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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 international capital flows induced by differential population aging and pension reform. It is well known that within each country, demographic change alters the time path of aggregate savings. This process may be amplified if pension reform shifts old-age provision towards more pre-funding. 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. In order to quantify these effects, we develop a multi-country overlapping generations model and use long-term demographic projections for several world regions to project international capital flows in the course of population aging. Our simulations suggest that capital flows from fast-aging industrial countries such as Germany, Italy or Japan to the rest of the world will be substantial. 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 patterns of population aging are similar in most countries, the timing differs substantially. It is well known that within each country, demographic change alters the time path of aggregate savings, even more so in countries where fundamental pension reforms – that is, a shift towards more pre-funding – are implemented (Börsch-Supan 1996; Reisen, 2000). To the extent that capital is internationally mobile, population aging will induce capital flows between countries.

In this paper, we present a quantitative analysis of capital flows induced by differential aging processes across countries and by pension reforms. We develop a stylized multi-country overlapping generations model and project international capital flows over a 50 year horizon using long-term demographic projections for different sets of countries. Although all countries and country sets are modeled symmetrically as large open economies, our presentation focuses on Germany as a prototypical example of a country with a severe aging problem and, at the same time, an almost completely pay-as-you-go (PAYG) financed public pension system in an ongoing, slowly progressing reform process. Analogous results hold for Italy and Japan which face similarly severe population aging and have dominant PAYG pension systems which are scheduled for long-term reform.

Our simulations predict substantial capital flows due to population aging. The results confirm that 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 Germany and Japan will be mainly capital exporters, while countries less affected by aging like the United States will import capital.

Our paper also adds to the discussion about the so-called "asset market melt-down hypothesis". Several articles in the popular press have attributed recent rises in stock market prices to population aging and raised the fear that an asset market melt-down might occur when the baby boom generation decumulates its assets. In the academic literature, there is no consensus on the asset market melt-down hypothesis (see e.g. Poterba, 2001; Abel, 2001; and Brooks, 2002). According to our view, closed-economy models conventionally used in the academic literature miss the important fact of international capital flows. We show that because of international diversification, the melt-down of the asset market is lower than predicted by the closed-economy version of our model. The decrease in the rate of return which results from both population aging and moving towards pre-funded pensions is modest, approximately 1.3 percentage points once we assume a closed economy. The return on capital can be improved by international diversification, that is, by investing pension savings in countries with a more favorable demographic transition path than Germany. With respect to pension reform, our simulations show that after a partially funded pension system is phased in, capital exports from Germany to OECD countries would be higher than if the pre-2002 pay-as-you-go system was preserved, never falling below 4% of GDP (after a peak of about 6% of GDP around 2025).

The effects of international diversification on savings behavior and its interaction with pension reforms receive rapidly 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 strongly 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.

Overlapping generations (OLG) 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. Our paper improves in several dimensions on the existing literature. Attanasio and Violante (2000) and Brooks (2003) analyze demographic effects on international capital mobility in stylized models (and in the case of Attansio and Violante, using also very stylized demographic projections). Both papers do not address the important issue of pension reform with its associated change in saving patterns. Like INGENUE (2001), our paper addresses issues related to pension reform. Moreover, it uses actual demographic projections which model population aging realistically as a more than one-dimensional event. 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 actual demographic forecasts; they are largely ignored in the stylized demographic transition schemes used in other work. Unlike INGENUE (2001), we explicitly model the inhomogeneity of population aging within Europe. For instance, France and Great Britain are aging much less than Germany and Italy. The resulting intra-European capital flows are of particular interest since they are not subject to exchange rate risks (at least as far as the Euro countries are concerned).

With the exception of Attansio and Violante (2000), existing studies such as INGENUE (2001) and Brooks (2003) have not addressed the impact of life-time uncertainty on household saving decisions. This is not only an important and salient extension of the classical life-cycle theory of consumption. Not including the underlying survival rates in the household problem also leads to inconsistencies in aggregation. Our paper incorporates life-time uncertainty in a slightly different, and – as we think – more elegant way than Attanasio and Violante (2000).

The remainder of this paper is structured as follows. Section 2 presents empirical evidence and theoretical explanations for the effects of population aging on international capital flows. In section 3, we present our multi-country overlapping generations model that can be used to evaluate these effects quantitatively. Section 4 contains our simulation results for various pension policy and capital mobility scenarios. Section 5 concludes.

2. Some facts about population aging and international capital flows

At mid-2000, world population stood at 6.1 billion. While the world population has constantly grown, its annual growth rate has decreased from 2.04% during the period from 1965 to 1970 to 1.2% annually now. It is expected that this decrease in world population growth will continue. In the medium variant of the United Nations' current world population projections, the growth rate is projected to decrease to 0.5% by 2050. By then, world population will have increased to 9.3 billion. Most of this increase in the size of the world population takes place in less developed regions (United Nations, 2001).

Throughout the world, demographic processes are determined by the so-called demographic transition which is characterized by falling mortality rates followed by a decline in birth rates, resulting in population aging and thereby reducing the population growth rate or turning it to negative. While the patterns of population aging are similar in most countries, the timing differs 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). 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 – in part due to the enormous impact of AIDS (United Nations, 2001).

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). In addition, some fraction of the capital stock may become obsolete due to the shrinking labor force and diminishing returns to scale, making the accumulation of capital even less attractive.

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.

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 (2002) 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. While this has been shown in other studies before, she can also show that across countries relative differences in the age structure are the most important determinants of capital flows, a finding that is even more important for the analysis of pension reform than the fact that the absolute age structure affects a country's capital balance. Moreover, as Lührmann (2002) shows, 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).[1] In their original contribution, Feldstein and Horioka have shown that national saving rates are highly correlated among 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 (see e.g. Taylor, 1994; Obstfeld and Rogoff, 1996; 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 international 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 (1999) 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 restrict attention to OECD countries, and we only model the polar cases of a closed economy and of perfect capital mobility within the OECD region. This approach allows to understand the effects of capital mobility on rates of return in the future even though the true effect might be smaller.

3. Aging and pension reform in a stylized overlapping generations 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. 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 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. Recent examples include Kotlikoff, Smetters and Walliser (1999), De Nardi, Imrohoroglu and Sargent (1999), and Altig, Auerbach, Kottlikoff, Smetters and Walliser (2001) for the United States, Miles (1999) for Great Britain, and Fehr (2000), Hirte (2002) and Börsch-Supan, Heiss, Ludwig and Winter (2003) for Germany. Miles and Iben (2000) present a comparative analysis of pension reform schemes for the United Kingdom and

[1] See Obstfeld (1995), Obstfeld and Rogoff (1996), and Coakley, Kulasi, and Smith (1998) for recent surveys.

Germany. Kotlikoff (1998) provides an overview of earlier applications of overlapping generations models.

An earlier version of the model used in this study was presented by Börsch-Supan, Ludwig and Winter (2002). We improve our earlier model along several dimensions. First, we treat all countries symmetrically with respect to demographic change by using UN population projections taken from the *World Population Prospects* (United Nations, 2000) for all countries.[2] Second, we allow for life-time uncertainty in the household optimization problem, and we explicitly model age-specific productivity. Finally, at a more technical level, we start our calculations in 1850 and therefore relax the assumption of a steady state in 2000.

3.1 The demographic transition

Demographic and labor force projections form the background of our analysis and are therefore a natural point of departure for the description of our simulation model. Based on annual demographic projections by the United Nations, we compute time paths for the number of workers and pensioners in each of the countries and world regions considered in our simulations. These projections enter our model via time-specific sizes of the living cohorts in year t of country i, denoted by $N_{t,a,i}$, where a is age. Cohorts are faced with mortality risk: we denote by $s_{t,a,i}$ the age and time-specific conditional survival probability and by $p_{t,a,i} = \prod_{a=0}^{t-1} s_{t,a,i}$ the unconditional survival probability. The economic life of a cohort begins at the age of twenty years, for which we set $a = 1$. The maximum age people are can reach is given by Z. We therefore take $N_{t,a,i}$ to be total population for $a = 1, ..., Z$, where $Z = 91$. In our simulations, we include age and time-specific weights that represent the fraction of the population that is currently working, unemployed or retired. Age-specific labor force participation and unemployment rates are derived from our labor market scenarios. The fraction of pensioners increases from 0 to 1 over an extended retirement window from age 48 through 80. The time paths of these weights are cohort-specific, reflecting shifts in labor supply and retirement behavior. For notational convenience, we represent these weights by the variables, $\nu_{t,a,i}$, $\mu_{t,a,i}$, and $\pi_{t,a,i}$ respectively. To summarize, $\nu_{t,a,i} \cdot N_{t,a,i}$ therefore reflects the number of workers, $\mu_{t,a,i} \cdot N_{t,a,i}$ the number of unemployed individuals and $\pi_{t,a,i} \cdot N_{t,a,i}$ the number of pensioners of age a in time period t and country i.

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[2] In our earlier paper, we used a more elaborate demographic projection for Germany which, however, was not fully consistent with the UN projections used for the other countries.

To fill this abstract framework with life, we use, for each country, long-term projections of the demographic structure as computed by the United Nations (United Nations Population Division, 2000).[3] These demographic projections are then augmented by labor force projections based on age and gender-specific employment rates. This approach allows us to analyze labor-supply variations along dimensions that are only partially modeled in many other models with endogenous labor force participation (namely, female labor supply and unemployment). We assume increases in female employment rates and decreases in unemployment rates especially for the countries of the European Union. Increases in the mean retirement age are also taken into account for countries in which an ongoing debate on political reforms of pension systems can be observed or where such reforms have already passed legislation such as Japan, Germany, the United States and all other countries of the European Union. A more detailed description of our labor market scenarios is given in the Appendix.

Figures 1 and 2 demonstrate the effects of demographic change and our assumed increases in employment rates for different world regions. First, we show the pure effects of demographic change on 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). Panel (a) of figure 1 shows that the working-age population is projected to decrease in virtually all world regions throughout the entire period from 2000-2050, except for the United States and the region called OECD 13.[4] Panel (b) of the same figure demonstrates the enormous impact of aging on the old-age dependency ratio which is projected to increase for all world regions. In absolute terms, Japan, the EU 14 and Germany, with increases in the old-age dependency ratio to 59, 52 and 49% respectively, are the regions most affected by aging. However, in relative terms, the region that comprises the other OECD countries, OECD 13, faces the most challenging aging process.

Panel (a) of figure 2 corresponds to panel (a) of figure 1. Here, we augment the projected demographic data with age-specific employment rates. A comparison of the two figures shows that the assumed increases in age-specific employment rates mitigate the effects of aging on aggregate employment. Movements of the aggregate employment rates parallel each other in Germany, the other countries of the European Union (EU 14), and the United States.

[3] In our simulation model we assume that a final steady state is reached in 2200. However, the United Nation’s population projections last only until 2050. We therefore forecast population until 2200 applying the assumptions underlying the United Nations long-term projections until 2100 and assuming constant fertility, mortality and zero migration after 2100 which then results in constant population growth rates.

[4] The region EU 14 summarizes all countries in the European Union except for Germany, the region OECD 13 summarizes all OECD countries except for the member states of the European Union, USA and Japan.

For Japan, the trend points into the same direction but the swings are exactly opposite. In the region OECD 13, a decrease of the aggregate employment rate sets in much later than for the other regions. The maximum decrease of the aggregate German employment rate occurs between the years 2013 and 2036 with a decrease of about 8.4%. While the assumed increases in employment participation rates mitigate the effects of aging, they can by far not offset increases in old-age dependency: as shown in panel (b) of figure 2, the ratio of the numbers of pensioners and workers increases tremendously in all world regions.

3.2 Stylized pension systems

Our next step is to model pension systems. Except for accounting for different insurance levels, we treat all countries alike. We further simplify our representation of social security by ignoring several features of the pension system such as the links with other social protection systems in Germany (for a more detailed analysis in a closed-economy setting, see Börsch-Supan, Heiss, Ludwig, and Winter, 2003; Hirte, 2002). The aspects we address in this contribution are unaffected by such institutional detail.

The pension system of each region *i* enters the model through time paths of the contribution rate, $\tau^P_{t,i}$. The contribution rate, in turn, is calculated from the exogenous policy variable, the time-specific replacement rate, $\gamma^P_{t,i}$ (defined as the ratio of net pension to net wage income at time *t*). Thus, the budget constraint of the public pension system is balanced at any time *t*. Since we ignore contributions to other social security systems, the budget constraint is given by:

$$(1) \qquad \tau^P_{t,i} \sum_{a=1}^{Z} w^g_{t,a,i} \upsilon_{t,a,i} N_{t,a,i} = \gamma^P_{t,i} ANI_{t,i} \sum_{a=1}^{Z} \lambda_{t,a,i} \pi_{t,a,i} N_{t,a,i} \,,$$

where $w^g_{t,a,i}$ are gross wages (which differ across age due to age-specific productivity, see below) and $\lambda_{t,a,i}$ is a weight that determines the pension entitlement of each pensioner (which is a function of the number of years worked). $ANI_{t,i}$ denotes average net income where the only difference between gross and net wages are contributions to the pension and the unemployment insurance system, $\tau^U_{t,i}$ as well as taxes on wage income, $\tau^I_{t,i}$. The direct contribution rate to the German PAYG pension system is currently at 19.1%. The replacement rate of the so-called standard pensioner – a pensioner who paid average contributions during a working period of 45 years – is currently about 70.4%. Assuming that this replacement rate remains constant, our stylized pension model predicts increases of the contribution rate to about 27 percentage points until 2050 (table 1).

To separate the direct effects of population aging on capital markets and potential feedback effects from pension reform, we present our projections for two counterfactual pension system scenarios: (a) maintaining Germany's former generous pension system, and (b) introducing a one-third transition to a funded pension system as described by Börsch-Supan (2002). These are two extreme cases, and they are both counterfactual. Scenario (a) has been overruled by the reform of the German pension system that was passed in February 2001, but this reform is more modest than scenario (b). Since the 2001 reform is unlikely to solve future problems of the German pension system (Schnabel, 2000), the most likely scenario for Germany's future pension system is somewhere between our two extreme scenarios. The demographic development is not only unfavorable for the German pension system but also for pension systems of other OECD countries. Hence, we also compare our results with the consequences of simultaneous stylized pension reforms in other countries.

Reform scenario (b) which demonstrates the beneficial effects of international capital flows under a pension reform is modeled in accordance to the "freezing" proposal by Börsch-Supan (2002).[5] We assume that such a pension reform is announced in 2002 and implemented in 2005 by freezing the contribution rate to the PAYG system at its 2005 level. Thus, households that started their economic live before 2002 have a period of three years to adopt their lifetime plans, while households that enter economic live after 2002 already face the new conditions. Since the pay-as-you-go pension system remains in place, freezing contribution rates results in lower public pension payments, given a rising old-age dependency ratio. This, in turn, results in lower replacement rates provided by the pay-as-you-go pillar of the pension system (table 1).

In our simulations, we do not explicitly model the funded component of the pension system. The funded component consists entirely of voluntary, private savings, as given by households' optimal life-cycle decisions. Rational behavior of households implies that these voluntary savings increase in proportion to the decrease of the pay-as-you-go pension replacement rate.

[5] To varying degree, the same mechanisms are at work in any scheme that involves the introduction of a funded component.

3.3 Stylized unemployment insurance

We model the unemployment insurance system in a stylized fashion as well, and again we abstract from any interactions between the various social security systems. The contribution rate to the unemployment insurance system, $\tau^U_{t,i}$, is determined by balancing the budget constrained and holding fixed a replacement rate, γ^U_i, here defined as the ratio of current average unemployment income to current average net wage income.

(2) $$\tau^U_{t,i} \sum_{a=1}^{Z} w^g_{t,a,i} \upsilon_{t,a,i} N_{t,a,i} = \gamma^U_i \sum_{a=1}^{Z} \mu_{t,a,i} N_{t,a,i} w^n_{t,a,i} .$$

The system of equations (1) and (2) simultaneously determines both the contribution rates to the pension and the unemployment insurance systems.

3.4 Main features of the overlapping generations model

General equilibrium in this overlapping generations model is constructed via the production sector where, given factor inputs (capital and labor), output and factor prices are determined. The production sector in each country consists of a representative firm that uses a Cobb-Douglas production function given by

(3) $$Y_{t,i} = F\left(K_{t,i}, \Theta_{t,i} L_{t,i}\right) = K^{\alpha}_{t,i} (\Theta_{t,i} \sum_{a=1}^{Z} \varepsilon_a \upsilon_{t,a,i} N_{t,a,i})^{1-\alpha} ,$$

where α is the factor share, assumed identical for all countries. $K_{t,i}$ denotes the capital stock of country i at time t and $\Theta_{t,i}$ is aggregate labor productivity, where $\Theta_{t+1,i}=\Theta_{t,i}(1+\eta)$. Note that we assume that the growth rate of labor productivity is constant for all countries and across time. In addition to this time trend in labor productivity we model age-specific productivity, ε_a, which is identical across countries. We divide equation (3) by $\Theta_{t,i} \sum_{a=1}^{Z} \varepsilon_a L_{t,a,i}$ to obtain the representation of the production function in terms of efficiency units,

(4) $$y_{t,i} = f\left(k_{t,i}\right) = k^{\alpha}_{t,i} ,$$

where $y_{t,i}$ is output and $k_{t,i}$ is the capital stock per efficiency unit of labor of country i.

From static profit maximization, we obtain the interest rate which is identical for all countries due to our assumption of perfect capital mobility. It follows that the capital stock per efficiency unit is also equal for all countries,

(5) $$r_t = f'\left(k_{t,i}\right) - \delta \;\; \forall i \quad \Leftrightarrow \quad k_{t,i} = k_t \;\; \forall i ,$$

where δ is the rate of depreciation of capital, assumed to be constant across time and identical for all countries. $f'(k_{t,i})$ is the first derivative of equation (4) with respect to capital. It follows that output per efficiency unit is also identical for all countries, i.e. $y_{t,i}=y_t \;\; \forall\, i$. Since in Germany 50% of social security contributions are formally (even though not economically) paid by the employer, gross wage rates are given by

$$(6) \qquad w^g_{t,i} = \Theta_{t,i} \frac{\omega_t}{1+0.5\left(\tau^P_{t,i} + \tau^U_{t,i}\right)} = \Theta_{t,i} \frac{\left(f(k_t) - k_t f'(k_t)\right)}{1+0.5\left(\tau^P_{t,i} + \tau^U_{t,i}\right)},$$

where ω_t is the marginal product of labor per efficiency unit.

In order to determine aggregate consumption, we next consider optimal household behavior derived from intertemporal utility maximization. By choosing an optimal consumption path, each generation *a* maximizes, at any point in time *t*, the sum of discounted future utility. A complication arises because households face the risk of prematurely dying with positive wealth. To rule out accidental bequests, we adopt the life-insurance framework by Yaari (1965). We assume that there exist one-period ahead perfect annuity markets that allow households to perfectly insure against the event of early death (see also Rios-Rull, 1996; 2001).[6] Since there is a large number of households, the idiosyncratic mortality risk is washed out at the economy wide level. Assuming perfect competition in the insurance sector, firms offer a contract of the following form to individuals of cohort *a*: one unit of this security in a given period exchanges for $1/s_{t,a,i}$ units of the capital good in the next period if the agent survives and zero otherwise. Since this contract is actuarily fair and effectively offers a higher return to capital than the market rate, individuals will hold all their wealth in such contracts.

While age-specific survival rates (and therefore the discount rates of households) differ across countries, preferences are otherwise assumed to be identical. The within-period utility function exhibits constant relative risk aversion, and preferences are additive and separable over time. The target function of generation *a*'s maximization problem at time *t* is given by

$$(7) \qquad U_{t,a,i} = \frac{1}{1-\sigma} \sum_{j=a}^{Z} \frac{1}{(1+\rho)^{j-a}} p_{t+j-a,j,i} \left(C_{t+j-a,j,i}\right)^{1-\sigma},$$

[6] One might object to the counterfactual assumption of perfect annuity markets and the absence of accidental bequests. However, this assumption is uncritical since it can be interpreted as an implicit redistribution scheme for accidental bequests under an imperfect annuity market. Using alternative redistribution schemes turns out not to significantly alter our simulation results.

where σ denotes the coefficient of relative risk aversion, ρ is the discount rate and $C_{t,a,i}$ is consumption. Denoting by $A_{t,a,i}$ total wealth, both specific to generation a at time t and equal to zero for $a=1$, maximization is subject to a dynamic budget constraint given by

(8) $$s_{t,a,i}A_{t+1,a+1,i} = A_{t,a,i}(1+r_t) + Y^n_{t,a,i} - C_{t,a,i}, \quad \text{where} \quad A_{t,1,i} = 0.$$

The left-hand side reflects the existence of perfect annuity markets. $Y^n_{t,a,i} = \upsilon_{t+j-a,i}Y^{n,L}_{t,a,i} + \pi_{t,a,i}Y^P_{t,a,i} + \mu_{t,a,i}Y^U_{t,a,i}$ is household net income, given by the weighted sum of (net) labor (L), pension (P) and unemployment (U) income.

The solution to the intertemporal optimization problem can be characterized by an Euler equation,

(9) $$C_{t+j-a,,j,i} = C_{t+j-1-a,j-1,i}\left(\frac{1+r_{t+j-a}}{1+\rho}\right)^{1/\sigma},$$

which reflects households' trade-off between current and future utility. As in any life-cycle model, this trade-off is determined by the ratio of the interest rate and the time preference rate, and by the degree of risk aversion. While the Euler equation determines the slope of the consumption profile of each individual, the initial level of consumption is determined by the present value budget constraint given by

(10) $$A_{t,a,i}(1+r_t) + \sum_{j=a}^{Z} p_{t+j-a,j,i}Y^n_{t+j-a,j,i}\prod_{m=a+1}^{j}\frac{1}{1+r_{t+m-a}} = \sum_{j=a}^{Z} p_{t+j-a,j,i}C_{t+j-1-a,j-1,i}\prod_{m=a+1}^{j}\frac{1}{1+r_{t+m-a}}.$$ [7]

Since factor prices (i.e., wage and interest rates) and both contribution rates to, and replacement rates of, the pay-as-you-go pension system are known, we can now determine the lifetime consumption paths of all generations using the Euler equation and the budget constraint. The resulting time paths of consumption determine aggregate net savings, aggregate net consumption and aggregate assets respectively given by:

(10) $$S_{t,i} = \sum_{a=1}^{Z} S_{t,a,i}N_{t,a,i} \qquad C_{t,i} = \sum_{a=1}^{Z} C_{t,a,i}N_{t,a,i} \qquad A_{t,i} = \sum_{a=1}^{Z} A_{t,a,i}N_{t,a,i},$$

Summing up the assets held by households living in country i across all countries $i=1,\ldots,R$ yields total world wealth holdings which in turn is equal to the world capital stock which then also gives the world capital stock per efficiency unit:

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[7] Note that we assume that the only income from abroad is asset income (see below).

(12) $$K_t = A_t = \sum_{i=1}^{R} A_{t,i} \quad \Leftrightarrow \quad k_t = \frac{K_t}{\sum_{i=1}^{R} \Theta_{t,i} L_{t,i}},$$

where R is the number of regions considered. From equation (4), the capital stock of each country is determined as

(13) $$K_{t,i} = k_t \Theta_{t,i} L_{t,i}.$$

Domestic investment in period t is the difference between the capital stock of each country in period t and period $t-1$ plus depreciation:

(14) $$I_{t,i} = K_{t+1,i} - (1-\delta) K_{t,i},$$

The difference between aggregate assets of a country $A_{t,i}$ and its capital stock $K_{t,i}$ is foreign assets, denoted as $F_{t,i}$. Equilibrium of the model therefore requires that the sum of all foreign assets across all regions is zero:

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

The current account surplus, $CA_{t,i}$, of country i at time t is the difference between foreign assets at times t and $t-1$.

(16) $$CA_{t,i} = F_{t+1,i} - (1-\delta) F_{t,i} = S_{t,i} - I_{t,i}.$$

Our aggregation scheme assumes that the only income from abroad is asset income. While figures on migration enter our demographic projections, savings and investments are the only endogenous factor flows between countries. Furthermore, we assume that there are no skill differences between natives and immigrants and that immigrants of a given age enter with the same amount of assets as natives of that age. Given that we are not concerned with the interactions between migration and social security reform these assumptions are innocuous (see Razin and Sadka, 1999, and Storesletten, 2000, for studies that model such effects explicitly).

3.5 Solution method and calibration

An equilibrium path of this overlapping generations model can be determined using a recursive numerical procedure, known as the Gauss-Seidel-Algorithm (see Auerbach and Kotlikoff, 1987). The solution algorithm starts with picking an arbitrary initial time path for the world capital stock per efficiency unit, $\{k_t^m\}_{t=1}^{T}$, in iteration step $m=1$. Taking the time path of the capital stock per efficiency unit and labor inputs as given we can then compute the value of aggregate productivity, $\Theta_{t,i}$, in each country by using actual GDP data and solving equation (3). The solution of the static optimization problem of the representative firm for a given trial value of the world capital stock $\{k_t^m\}_{t=1}^T$ and the labor inputs implied by the labor force projections gives time paths of factor prices (i.e., wage and interest rates). Given factor prices, we can solve the age and time-specific inter-temporal optimization problems of all cohorts at all points in time, which yields, after aggregating across households and countries, time paths of aggregate world asset holdings, which is equal to the world capital stock. Equation (12) is then used to determine the new world capital stock per efficiency unit:

$$(16) \qquad \tilde{k}_t^m = \frac{K_t}{\sum_{i=1}^{R} \Theta_{t,i} L_{t,i}} = \frac{\sum_{i=1}^{R} A_{t,i} L_{t,i}}{\sum_{i=1}^{R} \Theta_{t,i} L_{t,i}}$$

This new capital stock is consistent with household optimization (conditional on factor prices) but will not necessarily coincide with the trial time-path that we specified initially. So we need to change the initial capital stock and repeat the entire computation until convergence with respect to the time path of the capital stock is achieved and an intertemporal equilibrium of the dynamic economy is found.

We start calculations in 1850 assuming an initial steady state and end in 2200 assuming a final steady state. Since households in the model are forward looking and since we solve for the saddle path of all relevant variables from 1850 to 2000 we assume that households have anticipated all past changes to the environment, especially those that alter the structure of the public pension system. While this is a plausible first order approximation for general policy reforms and demographic developments, it is certainly not a good approximation to German reunification. We therefore model reunification as a shock that increases the number of households but only marginally increases the capital stock. This results in a decrease in the capital stock per efficiency unit – even though aggregate efficiency $\Theta_{t,i}$ also decreases – and a corresponding small increase in the rate of return to capital.[8] Since the unification treaty (*Vertrag zur deutschen Wirtschafts- und Währungsunion*) was signed in October 1990, we assume that households re-optimize at the beginning of 1991, taking the new conditions as given.

As noted in section 2, we use demographic projections taken from the United Nations (2000) world population prospects. These projections end in 2050. We use data from the long-term

[8] In our closed economy scenario – see below – this increase amounts to one percentage point while it is negligible if we open up the economy to international capital flows.

demographic projections by the United Nations to forecast population beyond that horizon until 2200. For simplicity, we assume constant mortality and fertility and zero migration after 2100 in all world regions such that population growth rates are stable around 2150 – a condition we need in order to calculate a final steady state of our simulation model.

In order to solve the pension system equation (1) for each country, we first assume that net replacement rates are constant over time at current levels. We then solve for the associated time path of the contribution rate. For Germany, the net replacement rate of the public pension system is set to its current level of 70.4%. There do not exist consistent measures of net replacement rates for a large cross-section of countries (see Palacios and Pallares-Miralles, 2000; OECD, 2001a). We therefore calculate equivalent net replacement rates using data on old age pension benefits by the OECD (OECD, 2000). The resulting replacement rates and contribution rates are summarized in table A3 (see the Appendix). For simplicity, the replacement rate of the unemployment insurance system is set to 0.6. Income taxes are set according to OECD (2001b) (see table A2 in the Appendix).

Further parameters of the model are the household's preference parameters, the parameters of the production function and values for the age-specific productivity profile. For the latter, we apply estimates for Germany presented in Fitzenberger, Hujer, MaCurdy, and Schnabel (2001). These authors use data from the West German *Beschäftigungsstatistik* of the Federal Employment Service to separate the evolution of wages into a life-cycle wage profile independently of the calendar year and a macroeconomic time trend for four different education groups. We employ their estimated age-wage profiles and weight them with the respective shares of each education group taken from the German Income and Expenditure Survey 1993 (*Einkommens- und Verbrauchsstichprobe*). This provides us with a representative age-wage profile that peaks at the age of 52 and then decreases slightly.

The calibration parameters used in this study are standard in the literature and summarized in table 2. The value of the share of capital used in production is 0.4 which is concordant with estimates by Börsch-Supan (1996). For η, the growth rate of labor-augmenting technical change, we use 1.5% per year based on Cutler, Poterba, Sheiner and Summers (1990). The average depreciation rate is set to 0.05 which is a reasonable estimate for Germany. The remaining parameter is $\Theta_{t,i}$, the aggregate efficiency parameter in the production function. For Germany, we adjust aggregate efficiency twice, first in 1990 when we solve the model prior to the German reunification employing equation (4) and GDP data for Germany. We then solve $\Theta_{t,i}=\Theta_{t-1,i}(1+\eta)$ backward until 1850 and forward until 2200 which is consistent with our deterministic model. We readjust $\Theta_{t,i}$ after reunification in 2000 and again solve $\Theta_{t,i}=\Theta_{t-t,i}(1+\eta)$ backward until 1991 and forward until 2200. For all other countries, we only adjust $\Theta_{t,i}$ in 2000 and proceed accordingly. For the discount rate, we use the value of 0.01 which is often applied in simulation studies, based on an estimate by Hurd (1989). The coefficient of relative risk aversion is usually set between 2 and 4. We use a value of 2 which gives us reasonable results for the capital-to-output ratio (around 3).

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. However, differences between the capital-to-output ratio, the rate of return to capital and households' saving rates are small across capital mobility scenarios. For that reason and since we are primarily interested in the reactions of households to a social security reform, we keep parameter values constant across all capital mobility scenarios.

Given benchmark calibration parameters, the model performs well in matching the empirical counterparts of the capital-to-output ratio. The rate of return to capital generated by our model is between 7.7% and 8% depending on the capital mobility scenario and therefore close to empirical estimates.[9] The saving rate of households predicted in our model – and consistent with our measurement concept of capital – is between 6.6 and 7.6% in 2000. The empirical counterpart is around 10% in 2000. Note that we only model low frequency savings and do not allow for any form of uncertainty which explains the relatively low saving rates generated by our model.

We carried out an extensive sensitivity analysis with respect to the values of the calibration parameters which confirmed that the findings reported below do not change qualitatively under alternative parameter values; detailed results are available upon request.

[9] For the twenty years between 1974 and 1993, the annualized aggregate rate of return to capital was 9.1 percent in the United States, 7.4 percent in Germany, and 7.1 percent in Japan (McKinsey Global Institute, 1996; Börsch-Supan, 1999).

4. 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 Germany as a country with one of the most severe aging problems in the world and with a pension system in an ongoing reform process (e.g. Börsch-Supan, 2002). To separate the direct effect of population aging on capital markets and potential feedback effects from pension reform, we present our projections for two pension policy scenarios: (a) maintaining Germany's current generous pension system, and (b) introducing a one-third transition to a funded pension system as described by Börsch-Supan (2002). As noted in the introduction, these are both extreme and unrealistic cases. However, 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. Hence, all figures have two panels: In panel (a), the effects of population aging are shown under the assumption that the pre-2002 PAYG pension systems stay as they are. In panel (b), we show the effect if Germany implements a fundamental pension reform of the "freezing" type as lined out in the earlier sections. Since the German old-age dependency ratio is projected to peak in 2035 (figure 1) we take 2035 as the benchmark year to evaluate the economic consequences of aging and of a fundamental pension reform.

In addition to our pension policy scenarios, we consider three alternative capital mobility scenarios: investment only within Germany (the closed-economy case), investment within the EU countries, and investment within the OECD countries. There are two reasons for choosing these rather modest capital mobility scenarios: 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, as we will show below, beneficial effects of capital mobility show up even when capital is freely mobile only among countries of the European Union, and including more countries does not change our results substantially. While we initially assume that a fundamental pension reform is implemented only in Germany, we end this section with a brief analysis of simultaneous pension reforms in other countries of the world.

4.1 Savings and capital stock

We begin by looking at aggregate savings. As figure 3 shows, the aggregate saving rate decreases throughout the entire observation period in all capital mobility scenarios since the baby boom generation decumulates assets. When the aging problem peaks in Germany around 2035-2040 (see figure 1), the saving rate reaches its trough. The decrease of the savings rate caused by population aging – the difference between the value in 2000 and the minimum reached in 2035-2040 – is about 4.7 percentage points in the closed-economy and EU 14 scenarios and 4.3 percentage points if we allow for capital mobility within the OECD. The lower saving rate in the OECD scenario in 2000 and afterwards is primarily due to high capital exports by Japan which partially crowd out German savings (see figure 5). The projected aggregate saving rates under a fundamental pension reform are substantially higher and the effect of a pension reform is stronger in the two open-economy 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 the open-economy scenarios, 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 often claimed.

Next, we aggregate savings to obtain Germany's capital stock and net foreign position. Figure 4 shows projections of capital-to-output ratio. The capital-to-output ratio increases until 2030 and then decreases when the baby boomers decumulate their assets. This decrease is less pronounced in the open-economy scenarios, especially in the OECD scenario. A pension reform in Germany leads to substantial increases in the capital-to-output ratio. The increase is much lower in the open economy suggesting that the additional savings shown in figure 3 are largely invested abroad.

4.2 International capital flows

Predicted German capital exports are shown in figure 5. As panel (a) in figure 5 illustrates, capital exports as a percentage of GDP are very flat in the EU scenarios whereas substantial swings can be observed in the OECD scenario. These larger swings result from the fact that investment in the open economy is much more volatile since it is shifted from period to period between countries to equilibrate the return to capital. In the OECD scenario, quite substantial capital flows result from population aging. First, capital exports increase until 2025 since investment declines sharply in Germany due to the aging population. Second, when the aging process starts to stabilize, investment bounces back, but baby boomers decumulate their assets (figure 3) and therefore capital exports become negative.

Next, we take a closer look at net capital flows in the OECD scenario. Figure 6 shows net capital exports of different regions within the OECD as a percentage of GDP. As panel (a) indicates, the model is able to generate capital flows of the correct sign not only for Germany, but also for the other world regions, especially the United States and Japan. Levels are, however, overestimated. This is not surprising since many important factors that drive international capital flows like capital market frictions, capital market risk, home bias and other forms of taxation are omitted from our analysis. Given that the US will continue to have a younger population than other regions, it will also continue to be a capital import country. For Japan the opposite holds. A comparison of figure 2 with figure 6 also shows how closely related the swings of capital exports are to the differential demographic processes. For example, the swings of Japanese capital exports are exactly opposite to the swings of German exports – just as the aggregate employment ratio. Also, while the OECD 13 is the youngest area, in relative terms, it is severely affected by aging. Accordingly, capital imports of this region decrease until the current account even becomes positive. Under a fundamental pension reform, German capital exports crowd out the capital exports of all other world regions by about 0.7 percentage points in each country until 2050.

4.3 Rates of return to capital

An important aspect in the public and academic debate is the decrease in the rate of return to capital induced by aging, the so-called asset market meltdown hypothesis. In figure 7 we quantify the decrease in the rate of return implied by our simulations. Panel (a) shows that a decrease in the rate of return on capital is evident for both the closed-economy and the two open-economy scenarios. However, the decrease is much less than often claimed in the public debate. Even in the closed-economy case, the decrease of the rate of return is about 1.3 percentage points, as measured by the difference between the rate of return in 2000 and the minimum for the period 2030-2040. Moreover, it is apparent that closed-economy models overestimate this reduction of the rate of return: its projected decrease is only about 1 percentage point for both capital mobility scenarios. In absolute terms, this is not a very large difference (even though the compound effect, over two or three decades, of even such a small difference matters when it comes to analyzing funded pension systems).

The beneficial effects of openness to international capital markets become much more evident when we analyze the effects of a fundamental pension reform in Germany. If a fundamental pension reform was implemented in Germany and if Germany was a closed economy, then the additional decrease of the rate of return to capital would be about 0.7 percentage points. But as panel (b) of figure 7 shows, there is virtually no difference of the rate of return between the two pension system scenarios if capital is freely mobile within the OECD. In the intermediate case, when capital mobility is restricted to the EU area, the decrease would be around 0.3 percentage points.

These results suggest that household savings induced by a fundamental pension reform should be invested internationally, not only for reasons of risk diversification (which of course are not present in our deterministic model), but also for the sake of higher returns that are available in other countries with different aging processes and more favorable capital/labor ratios. Our results also confirm our earlier claim that the most important beneficial effects of capital mobility do already show up under very modest capital mobility scenarios. Indeed, there is almost no difference between the OECD scenario and a scenario where we allow for perfect capital mobility in the entire world (results are not shown).

We conclude this section with a brief discussion of the effects of simultaneous pension reforms in several countries. We conduct a very simple experiment within our simulation model. We assume that in all countries, pension systems are simultaneously reformed in the same manner, by freezing contribution rates to the public pay-as-you-go pension system. This is not very realistic since almost all pension systems around the world are not as much affected by demographic change as the German pension system, so pension reforms in other countries are likely to be less dramatic. Recall that when Germany was assumed to be the only country that implements a pension reform, the rate of return on capital is projected to decrease by about 0.3 percentage points in the EU scenario. If all European countries reform their pension systems at the same time, the rate of return to capital is projected to decrease by almost the same amount as the increase observed in the closed-economy scenario from before. This is due to the fact that demographic changes and the resulting time paths of pension contribution rates are similar for European countries. However, if we assume that capital is mobile within the OECD and that all OECD countries simultaneously reform their pension systems, then the decrease of the rate of return to capital will be less than in the closed-economy scenario; it will only decrease by about 0.5 percentage points. Thus, even if all countries simultaneously reform their pension systems in the same manner, the decrease in the return to capital due to the additional savings is rather modest.

6. Conclusions

In this paper, we have analyzed the consequences of population aging and a fundamental pension reform – that is, a shift towards more pre-funding – for capital markets in quickly aging countries such as Germany, Italy and Japan and for international capital flows between countries with differential population aging processes. We developed an overlapping generations model to predict capital formation and movements over a long horizon, taking demographic projections as given.

Our results confirm that population aging results, at least initially, in a higher capital-to-output ratio, but when the baby-boom generations begin to consume their retirement savings after around 2030, the capital-to-output ratio will decrease. Our simulations suggest that the decrease in the rate of return on capital that results from secular shifts in the capital-labor ratio associated with an aging population and retirement saving, is around 1.3 percentage points if a quickly aging country such as Germany is counter-factually assumed to be a closed economy.

However, capital markets these days are anything but closed national markets, and the return on capital can be improved substantially by international diversification. Our analysis has shown that the decrease in the rate of return to capital due to aging is smaller when capital is invested abroad. Moreover, the additional decrease in the return to capital due to a fundamental pension reform is only 0.3 percentage points if capital is freely mobile within the countries of the European Union and close to zero if it is freely mobile within the OECD countries. The most important message of this paper is therefore that diversification through global capital markets is a substantial help in mastering the public finance challenges of population aging.

As always, models are stylized and can be made more realistic. We treated labor supply decisions and taxation as exogenous. Judging from our application of alternative labor force and tax scenarios, we do not anticipate that modeling labor supply and taxes as endogenous will change the basic message of our analysis. Furthermore, we did not analyze the effects of youth dependency on international capital flows. While youth dependency has been shown to have an effect on capital flows (see Bryant, Faruqee and Velculescu, 2001; Brooks, 2003; Lührmann, 2002), aging has much stronger effects as shown by Berkel, Börsch-Supan, Ludwig, and Winter (2003).

Our future work will be devoted to including financial markets risk in our model, an aspect that several authors have addressed in closed-economy OLG models (see the recent paper by Krueger and Kubler, 2002, and references therein). Our analysis concentrated on the long-term path of the rate of return on capital in a model with no stochastic aggregate fluctuations, so there was no role for risk. However, real-world investments are risky, and in their savings and portfolio decisions, households are concerned not only about the (expected) rate of return, but also about its variance, that is, about portfolio risk. This raises the question whether countries such as Germany are really willing to invest substantial fractions of their retirement wealth abroad.

Another important and non-trivial extension of our multi-country model is to relax the assumptions of (i) perfect capital mobility and (ii) the absence of exchange rate effects. Free capital mobility implies that there are no institutional restrictions on capital exports and that households are willing to hold unlimited foreign assets. Both assumptions are not realistic, as documented in the large literature on home bias in international capital holdings following French and Poterba (1991). With respect to the absence of exchange-rate effects, such an assumption is valid for capital flows among most European Union countries but exchange rate reactions between other regions of the world may be important. Exchange-rate effects have, indeed, no role in our one-good economies. A distinction between home and tradable goods, demanded differentially by the various age-groups, would imply real exchange-rate effects due to population aging.

While more research on these issues is certainly warranted, we are confident that our simulations are informative about the main effects of population aging on international capital flows. Our simulations suggest that significant effects of capital mobility arise even if capital flows are restricted to Europe or the OECD, and this does not appear to be an unrealistic scenario.

Appendix

A.1 Labor-market participation and employment projections

Age-specific employment rates are taken from OECD (2002). For 2003 through 2050, they are projected to increase linearly along several dimensions. These dimensions are (i) increases in female employment rates, (ii) increases in average retirement ages, and (iii) decreases in unemployment rates for regions in which unemployment is currently high. Table A1 summarizes these assumptions for each of the world regions. The procedure of the adjustments is described in detail by Ludwig (2002).

(i) *Increases in female employment rates:* The factor reported in the table, ψ, reflects the adjustment of the age-specific employment rates profile from 2003 until 2050. The female age-specific employment rate in 2050 is ψ times the male plus $(1-\psi)$ times the female age-specific employment rate in 2000.

(ii) *Increases in mean retirement ages:* Increases in mean retirement ages reflect either changes in legislation or ongoing proposals for parametric pension reforms (see

Ludwig, 2002). Since the group of OECD 13 countries is less affected by aging (figures 1 and 2), the mean retirement age is assumed to remain constant.

(iii) *Decreases in unemployment rates:* The assumed decreases reflect rebounds towards "natural rates" of unemployment. They are assumed to be higher for regions where unemployment is high such as Germany and the EU 14 with currently 8% and 10% according to OECD figures. For regions like the United States or Japan the assumed decreases are rather modest since only recently unemployment rates have increased above 5% due to cyclical fluctuations.

A.2 Labor income taxation

Labor income tax rates are computed from OECD (2001b); these tax rates reflect average personal income tax rates on gross labor income in 2001. They are summarized in table A2. For regions such as EU 14 and OECD 13, weights are based on GDP shares.

A.3 Pension system replacement rates

The definitions of pension system replacement rates differ across countries. Sometimes gross, sometimes net replacement rates are reported (see Palacios and Pallares-Miralles, 2000; OECD, 2001a). Accordingly, consistent measures on net replacement rates defined as the ratio of average net pension income to average net wage income are not available from public sources. We therefore take the definition of the net replacement rate for the German "standard pensioner" – a person who has worked for 45 years and has earned the average wage income throughout – as a benchmark and compute net replacement rates in the other regions using data on old age cash benefits taken from OECD (2000). Furthermore, we adjust pension entitlements in other regions relative to Germany according longer/shorter working years in specific regions which is reflected in the factor $\lambda_{t,a,i}$ of equation (1). For example, pension entitlements in Japan are higher than in Germany.

The imputation procedure of net replacement rates works as follows: We first calculate the ratio of old age pension expenditures as a percentage of GDP for all regions relative to Germany. Next, we calculate German pension expenditures relative to GDP, as implied by our model. For all other countries, pension expenditures are determined as the product of the German expenditures and the relative ratios taken from the data. Next, we impute net replacement rates. The resulting net replacement rates for the standard pensioner and the corresponding contribution rates are summarized in table A3. Note that the absolute values of net replacement rates do not affect the simulation results of our model much. However, the levels of international capital flows between regions, as depicted in figure 6, are affected by the *relative* replacement rates between countries and by the corresponding *relative* contribution rates.

References

Abel, A.B. (2001): Will bequests attenuate the predicted meltdown in stock prices when baby boomers retire? *Review of Economics and Statistics*, 83(4), 589–595.

Altig, D., A.J. Auerbach, L.J. Kotlikoff, K.A. Smetters, and J. Walliser (2001): Simulating fundamental tax reform in the United States. *American Economic Review*, 91, 574–595.

Ando, A. and F. Modigliani (1963): The 'life-cycle' hypothesis of saving: Aggregate implications and tests. *American Economic Review*, 89(3), 605–618.

Attanasio, O.P. and G.L. Violante (2000): The demographic transition in closed and open economy: A tale of two regions. Working Paper 412, Research Department, Inter-American Development Bank, Washington, D.C.

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

Berkel, B., A. Börsch-Supan, A. Ludwig, and J. Winter (2003): Sind die Probleme der Bevölkerungsalterung durch eine höhere Geburtenrate lösbar? Forthcoming in: *Perspektiven der Wirtschaftspolitik*.

Bloom, D.E. and J.G. Williamson (1998): Demographic transitions and economic miracles in emerging Asia. *World Bank Economic Review*, 12(3), 419–455.

Börsch-Supan, A. (1996): The impact of population aging on savings, investment and growth in the OECD area. In: *Future Global Capital Shortages: Real Threat or Pure Fiction?* Paris: OECD, 103–141.

Börsch-Supan, A. (1999): Capital productivity and the nature of competition. *Brookings Papers on Economic Activity – Microeconomics*, 205–248.

Börsch-Supan, A. (2002): A blueprint for Germany's pension reform. Discussion Paper No. 02-02, Mannheim Research Institute for the Economics of Aging (MEA), University of Mannheim.

Börsch-Supan, A. and A. Brugiavini (2001): Savings: The policy debate in Europe. *Oxford Review of Economic Policy*, 17, 116–143.

Börsch-Supan, A., F. Heiss, A. Ludwig, and J. Winter (2003): Pension reform, capital markets, and the rate of return. Forthcoming in: *German Economic Review.*

Börsch-Supan, A., A. Ludwig, and J. Winter (2002): Aging and international capital flows. In: A. Auerbach and H. Hermann (eds.): *Aging, Financial Markets and Monetary Policy*, Heidelberg: Springer, 55–83.

Brooks, R. (2002): Asset-market effects of the baby boom and social-security reform. *American Economic Review, Papers and Proceedings*, 92(2), 402–406.

Brooks, R. (2003): Population aging and global capital flows in a parallel universe. Working Paper No. 00/151, International Monetary Fund, Washington, D.C. Forthcoming in: *IMF Staff Papers*.

Bryant, R.C., H. Faruqee and D. Velculescu (2001): Youth dependency and demographic change: Implications for the global economy. Mimeo, Brookings Institution, Washington, D.C.

Buiter, W.H. (1981): Time preference and international lending and borrowing in an overlapping-generations model. *Journal of Political Economy*, 89(4), 769–797.

Coakley, J., F. Kulasi, and R. Smith (1998): The Feldstein-Horioka puzzle and capital mobility: A review. *International Journal of Finance and Economics*, 3(2), 169–188

Cutler, D.M., J.M. Poterba, L.M. Sheiner, and L.H. Summers (1990): An aging society: Opportunity or challenge? *Brookings Papers on Economic Activity*, No. 1, 1–73.

De Nardi, M., S. Imrohoroglu, and T.J. Sargent (1999): Projected U.S. demographics and social security. *Review of Economic Dynamics*, 2, 575–615.

Deardorff, A.V. (1985): Trade and capital mobility in a world of diverging populations. In: D.G. Johnson and R.D. Lee (eds.), *Population Growth and Economic Development: Issues and Evidence.* Madison, WI: University of Wisconsin Press.

Diamond, P.A. (1965): National debt in a neoclassical growth model. *American Economic Review*, 55, 1126–1150.

Fehr, H. (2000): Pension reform during the demographic transition. *Scandinavian Journal of Economics*, 102(3), 419–443.

Feldstein, M. and C. Horioka (1980): Domestic saving and international capital flows. *Economic Journal*, 90, 314–329.

Fitzenberger, B., R. Hujer, T.E. MaCurdy, and R. Schnabel (2001): Testing for uniform wage trends in West-Germany: A cohort analysis using quantile regressions for censored data. *Empirical Economics*, 26, 41–86.

French, K.R. and J.M. Poterba (1991): Investor diversification and international equity markets. *American Economic Review, Papers and Proceedings*, 81(2), 222–226.

Higgins, M. (1998): Demography, national savings, and international capital flows. *International Economic Review*, 39, 343–369.

Hirte, G. (2002): Welfare and macroeconomic effects of the German pension acts of 1992 and 1999: A dynamic CGE study. *German Economic Review*, 3, 81–106.

Hurd, M. (1989): Mortality risk and bequests. *Econometrica*, 57, 173–209.

INGENUE (2001): Macroeconomic consequences of pension reforms in Europe: An investigation with the INGENUE world model. Working Paper No. 2001-16, CEPREMAP, Paris.

Kotlikoff, L.J. (2000): The A-K OLG model: Its past, present, and future. In: Harrison, G. (ed.): *Using dynamic general equilibrium models for policy analysis,* 13–52.

Kotlikoff, L.J., K. Smetters, and J. Walliser (1999): Privatizing social security in the United States: Comparing the options. *Review of Economic Dynamics*, 2, 532–574.

Krueger, D. and F. Kubler (2002): Computing equilibrium in OLG models with stochastic production. Mimeo, Stanford University.

Ludwig, A. (2002): *Rentenreformen im globalen Kontext*. Frankfurt: Peter Lang.

Lührmann, M. (2002): The role of demographic change in explaining international capital flows. Mimeo, University of Mannheim.

McKinsey Global Institute (1996): *Capital Productivity.* Washington, D.C.: McKinsey Global Institute.

Miles, D. (1999): Modeling the impact of demographic change upon the economy. *Economic Journal*, 109, 1–36.

Miles, D. and A. Iben (2000): The reform of pension systems: Winners and losers across generations in the United Kingdom and Germany. *Economica*, 67, 203–228.

Modigliani, F. and R. Brumberg (1954): Utility analysis and the consumption function: An interpretation of cross-section data. In K.K. Kurihara (ed.): *Post-Keynesian Economics*. New Brunswick: Rutgers University Press, 388–436.

Obstfeld, M. and K. Rogoff (1996): Foundations of international macroeconomics, MIT Press, Cambridge, MA.

Obstfeld, M. and K. Rogoff (2000): The six major puzzles in international macroeconomics: Is there a common cause? *NBER Macroeconomics Annual*, 15, 339–390.

OECD (2000): *Social Expenditure Database*. Paris: OECD.

OECD (2001a): *Ageing and Income: Financial Resources and Retirement in 9 OECD Countries*. Paris: OECD.

OECD (2001b): *Taxing Wages 2000-2001.* Paris: OECD.

OECD (2002): *Labor force statistics*. Paris: OECD.

Pemberton, J. (1999): Social security: National policies with international implications. *Economic Journal*, 109, 492–508.

Pemberton, J. (2000): National and international privatization of pensions. *European Economic Review*, 44, 1873–1896.

Palacios, R. and M. Pallarès-Miralles: International patterns of pension provision. Social Protection Discussion Paper Series No. 0009, The World Bank, Washington, D.C.

Portes, R. and H. Rey (1999): The determinants of cross-border equity flows. Working Paper No. 7336, National Bureau of Economic Research, Washington, D.C.

Poterba, J.M. (2001): Demographic structure and assets returns. *Review of Economics and Statistics*, 83(4), 565–584.

Razin, A. and E. Sadka (1999): Migration and pension with international capital mobility. *Journal of Public Economics*, 74, 141–150.

Reisen, H. (2000): *Pensions, Savings and Capital Flows: From Aging to Emerging Markets*. Cheltenham, UK: Edward Elgar.

Rios-Rull, J.-V. (1996): Life-cycle economies and aggregate fluctuations. *Review of Economic Studies,* 63(3), 465–489.

Rios-Rull, J.-V. (2001): Population changes and capital accumulation: The aging of the baby boom. *Advances in Macroeconomics*, 1(1), Article 7.

Schnabel, R. (2000): *Die Rentenreform 2001: Gutachten zur Rentabilität, Generationengerechtigkeit und den wirtschaftlichen Annahmen der Regierung*. Köln: Deutsches Institut für Altersvorsorge.

Samuelson, P.A. (1958): An exact consumption-loan model of interest with or without social contrivance of money. *Journal of Political Economy*, 66, 467–482.

Storesletten, K., C. (2000): Sustaining fiscal policy through immigration. *Journal of Political Economy*, 108, 300–323.

Taylor, A.M. (1994): Domestic saving and international capital flows reconsidered. Working Paper No. 4892, National Bureau of Economic Research, Washington, D.C.

United Nations Population Division (2000): *World Population Prospects: The 1998 Revision*. New York: United Nations.

United Nations Population Division (2001): *World Population Prospects: The 2000 Revision*. New York: United Nations.

Yaari, M.E. (1965): Uncertain lifetime, life insurance, and the theory of the consumer. *Review of Economic Studies,* 32(2), 137–150.

Figure 1: Projections of the working-age population ratio and the old-age dependency ratio and for different world regions

Figure 1a: Working-age population ratio

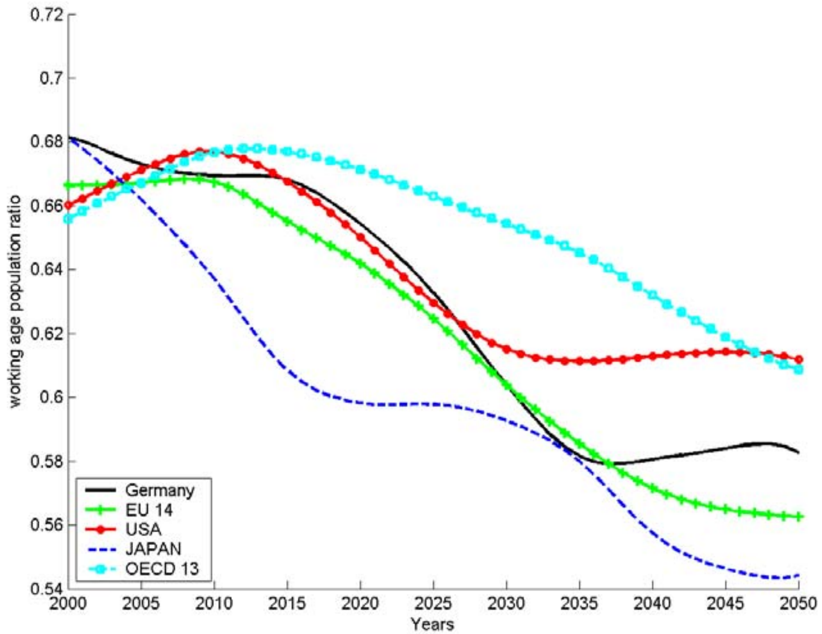
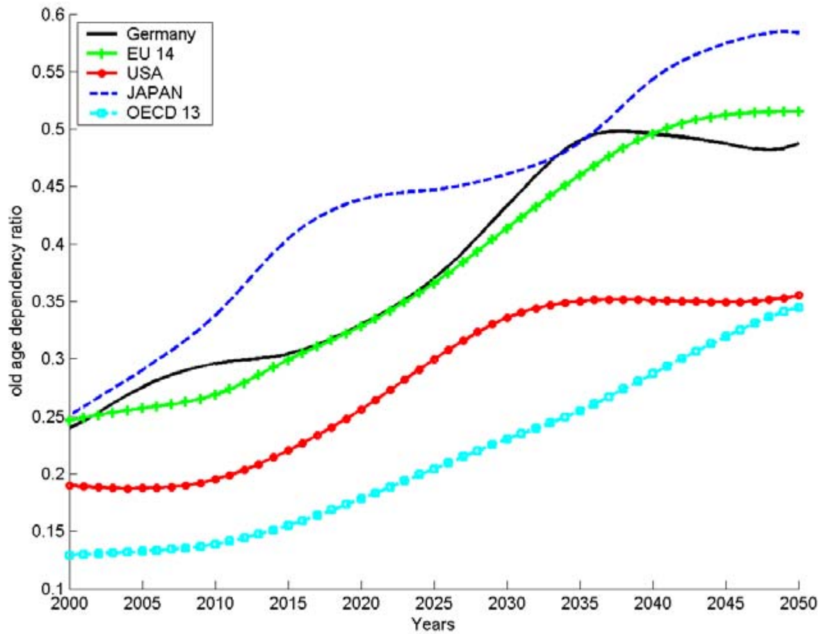


Figure 1b: Old-age dependency ratio



Notes: This figure shows 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. EU 14: all countries of the European Union except Germany. OECD 13: all OECD countries except for all member states of the European Union, USA and Japan.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific employment rates by the OECD (2002).

Figure 2: Projections of aggregate employment rates and the economic dependency ratio and for different world regions

Figure 2a: Aggregate employment rates

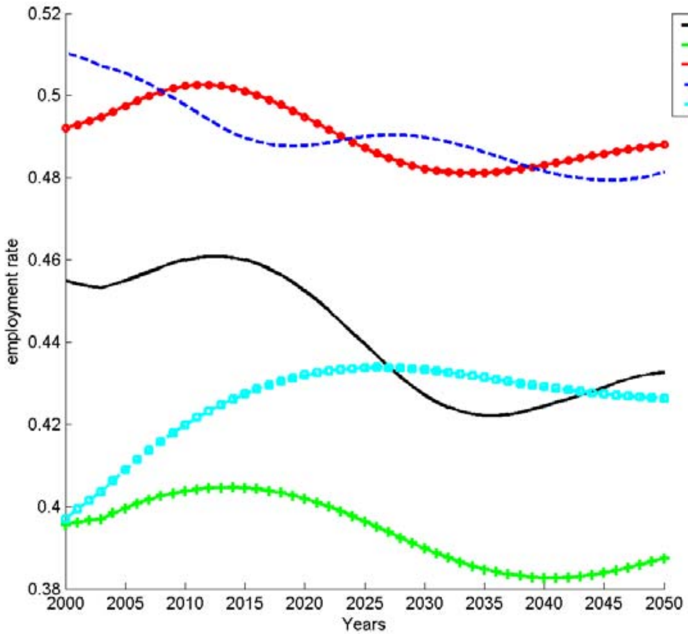
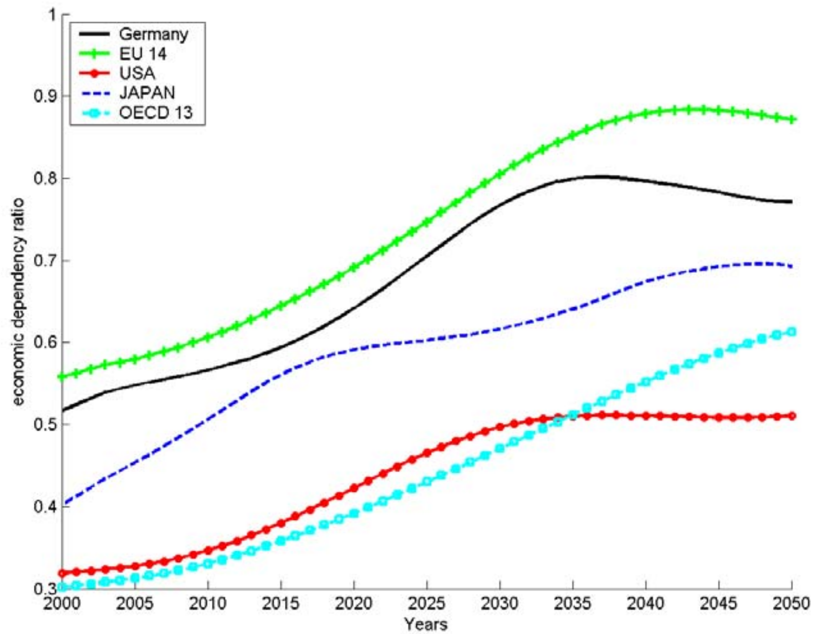


Figure 2b: Economic dependency ratio



Notes: This figure shows projections of the aggregate labor force participation rate – the aggregate employment as a percentage of total population – and the economic dependency ratio – the number of pensioners as a percentage of the number of workers – for five different world regions. EU 14: all countries of the European Union except Germany. OECD 13: all OECD countries except for all member states of the European Union, USA and Japan.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Figure 3: Projections of the German aggregate saving rate under alternative pension systems and capital mobility scenarios

Figure 3a: Pre-2002 pension systems

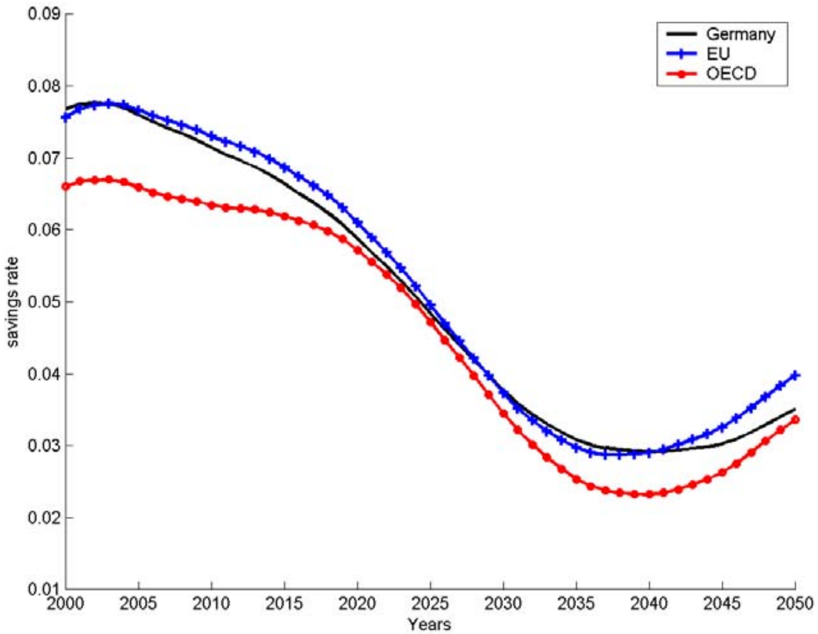
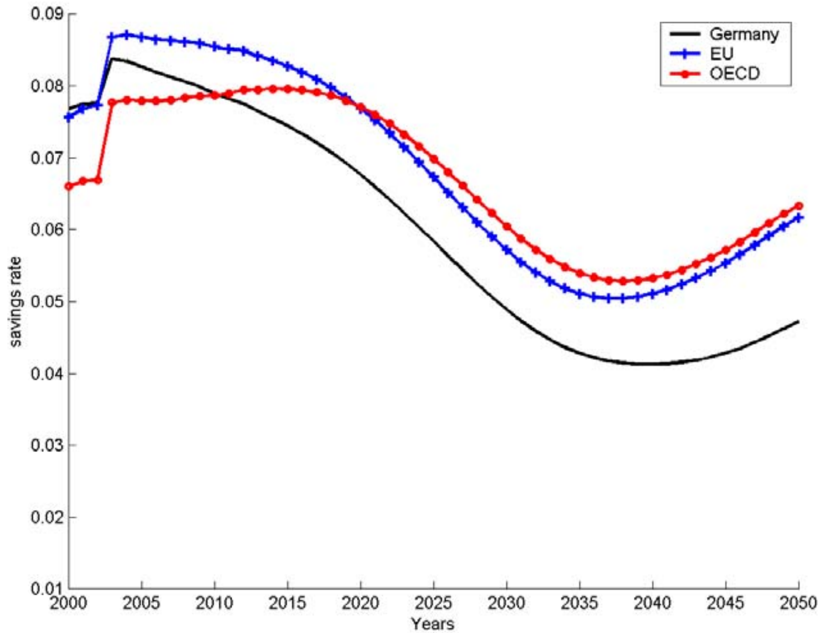


Figure 3b: Fundamental pension reform



Notes: This figure shows projections of the aggregate savings of German households as a percentage of GNP. Pension reform only in Germany. Germany: Germany as a closed economy, EU: perfect capital mobility in the EU area, OECD: perfect capital mobility in the OECD area.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Figure 4: Projections of the aggregate German capital stock to output ratio under alternative pension systems and capital mobility scenarios

Figure 4a: PRE-2002 pension systems

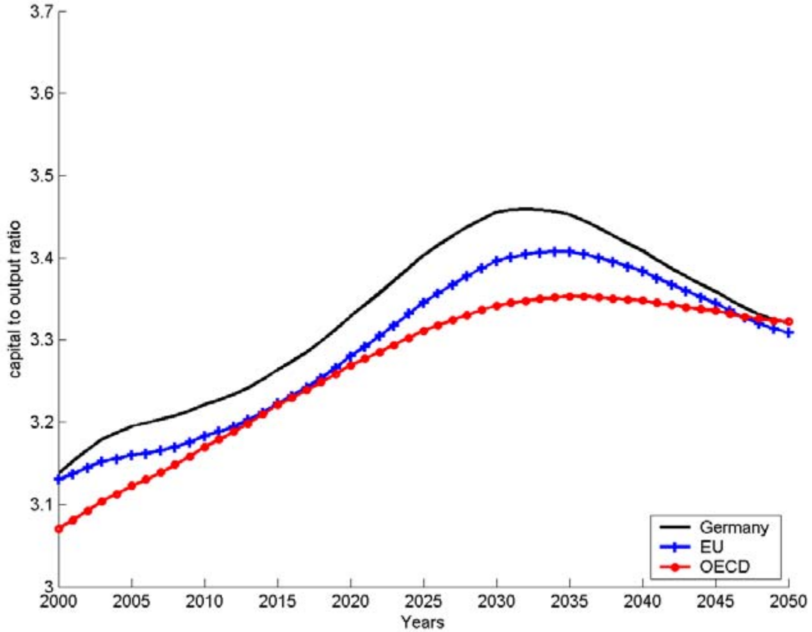
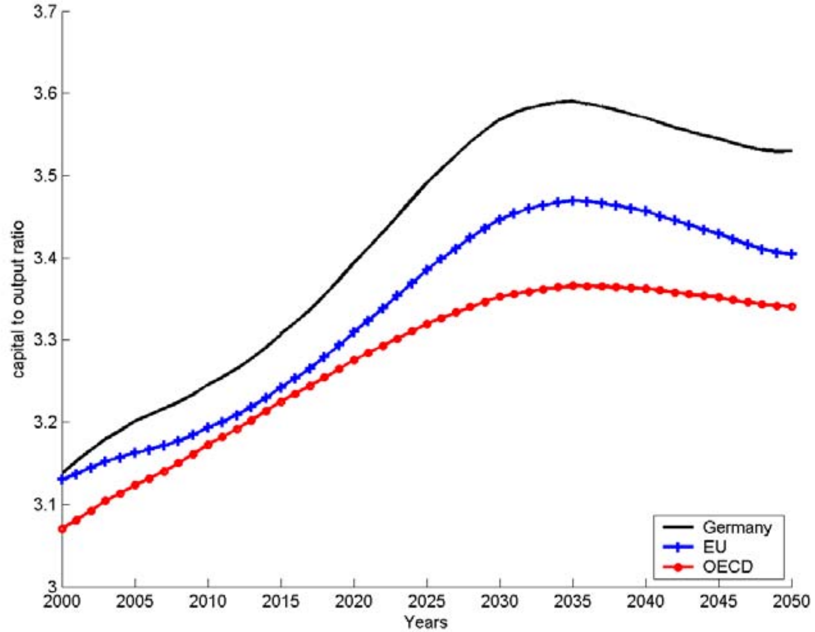


Figure 4b: Fundamental pension reform



Notes: This figure shows projections of the aggregate German capital-to-output ratio. Pension reform only in Germany. Germany: Germany as a closed economy, EU: perfect capital mobility in the EU area, OECD: perfect capital mobility in the OECD area.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Figure 5: Projections of German net capital exports under alternative pension systems and capital mobility scenarios

Figure 5a: PRE-2002 pension systems

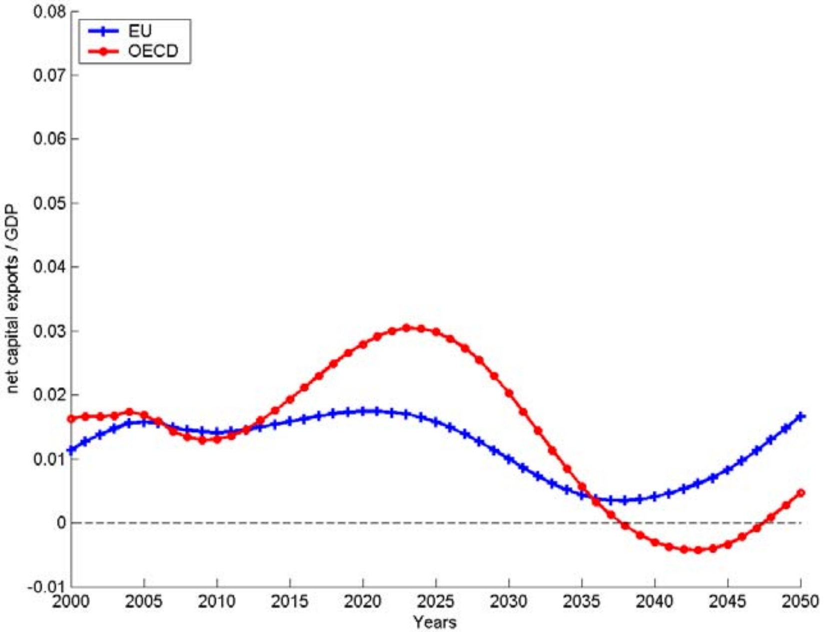
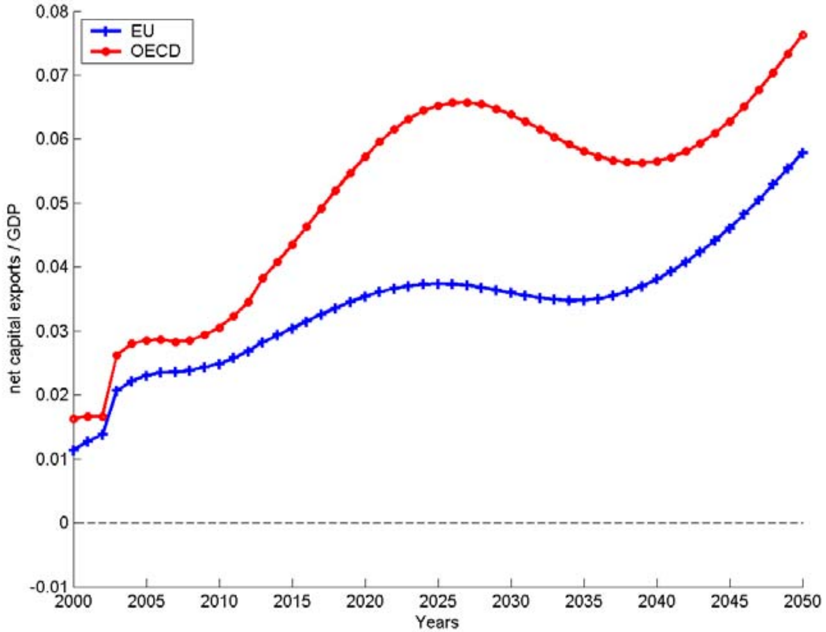


Figure 5b: Fundamental pension reform



Notes: This figure shows projections of German net capital exports as a percentage of German GDP towards the EU and the OECD respectively. Pension reform only in Germany. EU: net German capital exports to the other countries of the European Union when there's capital mobility only within the European Union, OECD: net German capital exports to the other countries of the OECD when there's capital mobility only within the OECD.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Figure 6: Projections of net capital exports of the OECD area under the assumption of perfect capital mobility within the OECD

Figure 6a: PRE-2002 pension systems

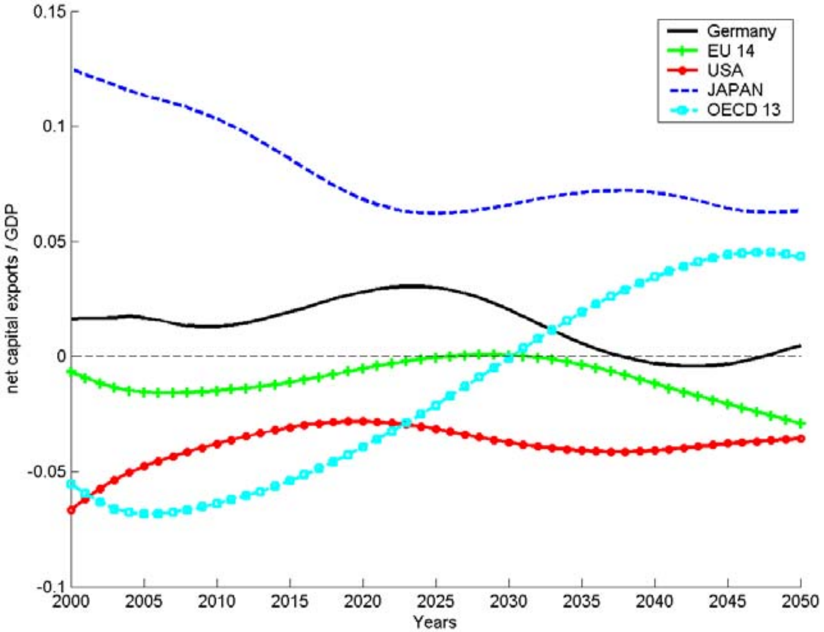
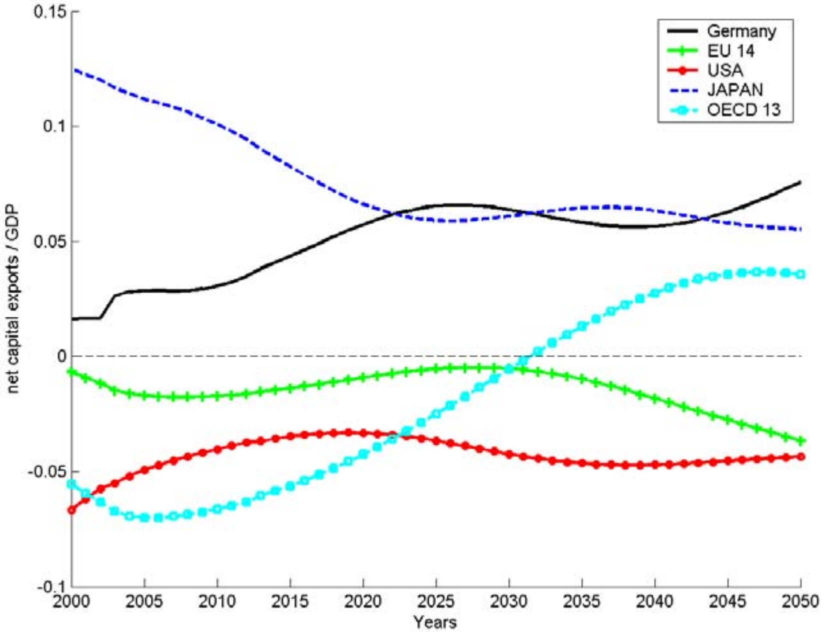


Figure 6b: Fundamental pension reform



Notes: This figure shows projections of net capital exports of the respective region as a percentage of GDP under the assumption of perfect capital mobility within the OECD. Pension reform only in Germany. EU 14: all countries of the European Union except Germany. OECD 12: all OECD countries except for the countries of the European Union, Japan and the United States.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Figure 7: Projections of the rate of return to capital under alternative pension systems and capital mobility scenarios

Figure 7a: PRE-2002 pension systems

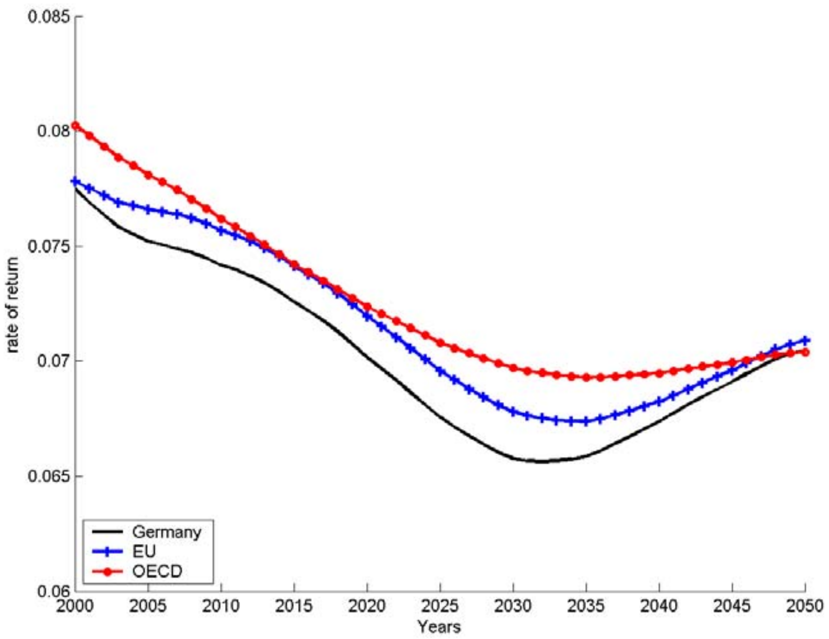
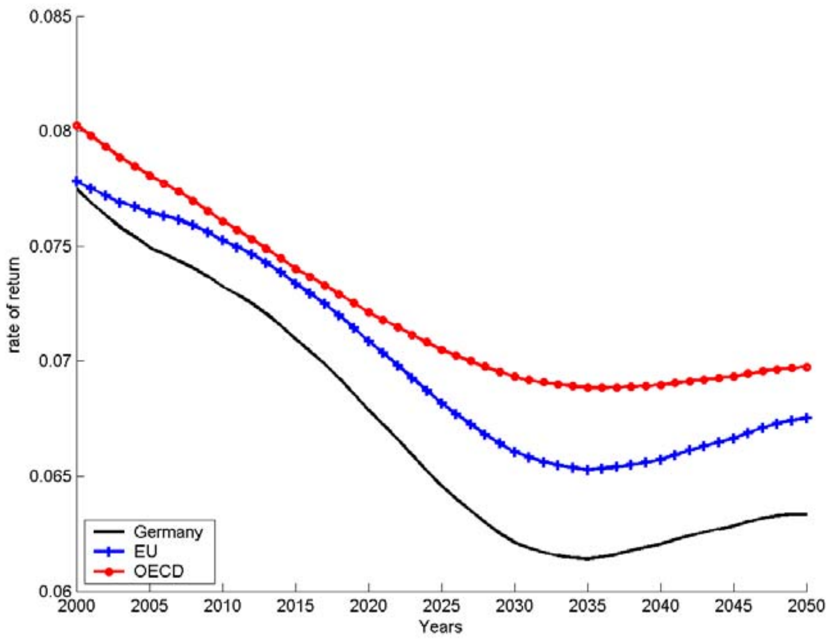


Figure 7b: Fundamental pension reform



Notes: This figure shows projections of the rate of return to capital. Pension reform only in Germany. Germany: Germany as a closed economy, EU: perfect capital mobility in the EU area, OECD: perfect capital mobility in the OECD area.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Table 1: Predicted contribution and replacement rates of the German PAYG pension system

	2002	2030	2050
Pre-2002 reform			
Contribution rate	19.1%	25.7%	26.7%
Replacement rate	70.4%	70.4%	70.4%
Freezing reform			
Contribution rate	19.1%	19.5%	19.5%
Replacement rate	70.4%	50.9%	48.8%

Notes: This table shows predicted contribution to and replacement rates of the public German PAYG pension system under stylized pension models.

Source: Own calculations, based on demographic projections of the United Nations (2000) and age and gender-specific labor force participation rates by the OECD (2002).

Table 2: Calibration of parameters in the overlapping generations model

α: output share of capital in the CES production function	0.4
η: growth rate of labor productivity	0.015
δ: depreciation rate of capital	0.05
ρ: rate of time preference	0.01
σ: coefficient of relative risk aversion	2

Table A1: Adjustments of age-specific employment rates

Change until 2050	Germany	EU 14	USA	Japan	OECD 13
Increase in female employment rates	0.5	0.5	0.5	0.5	0.5
Increase in mean retirement age	2	2	2	2	0
Decrease in unemployment rate	0.05	0.05	0.04	0.04	0.05

Notes: *Increase in female employment rates:* The factors reported in the table, ψ, reflect the adjustment of age-specific employment rates from 2003 until 2050. Female age-specific employment rates in 2050 are ψ times male plus $(1-\psi)$ times female age-specific employment rates in 2000. *Increase in mean retirement ages:* The numbers in the table reflect the number of years by which mean retirement ages are assumed to increase until 2050. *Decrease in unemployment rates:* The numbers in the table reflect "natural rates" of unemployment towards which actual unemployment rates are assumed to decrease until 2050.

Table A2: Labor income tax rates (in percent)

	Germany	EU 14	USA	Japan	OECD 13
Average personal income tax rates	20.2	15.7	16.9	6.2	12.4

Source: OECD (2001b) and own calculations.

Table A3: Contribution and net replacement rates of public pension systems (in percent)

	Germany	EU 14	USA	Japan	OECD 13
Contribution rate to PAYG pension system	19.9	20.4	11.8	11	7
Net replacement rate, standard pensioner	70.4	63.4	53.7	44.1	34.9

Source: OECD (2001a) and own calculations. The standard pensioner is a person who worked for 45 years and earned average net wage income.

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