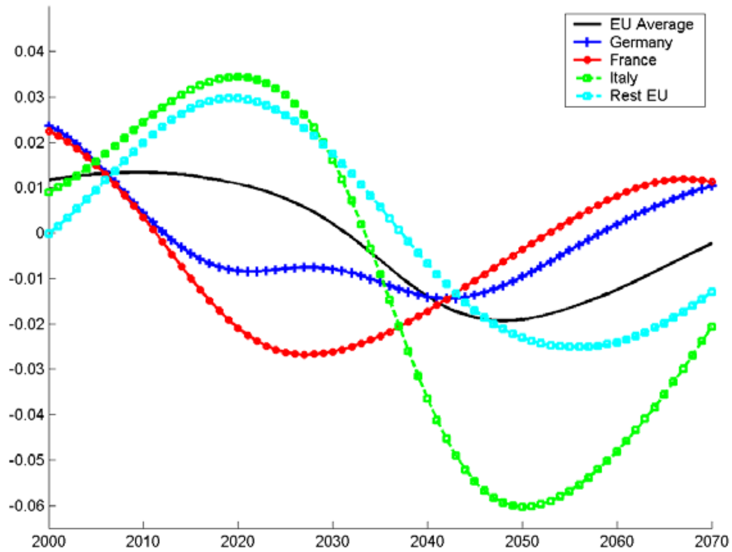


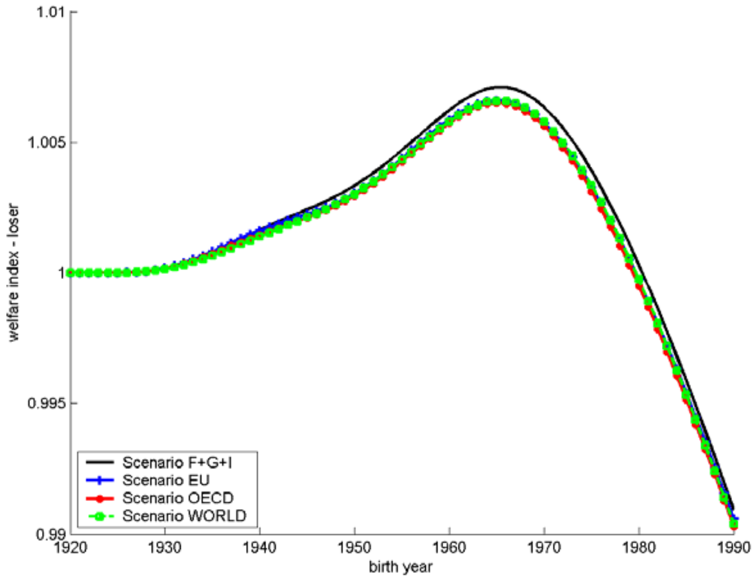
Figure 7b: Current account to output ratio



Notes: This figures show the projected saving rates and the current account to output ratios within countries of the European Union if capital mobility is restricted to the OECD area. EU Average: Average of all EU countries; Rest EU: all EU countries excluding France, Germany, and Italy.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 8: Index of welfare differences between the reform and the old system scenarios



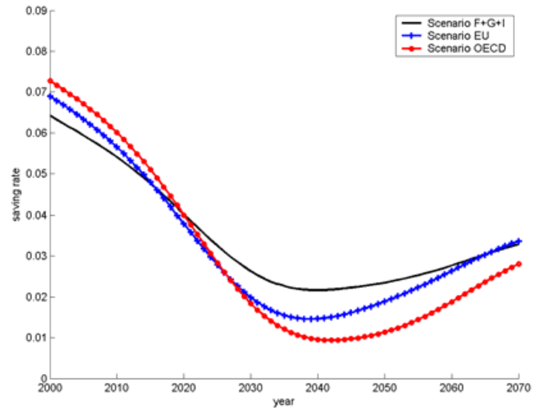
Notes: This figure shows the projected index of welfare differences between the old system scenario and the reform scenario for households living in Germany. Scenario F+G+I: perfect capital mobility within France, Germany, and Italy; Scenario EU: perfect capital mobility within the European Union; Scenario OECD: perfect capital mobility with the OECD; Scenario WORLD: perfect capital mobility across all world regions.

Source: United Nations (2002), WDI (2003), own calculations.

Figure 9: The influence of modeling adjustment costs (old system scenario)

Figure 9a: Saving rates

Benchmark Model



Alternative Model I

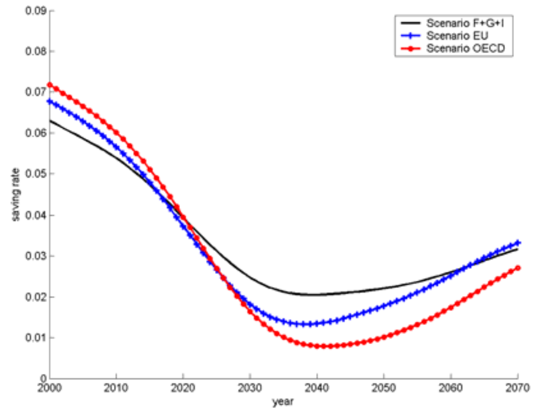
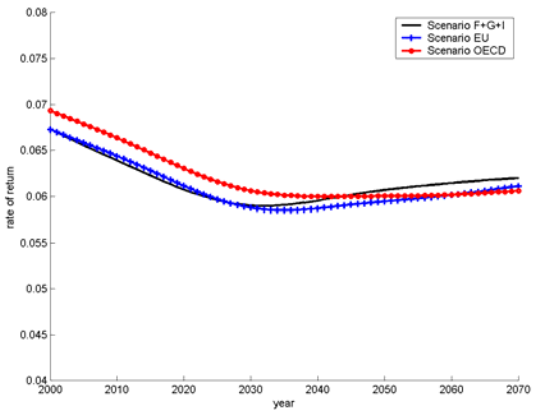


Figure 9b: Rates of return to capital

Benchmark Model



Alternative Model I

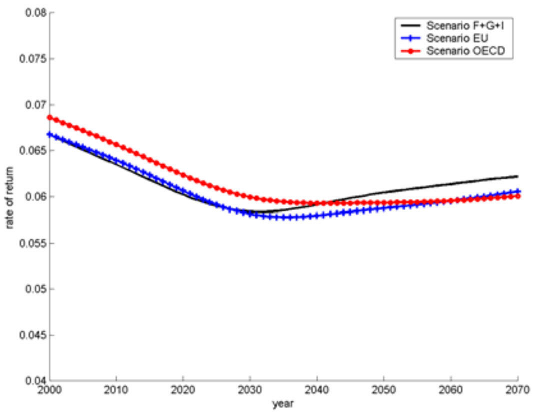
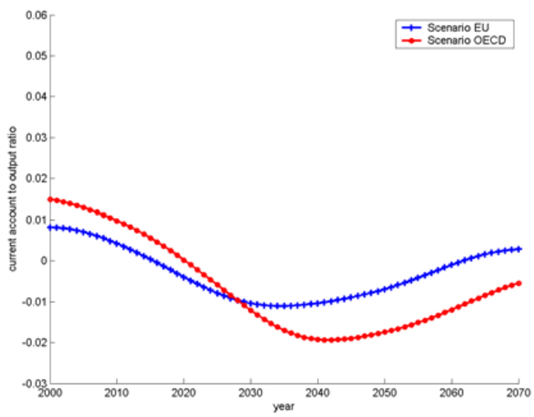
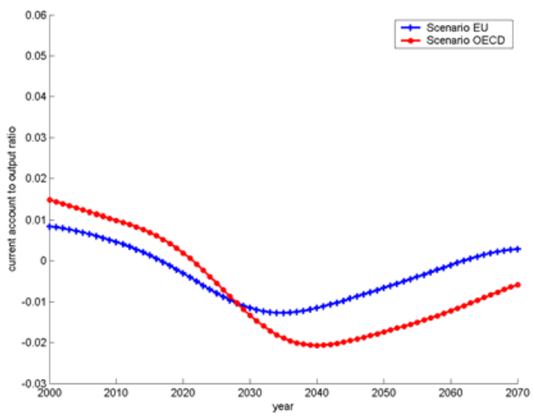


Figure 9c: Current account to output ratios

Benchmark Model



Alternative Model I



Notes: These figures show projections for the benchmark model and the alternative model I. F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 10: The influence of imposing perfect annuity markets (old system scenario)

Figure 10a: Saving rates

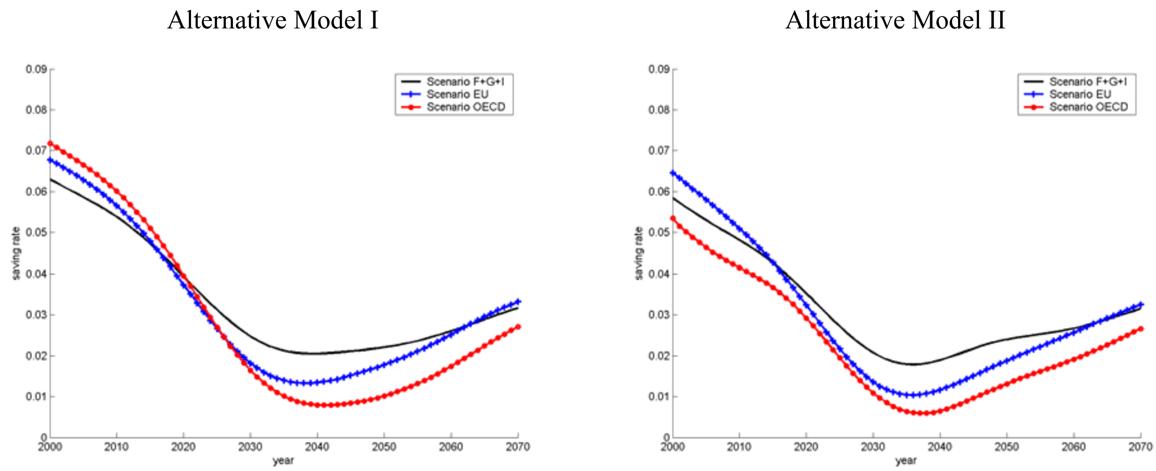


Figure 10b: Rates of return to capital

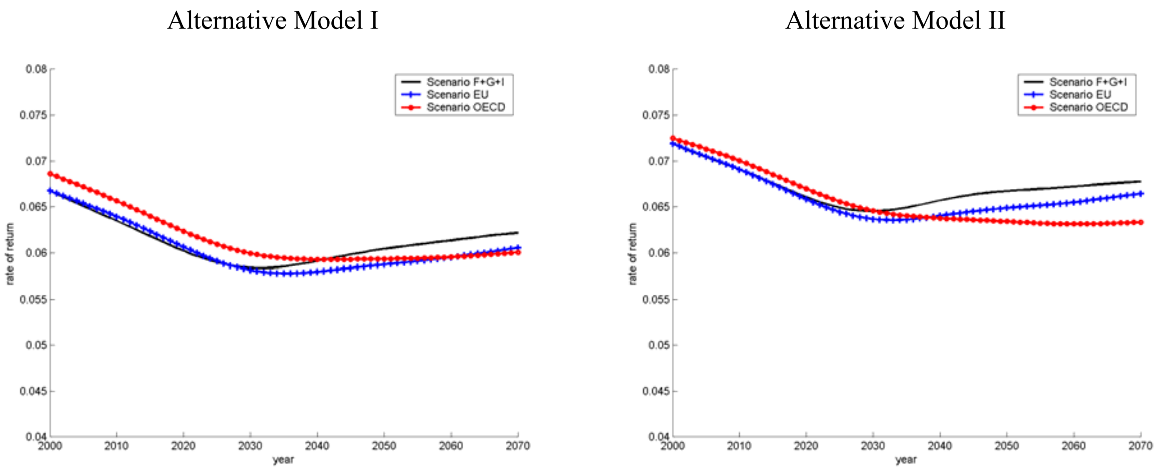
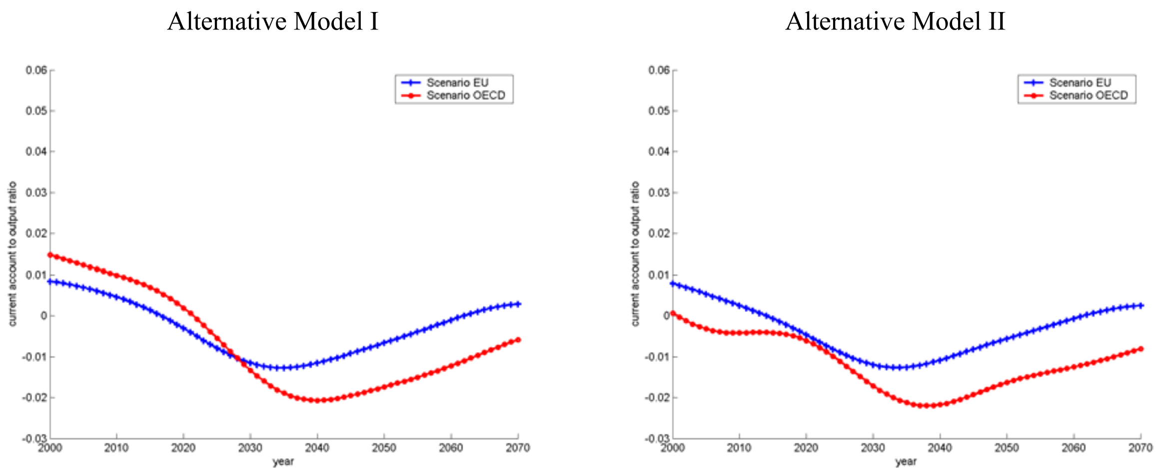


Figure 10c: Current account to output ratios



Notes: These figures show projections for Alternative Model I and Alternative Model II. F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 11: The influence of modeling endogenous labor supply: Saving rates

Figure 11a: Old system scenario

Alternative Model I | Alternative Model III

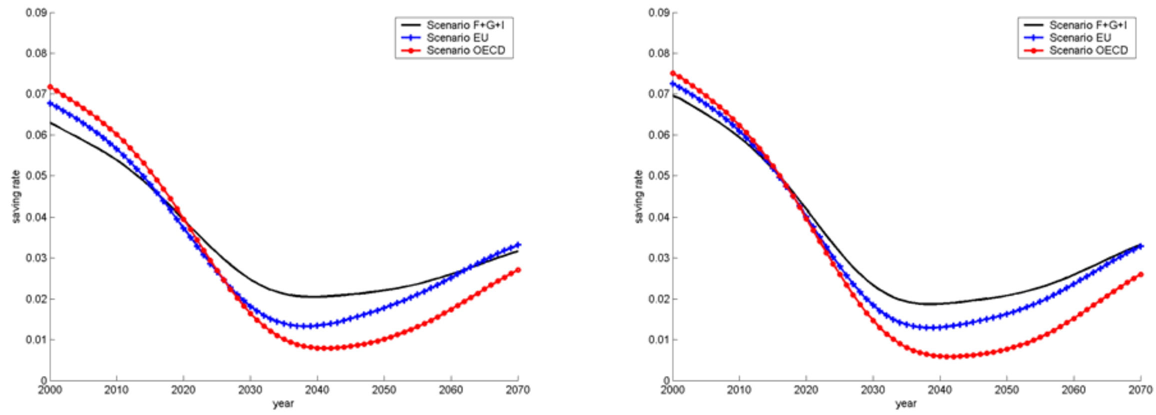
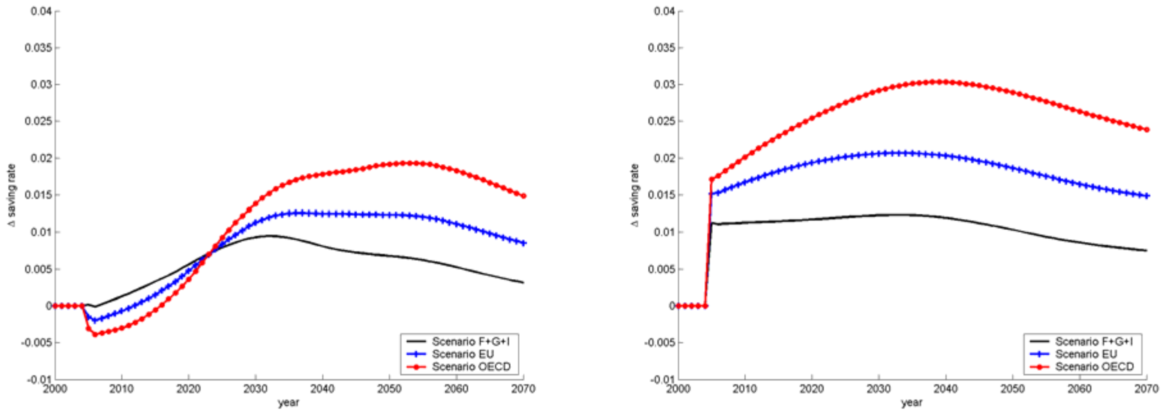


Figure 11b: Difference between the reform and the old system scenarios

Alternative Model I | Alternative Model III



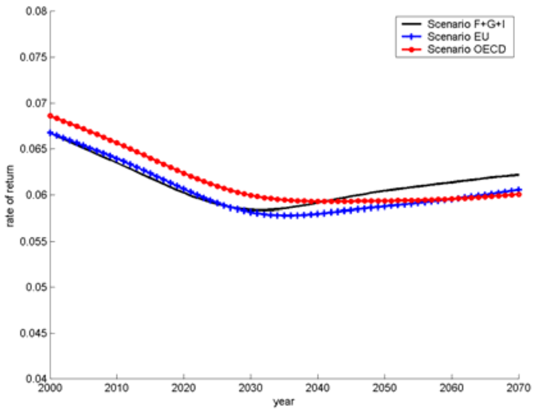
Notes: These figures show projections of the saving rate for Alternative Model I and Alternative Model III. F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 12: The influence of modeling endogenous labor supply: Rates of return to capital

Figure 12a: Old system scenario

Alternative Model I



Alternative Model III

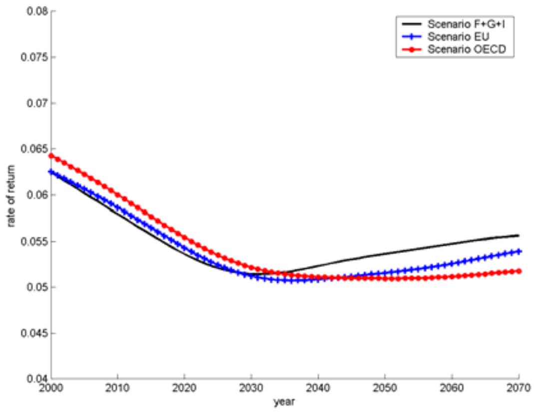
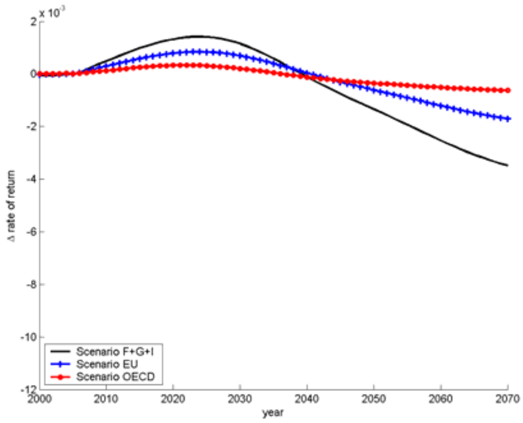
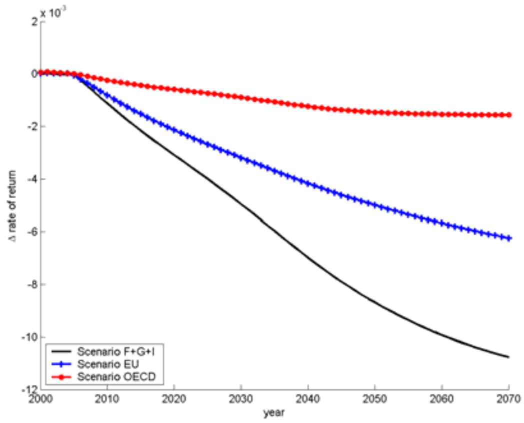


Figure 12b: Difference between the reform and the old system scenarios

Alternative Model I



Alternative Model III



Notes: These figures show projections of the rate of return to capital for Alternative Model I and Alternative Model III. F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 13: The influence of modeling endogenous labor supply: Current account to output ratios

Figure 13a: Old system scenario

Alternative Model I | Alternative Model III

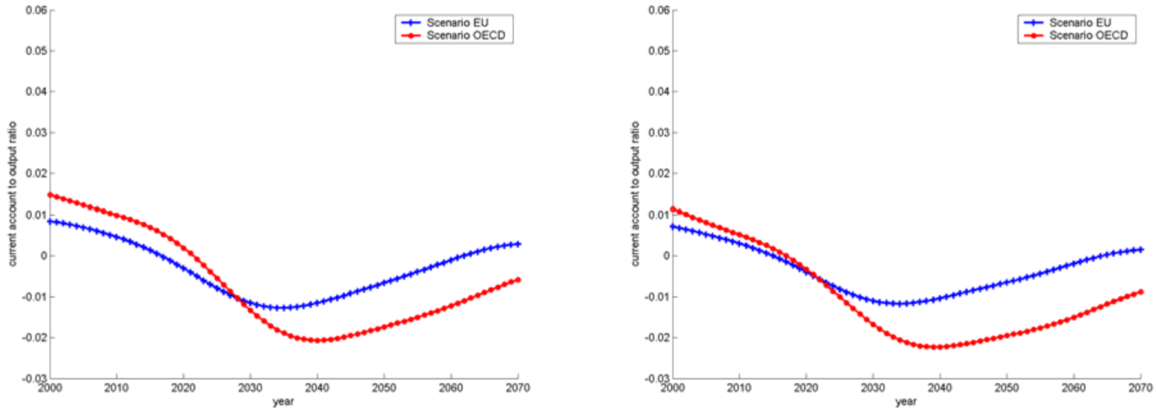
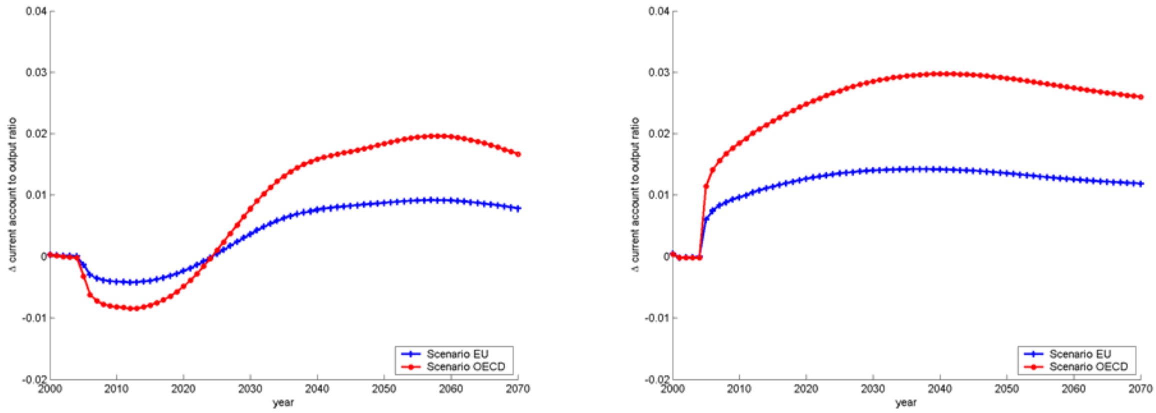


Figure 13b: Difference between the reform scenario and the old system scenario

Alternative Model I | Alternative Model III



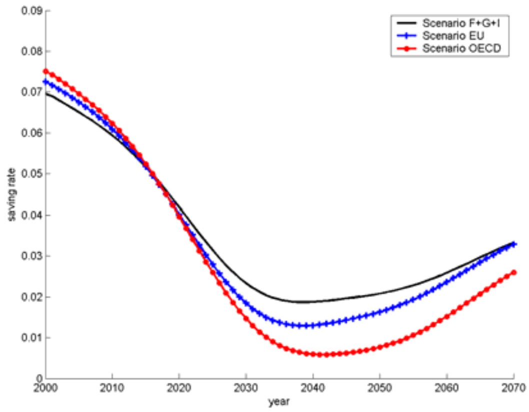
Notes: These figures show projections of the current account to output ratios for Alternative Model I and Alternative Model III. F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 14: The influence of modeling PAYG pension systems

Figure 14a: Saving rates

Alternative Model III



Alternative Model IV

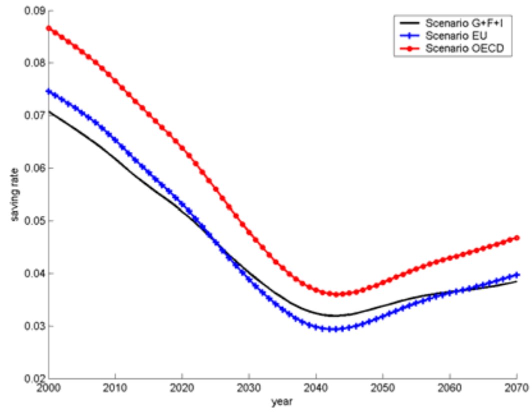
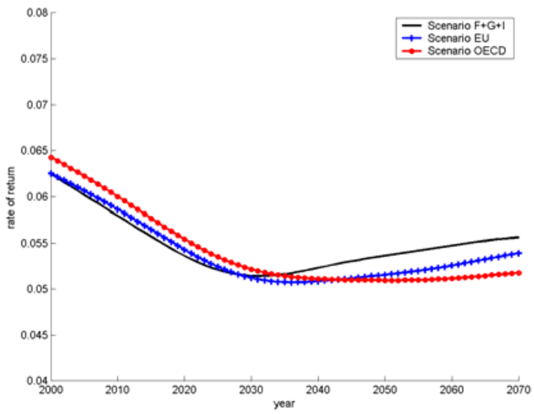


Figure 14b: Rates of return to capital

Alternative Model III



Alternative Model IV

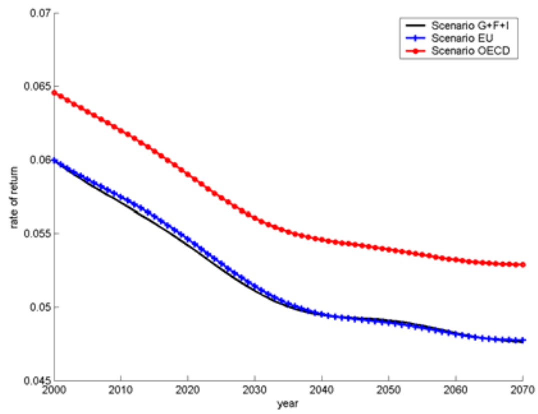
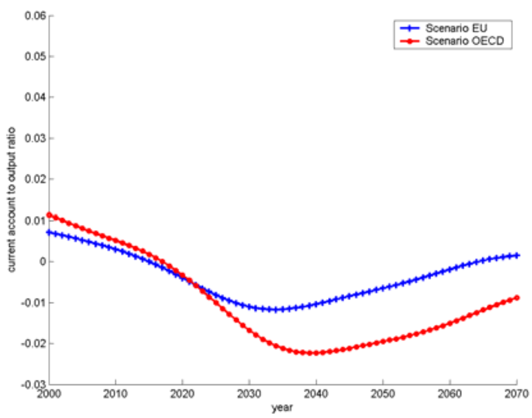
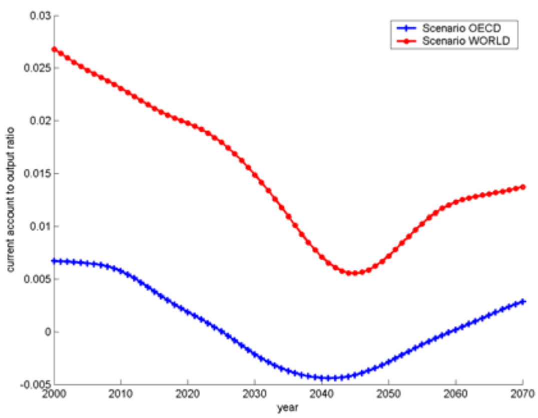


Figure 14c: Current account to output ratios

Alternative Model III



Alternative Model IV



Notes: These figures show projections for Alternative Model III and Alternative Model IV (both with exogenous labor supply). F+G+I: France, Germany, and Italy; REST EU: the remaining countries of the European Union; USA+CAN: the United States and Canada; REST OECD: the remaining OECD countries.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 15: Structural model parameters and the saving rate

Figure 15a: The influence of relative risk aversion (intertemporal elasticity of substitution)

Old system scenario | Reform scenario

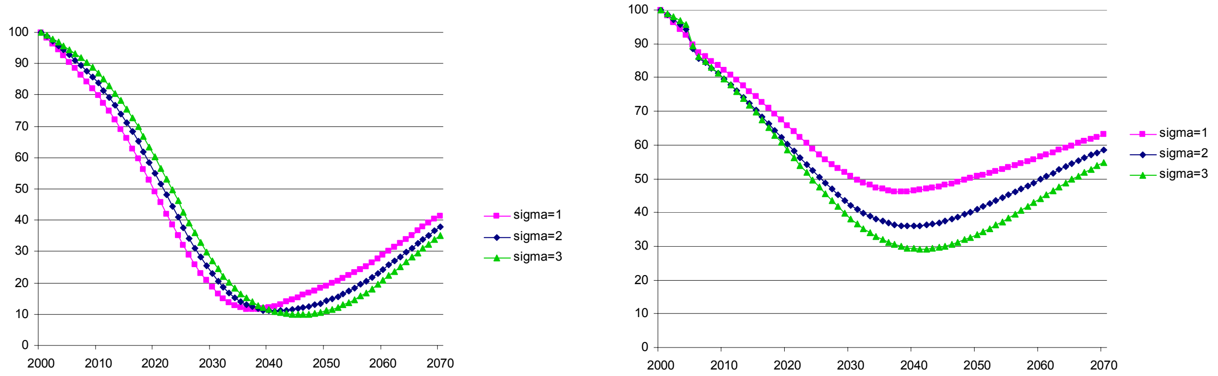


Figure 15b: The influence of the intratemporal substitution elasticity between consumption and leisure

Old system scenario | Reform scenario

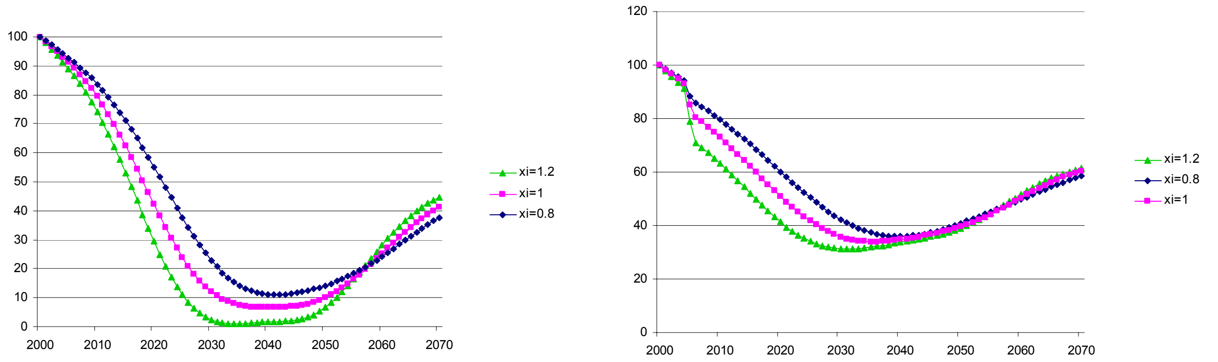
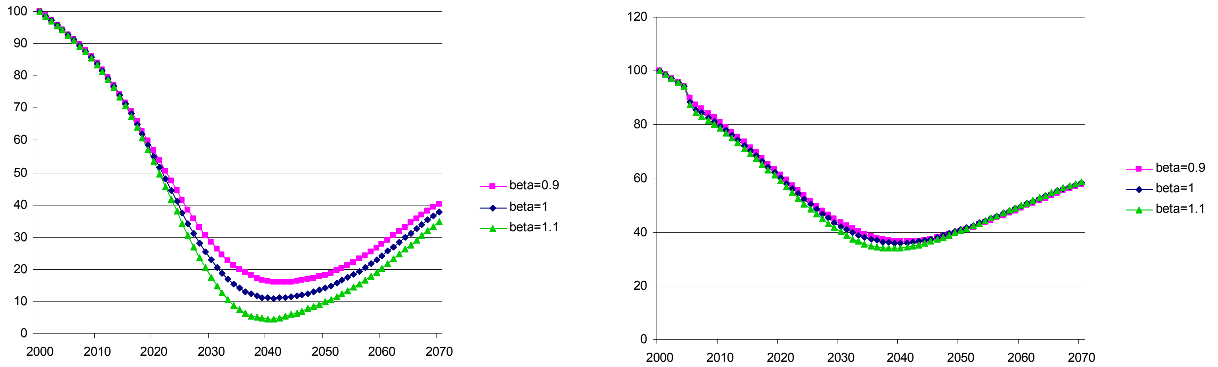


Figure 15c: The influence of the intratemporal substitution elasticity between capital and labor

Old system scenario | Reform scenario



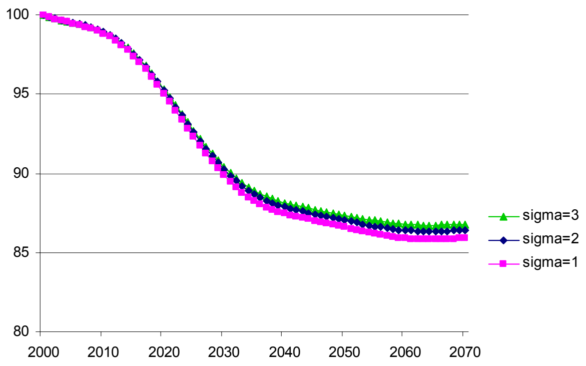
Notes: These figures show projections for the saving rate in F+G+I (France, Germany, and Italy) under perfect capital mobility within the OECD for various sets of structural model parameters.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 16: Structural model parameters and labor supply

Figure 16a: The influence of relative risk aversion (intertemporal elasticity of substitution)

Old system scenario



Reform scenario

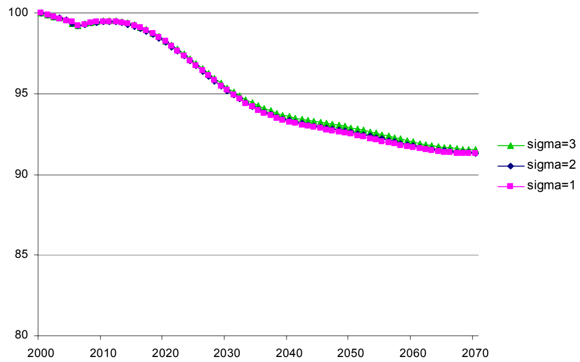
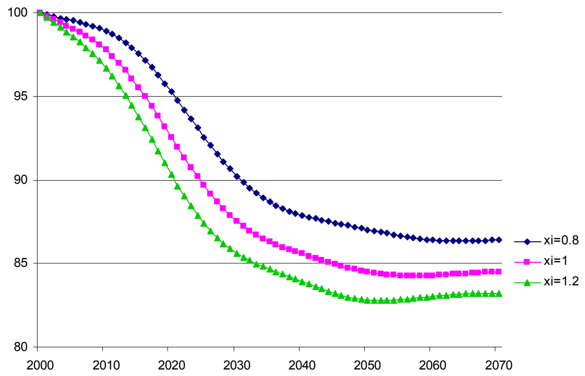


Figure 16b: The influence of the intratemporal substitution elasticity between consumption and leisure

Old system scenario



Reform scenario

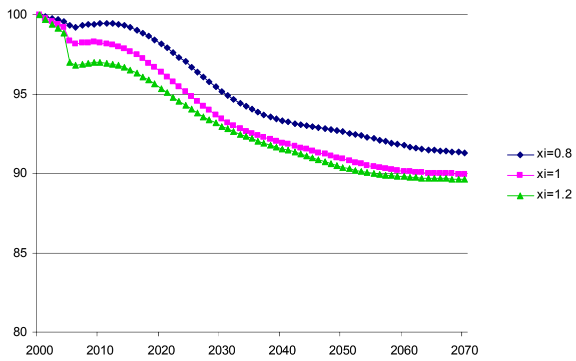
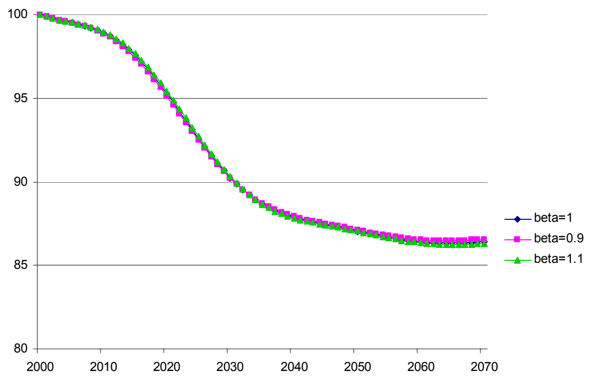
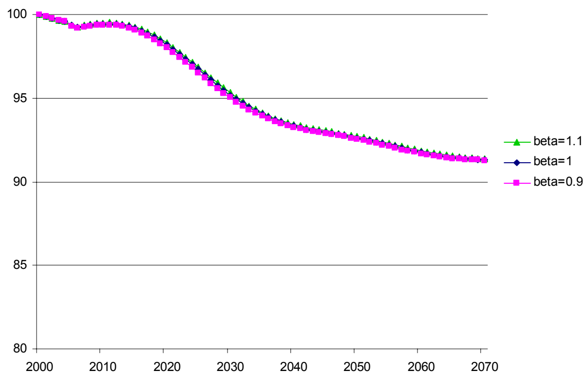


Figure 16c: The influence of the intratemporal substitution elasticity between capital and labor

Old system scenario



Reform scenario



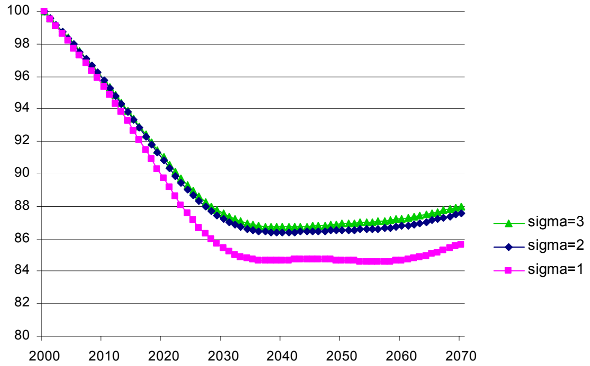
Notes: These figures show projections for the saving rate in F+G+I (France, Germany, and Italy) under perfect capital mobility within the OECD for various sets of structural model parameters.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Figure 17: Structural model parameters and the rate of return

Figure 17a: The influence of relative risk aversion (intertemporal elasticity of substitution)

Old system scenario



Reform scenario

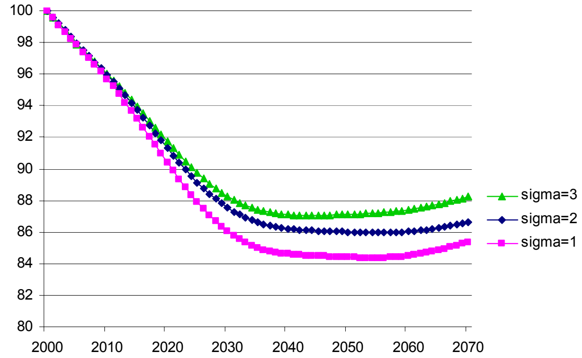
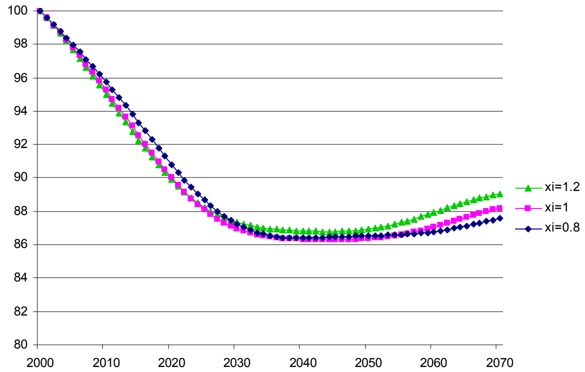


Figure 17b: The influence of the intratemporal substitution elasticity between consumption and leisure

Old system scenario



Reform scenario

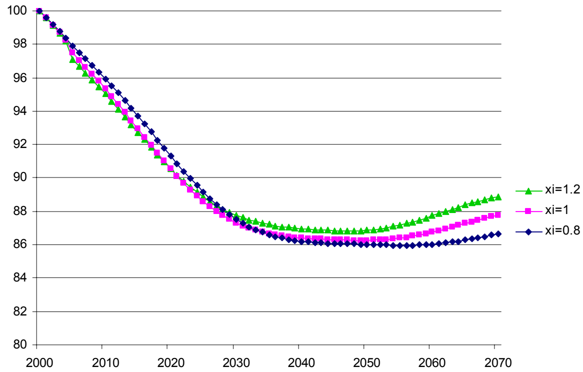
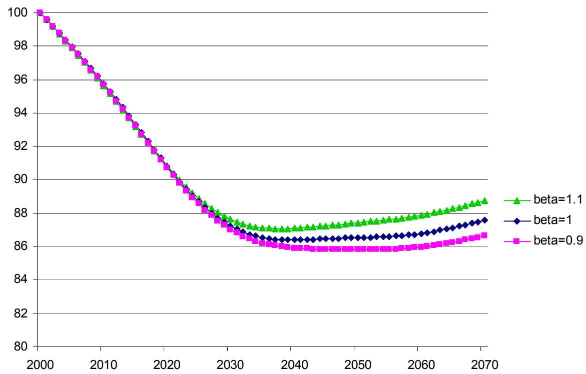
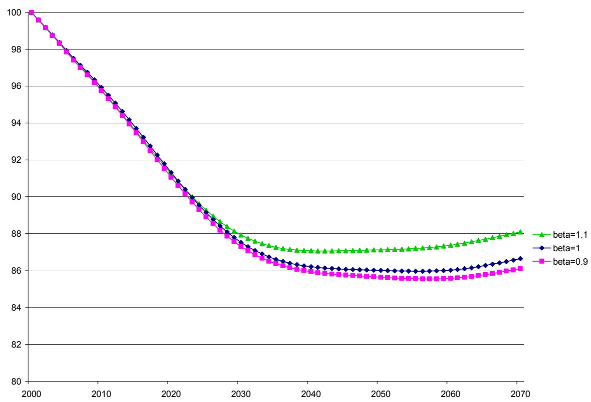


Figure 17c: The influence of the intratemporal substitution elasticity between capital and labor

Old system scenario



Reform scenario



Notes: These figures show projections for the saving rate in F+G+I (France, Germany, and Italy) under perfect capital mobility within the OECD for various sets of structural model parameters.

Source: Own calculations, based on demographic projections of the United Nations (2002).

Table 1: Calibration of parameters in the overlapping generations model

α: output share of capital in the CES production function	0.35
β elasticity of substitution between consumption and labor in the CES production function	1
g: growth rate of labor productivity	0.015
δ: depreciation rate of capital	0.05
ψ: adjustment costs parameter	1.5
ρ: rate of time preference	0.011
σ: coefficient of relative risk aversion	2
ξ: intratemporal substitution elasticity	0.8
Ω_i: technology level	0.05 - 0.07
$\overline{\omega}_{a,i}$: consumption share parameter	0.535 - 0.665
$\Delta\omega_i$: increment of consumption share parameter	0.015 - 0.02

Table 2: Predicted contribution and replacement rates of PAYG pension systems

	France			Germany			Italy		
	2000	2030	2050	2000	2030	2050	2000	2030	2050
Old system scenario									
Contribution rates	0.275	0.356	0.375	0.268	0.375	0.415	0.325	0.476	0.534
Net replacement rates	0.654	0.654	0.654	0.7	0.7	0.7	0.646	0.646	0.646
Reform scenario									
Contribution rates	0.275	0.295	0.295	0.268	0.294	0.294	0.325	0.34	0.34
Net replacement rates	0.654	0.549	0.513	0.7	0.568	0.504	0.646	0.489	0.415

Notes: Figures shown in the table refer to the open economy scenario “OECD”.

Table 3: Models used for sensitivity analysis

	Adjustment costs	**Annuity markets**	**Labor supply**	**PAYG pension system**
Benchmark Model	Yes	Perfect	Endogenous	Yes
Alternative Model I	**No**	Perfect	Endogenous	Yes
Alternative Model II	**No**	**Accidental bequests**	Endogenous	Yes
Alternative Model III	**No**	Perfect	**Exogenous**	Yes
Alternative Model IV	**No**	Perfect	**Exogenous**	**No**

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