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Fostering Sustainability in Times of Aging: Pension Policies and Household Behavior in a Macroeconomic Setting

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Content

List of abbreviations

Asia2	Combination of the two countries China and India
CES	Constant elasticity of substitution
CEV	Consumption equivalent variation
CGE	Computable general equilibrium
DB	Defined benefit
DC	Defined contribution
ET	Earnings test
EU3	Combination of the three countries France, Germany, and Italy
FF	Fully-funded
GDP	Gross domestic product
GNP	Gross national product
GSOEP	German Socio-Economic-Panel
IES	Inter-temporal elasticity of substitution
MIU	Money-in-the-utility
NDC	Notional defined contributions
OECD	Organization for Economic Co-operation and Development
OLG	Overlapping generations
PAYG	Pay-as-you-go
p.c.	Per capita
p.p.	Percentage point
SEA	Statutory eligibility age
TFP	Total factor productivity

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1. Fostering sustainability in times of aging

1.1 General introduction

One of the great mistakes is to judge policies and programs by their intentions rather than their results.
-Milton Friedman

Demographic change is a global phenomenon and affects almost all modern societies. Nevertheless, there are substantial differences between countries with respect to the speed and extent of the aging process, especially between the US, Europe, and Asia: while many European countries already face an older population, the US is and will remain relatively young. In contrast, many Asian countries will soon go through a rapid aging process.

Increased longevity is a great feat for modern societies, but it also poses major challenges to policy makers as they try to keep social security systems sustainable. The uncertain future of public and private pension systems is a topic of high priority and large controversy. The pressures on pension systems are particularly pronounced in Europe and Asia – in Europe because the number of retirees per worker is already high and increasing further until about 2050, and in Asia because the speed of population aging is so fast. This strain will affect all types of pension systems, whether they are pay-as-you-go (PAYG), fully-funded (FF), defined benefit (DB), or defined contribution (DC), albeit to different extents. In general, it is often feared that decreasing replacement rates or surging contribution rates will lead to old-age poverty or an unbearable burden for workers, respectively. Furthermore, when it comes to the sustainability debate, good arguments emerge which attempt to point out both how to establish a new framework and avoid a possible crash of the system as well as how to balance social expectations regarding retirement, income stability, and future well-being. The pressing demographic transition and the negative effects of early retirement urged countries to take pension and labor market reforms that could no longer wait to be implemented, especially given the risk of unsustainability and the financial crisis that has undermined the budgets of many countries in the last decade.

Addressing the challenge of steadily increasing dependency ratios, numerous reforms have been put forward by policy makers to promote more active aging and a longer working life (Graf, et al., 2011; Börsch-Supan, 2007; Huber, et al., 2016; Sonnet, et al., 2014; Börsch-Supan, et al., 2016b). Such reforms have included, for instance, increasing the statutory eligibility age[1] in Germany or

[1] The term “statutory eligibility age“ (SEA) will be used throughout this dissertation for the age at which an individual is eligible for full public old-age pension benefits, without reduction for early claiming. In general,

Italy (Börsch-Supan, 2007; Boeri, et al., 2016), the introduction of flexible retirement mechanisms in Norway and the UK (Börsch-Supan, et al., 2018c), and even profound changes in the main framework of the pension system (Palmer, 2000; Börsch-Supan, 2005). At the same time, new reform proposals are constantly put forward by politicians, especially during election campaigns.

Even if direct consequences of such reforms (proposals) are taken into account in the political and economic discussion, policy evaluations still sometimes lack the study of incentive effects and possible backlash effects. For some reforms, these repercussions may be even stronger than direct incentive effects (Eisensee, 2006). Most of the time, these repercussions or feedback cycles stem from macroeconomic developments in the aftermath of reforms that are often not taken into account when only studying direct, partial reform effects. At this point, suitable economic models are required to evaluate these reform proposals in a macroeconomic setting and their impact on the behavior of individuals and, ultimately, the sustainability of pension systems. Traditionally, this task has been carried out using models incorporating life-cycle behavior and assuming that households make decisions within a framework of time-consistency (Auerbach & Kotlikoff, 1987; Feldstein & Samwick, 1998). However, model outcomes, and, therefore, policy recommendations, strongly depend on this assumption. As a matter of fact, empirical studies on choice behavior (e.g. Chan (2017) and Read & van Leeuwen (1998)) reveal that individuals fail to commit to their decisions and previous choices often get reversed. Therefore, it becomes clear that household behavior and, especially, possible differences in household behavior must be the central point of analysis when evaluating (pension) reforms and their consequences for social security systems.

Addressing these concerns, the goal of this dissertation is to evaluate several actual and proposed pension policies allowing for a variety of household behavior and reactions. To allow for possible feedback effects, reforms and household behavior are embedded in an overlapping generations (OLG) model, which aggregates individuals' decisions in macroeconomic variables, such as capital stock or aggregate labor supply in the economy. These aggregate decisions can, in turn, have consequences on individual decisions as second round effects, so called feedback effects. In doing so, it is essential to address differing household behavior since they are the key to understanding pension reforms: while Chapter 2 starts with a classical homo economicus setting with perfect foresight, full information, and time-consistency, Chapters 3 and 4 introduce several dimensions of heterogeneity between household behavior such that different reactions to pension reforms can be taken into account. In Chapter 3 these differences are captured in so-called skill groups which differ in life-cycle productivity profiles, weight of leisure in the utility function, and

there may be a (relatively short) contribution history required, which is sometime less than the number of years of contribution required in order to claim early retirement benefits.

fixed costs of work. Chapters 5 and 6 go one step further and relax the classical assumption of time-consistency and allow for time-inconsistent behavior of households. Hereby, Chapter 5 lays the focus on varying shares of present biased agents between countries resembling the availability of institutions as commitment devices rather than actual differences in people's behavior. Chapter 6 refines this analysis and evaluates a set of pension reforms under both assumptions of time-consistency and time-inconsistency focusing on labor supply differences. Another important macroeconomic phenomenon is investigated in Chapter 6, where the effects of aging and the presence of a pension system on inflation rates are investigated.

The methodology applied extends earlier research by Börsch-Supan et al. (2006) and Börsch-Supan & Ludwig (2010), building an OLG framework (except in Chapter 4) which allows for the circumstance that several generations of households are alive at a point in time. This framework adds the macroeconomic perspective, which allows for feedback cycles discussed above. The main advantages of this method are that it is well suited to study demographic change in a very detailed manner since population size and population structure are defined on a yearly basis. In addition, the object of most reforms in this dissertation, namely a PAYG pension system, can intuitively be modeled and studied in this framework. Embedded in this OLG structure are, next to the already mentioned PAYG pension system, a representative firm and heterogeneous households, which optimize along their life-cycle. The firm produces consumption goods using aggregate labor and the capital stock of the economy as production inputs. This is a very simple treatment of firms' behavior. However, the aim of this dissertation is not to study the behavior of firms in the aftermath of pension reforms but rather that of households. Still, modeling production allows for feedback effects stemming from aggregated households' decisions (savings, labor) on equilibrium interest rates and wages, which delivers interesting insights from a macroeconomic perspective. Household behavior, in contrast, is modelled in great detail: while in Chapter 2 a neoclassical optimization of consumption and hours worked is carried out over the life-cycle, Chapters 3 and 4 add an endogenous retirement decision at which exit age from the labor force is decoupled from claiming pension benefits (Chapter 4). Chapters 5 and 6 model time-inconsistency in household behavior and compare model outcomes to the well-known neoclassical results.

In short, the analysis in Chapter 2 shows that direct quantity effects and indirect behavioral effects of population aging are indeed large. Due to interaction effects between the pension system and the labor market, a smart combination of pension and labor market policies can serve as a measure to stabilize living standards. Also taking retirement decisions into consideration, Chapter 3 suggests that individual retirement decisions are strongly influenced by numerous incentives produced by the pension system and macroeconomic variables, such as the statutory eligibility age, actuarial adjustment rates, the presence of a replacement rate, and changes in interest rates and wages. Those retirement decisions, in turn, again have important impacts on the economy which can create feedback cycles working through equilibrium interest rates and wages. Abolishing an earnings test in Chapter 4 as part of a “flexibility reform” may indeed create more labor supply, as was desired, but, at the same time, reduce the average claiming age when adjustments remain less than actuarial, thereby worsening rather than improving the sustainability of public pension systems. International capital flows, which are studied in Chapter 5, are in general lower in a model with than without procrastinators, however, in a world with asymmetric shares of procrastinators they also have an effect on welfare. In addition, labor market reforms in Europe can have global spillover effects through these international capital flows and through the global interest rate. Checking for differences in reform evaluations when allowing for time-inconsistency in Chapter 6, results indeed differ from established findings: while the direction of the effect is mostly the same, the quantitative effects are not. Through labor supply decisions of present-biased households, effects of pension reforms can be diminished or strengthened depending on the type of reform. Lastly, studying the connection between aging and inflation, Chapter 7 establishes that changes in population size seem to be the main driver of this relationship, while changes in population structure are of a smaller magnitude. This becomes especially interesting when comparing a set of countries: young countries with high fertility rates, like the US and India, will go through inflationary pressures stemming from population growth, while a changing population structure will only play a minor role.

The remainder of this introduction summarizes the aforementioned six chapters in more detail with respect to their objectives, methodology and main results. Following these short summaries, Chapters 2-7 contain the full studies.

1.2 Aging in Europe: Reforms, international diversification and behavioral reactions

Joint work with Axel Börsch-Supan and Alexander Ludwig.

Objective: This chapter studies the effects of population aging on the interactions between economic growth and living standards in Europe with labor market and pension reform, behavioral adaptations, and international capital flows. The research question is whether living standards in Europe can be sustained in times of aging and what mix of reforms is suitable to achieve this goal.

Methodology: The analysis is based on a general-equilibrium OLG model with labor supply reactions to reforms which is extended to a multi-country setting. The pension system is an earnings-related PAYG pension scheme typical for France, Germany, and Italy. A labor market reform package consisting of an increase in the retirement age by 2 years, a decrease in the job entry age by 2 years, a convergence of female labor force participation to 90 percent of the rate for men, and a reduction of unemployment, is simulated. Job entry ages and retirement ages are exogenously set such that the behavioral reaction works through intensive labor supply changes.

Main findings: The analysis shows that direct quantity effects and indirect behavioral effects of population aging are large. Direct quantity effects come from releasing restrictions on European labor markets. This increases labor supply, induces more retirement saving and a higher domestic capital stock. Moreover, additional saving is invested abroad and generates international capital flows. Indirect behavioral effects strengthen saving further but substantially weaken labor supply. Due to the interaction effects between the pension system and labor markets, a smart combination of pension and labor market policies can do more than each of such policies in isolation and is a possible candidate to maintain living standards at least to a large extent. The main message of the chapter is twofold. First, it is misleading that Europe could resolve all aging related problems by mobilizing the employment pool. Such policy proposals target the extensive margin of labor supply and ignore behavioral reactions at the intensive margin. Hence, responses to demographic change do not only require structural reforms of labor markets and pension systems but also changes in the attitudes towards reforms. Second, the analysis suggests that such reform proposals can only be effective when households are constrained in their labor choice by institutions.

A shorter version of this chapter has been published in a journal article (Börsch-Supan, et al., 2014).

1.3 Endogenous retirement behavior of heterogeneous households under pension reforms

Joint work with Axel Börsch-Supan, Duarte Nuno Leite and Alexander Ludwig.

Objective: To measure the implications of various reforms of the pension system on retirement decisions and macroeconomic indicators in the face of demographic change, a unified model framework is proposed. The reforms studied are as follows: increasing the statutory eligibility age to 67, connecting the eligibility age automatically to increases in life-expectancy, introducing actuarial neutral adjustment rates, and returning to a DB pension scheme. Because of the rich nature of the unified model framework, it is able to rank the reform proposals according to several individual and macroeconomic measures, thereby providing important support for policy recommendations on pension systems.

Methodology: Endogenous retirement decisions of households are explicitly modeled within a life-cycle context embedded in an OLG framework. Heterogeneity with respect to consumption preferences, wage profiles, and survival rates is introduced in the model (skill groups). The focus is on incentives for retirement within the pension system: the model incorporates a PAYG system that connects individual contributions to benefits when retired (point system), which is partially or fully implemented in countries like France, Germany, and Norway. Furthermore, individual deductions or premia for retiring before or after the statutory eligibility age, respectively, are taken care of. The general effects are then examined on a deeper level when simulated under different macroeconomic regimes.

Main findings: Besides the expected direct effects of this set of reforms on the behavior of households, we observe that relevant feedback effects also do occur. Results suggest that individual retirement decisions are strongly influenced by numerous incentives produced by the pension system and macroeconomic variables, such as the statutory eligibility age, actuarial adjustment rates, the presence of a replacement rate, and changes in interest rates and wages. Those retirement decisions, in turn, indeed have important impacts on the macro-economy which can create feedback cycles working through equilibrium effects in interest rates and wages.

In detail, the simulation with actuarial neutral adjustment rates leads to beneficial effects for the pension system: households work longer, taking pressure off the pension system's budget equation. This results in lower contributions and higher pension levels. In terms of welfare, households are better off under this reform than in the baseline scenario without any reform and the welfare gap narrows between skill groups. Another simulation that abolishes the dynamics of the replacement rate and holds it constant shows reverse results: contribution rates would have to rise by roughly 6 percentage points (p.p.) to balance the pension system's budget equation. In this case, households retire much earlier due to the inflated size of the pension system. In contrast, connecting the statutory eligibility age to the rise in life expectancy in an automatic way has very beneficial effects for contribution rates and the replacement rate. This allows the contribution rate to fall by up to 3 p.p. relative to the baseline scenario and the replacement rate to stabilize. Additionally, different assumptions for macroeconomic regimes like low interest rates and low technological growth show that all reforms perform similarly, independent of the macroeconomic regime. In terms of welfare, the reforms provide a larger improvement for all skill groups (or smaller deterioration in the case of the constant replacement rates reform), which further stresses the importance of these reforms in every macroeconomic context.

A very similar version of this chapter has been published as a MEA Discussion Paper (Börsch-Supan, et al., 2018b).

1.4 Earnings test, non-actuarial adjustments and flexible retirement

Joint work with Axel Börsch-Supan and Duarte Nuno Leite.

Objective: In response to the challenges of increasing longevity, an obvious policy response is to gradually increase the statutory eligibility age and to shut down pathways to early retirement. As an alternative, many countries have introduced “flexibility reforms” which allow combining part-time work and partial retirement. A key measure of these reforms is the abolishment of earnings tests. It is claimed that these reforms increase labor supply and therefore, the sustainability of pension systems. We show that these claims may not be true in the circumstances of most European countries.

Methodology: We employ a life-cycle model of consumption and labor supply where the choices of labor force exit and benefit claiming age are endogenous and potentially separate. The pension system is an earning-related pension scheme connecting individual contributions to later benefits. It is shown that findings are stable with respect to alternative retirement mechanisms such as life-cycle profiles of time costs of working, productivity profiles, and leisure weights.

Main findings: Earnings tests force workers to exit the labor market when claiming a pension. After abolishing the earnings test, workers can claim their benefits and can keep on working, potentially increasing labor supply. The key result is that the difference between exit and claiming age strongly depends on the actuarial neutrality of the pension system and can become very large. Abolishing an earnings test as part of a “flexibility reform” may therefore create more labor supply, but, at the same time, reduce the average claiming age when adjustments remain less than actuarial, thereby worsening rather than improving the sustainability of public pension systems.

This chapter has been published as a MEA Discussion Paper (Börsch-Supan, et al., 2017) and has been submitted to the journal Economics Letters.

1.5 Who cares about the day after tomorrow? Pension issues when households are time inconsistent

Joint work with Axel Börsch-Supan and Duarte Nuno Leite.

Objective: This chapter sheds light on several aspects of pension economics when the assumption of perfect foresight and time-consistency do not hold using a multi-country model of procrastinating households. The focus is on the interaction between the share of procrastinators in a country, the speed and extent of population aging, and the size of an existing PAYG-DB pension system. The three main research questions are: What are the consequences for the balance between PAYG and FF pension systems? Where will retirement savings be invested in a globally linked world with very different pension systems and demographics? How large are global spillover effects of pension reforms in one region for the other regions in the world?

Methodology: We apply a multi-country OLG framework that allows for capital flows between countries. Each country is inhabited by a pre-defined group of perfectly time-consistent and a group of present-biased households whose relative size may vary between countries. The pension system in place is either a FF or a flat PAYG pension scheme. Section 5.4, which focuses on different shares of hyperbolic consumers between countries, models labor supply next to consumption decisions (endogenous labor supply) of households, while Section 5.5 does not allow for backlash effects from labor supply reactions in the aftermath of the prototypical reform package (exogenous labor supply). Addressing this, an endogenous reaction of labor supply in the aftermath of pension reforms when households are present-biased is studied in Chapter 6 of this dissertation.

Main findings: Regarding the first research question, it is well-known that savings are lower if a fraction of households is procrastinating. This has repercussions on the world interest rate and wages, affecting the relative merits of PAYG versus FF pension systems. Nevertheless, PAYG-DB systems provide higher welfare due to the low consumption in old age. International capital flows are generally lower if households are procrastinating. This general pattern, however, does not hold once population processes are very different across countries. Matters are even more complex when the share of procrastinators across countries or regions differs: while contribution rates to PAYG-DB pension systems generally increase with the share of procrastinators, countries with a high share of procrastinators and a large PAYG-DB pension system may have a slower increase of the contribution rate than in a time-consistent scenario if the labor supply effects dominate the effects generated by a higher world interest rate.

International capital flows in a world with asymmetric shares of procrastinators also affect welfare. First, time-consistent households enjoy higher life-time welfare than procrastinating households. Second, younger cohorts will have lower life-time welfare than older cohorts. Third, aggregate welfare is higher in an economy with a relatively low share of procrastinators. For the cohorts entering the labor market until about now, each household type is better off living in an economy with a high share of procrastinators. For later cohorts, however, the opposite is the case.

Concerning the third question, a parametric labor market reform in Europe has global spillover effects through the global interest rate: changes in key labor market and pension parameters in Europe also improve the sustainability of pension systems and economic growth in Asia.

This chapter has been published in a journal article (Börsch-Supan, et al., 2018a).

1.6 Evaluating pension reforms and labor supply under time-(in)consistency

Objective: Challenging derivations based solely on rational agents with time-consistent behavior, this chapter focuses on evaluations of a set of pension reforms when the assumption of time-consistent behavior of households is relaxed. A special focus is laid on the intensive margin of labor supply and its varying response to pension reforms. In addition, differences between model versions on the individual household level and on the macro-level are investigated. The reforms studied are as follows: increasing the statutory eligibility age to 67, connecting the eligibility age automatically to increases in life-expectancy, and returning to a defined benefit pension scheme.

Methodology: The applied single-country OLG framework allows for feedback effects from pension reforms through labor supply stemming from wage and interest rate reactions, which are potentially different between models with time-consistent and present-biased agents. Hereby, the entire demographic transition path is simulated, allowing for an evaluation of reforms for different generations. While Section 5.5 does not assume behavioral feedbacks on labor supply stemming from the labor market reform package (exogenous labor supply), in this chapter, an endogenous reaction of labor supply in the aftermath of pension reforms is studied.

Main findings: Results indeed differ from established findings: while the direction of the effect is mostly the same, the quantitative effects are not. Through labor supply behavior of present-biased households, positive effects on the pension system of those reforms which increase the retirement age are diminished. For reforms stabilizing the replacement level, the presence of present-biased households reinforces reform effects on the pension system. In terms of welfare, however, including time-inconsistency reinforces positive welfare effects for reforms of the retirement age but dampens negative effects of holding the replacement rate constant. While these differences on the individual level are found to be large, macro-variables do not differ substantially between models.

1.7 The aging-inflation puzzle: on the interplay between aging, inflation and pension systems

Joint work with Duarte Nuno Leite.

Objective: This chapter studies how aging, inflation, and pension systems are interconnected and re-examines the aging-inflation puzzle of whether aging might be one of the causes for recent price developments. It puts the different existent empirical findings in the literature on the interconnection between aging and inflation into perspective using a theoretical framework. This chapter contributes to the literature by applying a model that provides a partition of demographic change as a combination of a change in population size and structure. While in the literature usually only one of the mechanisms is examined, both of them are analyzed jointly in this chapter. Another contribution of this chapter is to study the effects of aging on inflation in a stratified manner as well as the effects of the introduction of a PAYG system on inflation, which has strong implications on the inflation process.

Methodology: Using a detailed OLG framework, we carefully differentiate between how changes in population size and structure affect price changes in aging societies. Households inhabiting the economy face a consumption/savings tradeoff, a labor/leisure decision, and real money holdings optimization to capture the main channels connecting demographic change and inflation (money-in-the-utility framework). By first applying a partial equilibrium and then later a general equilibrium setting, we can identify and quantify possible channels through which aging affects inflation.

Main findings: We find changes in population size to be the main driver of the aging-inflation connection while changes in population structure are of a smaller magnitude. Since the structure effect depends on the change of shares of each age group, the decline in the (relative) size of those groups which are situated at the peak of life-cycle consumption leads to a decline in consumption and money demand, negatively affecting inflation. We also explore how the introduction of a public PAYG pension system has a negative impact on inflation. In contrast, endogenous labor reactions are found to have a mitigating effect on this negative effect on inflation. Finally, a comparison of different stages of demographic change and size of pension systems is carried out for a sample of countries using a general equilibrium setting. According to our simulations, aging countries like Germany, Italy, and Japan already face deflationary pressures while China will experience a similar trend in the next decades. The structure effect is found to be especially prominent in Japan starting in the early 1990s, which is explained by early increases of the age dependency ratio. Young countries with high fertility rates, like the US and India, will further go through inflationary pressures stemming from the size effect, while the structure effect will not play a major role.

1.8 Concluding remarks

This dissertation covers six studies addressing pension policies and varying household behavior towards these policies embedded in a macroeconomic setting. The aim is to evaluate pension reforms and various reform proposals with respect to their impact on the sustainability of pension systems and households' welfare, especially taking into account behavioral reactions of households. In doing so, each chapter focuses on a special aspect of household behavior in interaction with institutional settings.

The prototypical reform package in Chapter 2 lifts frictions in the labor market and consequently allows households to work longer, therefore activating labor resources that can potentially help stabilize the pension system. Indeed, it is found that such a reform can help to counteract the decrease in consumption and the increase in contributions. Chapter 3 adds an endogenous retirement decision with respect to the benefit claiming age, incorporating heterogeneous households with potentially different behavioral reactions towards reforms. This is an important extension since pension reforms can have differing impacts on individuals and might, in the worst case, increase inequality in the general population. In order to avoid such unwanted outcomes, it is essential to have suitable models at hand that incorporate heterogeneous agents. Next, in Chapter 4, a detailed focus is laid on a specific change of institutional settings of a pension system, namely the abolishment of an earnings test when claiming pension benefits. This is a very interesting example where theory beats first intuition, which would predict that contributions to the pension system would rise due to augmented labor supply in the aftermath of the abolishment of an earnings test. However, Chapter 4 shows that this is only the case when adjustment rates for early/late retirement are at least actuarial neutral. If they are lower, contributions might even decrease due to early retirement, therefore worsening the condition of the pension system. Chapters 5 and 6 again address varying household behavior towards reforms and deviate from the standard homo economicus household with full rationality by relaxing the assumption of time-consistency. Thereby, Chapter 5 focuses on differences in the degree of procrastination between countries and its consequences for capital movements while Chapter 6 puts its attention on labor supply of time-inconsistent workers when evaluating pension reforms. Relaxing the assumption of time-consistency gives valuable insight for capital flows, households' welfare, and the sustainability of pension systems in the aftermath of various pension reforms. Last, individual household behavior and the type of a pension system in times of aging can also have an impact on inflation rates, which Chapter 7 investigates. These effects can possibly differ between countries, depending on the country's characteristics of population aging.

Despite taking these various perspectives on household behavior when evaluating pension reforms, several simplifying assumptions were made during the course of this dissertation. First, demography was assumed to be an exogenous force in all chapters. In detail, fertility rates, mortality, and migration were taken from external projections during the analysis. However, a detailed, comprehensive modelling of all incentives that influence fertility and migration is beyond the scope of this dissertation. As a consequence, long-run projections which are independent of economic growth, pension schemes, and varying household behavior are the core of demographic developments in this dissertation. Furthermore, there is no uncertainty modelled about the future. This is the case in order to keep the analysis tractable. Still, PAYG pension systems might possibly serve as an insurance against risks vis-à-vis a FF pension scheme. However, the scope of this dissertation is not to contrast PAYG and FF pension systems but rather to point out varying household behavior in combination with changing institutional settings in the aftermath of reforms of PAYG systems, which weakens the role of uncertainty. The discussion of further assumptions, which are specific to individual model set-ups, takes place in the relevant model descriptions or discussions of each chapter.

2. Aging in Europe: Reforms, international diversification and behavioral reactions

This chapter was written in co-authorship with Axel Börsch-Supan and Alexander Ludwig.

2.1 Introduction

While aging is global, there are marked international differences in the speed and extent of the aging processes, notably also among the US, Europe, and Asia. While the US is and will remain relatively youthful, Europe faces a much older population while some Asian countries will go through a very fast aging process. This chapter focuses on the three largest Continental European countries: France, Germany, and Italy, and juxtaposes them with the US. These three European countries do not only feature a much larger decline in the support ratio (number of workers per population) than the US but also have substantially larger public budgets including their pay-as-you-go financed social security systems. Moreover, these countries have labor markets characterized by low participation rates of young women and individuals aged 55 and over. In spite of these structural problems, France, Germany and Italy have been remarkably resistant to labor market and pension reforms.

This chapter extends a line of research based on multi-country overlapping generations models to study the effects of population aging on the interactions between economic growth and living standards with relatively mild labor market, pension and educational reforms, behavioral adaptations, and international capital flows. The key question is which policy mixes are suitable to maintain living standards despite the strong decline in the support ratio.

2.2 The model

We extend the overlapping generations model of the Auerbach & Kotlikoff (1987) type in several dimensions: we acknowledge the international trade and capital flows of European countries by a multi-country version of the model in Börsch-Supan et al. (2006); we model the large frictions in European labor markets by the distinction between exogenous and endogenous labor supply components (Börsch-Supan & Ludwig, 2010); and, in this chapter, we add a model of an earnings-related pay-as-you-go public pension scheme typical for France, Germany, and Italy which combines aspects of a defined contribution system with those of defined benefits. A focus on Asia and global capital markets can be found in Börsch-Supan & Ludwig (2009).

Europe does not live in splendid isolation. There are trade and corresponding international capital flows. Saving and investment decisions are governed by a common global interest rate which, via international capital flows, equalizes the return to capital across countries. Assets held by households in country *i* therefore do not necessarily equal the capital stock in country *i* nor does saving necessarily equal investment in a single country.

After describing the household model in the next section, the remainder of the model is conventional. Exogenous demography, determined by mainstream fertility, mortality, and migration assumptions (Eurostat, 2013), determines cohort sizes and provides the main exogenous driver of the model: population aging. Production and wage setting in each country is neoclassical. Equilibrium is achieved if supply equals demand in the national labor markets and in the global capital market. Further details including the numerical solution and calibration procedures are discussed in the following sections.

2.2.1 Households

Households have preferences over consumption and leisure. Total labor supply of a household of age *j* at time *t* in country *i* is the product of an exogenous component, $l_{t,j,i}$, and an endogenous component, $h_{t,j,i}$. The exogenous component, $l_{t,j,i}$, can be thought of as the maximum life-time number of hours possible for a household, given by restrictions in labor market entry (e.g., due to length of mandatory schooling), restrictions during main working life (e.g., the availability of day care facilities for families, or the 35-hour week in France), and in older age by restrictions through mandatory retirement. Households have some ability to choose their preferred labor supply by choosing $h_{t,j,i}$, the endogenous component of labor supply. They can be thought of as hours within the maximum life-time number of labor hours, $l_{t,j,i}$. This ability, however, is limited and asymmetrical as $h_{t,j,i}$ may not exceed an upper limit $\hbar$.

More formally, a household of age *j* at time *t* in country *i* derives utility from consumption, $c_{t,j,i}$, and leisure, $1 - h_{t,j,i}l_{t,j,i}$, where the household's per period utility function is given by

$$u\left(c_{t,j,i}, 1 - h_{t,j,i}l_{t,j,i}\right) = \frac{1}{1-\theta}\left[(c_{t,j,i})^{\phi}(1 - h_{t,j,i}l_{t,j,i})^{1-\phi}\right]^{1-\theta}. \quad (2.1)$$

The maximization problem of a cohort born in period *t* at *j=0* is given by

$$max\ \sum_{j=0}^{J}\beta^{j}\,\pi_{t,j,i}u\left(c_{t+j,j,i}, 1 - h_{t,j,i}l_{t,j,i}\right), \quad (2.2)$$

where β is the pure time discount factor. In addition to pure time discounting, households discount future utility with their unconditional survival probability, $\pi_{t,j,i} = \prod_{k=0}^{j} s_{t+k,k,i}$. Here, $s_{t+k,k,i}$ denotes the probability to survive from period *t+k*, age *k* to period *t+k+1*, age *k+1* in country *i* with $s_{t,0,i} = 1$. We assume that accidental bequests resulting from premature death are taxed by the government at a confiscatory rate and used for otherwise neutral government consumption[2]. We do not include intended bequests in our model.

Labor productivity changes over the life-cycle according to age-specific productivity parameters, ε_j. Hence, the age-specific wage is $w_{t,j,i} = w_{t,i}\varepsilon_j$.

Denoting total assets by $a_{t,j,i}$, maximization of the household's intertemporal utility is subject to a dynamic budget constraint given by

$$a_{t+1,j+1,i} = a_{t,j,i}(1 + r_t) + \lambda h_{t,j,i} l_{t,j,i}\left(1 - \tau_{t,i}\right) + (1 - \lambda) p_{t,j,i} - c_{t,j,i} \ , \tag{2.3}$$

where $\lambda=1$ for $j=0,\dots,R$ and $\lambda=0$ for $j>R$ and R is the exogenous retirement age. $\tau_{t,i}$ denotes the contribution rate to the pay-as-you-go financed public pension system and $p_{t,j,i}$ the pension income, see below.

As pointed out above, maximization is subject to the constraint that the endogenous component of labor supply ("hours worked within the limit") is positive and may not exceed the upper limit $\hbar$. Since the model cannot distinguish between the limit $\hbar$ and the exogenous labor supply component, we normalize $\hbar$ to one:

$$0 \leq h_{t,j,i} \leq 1 \ . \tag{2.4}$$

In those variants of our model in which the labor supply is fully exogenous, we replace the constraint (2.4) with the constraint that $h_{t,j,i} = 1$ for all *t,j,i*.

The government organizes a prototypical European earnings-related pay-as-you-go financed pension system. Benefits are given by

$$p_{t,i} = \rho_{t,i} w_{t,i}\left(1 - \tau_{t,i}\right) s_{t,j,i}, \tag{2.5}$$

where $\rho_{t,i}$ denotes the replacement rate (generosity of the pension system) and $\tau_{t,i}$ the contribution rate of the pension system in country *i* at time *t*. The pension stock - which captures

[2] An alternative assumption would be to redistribute accidental bequests to the population according to some scheme. The redistribution would, however, not affect our results much and we therefore opted for this simplifying assumption.

the earnings related component of the system and is denoted by $s_{t,j,i}$ - accumulates over the life-cycle according to

$$s_{t+1,j+1,i} = s_{t,j,i} + \frac{\varepsilon_j h_{t,j,i} l_{t,j,i}}{R\,\bar{h}_{t,i}}\,, \tag{2.6}$$

where

$$\bar{h}_{t,i} = \frac{\sum_{j=1}^{R} \varepsilon_j h_{t,j,i} l_{t,j,i} N_{t,j,i}}{R \sum_{j=1}^{R} h_{t,j,i} l_{t,j,i} N_{t,j,i}}\,. \tag{2.7}$$

Households thus earn one earnings point if they receive average wage income in a given period. Earning points are normalized by the length of the working period R. As we do not model intra-generational heterogeneity here, differences in wage income are induced by age-specific productivity only. The scheme well approximates the current legislation in Germany and France with their earnings point systems, and Italy with the new entrants' notional defined contribution system.

Households fully understand the linkage between contributions to the pension system and pension payments in old age. Therefore, relative to a Beveridgian pension system – in which pension payments are lump-sum – labor supply distortions are smaller in such a Bismarckian scheme because of the earnings related linkage. They are not zero, however, as often claimed in the public debate, because the rate of return on the capital market exceeds the implicit return of the pension system in a dynamically efficient economy[3] to the effect that labor is distorted. Due to compounded interest, this effect is stronger for younger households and monotonically decreases (but never becomes zero) with age.

We assume that the budget of the pension system is balanced in all t,i such that

$$p_{t,i} \sum_{j=jr+1}^{J} N_{t,j,i} = w_{t,i} \tau_{t,i} \sum_{j=1}^{jr} N_{t,j,i}. \tag{2.8}$$

The main policy parameters of the pension system are either the net replacement rate, $\rho_{t,i}$, or the contribution rate, $\tau_{t,i}$. The other parameter is determined endogenously since the pension system's budget is assumed to always be balanced. If $\rho_{t,i}$ is large, public pensions substantially crowd out private saving through the households' saving decision given by (2.1) and (2.2).

[3] We calibrate our model such that the economy is dynamically efficient.

If $\rho_{t,i} = 0$, all old age provisions will be private savings. This represents the textbook life-cycle model in which intertemporal consumption smoothing over the life-cycle provides the retirement income through saving in young age and dissaving after retirement.

2.2.2 Demography

Time in our model is discrete and extends from $t=0,\ldots,T$. Each model period t reflects a time interval of 5 years. Our demographic projections, however, are more detailed with an annual periodicity. These detailed demographic projections form the background of our analysis. Demography is taken as exogenous. It represents one of the main driving forces of our simulation model, in addition to exogenous changes in labor supply restrictions and pension policy changes.

Households in our model economies enter economic life at age 15 which we denote by $j=0$. The maximum age is 100 years. Accordingly, the maximum economic age, denoted by J, is 85. We assume that households give birth between ages 0,…,*jf*, the age of menopause. Migration is assumed to be done by the age of 15 ($j=0$) so that we can treat newborns and immigrants in the economic model alike. Accordingly, in each country i, the size of population of age j in period t, $N_{t,j,i}$, is given recursively by

$$N_{t+1,j+1,i} = N_{t,j,i}\varsigma_{t,j,i}\ for\ j > 0\ and\ N_{t+1,0,i} = \sum_{j=0}^{if} f_{t,j,i}N_{t,j,i} + M_{t,0,i}, \tag{2.9}$$

where $\varsigma_{t,j,i}$ denotes the age-specific conditional survival rate, $f_{t,j,i}$ the age-specific fertility rate and $M_{t,0,i}$ the net migration into country i. We assume that the total fertility rate is constant until 2050 as in the constant fertility variant of United Nations World Population Prospects (United Nations, 2012). Life expectancy is computed from life tables provided by the Human Mortality Base (2012) and projected into the future by applying the Lee-Carter method (Lee & Carter, 1992). Data and assumptions on migration are again taken from United Nations (2012). Table 2.1 summarizes the information on total fertility rates and life expectancies at birth.

Table 2.1: Total fertility rates and life expectancies

Life expectancy	**2010**	**2050**
France	79.95	86.29
Germany	78.88	84.72
Italy	80.81	87.43
United States	77.68	83.01
Total fertility rate	**2010**	**2050**
France	1.90	1.90
Germany	1.36	1.36
Italy	1.33	1.33
United States	2.01	2.01

Notes: Data for Germany are for West Germany. Source: own calculations based on United Nations (2012) and the Human Mortality Base (2012).

2.2.3 Production

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

$$Y_{t,i} = F\left(\Omega_{t,i}, K_{t,i}, L_{t,i}\right) = \Omega_{t,i} K_{t,i}^{\alpha} {L_{t,i}}^{1-\alpha}, \tag{2.10}$$

where $K_{t,i}$ denotes the capital stock and $L_{t,i}$ is aggregate effective labor supply of country *i* at time *t*. α is the capital share and $\Omega_{t,i}$ is the technology level of country *i* growing at the exogenous rate g.

The firm's problem is static such that wages and interest rates are given by

$$w_{t,i} = \Omega_{t,i}(1-\alpha)k_t^{\alpha}, \tag{2.11}$$

$$r_t = \alpha k_t^{\alpha-1} - \delta\ , \tag{2.12}$$

where k_t is the capital stock per efficient unit of labor and δ is the depreciation rate of capital.

2.2.4 Equilibrium

We define equilibrium in this economy sequentially. Given initial capital stocks $K_{0,i}$, a competitive equilibrium of the economy is defined as sequences of disaggregate variables for the households $\{c_{t,j,i}, l_{t,j,i}, h_{t,j,i}, a_{t,j,i}\}$, sequences of aggregate variables, $\{C_{t,i}, L_{t,i}, K_{t,i}\}$, prices for labor as well as contribution rates to the pension system, $\{w_{t,i}, \tau_{t,i}\}$, in each country *i*, and a common world interest rate $\{r_t\}$ such that

- given prices and initial conditions, households maximize life-time utility in (2.2) subject to the constraints in (2.3) to (2.8);
- factor prices equal their marginal productivities as given in equations (2.11) and (2.12);
- government policies satisfy (2.5) in every period and

$$G_{t+1,i} = \sum_{j=1}^{J} a_{t+1,j+1,i} N_{t,j,i}(1 - \varsigma_{t,j,i}), \tag{2.13}$$

where $G_{t,i}$ is (otherwise neutral) government consumption (financed by taxing accidental bequests at a confiscatory rate);

- all markets clear in all *t*,*i*.

$$L_{t,i} = \sum_{j=0}^{J} \varepsilon_j h_{t,j,i} l_{t,j,i} N_{t,j,i}, \text{ for all } t,i, \tag{2.14}$$

$$\sum_{i=1}^{I} K_{t+1,i} = \sum_{i=1}^{I} \sum_{j=0}^{J} a_{t+1,j+1,i} N_{t,j,i}, \tag{2.15}$$

$$\sum_{i=1}^{I} \sum_{j=0}^{J} c_{t,j,i} N_{t,j,i} + \sum_{i=1}^{I} K_{t+1,i} + \sum_{i=1}^{I} G_{t,i} = \sum_{i=1}^{I} \Omega_{t,i} K_{t,i}^{\alpha} L_{t,i}^{1-\alpha} - (1-\delta) \sum_{i=1}^{I} K_{t,i}. \tag{2.16}$$

2.2.5 Numerical implementation

Our time line has four periods: a phase-in period, a calibration period, a projection period, and a phase-out period. First, we start calculations 110 years before the calibration period begins with the assumption of an "artificial" initial steady state in 1850. The time period between 1960 and 2010 is then used as the calibration period in order to determine the structural parameters of the model. Our projections run from 2010 through 2100. Results are displayed until the year 2050 to show the main period of population aging. The phase-out period after 2100 has two parts: a transition to a steady-state population in 2200 and an additional 100-year period until the macroeconomic model reaches a final steady state in 2300.

For each sequence of outer loop variables (see above), we solve the household model by looping backward in age, applying first-order methods and appropriately handling the constraints. We can characterize solutions in closed form, conditional on guesses for final consumption of households, c_J, for each period t and country i. To avoid costly inner loops for solutions of the household model, we update these guesses jointly with other outer loop variables as described next.

We determine the equilibrium path of the overlapping generations model by using the Gauss-Seidel-Quasi-Newton method developed by Ludwig (2007). The algorithm searches for equilibrium paths (outer loop variables) of capital to output ratios, pension contribution rates (or, depending on the pension system scenario, replacement rates), average earnings and final period household consumption in each country.

2.2.6 Calibration

We solve the model at a 5 year frequency. We calibrate a subset of structural model parameters as first-stage parameters without using the model. Accordingly, we set the capital share α to 0.40, based on estimates of the wage share. We set the long-run growth rate of productivity g to 0.015 based on estimates of real total factor productivity (TFP) growth in OECD countries. The depreciation rate δ is 5% which, given our calibration target of a capital output ratio of 2.65 (based on estimates of the stock of fixed assets to output) and our choice of the capital share implies an investment to output ratio of about 20%. The inter-temporal elasticity of substitution (IES, $1/\theta$) is set to 0.5 in reference to other studies, see, e.g., the review provided in Bansal & Yaron (2004).

The discount factor, as well as the consumption weight in the utility function, is calibrated by using the model such that it produces a capital output ratio of about 2.65 and a share of time devoted to labor of about one third. This requires setting the discount factor β close to one (0.99), i.e., pure time discounting is weak. Recall, however, that households discount future utility with the probability of surviving into the future. The value of the consumption share in utility ϕ is 0.66.

Table 2.2: Structural model parameters

α: capital share in production	0.40
g: growth rate of labor productivity	0.015
δ: depreciation rate of capital	0.05
Ω_i: technology level	0.05 - 0.07
β: discount factor	0.99
θ: inverse inter-temporal substation elasticity	2.0
ϕ: consumption share parameter	0.66

2.3 Results

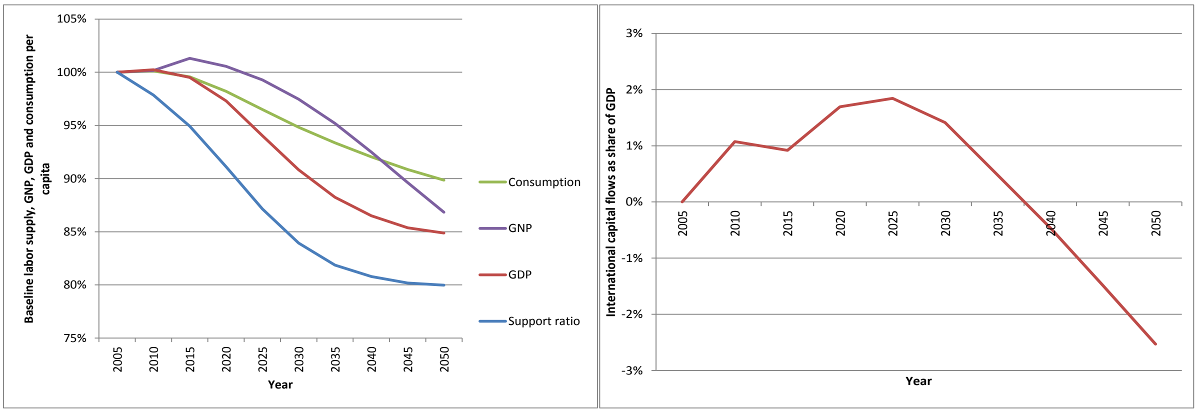
2.3.1 Baseline results

Our baseline is defined as the status quo in terms of the labor market and pension system. We assume constant age and gender-specific labor force participation rates and a constant replacement rate, $\rho_{t,i}$, see equation (2.5). Initially, we also assume equal productivity for all ages. All results refer to EU-3, the aggregate of France, Germany, and Italy. As their populations age, the support ratio declines by 20 percent from 2005 until 2050. As a consequence, the gross domestic product (GDP) per capita would decline by 15 percent and consumption per capita by about 10 percent relative to a non-aging economy with the same total factor productivity if policies and behavior were to remain at the current status quo, see the left panel of Figure 2.1.

Figure 2.1: Baseline results

Baseline labor supply, GNP, GDP and consumption per capita

International capital flows as share of GDP



Note: own calculations. Variables in the left panel are normalized to 100% in 2005 and net of TFP trend. Capital flows are savings minus domestic investment in Europe, relative to GDP and normalized to a balance of zero in 2005.

2.3.2 International capital flows

The decline in GDP per capita is smaller than the decline of the support ratio because scarce labor due to population aging is partially substituted by additional capital. This adaptation occurs in response to rising wages and falling interest rates. Since the US is aging much less than Europe, the return to capital would fall less (and wages increase less) than in Europe if these two regions were economically isolated. In an open economy setting, however, European households will invest in foreign capital deriving higher returns until a common interest rate is achieved in equilibrium. From a life-cycle point of view, such behavior differs according to age: eventually, households will repatriate their foreign savings and, according to the life-cycle mechanism underlying equations (2.1) and (2.2), enjoy their retirement consumption. The aggregate effect depends on demography. The large cohort sizes born in the 60s and 70s lead to first rising, then falling net capital outflows, until they turn negative after about the year 2035, see the right panel of Figure 2.1. These international capital flows reach almost 2% of GDP and are substantial in the sense that consumption per capita falls by about 5 percentage points less than GDP per capita in 2050. It also implies that de-trended gross national product (GNP) is substantially larger than de-trended GDP until about 2055 (Figure 2.1). These capital flows become even larger if the "rest of the world", seen from Europe, includes Asia, see Börsch-Supan & Ludwig (2009), although the long-term effect is smaller than might be expected since the higher speed of the population aging process in Asia generates convergence of population structures between Asia and Europe.

2.3.3 Labor market reform

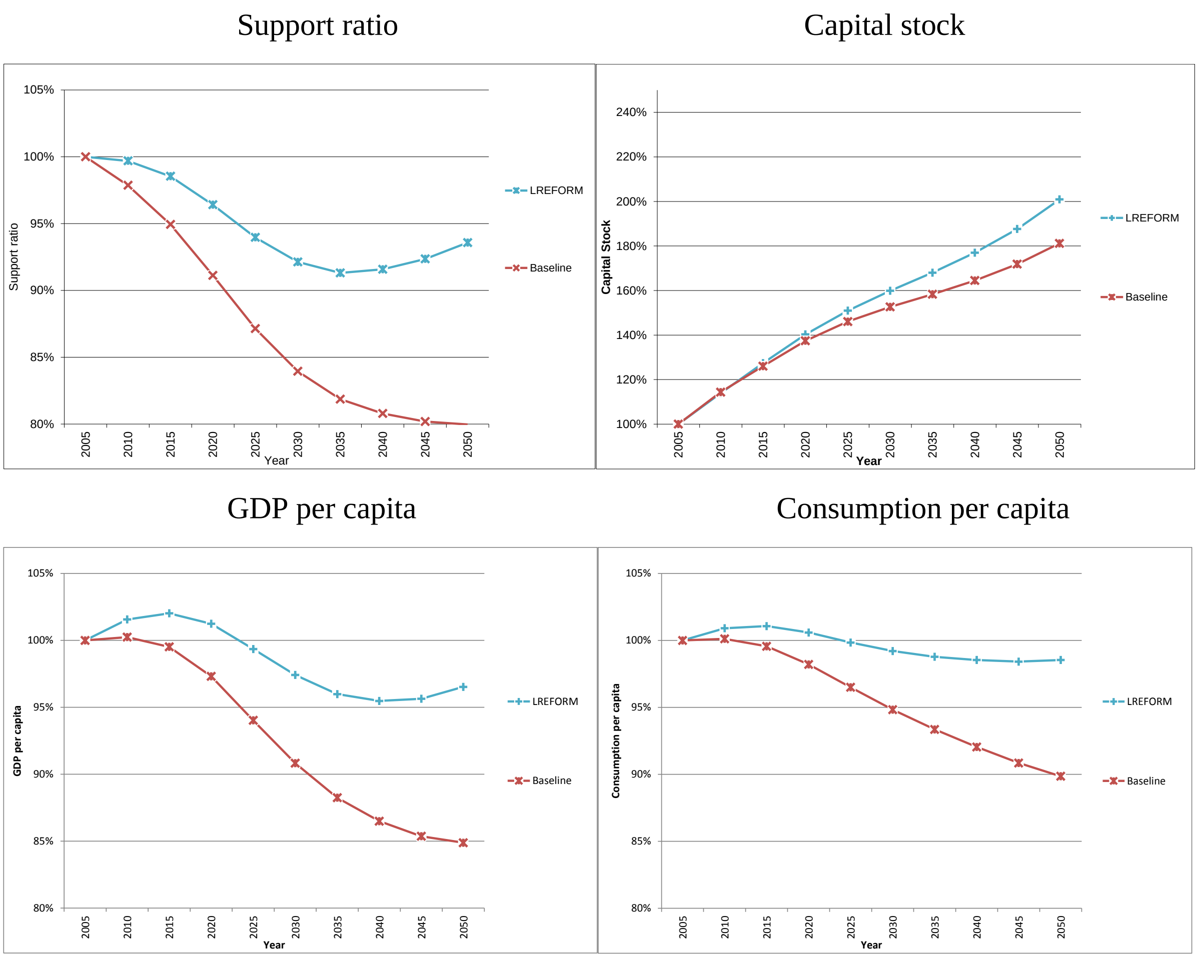
Labor market reform is supposed to relieve some of the current restrictions on European labor markets in order to increase labor supply and to offset the decline of the support ratio in the course of population aging. In the language of our model, the exogenous component $l_{t,j,i}$ will be increased. As a realistic example, our labor market reform scenario includes four policy changes:

- increase in the retirement age by 2 years;
- decrease in the job entry age by 2 years;
- convergence of female labor force participation to 90 percent of the rate for men;
- reduction of unemployment to the NAIRU rate (Ball & Mankiw, 2002).

These reform steps are motivated by actual policy proposals. The Monti-government in Italy has raised its retirement age; in Germany, the statutory eligibility age is gradually rising from 65 to 67 years until the year 2029; and in France, the minimum pensionable age of 60 has been raised to 62. The change in the European high school and university system (the so called Bologna process) is expected to decrease duration of schooling by about 2 years. These reform steps will be phased in linearly between 2010 and 2030.

If hours' supply $h_{t,j,i}$ is exogenous, the economy increases its capacity accordingly and the decline in the support ratio is offset to about 94%, see the upper left panel in Figure 2.2. In addition, saving and investment behavior reacts, leading to a small increase in the domestic capital stock relative to the baseline scenario of Section 2.3.1 (upper right panel), thereby increasing GDP per capita slightly above the trend of the support ratio (lower left panel). Furthermore, added saving flows abroad and eventually increases consumption per capita more strongly than per capita GDP (lower right panel). As a result, economic living standards, here measured as per capita consumption, can essentially be stabilized in spite of population aging in Europe.

Figure 2.2: Labor market reform with exogenous hours

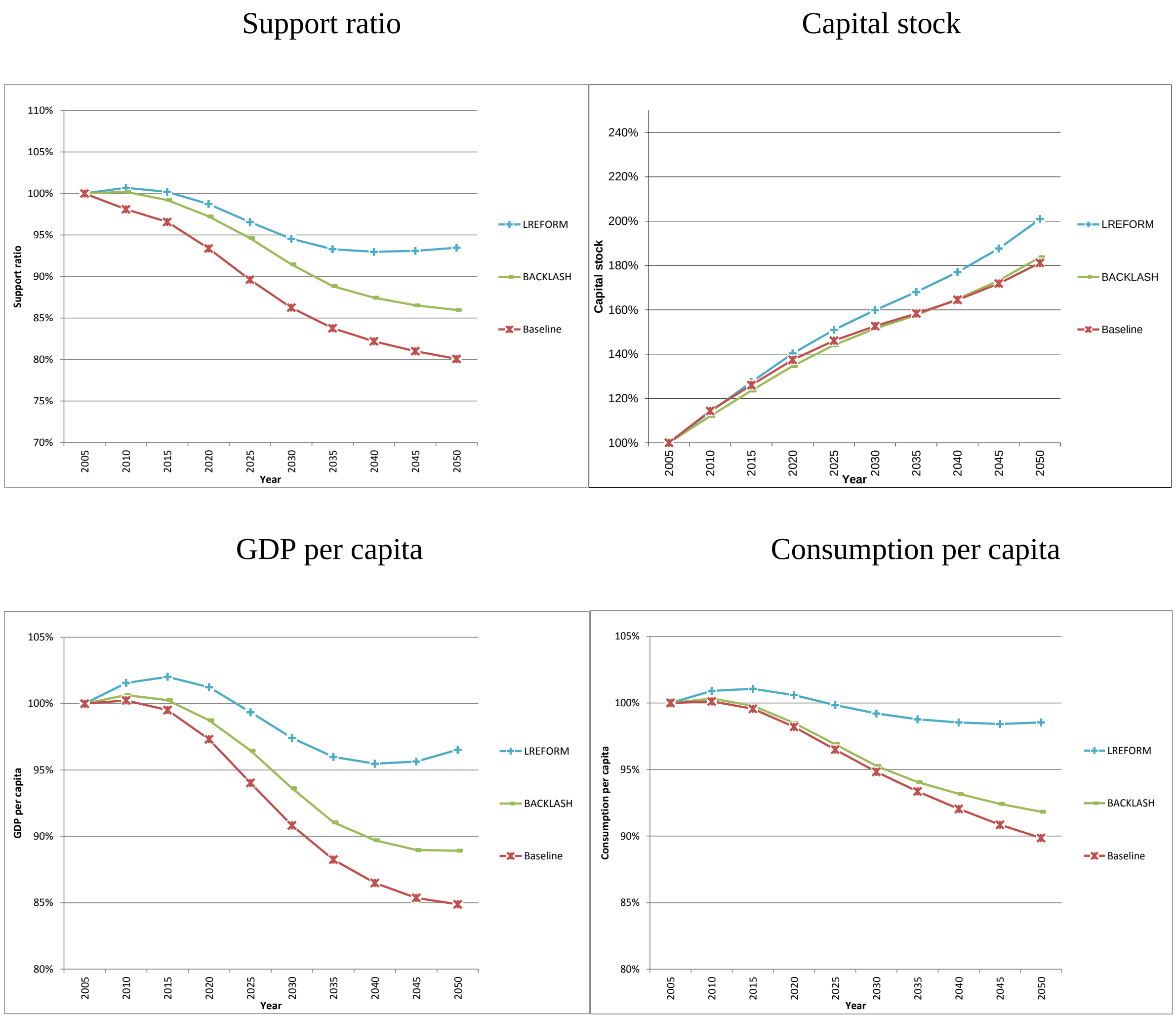


Note: own calculations. All series normalized to 100% in 2005. GDP and consumption per capita are net of TFP growth.

2.3.4 Backlashes to labor market reform

Overall, these reform steps do not appear to be overly radical; in fact, their combination would in 2040 lead to labor force participation rates fairly similar to those in Denmark, Sweden or Switzerland today. Nevertheless, attempts to actually execute reforms with those goals have faced stiff opposition in France and Italy, and also most recently during the new grand coalition government's formation in Germany.

Figure 2.3: Baseline results



Note: own calculations. All series normalized to 100% in 2005. GDP and consumption per capita are net of TFP growth.

Such backlash appears in our model in the substitution between the endogenous component, $h_{t,j,i}$, and the exogenous component, $l_{t,j,i}$. In the absence of constraints, the two components of labor supply are perfect substitutes such that the exogenous variation of $l_{t,j,i}$ leaves the labor supply of the household unaffected: as the age-specific employment, $l_{t,j,i}$, is exogenously increased, the household endogenously decreases hours worked, $h_{t,j,i}$. The exogenous variation of $l_{t,j,i}$ affects total effective labor supply, however, for those households for whom the time endowment constraint $\hbar$ is binding. As a consequence, the exogenous employment variation of $l_{t,j,i}$ has a positive effect on labor supply but the overall effect is substantially smaller than in the previous section where labor supply was fully exogenous. The interplay between $l_{t,j,i}$ and $\hbar$ is most obvious in the household context where female and male working hours are jointly determined.

In our model, the resulting substitution is extreme for households in the middle ages of their life-cycle who are unconstrained. In the real world, we would probably expect a less than one for one reduction of male hours when female hours increase.

2.3.5 Pension reform

The public pension systems in France, Germany and Italy are pay-as-you-go financed. They used to be DB systems in which the contribution rates were raised to maintain a politically determined relatively high replacement rate. Recently, reforms have initiated a process which introduces elements of notional defined contribution (NDC) systems in these DB systems. This transition is strongest in Italy, where a formal NDC system of the Swedish type has been introduced for new entrants, and has recently been accelerated by the Monti government. France and Germany have earnings-related pension systems in which the labor market risk to pension benefits is borne by workers, an important element of a DC system. In addition, Germany has introduced a "sustainability factor" which adjusts pension benefits not only to productivity increases, but also to the ratio of pensioners to workers, effectively transiting to a mixed system with DB and DC features.

Our model captures the earnings-related nature of the pension systems in France, Germany, and Italy. In addition, we simulate two policies to set the replacement and the contribution rate which bracket the current mixture of DB and DC:

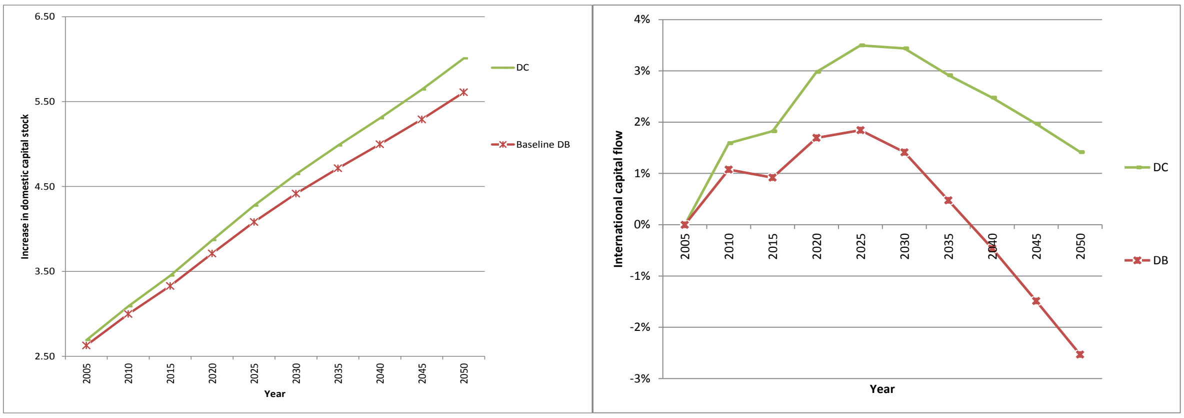
- the replacement rates are constant and roughly correspond to the 2010 levels (OECD, 2013). This corresponds to a DB system; the contribution rate adjusts accordingly to maintain a balanced budget;
- the contribution rates are frozen at their 2010 levels corresponding to a DC system; the replacement rate adjusts accordingly to maintain a balanced budget.

Figure 2.4 shows the resulting increase in the European capital stock, expressed in relation to GDP and for the case of exogenous labor supply. The base case is a DB system in which the replacement rate is fixed. In a DC system, the declining replacement rate induces workers to save more for their retirement, resulting in a larger domestic capital stock. Moreover, international capital flows also increase substantially to about 3.5 percent of GDP, more than offsetting the reversal after 2035 in the baseline scenario since the new young cohorts keep building up assets to finance their retirement consumption.

Figure 2.4: Pension reform

Increase in domestic capital stock

International capital flow



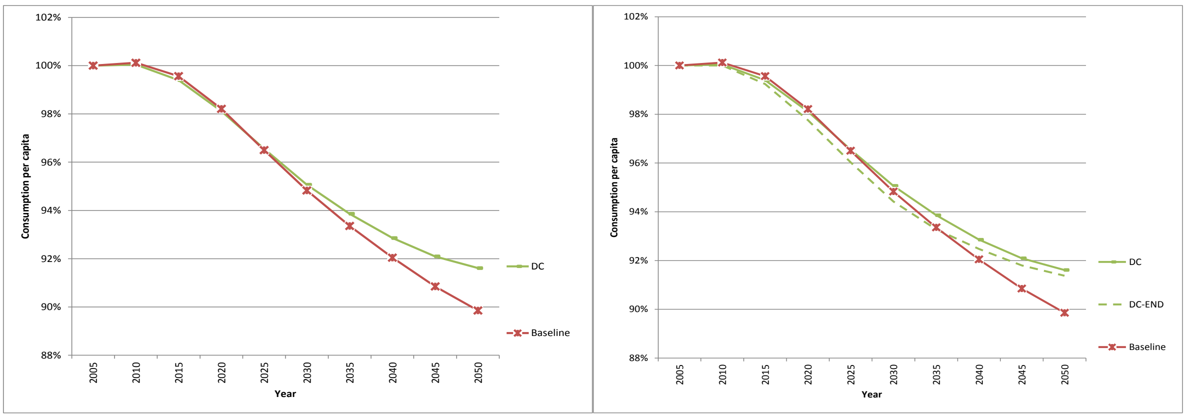
Note: own calculations. Capital stock as a multiple of GDP. Capital flows are savings minus domestic investment in Europe, normalized to a balance of zero in 2005.

The higher capital stock plus the larger foreign assets lead to higher consumption per capita, see the left panel of Figure 2.5. Such pension reform steps will not only generate reaction in saving behavior but also influence labor supply. However, compared to the reactions to labor market reform, the negative behavioral responses are relatively modest as can be seen in the right panel of Figure 2.5.

Figure 2.5: Consumption per capita after pension reform

Exogenous hours

Endogenous hours

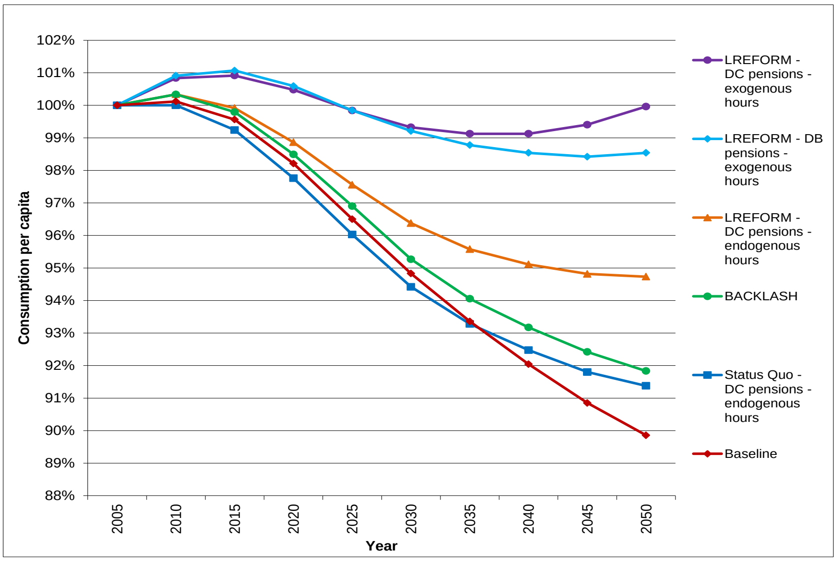


Note: own calculations. All series normalized to 100% in 2005 and net of TFP growth.

2.4 Discussion

Our study shows that direct quantity and indirect behavioral effects of population aging on the economy are large. Direct quantity effects come from releasing restrictions on European labor markets. This increases labor supply, induces more retirement saving and a higher domestic capital stock. Moreover, additional saving is invested abroad and generates international capital flows. They go first from the old to the young countries until the savings are repatriated to increase retirement consumption. Indirect behavioral effects strengthen saving further but substantially weaken labor supply. Both effects significantly affect economic growth and living standards. Due to the interaction effects between pension system and labor markets, a smart combination of pension and labor market policies can do more than each of such policies in isolation. These interaction effects are shown in Figure 2.6. A combination of a relatively moderate labor market reform with a pension policy to keep the contribution rate at the current level will reduce the baseline decline of consumption per capita ("Baseline" in Figure 2.6) to about a half ("LREFORM – DC pensions – endogenous hours" in Figure 2.6). While switching from a DB to a DC pension system increases de-trended consumption per capita by 1.5 percentage points, and creates more labor supply by 1.9 percentage points, the combined effect of labor market and pension reform is 4.8 percentage points, including their interactions which are about 25% of the total effect.

Figure 2.6: Consumption per capita when policies are combined



Note: own calculations. All series are normalized to 100 percent in 2005 and net of TFP growth.

The biggest obstacle to further reductions are behavioral effects generated by the high preference for leisure and other incentives not explicitly modeled here but implicitly captured by the interplay between the hours' limit $\hbar$ and the exogenous labor volume $l_{t,j,i}$ (difference between

"LREFORM – DC pensions – endogenous hours" and "LREFORM – DC pensions – exogenous hours" in Figure 2.6).

The main message of the chapter is therefore twofold. First, it is misleading that Europe could resolve all aging related problems by mobilizing the employment pool. Such policy proposals target the extensive margin of labor supply and ignore behavioral reactions at the intensive margin. In the same vein, budgetary projections based on employment scenarios are severely biased because they implicitly assume that hours worked per person are kept constant. Hence, responses to demographic change do not only require structural reforms of labor markets and pension systems but also changes in the attitudes towards reform.

Second, our analysis suggests that such reform proposals can only be effective when households are constrained in their hours choice by institutions. Yet, we neither explicitly model these institutions nor the complex household joint labor supply decisions. We leave an extension of our model along these dimensions for future research. The strong substitution between the endogenous hours $h_{t,j,i}$ and the exogenous labor volume $l_{t,j,i}$ in our model may generate too pessimistic an estimate of the reform backlash and its effects on economic growth and living standards. The fact, however, that all three new governments in France, Germany, and Italy are currently reverting pension and labor market reforms enacted by their predecessors shows how real the effects are of these governments' fear of resistance to reform.

3. Endogenous retirement behavior of heterogeneous households under pension reforms

This chapter was written in co-authorship with Axel Börsch-Supan, Duarte Nuno Leite and Alexander Ludwig.

3.1 Introduction

Pension reforms are a subject of controversy in many countries as they affect all sectors of society and are always at the center of public debate. In Europe, where the number of retirees per worker will continue to increase until about 2050, unsustainability threatens public PAYG systems. Several arguments have emerged pointing out how to establish a new pension system framework in order to avoid imbalances of the system and how to handle social expectations regarding retirement, income stability, and future well-being. It is feared that decreasing replacement rates or increasing contribution rates will lead to old-age poverty or disincentives in labor supply at younger ages. Furthermore, when it comes to the area of sustainability debate, arguments emerge which point out both how to establish a new framework and avoid imbalances of the system and how to balance social expectations regarding retirement, income stability and future well-being. The pressing demographic transition and the negative effects of early retirement urged countries to take reforms that could no longer wait to be implemented, especially given the risk of unsustainability and the financial crisis that has undermined the budgets of countries in the last decade.

Facing this challenge, numerous reforms have been put forward by policy makers to promote more active aging and a longer working life (Börsch-Supan, 2007; Huber, et al., 2016; Sonnet, et al., 2014; World Bank, 1994; OECD, 2017; Börsch-Supan, et al., 2016b; Graf, et al., 2011). Such reforms have include increasing the statutory eligibility age in Germany or Italy (Börsch-Supan, 2007; Boeri, et al., 2016), the introduction of flexible retirement mechanisms in Norway and the UK (Börsch-Supan, et al., 2018c), and even profound changes in the main framework of the pension system (Palmer, 2000; Moscarola & Fornero, 2009). All of these reforms must be evaluated as individuals adapt to the new environment and possibly re-evaluate their life-cycle decisions. Even when direct incentive effects of reforms are taken into account, evaluations still sometimes lack possible backlash effects (see Chapter 2 of this dissertation). Accordingly, reforms aiming at increasing the extensive margin of labor supply might lead to smaller reform effectiveness due to negative labor supply adjustments on the intensive margin. Not taking this into account could therefore bias reform evaluations.

There is a long and rich literature that examines endogenous behavior of households. Studies have shown that wealth and financial incentives have a great impact on retirement decisions (French, 2005; Chan & Stevens, 2008) as well as on the household composition and income status of individuals (Coile, 2004; van der Klaauw & Wolpin, 2008; Gustman & Steinmeier, 2004; Fuster, et al., 2003). As will also be discussed in Chapter 4 of this dissertation, the design of pension systems is of great importance for determining the impact on retirement behavior because individuals react to changes in incentives and in the framework of pension systems (Gustman & Steinmeier, 2005; Duggan, et al., 2007; Kotlikoff, et al., 2007; Börsch-Supan & Schnabel, 1998; Gruber & Wise, 1999).

We build a rich OLG model of the Auerbach and Kotlikoff type (Auerbach & Kotlikoff, 1987) and quantify the effects of pension reforms on retirement decisions, taking into account demographic change and macroeconomic feedback cycles. Our model shares features with many recent papers, such as Sánchez-Martín (2010) and Fehr et al. (2012), it extends the reform settings in a comprehensive way by analyzing a number of new reform scenarios, enabling us to provide comparable outcomes from different reform proposals that have emerged in the literature. As a central contribution of this chapter, our model allows for a unified framework to compare different reform proposals and give valuable policy recommendations. In the literature, studies tend to look only at a specific reform (e.g. increase in statutory eligibility age) or combine initial reforms with supplementary ones without exploring the individual effects of each one. We, in contrast, separately examine every reform using the same framework. Under this approach, the isolated effects of reforms can be scrutinized and the outcomes are not mixed up. Secondly, we compare a set of newly proposed reforms and evaluate them. This provides the literature with an extended analysis of the effects of the new solutions on the sustainability of pension systems and the endogenous effects that could be expected from each one.

Following the existing literature (Sánchez-Martín, 2010; Catalan, et al., 2010; Fehr, et al., 2012), we start by setting a benchmark scenario with a statutory eligibility age of 65. We study incentives for retirement by focusing on the pension system: the model incorporates a PAYG system that connects individual contributions to social security and to benefits when retired (point system), which is partially or fully implemented in countries like France, Germany, and Norway (Social Security Administration, 2014). We add to the model working costs which not only mimic commuting time to work but also other costs associated with declining health of workers. These costs may influence labor decisions and are not always introduced in these types of models. We introduce heterogeneity with respect to individual consumption preferences, wages, and survival rates by defining three equally large groups of individuals. These dimensions lead to interesting insights regarding endogenous retirement decisions and distributional effects of pension reforms, such as lower retirement ages for agents with low consumption preferences, as well as unequal effects of reforms between skill groups with respect to welfare.

In our baseline scenario, agents choose early retirement: during the given age interval of 60-72, agents retire between the ages of 60 and 65. We assume that an earnings test is in place, meaning households leave the labor market at the time of claiming pension benefits. This mimics most pension systems that currently produce incentives for early retirement, which is mainly due to low actuarial adjustments before the statutory eligibility age (Börsch-Supan, 2004; Werding, 2007; Gasche, 2012b). All further pension reforms are discussed, simulated and compared to this baseline scenario.

As a first reform, we simulate an increase of the statutory eligibility age from 65 to 67, which has already been or is still being introduced in several countries such as France, Germany, the UK, and others (Social Security Administration, 2014). Our results lead to the same increase in the labor force participation among older workers as observed empirically in Hanel & Riphan (2012) and Blundell & Emmerson (2007). However, actual retirement ages might not react fully to the increase in the statutory eligibility age. Still, agents work longer which takes pressure from the pension system's budget constraint and leads to beneficial effects for the PAYG pension system, which allows for lower contributions and higher pension levels. However, this is the case because adjustment rates are currently low in most European countries, otherwise, with actuarial neutral adjustment rates in place, expenditure effects would be neutral when actual retirement ages change. In terms of welfare measures, households are better off in this case than in the baseline scenario in this simple setting. Positive welfare consequences for increasing statutory eligibility ages are in agreement with the literature (Beetsma, et al., 2003; Catalan, et al., 2010; Kotlikoff, et al., 2007). However, reform success turns out to be only temporary until the previous imbalances, which were controlled a decade before, emerge again since life expectancy is persistently increasing. That is why an increase in the statutory eligibility age today to 67 would lead, in about a decade, to the same problems currently being faced by the pension system. A way to prevent a repetition of this political discussion every decade is proposed by Börsch-Supan (Börsch-Supan, 2007; OECD, 2017). This proposal suggests that the connection between the statutory eligibility age and the increase in life expectancy is automatic. We model this reform in a second scenario and find very beneficial effects on contribution rates and welfare.

We further simulate a third scenario with actuarial neutral adjustment rates before and after the statutory eligibility age. In this case, agents work longer, removing pressure from the pension system's budget. This confirms previous findings in the literature. We extend these findings in a dynamic model, which shows that high adjustment rates do not always imply high retirement ages. In many cases retirement still occurs before the statutory eligibility age. Due to heterogeneity between groups, we observe that lower skilled groups are the ones who react the strongest. In terms of welfare measures, households are better off when actuarial neutral adjustment rates are added in the previous scenario.

Despite these mostly positive findings, we simulate a fourth reform which refers to policy proposals that sometimes result from a political backlash to previous pension reforms: political supporters of this reform propose the replacement rate to be held constant at current levels in order to respond to challenges of old-age poverty. Accordingly, the evolution of the benefit level is not connected to developments in wages and the ratio of retirees to contributors anymore. We conclude that it leads to a 7.5 percentage point raise in the contribution rate and households work less due to the larger size of the pension system. Especially future generations suffer from this reform proposal in terms of welfare, while earlier generations can slightly profit. However, low skilled households are harmed less than their high skilled counterparts reducing the gap between them.

In order to state a point regarding the effects of the prevailing macroeconomic regime on the performance and impacts of each reform, we define two different macroeconomic regimes. Since the last financial crisis, interest rates have been low for a long period of time; therefore, we define a first regime where interest rates are set to be much lower than in the benchmark regime. We conclude that under such macroeconomic conditions, the pension system still becomes more sustainable than in the baseline scenario because of later retirement decisions from individuals. The second regime simulates a lower technological growth in the economy that also corresponds to a scenario of low economic growth. Under this regime, the effects of each reform are similar to the ones observed under the benchmark regime of high technological growth.

The chapter is structured as follows: Section 3.2 introduces the model and its components. Model solution and calibration are described in Section 3.3. An analysis of the different effects of each reform are shown and discussed in Section 3.4. In Section 3.5, the performance of reforms under different macroeconomic regimes is tested. Section 3.6 concludes.

3.2 Endogenous retirement decision model

We extend the OLG model of the Auerbach and Kotlikoff (1987) type in several dimensions: we add a model of a detailed earnings-related PAYG public pension scheme which combines aspects of a defined contribution system with those of defined benefits. In addition, we include monetary incentives for early or late retirement through the adjustment of pension benefits. Consequently, we allow for a discrete endogenous choice on retirement in addition to the continuous leisure/work and consumption/saving trade-offs. Furthermore, we introduce household skill groups, which differ with respect to four dimensions: consumption preferences, wage profiles, survival rates, and time costs of working. This detailed setting allows for numerous reforms within the same model framework, which will be discussed in Section 3.4.

3.2.1 Household problem

There are $k = 3$ different types of perfectly foresighted households at every point in time t with age j (heterogeneous agent setting). Each k-group has a population size equal to $1/k$ of the total population at each time, t. It is assumed that they live up to a maximum age of J years. Households have preferences over consumption and leisure. Accordingly, household k receives utility from consumption and leisure as given by the following CES-type per-period utility function

$$u^k\left(c_{t,j}^k, l_{t,j}^k\right) = \frac{1}{1-\theta}\left[(c_{t,j}^k)^{\phi_j}(l_{t,j}^k)^{1-\phi_j}\right]^{1-\theta}. \qquad (3.1)$$

u^k is twice continuously differentiable, strictly increasing in consumption and leisure, and strictly concave. ϕ_j denotes the utility weight of consumption versus leisure and it is age-dependent. Risk aversion is described by the parameter, θ, and a von Neumann-Morgenstern expected utility maximization program over the entire life-cycle.

Leisure is time endowment (normalized to one) less hours worked, $h_{t,j}^k$. Additionally, a time cost $\vartheta\left(h_{t,j}^k\right)$ to take up work (also measured in hours) is introduced:

$$l_{t,j}^k = 1 - h_{t,j}^k - \vartheta\left(h_{t,j}^k\right). \qquad (3.2)$$

Time costs $\vartheta(h_{t,j}^k)$ are present when households work and mimic the effect of declining health on the disutility of work (Börsch-Supan & Stahl, 1991). This effect may be non-linear, increasing with the number of hours worked. The cost function is given by

$$\vartheta\left(h_{t,j}^k\right) = \chi_j\left(1 - \frac{1}{\left(1+h_{t,j}^k\right)^{\xi}}\right), \qquad (3.3)$$

where χ_j is the age-dependent time costs of disutility of work and health decline and ξ is a smoothing parameter for these time costs of working. We assume that these time costs are, at the age of 80, equal to 27% of the total available unit of time.

Each household k maximizes utility

$$max\ \sum_{j=0}^{J} \beta^j\, \pi_{t,j}^{k} u^k\left(c_{t,j}^{k}, l_{t,j}^{k}\right), \tag{3.4}$$

where β^j is the discount factor and $\pi_{t,j}^{k} = \prod_{u=0}^{j} \varphi_{t,j}^{k}$ is the type-dependent (unconditional) survival probability. $\varphi_{t,j}^{k}$ is the corresponding conditional survival probability. Thus, households have uncertainty about the time of death and, therefore, have their life expectancy determined by the introduction of survival rates, which allows them to account for the probability of dying before reaching age, J. We do not include intended bequests in our model and assume that accidental bequests resulting from premature death are taxed away by the government at a confiscatory rate and used for otherwise neutral government consumption.

Wages depend on age and household type,

$$w_{t,j}^{k} = w_t \varepsilon_j^k, \tag{3.5}$$

where ε_j^k generates age and type specific wage profiles.

The budget constraint is given by

$$a_{t+1,j+1}^{k} = a_{t,j}^{k}(1 + r_t) + h_{t,j}^{k} w_{t,j}^{k}(1 - \tau_t) + p_{t,j}^{k} - c_{t,j}^{k} \tag{3.6}$$

with

$$0 \leq h_{t,j}^{k} \leq 1 - \vartheta(h_{t,j}^{k}) \text{ and } c_{t,j}^{k} > 0. \tag{3.7}$$

$p_{t,j}^{k}$ are individual pension benefits (see below) and $a_{t,j}^{k}$ denotes assets. τ_t is the contribution rate of the public pension system.

3.2.2 The public pension system

The benchmark PAYG pension system is earnings-related and links individual past contributions to future pension benefits (via a pension point system). The point system allows one to relate individual benefits to the number of years contributed to the system and the relative earnings position compared to the economy’s average. As a result, households understand the link between contributions and later pension benefits.

Furthermore, we introduce a hybrid DB/DC-PAYG system which works as a balancing mechanism that moderates the negative impacts of population aging between different generations. A pension system of the DB type means that a cohort of retirees is promised a pension benefit, $p_{t,j}^k$, which is typically defined by a replacement rate that is independent from the demographic and macroeconomic environment. The contribution rate to the system must then be adjusted to keep the PAYG system balanced. This set-up puts the highest burden on the young (working generation) since the contribution rate has to adjust in order to balance the pension budget equation (3.8). It is also possible to define the PAYG system as the DC type. In this case, the pension system fixes the contribution rate for a cohort of workers. Therefore, the replacement rate reacts passively to developments in demography and employment. The DC system protects the younger generation from increases in the contribution rate, but population aging will make the older generation worse off by reducing their benefits in proportion to the decline in the system's dependency ratio. The aforementioned mechanism balances the burden of demographic change between different generations. Accordingly, the contribution rate to the pension system has to adjust less in times of population aging since the adjustment rate automatically scales down individual pension payments. An example of such a mechanism in the framework of earnings-related public PAYG pensions is the introduction of a "sustainability factor" in Germany (Börsch-Supan & Wilke, 2005). It introduces DC elements into a pension system that remains framed as a DB system in order to appeal to voters' preferences. This hybrid DB/DC-PAYG system combines first the French and German point system when it comes to the question how individual earnings are related to pension benefits. Second, the system is a mixture of the Italian and German DC and DB systems and, thereby, resembles a synthetic continental European pension system.

The yearly pension budget equation is assumed to be balanced and given by

$$\tau_t w_t \sum_{k=1}^{K} \sum_{j=1}^{R_t^k} \varepsilon_j^k h_{t,j}^k N_{t,j}^k = \sum_{k=1}^{K} \sum_{R_t^k+1}^{J} p_{t,j}^k N_{t,j}^k, \tag{3.8}$$

with individual pension benefits, $p_{t,j}^k$,given by

$$p_{t,j}^k = \gamma_{t,j}^k b_t w_t \big(1 - \tau_{t,i}\big) \overline{h}_t \frac{s_{t,j}^k}{\overline{R}_t}. \tag{3.9}$$

$\overline{R}_t$ is the statutory eligibility age and R_t^k is the actual retirement age of household type k and the cohort retiring in t. $N_{t,j}^k$ represents the number of people aged j, at time t and in skill group k.

Further definitions are given by

$$s_{t,j}^k = \sum_{m=0}^{j} \frac{\varepsilon_m^k h_{t-j+m,j}^k}{\overline{h}_{t-j+m,j}^k}\,, \tag{3.10}$$

where

$$\overline{h}_t = \frac{\sum_{k=1}^{K}\sum_{j=1}^{R_t^k} \varepsilon_j^k h_{t,j}^k N_{t,j}^k}{\sum_{k=1}^{K}\sum_{j=1}^{R_t^k} N_{t,j}^k}. \qquad (3.11)$$

$s_{t,j,i}^k$ evolves according to

$$s_{t+1,j+1}^k = s_{t,j}^k + \frac{\varepsilon_j^k h_{t,j}^k}{\overline{h}_t}. \qquad (3.12)$$

The term $s_{t,j}^k$ links individual labor (and therefore contributions to the pension system) to the aggregate economy ($\overline{h}_t$) and resembles the accumulation of pension points over the life-cycle. Accordingly, when working the average hours of the economy in a given year t, the household receives one pension point. Upon retirement, the quantity of accumulated pension points decides the level of pension benefits.

Finally, we introduce the mechanism to replicate the hybrid DB/DC-PAYG system, b_t, that scales the pension benefits in equation (3.9) up or down according to developments in wages and demographics. The replacement rate evolves according to

$$b_t = b_{t-1} * \frac{w_{t-1}(1-\tau_{t-1})}{w_{t-2}(1-\tau_{t-2})} * \left(\frac{RQ_{t-2}}{RQ_{t-1}}\right)^{\mu}. \qquad (3.13)$$

RQ_t is the ratio of the number of retirees to the number of contributors to the pension system at time *t*. Accordingly, pension benefits are scaled down (up) when net wages decrease (increase) and when the quotient RQ_t increases (decreases) over time, which is the case in times of population aging. As Börsch-Supan et al. (2016b) argue, the parameter μ can be set as a political compromise between current voters' preferences and the financial sustainability of the pension system. The parameter captures the intergenerational distribution of the demographic risk generated by population aging. Setting $\mu=0$ stabilizes the replacement rate of pension benefits to the older generation, while $\mu=1$ stabilizes the contribution rate of the younger generation. We assume a political compromise of $\mu=0.25$ and an initial steady state of the replacement rate of $b_0 = 60\%$ and allow it to adjust afterwards according to equation (3.13). Making pension payments dependent on demographic developments and economic growth through a factor which adjusts the replacement rate is a similar idea as in NDC pension systems, which were introduced in Sweden and Italy in the 1990s, for instance.

3.2.3 Endogenous retirement decision

A specific feature of the model is that households decide on the age of retirement. An endogenous retirement decision is modeled and households take into account the optimization of their consumption/savings and hours worked/leisure to define their own optimal age for retirement. Most modern pension systems have a window of retirement defined by an earliest and a latest eligibility age, $R_E \leq R \leq R_L$, which bracket what is colloquially termed the "normal retirement age," R. Accordingly, households have a choice to retire within a given window. Retirement age is defined as the age when the household simultaneously leaves the labor market and claims pension benefits. Accordingly, a full earnings test is in place (see also Chapter 4 of this dissertation for a deeper discussion of earnings tests).

To penalize earlier retirement and to promote a later retirement age, the pension system incorporates actuarial adjustments before and after the statutory eligibility age to pension payments if households retire before or after the statutory eligibility age, $R_E \leq \overline{R}_t \leq R_L$. These actuarial adjustment factors behave as described in equation (3.14).

$\gamma_{t,j}^k$ is the individual specific adjustment factor of the retirement formula (3.9). The factor equals 1 if the household retires at the statutory eligibility age. If the household decides to retire earlier, there is a deduction of ω_t percent (adjustment rate) of pension benefits for every year. For each year of delayed retirement, there is a premium of ω_t percent. However, there will always be an earliest retirement age, R_E, that households cannot undercut[4]. An overview for $\gamma_{t,j}^k$ is given by

$$\gamma_{t,j}^k = 1 + \left(R - \overline{R}_t\right)\omega_t \qquad \text{for} \qquad R \geq R_E. \tag{3.14}$$

As previously mentioned, the adjustment rate, ω_t, creates strong incentives for when to retire (Desmet & Jousten, 2003; Gruber & Wise, 2005; Fisher & Keuschnigg, 2010). Occasionally, it is referred to as "actuarial adjustment rate," although the term "actuarial" only applies when ω_t is introduced in the pension system such that the present discounted value PDV_t of participating in the pension system for all households is independent of their retirement age, R.

$$PDV_t(R) = \sum_{j=R+1}^{\infty} p_{t+j}(R;\omega_R)\,\pi_{t+j,j}\left(\frac{1}{1+r}\right)^j - \sum_{j=0}^{R} \tau_{t+j} w_{t+j}\,\pi_{t+j,j}\left(\frac{1}{1+r}\right)^j \tag{3.15}$$
$$= \text{constant for all } R \in [R_E, R_L].$$

[4] Note that we abstract from disability insurance in our model setting.

The resulting ω_t depends on the interest rate, r, and survival probabilities $\pi_{t+j,j}$ of cohort t for age j. Pension systems with benefits independent of the individual retirement age (i.e. $\omega_t = 0$) are not actuarially neutral since they redistribute income from late retirees to early retirees who receive the same benefits over a longer period of time. Therefore, $\omega_t = 0$ creates a strong incentive for workers to retire early. The same argument applies when adjustment rates are lower than the actuarially neutral value. This is the case in many countries; see Table 3.1.

Table 3.1: Actuarial adjustment rates at earliest age of retirement benefits

	Current legislation	Actuarially neutral
Austria	4.2	7.5
Canada	7.2	7.3
Finland	4.8	7.7
Germany	3.6	6.3
Italy	1-2	7.6
Japan	8.4	6.6
Spain	6.5-8	7.4
Sweden	4.1 - 4.7	6.9
US	5.0 - 6.67	8.2

The table shows the adjustment rates for statutory early retirement. Many countries have additional pathways not included here. The underlying interest rate is 2%. Source: Blundell et al. (2017), OECD (2015) and Queisser & Whitehouse (2006).

Similar actuarially neutral adjustment rates ranging between 5 and 7% for Germany have been found by Börsch-Supan (2004), Werding (2007) and Gasche (2012) for an interest rate of 3%, with several assumptions about future mortality.

3.2.4 Production

The production sector consists of a representative firm. Production is given by a Cobb-Douglas production function using capital stock, K_t, and aggregate effective labor, L_t, as inputs.

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}, \tag{3.16}$$

A_t is technology (growing at rate g_t). α is the capital share in the economy. Since factors earn their marginal product, the wage and interest rate are given by

$$w_t = A_t(1-\alpha)k_t^{\alpha}, \tag{3.17}$$

$$r_t = \alpha k_t^{\alpha-1} - \delta \, , \tag{3.18}$$

where k_t denotes the capital stock per efficient unit of labor ($K_t/(A_t L_t)$) and δ is the depreciation rate of capital. We also introduce a wedge between the interest rate perceived by households and the market interest rate/marginal product of capital.

3.3 Model solution and calibration

3.3.1 Computational algorithm

This computable general equilibrium (CGE) model has to be solved numerically. The algorithm searches for equilibrium paths of consumption, hours worked, capital to output ratios and, in case there are social security systems, pension contribution rates. We determine the equilibrium path of the OLG model by using the modified Gauss-Seidel iteration as described in Ludwig (2007). The solution of the life-cycle optimization is solved recursively by taking initial guesses for consumption at last age. Then, the model is solved backwards using recursive methods by applying first order conditions and appropriately handling the constraints. This procedure delivers first guesses for the vectors of consumption and hours worked. Labor time costs are taken into account when calculating hours worked. Costs tend to increase in age and reflect the additional burden of older workers remaining in the labor market. We then calculate savings and assets, using the budget constraint (3.6). The consumption profile, including consumption at last age, is then updated. This procedure is repeated until consumption and the hours profile converge. We do not allow the household to re-enter the labor market.

The endogenous decision of retirement is a second step of the algorithm and a by-product of the main optimization method. To solve it and calculate the retirement age, we use an outer loop that searches for the retirement age which maximizes the household's utility. Hereby, we carefully take into account the adjustment rate that gives incentives for early or late retirement.

After the convergence of these inner loops, all cohorts' asset holdings and hours worked at a given year, t, are aggregated to receive the capital stock, K_t, and labor supply, L_t. By using equations (3.17) and (3.18), the wage and interest rate can be updated.

Our timeline has four periods: a phase-in period, a calibration period, a projection period, and a phase-out period. First, we start calculations with the assumption of an "artificial" initial steady state in 1850. The time period around 2015 is then used as the calibration period to determine the structural parameters of the model. Our projections run from 2015 until 2075. For technical reasons, the model then runs further during a transition to a steady-state population in 2150 and an additional 100-year period until the model reaches its final steady state in 2250.

3.3.2 Calibration

3.3.2.1 Skill groups

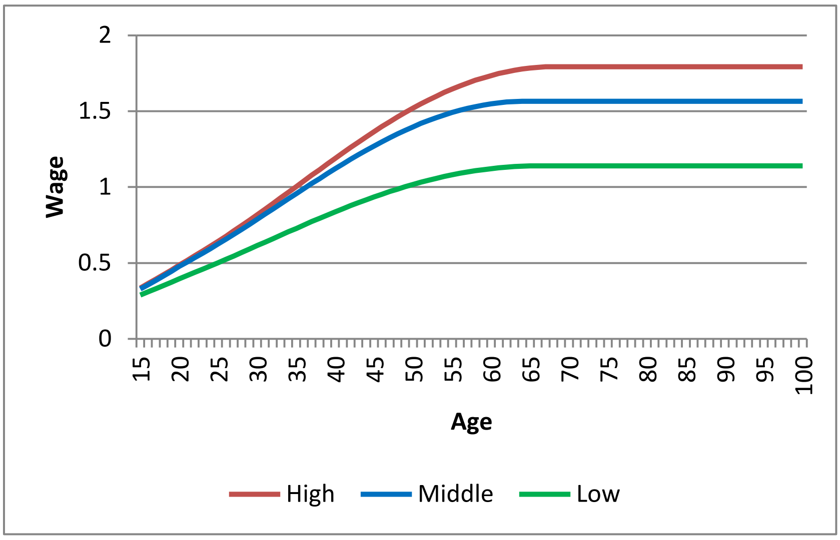
We introduce three skill groups and model them by including different life-cycle profiles for wage profiles and survival rates. In the majority of the literature, wage profiles are used to model endogenous retirement decisions (Altig, et al., 2001; Huggett, et al., 2011; French, 2005). Often, these wage profiles are hump-shaped, i.e. individual productivity first increases when young and reaches a peak in middle age. Afterwards, productivity decreases again as a consequence of the aging process, like deteriorating health or declining cognitive skills. Lower wages in old age induce retirement at some point because the disutility of work outweighs the utility from receiving income. As Casanova (2013) argues, these hump-shaped wage-age profiles in econometric studies usually stem from "pooling observations of full- and part-time workers." According to her study, however, when only full-time workers are considered, wage-age profiles are flat in later ages. This point is also discussed in detail by French (2005). When estimating hourly wage profiles, he also finds a hump-shaped pattern over age. However, as soon as he controls for part-time work and considers exclusively full-time workers in his regressions, he finds flat wage-age profiles for later ages. The latter finding is consistent with studies that show that there is no decreasing labor productivity at later ages of workers (Börsch-Supan & Weiss, 2016). Accordingly, we introduce wage profiles that do not decline in old age, but rather stay constant after reaching their maximum (see Figure 3.1).

The life-cycle wage profiles ε_j^k depicted in Figure 3.1 are estimated following the procedure of Altig et al. (2001) and Fullerton & Rogers (1993). For empirical estimation, we use waves from 1984 until 2013 of the German Socio-Economic-Panel (GSOEP). The wage profiles are calculated according to the formula

$$\varepsilon_j^k = e^{\zeta_0^k + (g + \zeta_1^k) j + \zeta_2^k j^2 + \zeta_3^k j^3}, \tag{3.19}$$

where j stands for age, k for the skill group and g is the constant rate of technological progress. The ζ coefficients are received according to the following procedure (see p. 581 in Altig et al. (2001)). Firstly, hourly wages are regressed on fixed-effect dummies, age-squared, and interactions between age and other demographic variables. Secondly, the coefficients obtained from the previous regression are used to generate predicted life-cycle wage profiles. As a next step, the data is sorted according to the present value of lifetime income and three skill groups are generated by quintiles. Lastly, the coefficients of equation (3.19) are estimated from the simulated data profiles of each of the three skill groups. These estimated profiles ε_j^k are used in equation (3.5) to determine individual life-cycle wage profiles for the three skill groups, taking the prevailing aggregate wage rate w_t in the economy as given.

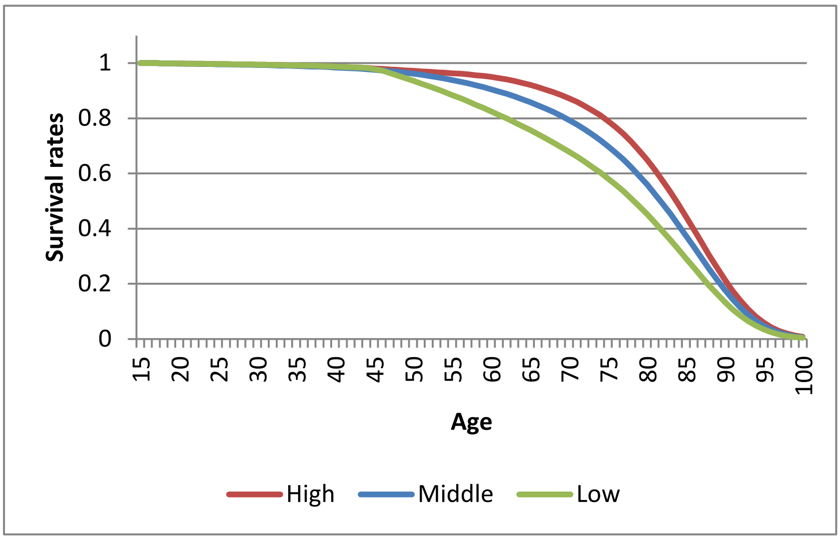
Figure 3.1: Wage profiles



Source: own calculations.

As a second dimension of heterogeneity, we include mortality risk, which increases with age. Type-dependent survival rates, $\pi_{t,j}^k$, for the three skill groups are computed in several steps. Danish register data (Kallestrup-Lamb & Rosenskjold, 2017) suggests that there is a gap in life expectancy of two years between the middle and highest income/wealth groups, while there is a larger gap of 4-4.5 years between the low and middle groups. As a second step, average survival rates for the EU28 countries (Eurostat, 2010) are adjusted such that they reproduce the aforementioned gaps in life expectancy. These estimates of the unconditional survival rates, $\pi_{t,j}^k$, for the three skill groups are shown in Figure 3.2. They are used in equation (3.4) to discount future utility in addition to pure time discounting, β^j.

Figure 3.2: Unconditional survival rates

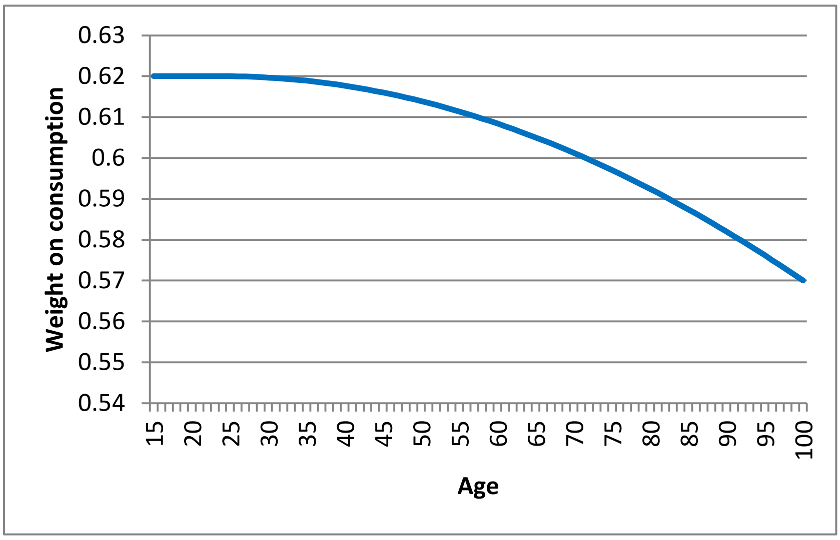


Source: own calculations.

3.3.2.2 Consumption preferences and time costs of working

Representing a parameter that changes through the life-cycle, Figure 3.3 shows the life-cycle profile of the consumption weight parameter.

Figure 3.3: Consumption preference profile

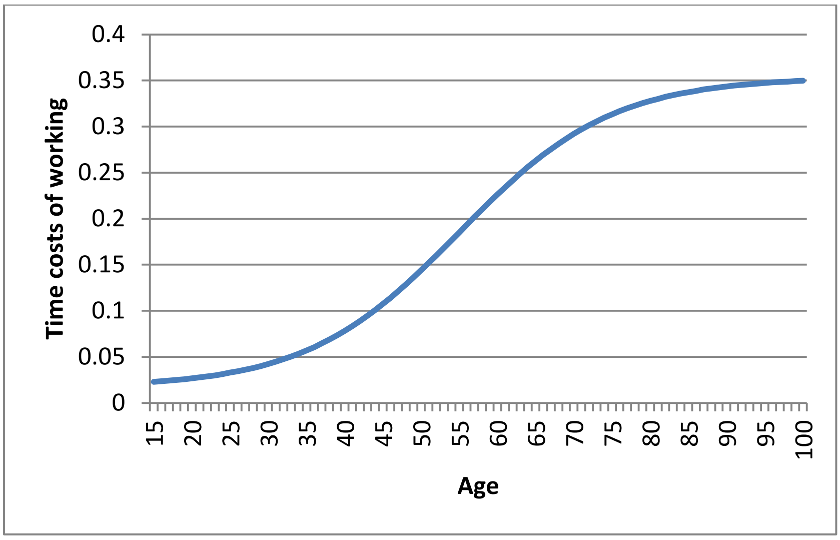


Source: own calculations.

In general, we assume declining preferences of consumption for mimicking the aging process, like degenerating health or cognitive decline. We then model the consumption weight parameter as age-dependent. These high preferences toward leisure during old age (low preferences on consumption) are a way to induce retirement. The decline is assumed to be 0.05. Accordingly, with initial preferences of 0.62, we assume that preferences could decrease until reaching 0.57 at the end of life.

Following French (2005), Rogerson & Wallenius (2013) and Cogan (1981), we model time costs $\vartheta(h_{t,j}^{k})$ as time costs that are deducted from leisure and emerge when hours worked are positive. If the household decides not to work, there are no time costs. Intuitively, they reflect costs like commuting time to work, but also other costs associated with declining health, opportunity costs, or subjective value given to work by workers. Therefore, we assume that time costs increase with age and are equal for all groups of individuals. These costs are modeled considering two components. As it is shown in equation (3.3), there is χ_{j}, which is age-dependent, and the ratio $\frac{\chi_j}{(1+h_{t,j})^{\xi}}$. We assume that χ_j increases over time until a maximum value of 29% of total time available for the household. This value is attained only at age 80. At the highest possible retirement age, costs can reach a maximum of 29% (see Figure 3.4).

Figure 3.4: Time costs of working



Source: own calculations.

However, since they also depend on hours, costs never reach such high values. Due to the ratio in the cost function, the calibrated value of $\xi = 12$ and the decisions of households regarding leisure and consumption, the cost function will never attain the maximum cost value at any age but will asymptotically approach it for higher working hours. Note that with a value of $\xi = 12$, the cost function quickly approaches zero when hours worked are small. We use this shape of the cost function to avoid discrete jumps in time costs at $h_{t,j} = 0$. Instead, the function smooths the cost function for values of hours worked close to zero. These assumptions lead to a more realistic hours profile and, of course, also shape retirement decisions of households.

3.3.2.3 Structural parameters and population data

The life span of the household is assumed to be 100 years. The household enters the labor market at age 15. The structural parameters of the household model are chosen to achieve several calibration targets with reference to other studies. Table (3.2) gives an overview:

Table 3.2: Parameter calibration

Parameter	**Values**
Discount rate (ρ)	0.02
Risk preference (θ)	2
Earliest retirement age	60
Latest retirement age	72
Initial steady state replacement rate	0.6
Adjustment rate	0.036
Capital share in production (α)	0.33
Growth rate of labor productivity (g)	0.015
Depreciation rate of capital (δ)	0.05
Demographic risk sharing (μ)	0.25
Wedge (capital income tax)	0.264

We choose parameter values such that the simulated moments of our model match their empirical counterparts in the data. Our calibration year is 2017. We target a capital-output ratio of 2.6 (based on estimates of the stock of fixed assets to output). In addition, parameter values are chosen such that people retire around the age of 62 to 64 in the year 2017, which is close to the actual retirement ages in several European countries in previous years (Börsch-Supan, et al., 2018c; OECD, 2015). To achieve these targets, the discount rate, ρ, is set to 0.02 (see overview by Frederick et al. (2002)). The risk preference parameter, θ, is assumed to be 2, which makes the household slightly risk averse and lies in the middle of estimates in the literature (see overview by Bansal & Yaron (2004) and Browning et al. (1999)). The capital share, α, in the economy is assumed to be 0.33 and annual productivity growth is 1.5%. The depreciation rate of capital is 5% per year. For the different macroeconomic regimes, the simulation method to implement lower interest rates considers a wedge between marginal productivity of capital and the interest rate perceived by the households is assumed to be 26.4%. For the low growth regime, we assume productivity growth to be 0.5%. This will force economic growth to be in the regime we want to test.

We choose a retirement window from $R_E = 60$ until $R_L = 72$. Age 60 was the former earliest legal retirement age for women in several European countries, for instance in France (age 61), Italy (age 62) or Germany (age 63) (Social Security Administration, 2014; Deutsche

Rentenversicherung Bund, 2015a; OECD, 2015) and it is therefore taken as the first possible retirement age. Theoretically, there is no upper bound for late retirement in existence. However, to keep some plausibility in the decisions, we assume 72 as the highest possible retirement age, in accordance with US Social Security regulations. We assume the lower bound value of current adjustment rates across OECD countries (see Table 3.1), therefore $\omega_t = 3.6\%$ (see equation (3.14)). As described in Section 3.2.2, the replacement rate adjusts endogenously and scales the pension system up or down depending on demographic evolutions and economic circumstances. We hold the replacement rate constant at a value of 60% until the year 2004 and let it adjust from that year onward according to equation (3.13).

Demography is described by the size of each cohort, the survival of that cohort and additions through net migration. We treat all three demographic forces as exogenous. The size of the population aged *j* in period *t* is given recursively by

$$N_{t+1,j+1} = N_{t,j}\varphi_{t,j}, \tag{3.20}$$

where $\varphi_{t,j}$ denotes the age-specific conditional survival rate. The original cohort size for cohort *c* depends on the fertility of women aged *k* at time *c*=*t*-*j*:

$$N_{c,0} = \sum_{k=0}^{\infty} f_{c,k} N_{c,k}. \tag{3.21}$$

Population aging has three demographic components: past and future increases in longevity, expressed by $\varphi_{t,j}$; the historical transition from baby boom to baby bust expressed by past changes of $f_{c,k}$; and fertility below replacement in many countries expressed by current and future low levels of $f_{c,k}$. Population data for Germany, age distributions, and assumptions on projections for fertility, mortality, and migration rates are taken from the Human Mortality Database (2016). Life expectancies are also computed from life tables provided by this source.

3.4 Comparisons between pension reforms

As referred to before, we start by analyzing the effects of different types of pension reforms. This delivers a clear message on how each reform impacts retirement ages, the sustainability of the pension system, represented here by replacement rates, and contribution rates behavior. Furthermore, we examine how different skill groups' welfare is affected by each reform and how unequal the welfare gap between those groups becomes. This last step is undertaken through the analysis of consumption equivalent variation (CEV) for each group through time. We will start with the baseline scenario that is also the benchmark regime scenario, which will be the basis of comparison in Section 3.5 for the other two macroeconomic regimes. Afterwards, each reform will be separately analyzed and a summary of all reforms and their own specific effects will be made at the end of this section.

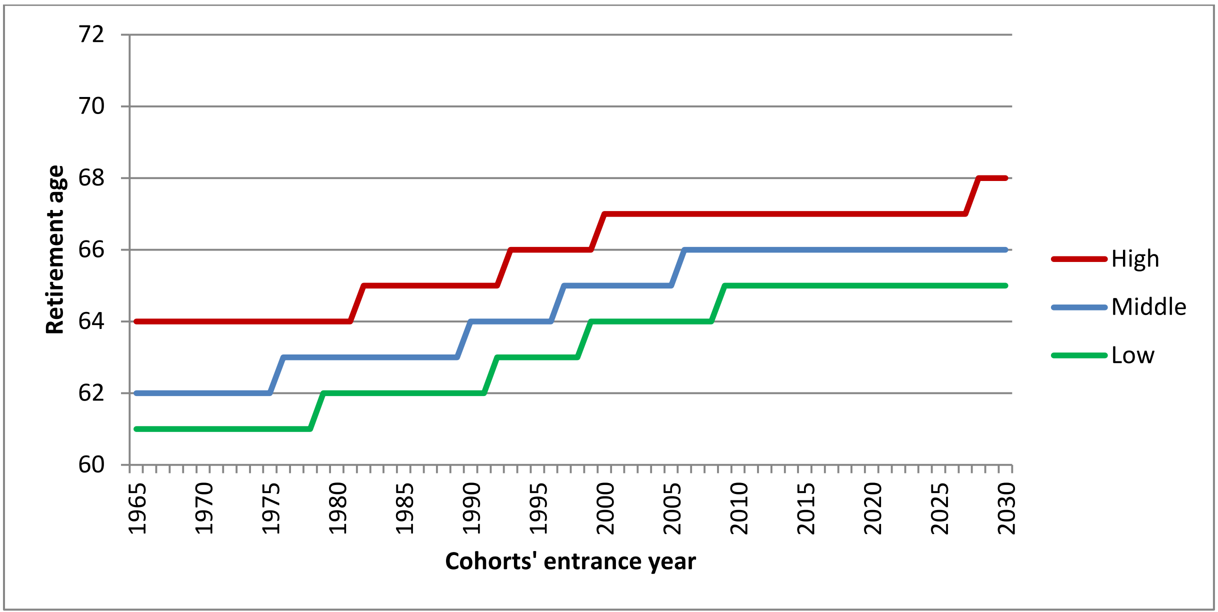
3.4.1 Baseline scenario

As a first step, we describe a scenario without any reform that will serve as the baseline case. The parameters used are described in the previous section. This baseline scenario is calibrated such that outcomes match our calibration targets described above. All later reform scenarios will be compared to this baseline case.

Figure 3.5 depicts the evolution of the resulting retirement ages over time for the three skill groups. Note that the horizontal axis shows the point in time when a specific cohort is entering the labor market at age 15 (cohorts' entrance year). For instance, the first data point for the lowest skill group means that the cohort entering the labor market in 1965 (born in 1950) retires at age 61, i.e. in the year 2011.

Three main observations can be derived immediately. The first one suggests that agents generally choose early retirement. During the given retirement window of 60-72 during which retirement is allowed to take place, agents retire between the ages of 60 and 65 for cohorts entering the labor market before 1975. This mimics several public pension systems that currently produce incentives for early retirement (for further simulations concerning this topic, see Gasche (2012a)). This is mainly due to too low adjustment rates.

Figure 3.5: Retirement ages – Baseline scenario

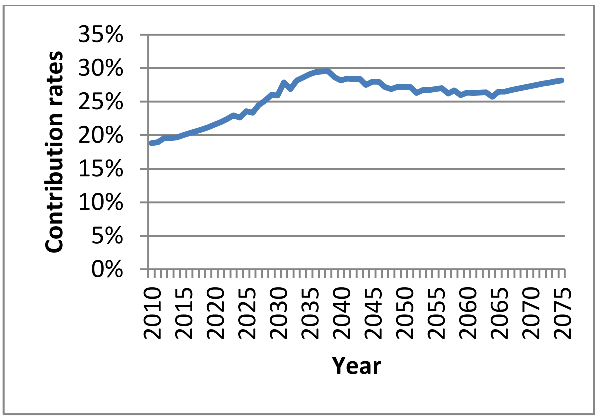


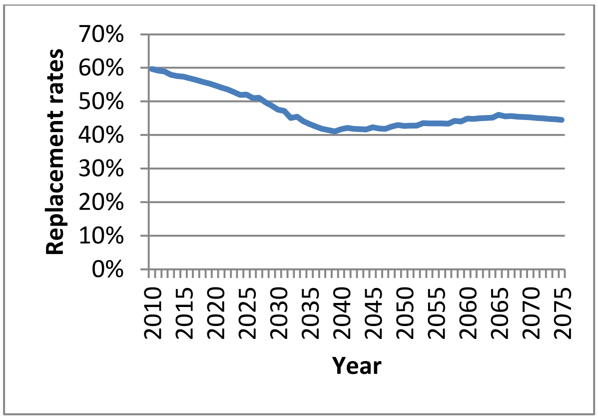
Source: own calculations.

As described in Section 3.3.2, we use an average value corresponding to many developed aging countries: for every year of retirement before the statutory eligibility age, pension payments are reduced by 3.6%. Second, retirement ages are low for early years and increase gradually over time for all three skill groups. Due to population aging, interest rates decrease over time, labor becomes scarcer, and the capital stock rises because of higher savings. This increases the relative wages vis-à-vis the decreasing interest rate, which induces incentives to work longer. As an overall effect, all groups' retirement ages rise even without any exogenous reform. As a third finding, households from low skill groups retire earlier than those from the high skill group. This stems from two main causes. On the one hand, higher consumption preferences of high skill groups lead to later retirement, as individuals prefer not to be penalized in present and future consumption by the deductions imposed by the adjustment rates. Moreover, they value consumption more than leisure, meaning they prefer to continue to work additional years and benefit from higher income and, hence, higher consumption. On the other hand, the structure of the pension system influences their decisions. Benefits paid out to pensioners strongly depend on average wages in the economy. For high skill households, this means a substantial drop in relative income, whereas low skill groups are not affected so severely. The opportunity costs of retirement are therefore higher for high skill agents and thus lead to later retirement.

Following demographic trends, the equilibrium path of contribution rates to the PAYG pension system and replacement rates are depicted in Figure 3.6. Note that the horizontal axis refers to actual years and not to the cohorts' entrance years. The contribution rates are calculated by assuming that the pension system's budget constraint has to be balanced every year (equation (3.8)). The replacement rate (equation (3.14)) is defined by the evolution of demographics and wage growth.

Figure 3.6: Contribution rates and gross replacement rates





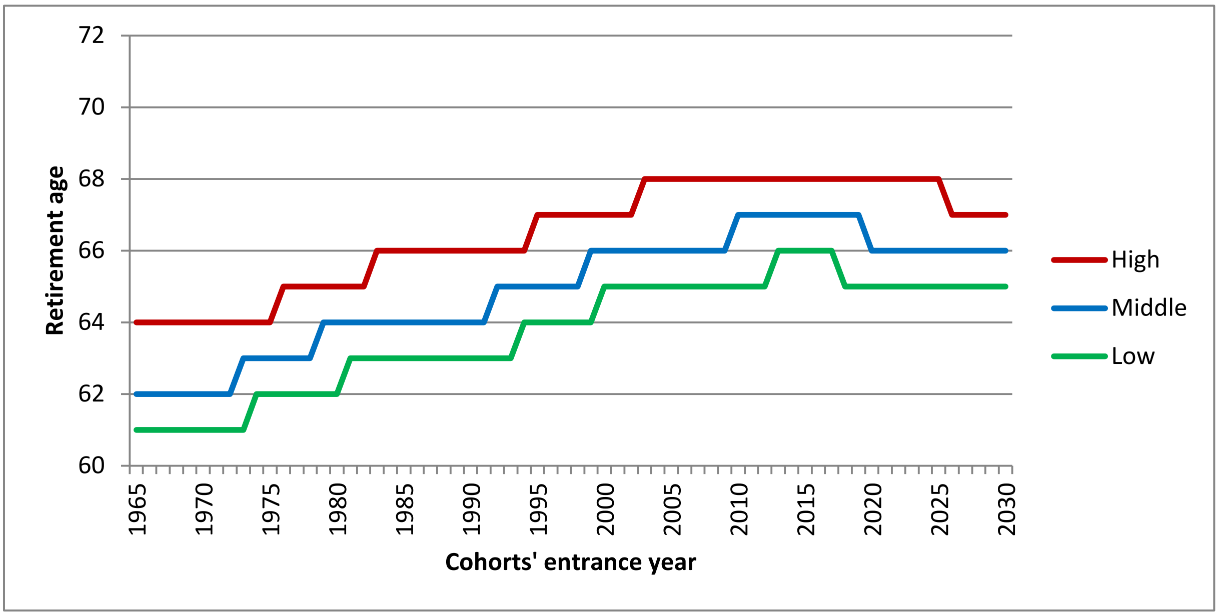
Source: own calculations.

Not surprisingly, the contribution rate rises from levels around 18% to levels around 28%. The initial increase is very steep due to the retirement of the baby boomers. However, contribution rates would rise even more if it was not for the hybrid DB-DC system, which reduces replacement rates (see Figure 3.6, right) and dampens some of the demographic pressure on the PAYG pension system: the factor decreases simultaneously from values around 60% to slightly below 50% and stabilizes there.

3.4.2 Increasing the statutory eligibility age

In order to create incentives for older ages to work longer and to make public pension systems more sustainable, many countries have increased (or are still increasing) their statutory eligibility age at which people can retire without any deductions. In France, the statutory eligibility age is gradually rising from age 65 to 67 from 2016 to 2022 and in Italy it will reach 67 in 2028. Similar to the evolution in these countries, the statutory eligibility age is also gradually rising from age 65 to 67 in Germany from 2012 until 2029. In detail, the statutory eligibility age increases one month every year until 2023 and two months every year from 2024 onwards. As an assumption we use the pathway of Germany in our model. In this section, we implement this reform in our simulations. Figure 3.7 depicts the evolution of the resulting retirement ages over time for the three skill groups.

Figure 3.7: Retirement ages

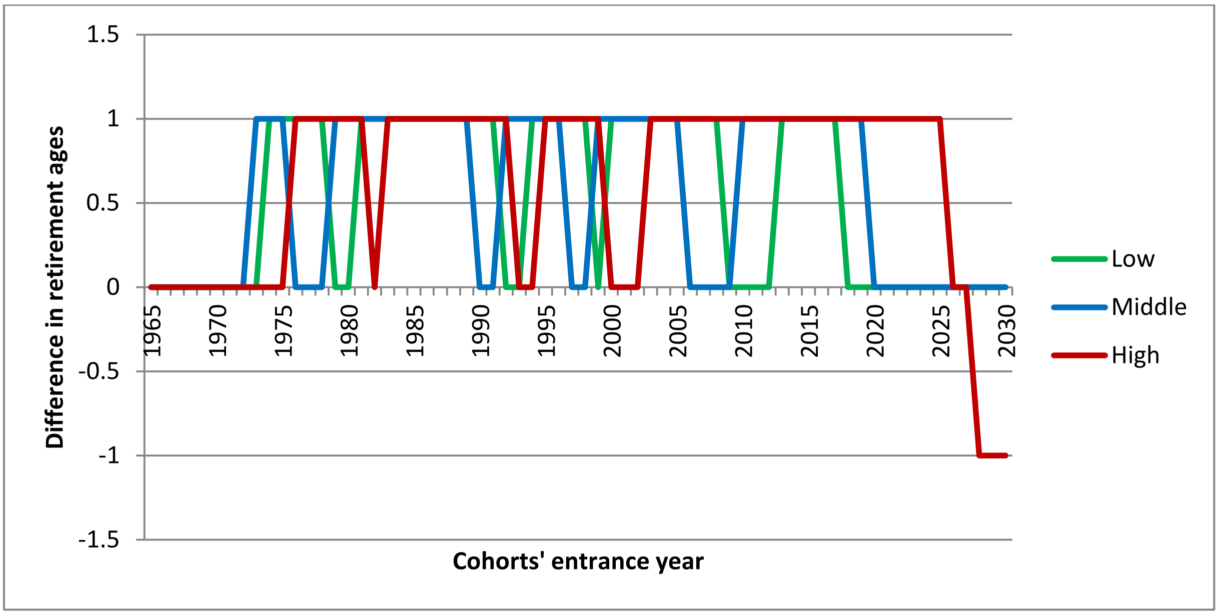


Source: own calculations.

Again, the same three general findings as in the baseline scenario still hold: generally low retirement ages (60-66) for early cohorts, increasing retirement ages over time and higher retirement age for higher skill groups. However, the increase of the statutory eligibility age by two years indeed influences the actual retirement ages for several cohorts. To see this more precisely, Figure 3.8 shows the difference in retirement ages between the reform and the baseline scenario for every skill group. Positive values mean that households retire later in the reform scenario than in the baseline case for a specific cohort. Zero values mean that cohorts retire at the same age in both scenarios.

We can observe the following outcomes. First, cohorts entering the labor market before 1972 do not change their retirement ages (zero values in Figure 3.8): since these cohorts retire before or only shortly after the reform is implemented, they do not change their retirement behavior. Second, for cohorts entering the labor market after 1972, there is an increase in retirement ages. The reason is the change in retirement incentives: if the statutory eligibility age is elevated by two years from 65 to 67, sticking to the hypothetical pre-reform retirement age would cost two more years of deductions from pension benefits. Since households want to avoid this additional penalty, they increase their actual retirement age. However, it is essential to note that this increase is smaller than the change in the statutory eligibility age by two years: most of the time, there is only an increase of one year in retirement ages. This finding is in line with previous studies (Fehr, et al., 2012). Some cohorts or skill groups do not even change their retirement behavior at all (e.g. the middle skill group for cohorts entering after 2020). This group already retires relatively late in the baseline scenario and therefore does not adjust its retirement ages upwards.

Figure 3.8: Retirement ages (differences)

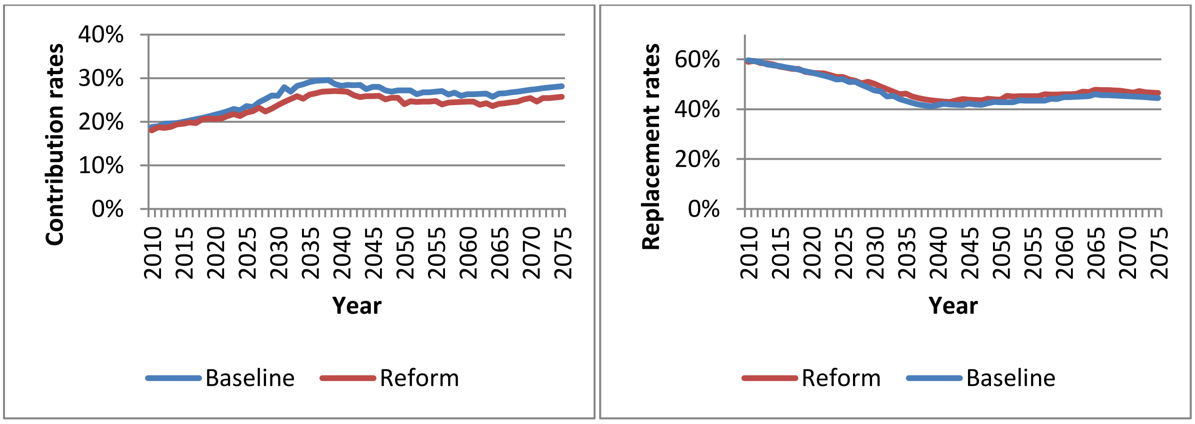


Source: own calculations.

This observation can be interpreted as another form of backlash in pension reform: instead of working two years longer and reacting to the reform one to one, households also optimize hours worked during their working life and only retire roughly one year later. This reaction is important to understand when thinking about pension reforms or reform proposals and their impact on the pension system.

The ultimate goal of pension reforms, such as increasing the statutory eligibility age, is to make public pension systems more sustainable. One indicator for sustainability is the contribution rate, i.e., the percentage of gross work income that workers have to contribute to the PAYG public pension system. Figure 3.9 (left) displays the evolution of the contribution rates after the reform.

Figure 3.9: Contribution rates and replacement rates



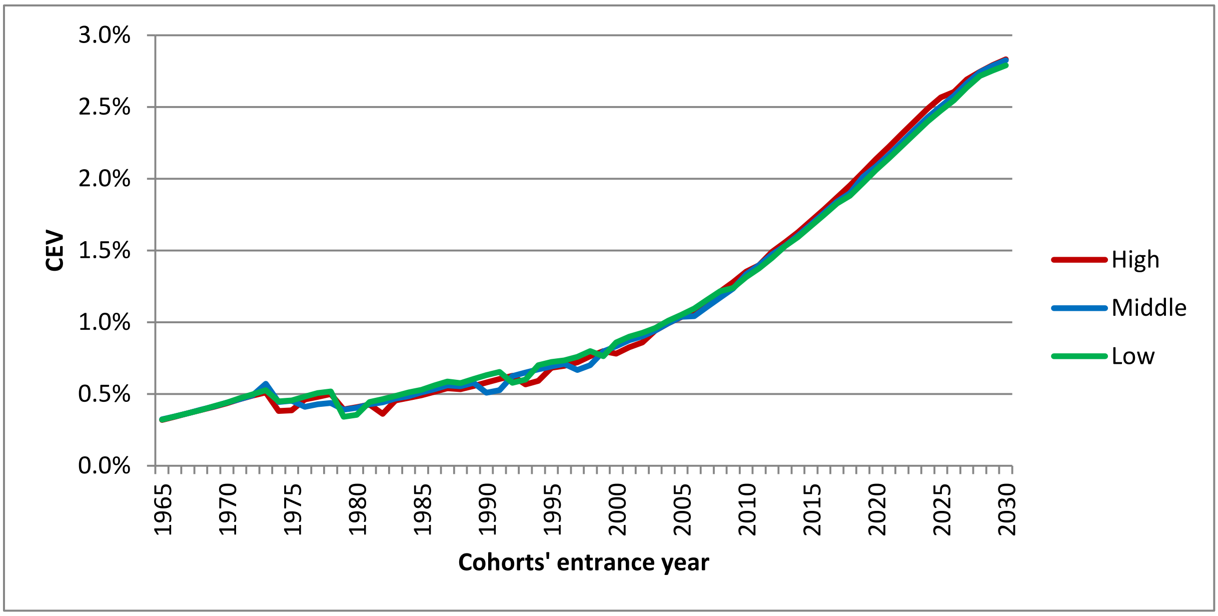
Source: own calculations.

It becomes clear that the reform meets its goal: the contribution rate is roughly 2 percentage points lower if there is an increase in the statutory eligibility age. At the same time, not only is the contribution rate lower than in the baseline case but also the average replacement rate in the economy is higher (see Figure 3.9, right). It is roughly 2-3 percentage points higher in the reform case than in the baseline scenario.

A lower contribution rate combined with a higher replacement rate is a clear argument that the reform indeed makes the pension system more sustainable despite endogenous reactions of households to the reform. However, this finding results from the fact that applied adjustment rates are lower than actuarially neutral. Otherwise, expenditure effects would be neutral when actual retirement ages change.

In addition to a more sustainable public pension system after the reform, lifetime utility of households is also higher in the reform case. Figure 3.10 shows the consumption equivalent variation for cohorts entering the labor market at the time indexed on the horizontal axis. The vertical axis shows the percentage of lifetime consumption that a household would be given in the baseline scenario in order to be as well off as in the reform scenario. Positive values, therefore, denote that cohorts in the reform case are better off than in the baseline scenario.

Figure 3.10: Consumption equivalent variation



Source: own calculations.

Households entering the labor market in the second half of the 20th century are only slightly better off since they only profit during retirement from the higher replacement rates or late in working life from lower contribution rates. For cohorts that enter after the reform is implemented, they see their welfare increasing substantially: CEVs increase almost 3% and stay at this level afterwards. In sum, small short-term welfare improvements are followed by large long-term welfare gains. We can also observe that this reform does not grant sufficient additional gains in work income for the low skilled households, which could lead to a more than proportional increase in consumption and welfare in comparison to the high skilled. Therefore, welfare effects are similar for all skill groups, which means inequality between skill groups remains unaffected.

3.4.3 The 2:1 reform

Aging, as the main driving force of imbalances on pension systems around the world, is caused by increasing life expectancy. As we presented before, several reforms can have a positive effect on halting the pernicious outcomes on the pension system. However, reform success turns out to be only temporary until the previous imbalances, which were controlled a decade before, emerge again since life expectancy is persistently increasing. This is why an increase in the statutory eligibility age today to 67 would lead, in about a decade, to the same current problems faced by the pension system. It would again require a discussion about whether or not to increase the retirement age, to which age, and when.

A possible solution for this, which was previously presented by Börsch-Supan (2007), offers a systematic and clear rule that could be understood by any citizen and that accommodates changes on demographic dynamics. This rule, called the 2:1 rule, dictates that sufficient increases in life expectancy of individuals should be compensated by increases in the statutory eligibility age on a proportional basis. As a rule of thumb, since an individual works approximately two thirds of his life, for instance, an increase of 3 years in life expectancy should promote an increase of 2 years in the statutory eligibility age and 1 year spent in retirement – the 2:1 rule. In order to implement this rule, we define a benchmark life expectancy age of cohorts retiring in 2017. From this year on, any cohort whose life expectancy exceeds 1.5 years from the benchmark will face an increase in the statutory eligibility age of 1 year. This life expectancy will be the new benchmark and later on, any other cohort with 1.5 years more of life expectancy will face another increase in the statutory eligibility age.

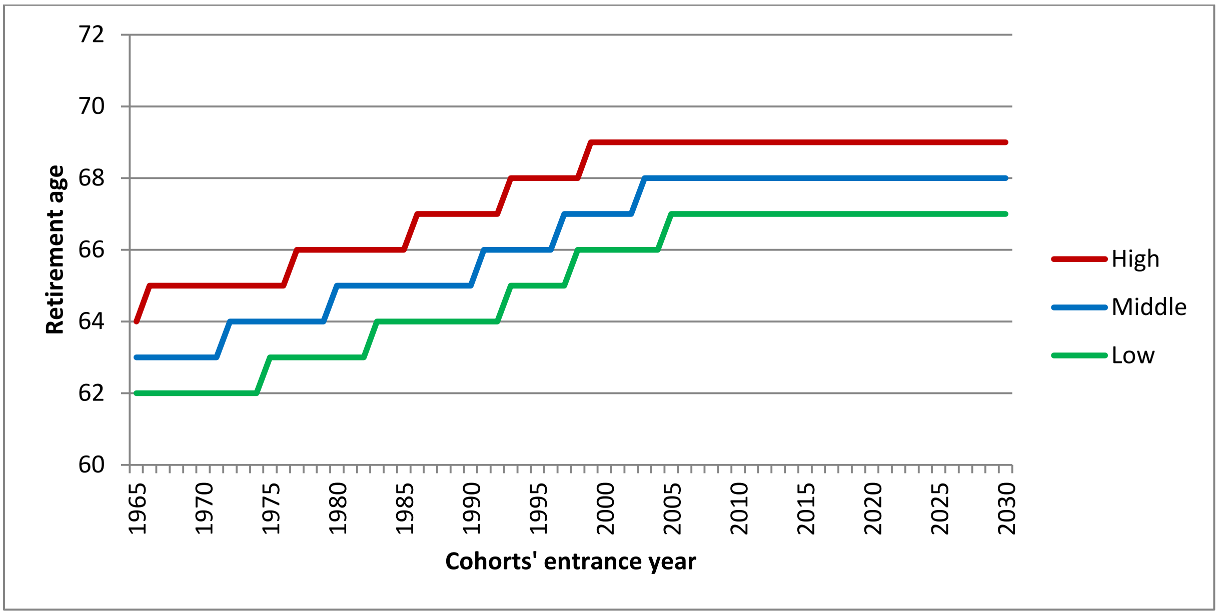
After we examine an increase of the statutory eligibility age, we can already expect that the 2:1 reform will also lead to a rise in actual retirement ages. Since the forecasts of life expectancies suggest a continuous climb over time, the 2:1 rule will be automatically applicable such that statutory eligibility ages will increase during the life span under our analysis. As Figure 3.11 shows, actual retirement ages will follow this trend and continually rise with time.

Table 3.3: Evolution of statutory eligibility ages

Years	Statutory eligibility age
2017-2021	65
2022-2028	66
2029-2037	67
2038-2042	68
2043-2051	69
2052 - onwards	70

Source: own calculations using data from the Human Mortality Database (2016).

Figure 3.11: Retirement ages

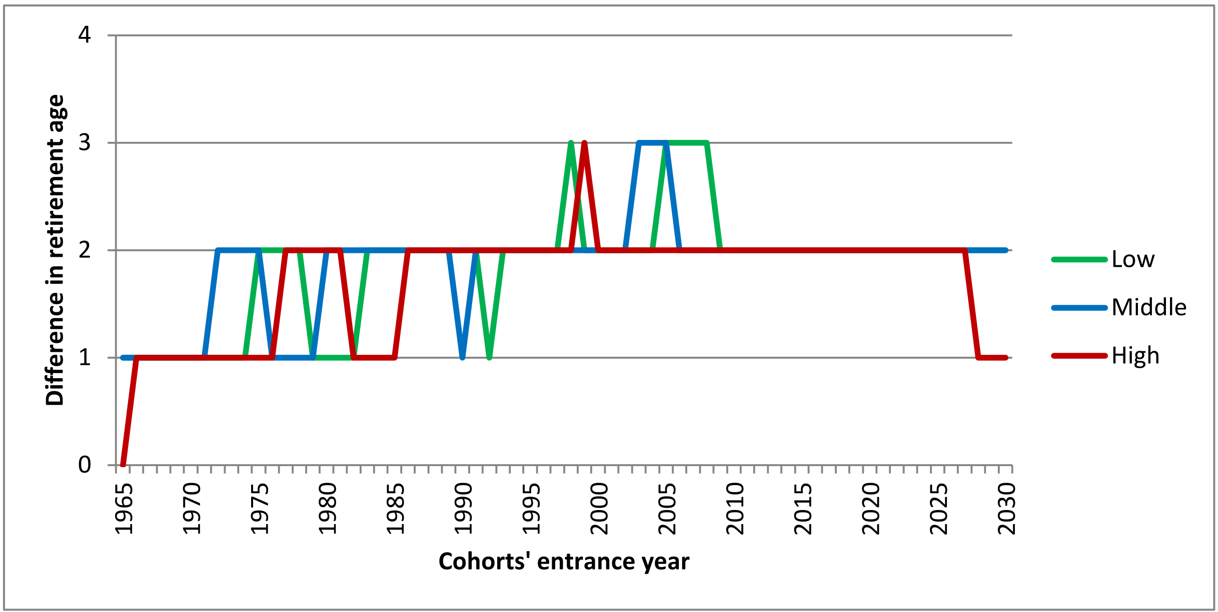


Source: own calculations.

In general, retirement ages increase due to changes in the statutory eligibility ages. Actuarial adjustment rates will also take into account the new threshold for retirement age, meaning they now assume a value of zero at the new statutory eligibility age. Therefore, negative adjustment rates will now be prevalent until later ages. This augments incentives for later retirement. If cohorts keep the same behavior as previous cohorts, they would see a larger share of their pensions being cut due to higher adjustment costs.

We see that all skill groups increase their retirement ages consistently over time. All skill groups raise their actual retirement ages by 2-3 years (see Figure 3.12) for cohorts entering the labor market after 1985. The high skill group is still the one with later retirement, but the most significant outcome is the rapid increase in retirement ages of the lowest skill groups. They perceive the high costs of retiring too early and react to it by quickly increasing their retirement ages.

Figure 3.12: Retirement ages (differences)

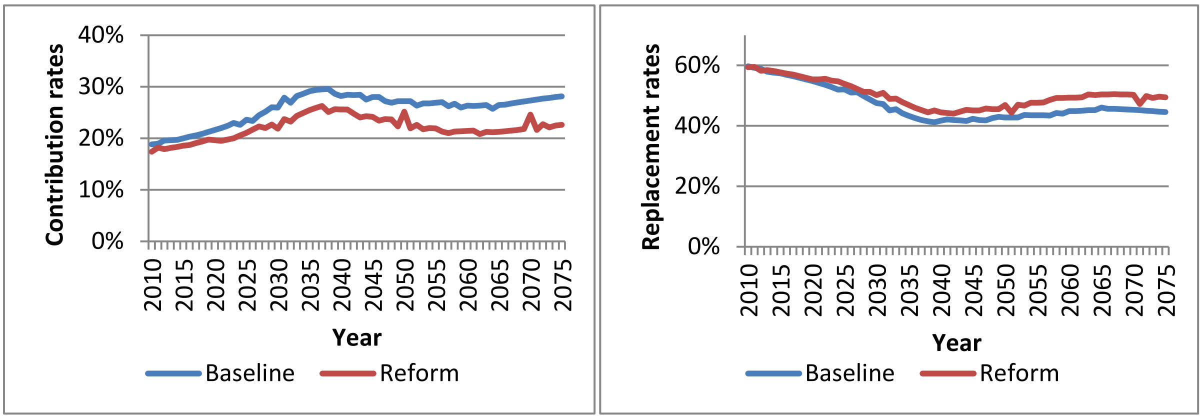


Source: own calculations.

The difference between the baseline and this scenario is slightly smaller in earlier and later years for the highest group (Figure 3.12) because retirement ages are already high in the baseline scenario, which means that differences tend to be lower in the later years of our time range. Therefore, it does not reflect a decrease in retirement ages in the reform scenario but a convergence of retirement ages close to 72.

Figure 3.13 (left) shows the corresponding contribution rates. We observe that contribution rates attain a lower value in the long run than in the baseline scenario (3-5 p.p. less in the mid-term and long-term, respectively). The evolution of the replacement rates is also very beneficial since it tends to be almost 5 p.p. higher than in the baseline scenario. The reason stems from the increase in the actual retirement ages, which allows for a postponement of the payment of benefits. Since actuarial adjustments are linked to the new statutory eligibility ages, when changing the statutory eligibility age, the age threshold for the null adjustment rate also changes. Therefore, increasing statutory eligibility ages creates extra incentives for later retirement without raising the premia in the pension payments. Again, note that this finding stems from adjustment rates which are lower than actuarially neutral. Otherwise, expenditure effects would be neutral when actual retirement ages change.

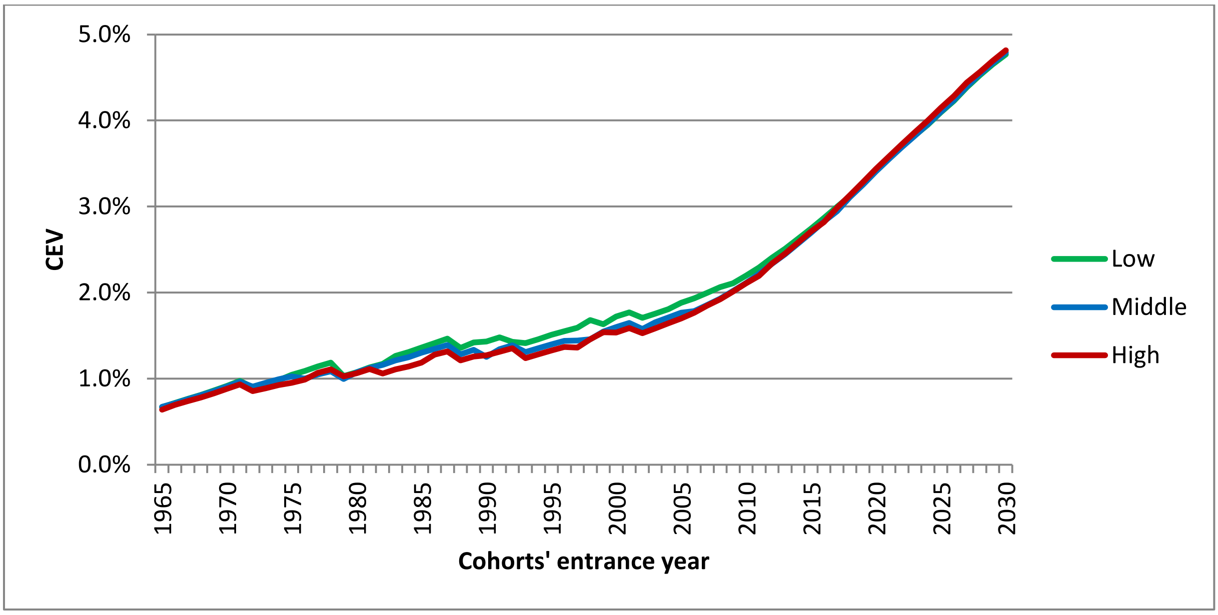
Figure 3.13: Contribution rates and replacement rates



Source: own calculations.

Comparing utility in terms of the CEV, Figure 3.14 shows how different cohorts benefit from this new reform. As expected from the previous explanations, cohorts are substantially better off with this reform. The gains attained are almost 7% for cohorts entering in the long-term. These values are higher than in any other scenario and corroborate with what we previously explained regarding lower contribution rates and higher replacement rates than in the baseline case. The lower contribution rates make cohorts extremely better off since they earn more and pay less than in the baseline scenario or in any other scenario. Older cohorts do not benefit very much because they only benefit in the last years of their lives based on the new changes in the pension system.

Figure 3.14: Consumption equivalent variation



Source: own calculations.

Regarding distributional effects, two different phases should be distinguished. For cohorts entering the labor market before 2010, low skilled groups benefit more in terms of welfare because this cohort mainly profits from increasing replacement rates. This happens because the 2:1 reform, in comparison to the previous reform, only fully takes place in the very long run (as visible in Table 3.3). Therefore, for older cohorts, the main effect of higher statutory eligibility ages works through a higher replacement rate. Low skilled households benefit more than high skilled because the growth in their pension income represents a proportionally larger increase in income than for the high skilled, which expands their consumption possibilities. This will tighten the inequality gap between high and low skilled households.

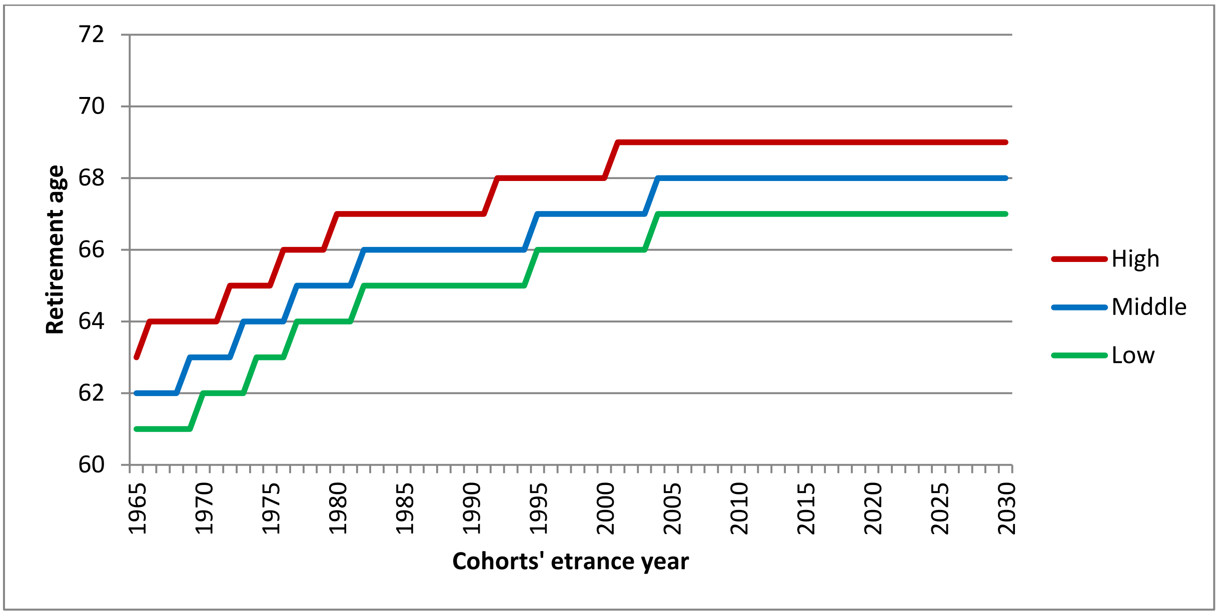
In the long run, the decrease in contribution rates becomes more prominent. In reaction to lower contribution rates, high skilled households work longer both intensively and extensively and their reaction is stronger than that of low skilled. Therefore, welfare gains of these cohorts are similar and even larger for skilled households. In contrast to the short run, the inequality gap does not close.

3.4.4 Actuarial neutral adjustment rates

So far, we used relatively low adjustment rates of 3.6%, which mirrors early retirement incentives given by many pension systems across countries (see Table 3.1). However, actuarially neutral adjustment rates ranging from 5 to 8% have been found by Börsch-Supan (2004), Werding (2007), Gasche (2012) and Queisser & Whitehouse (2006) for the different OECD countries. Therefore, in this section we simulate our model with adjustment rates closer to the actuarial neutral values and use the lower bound early adjustment rate of 6.3% for early and late retirement. We further assume that this hypothetical reform is implemented in the year 2017. From then on, adjustment rates rise linearly from their current levels until the year 2032, where they reach their final values of 6.3%. Figure 3.15 displays the resulting retirement ages.

As a consequence of higher adjustment rates, retirement ages increase faster and steeper than in the baseline scenario (see also Figure 3.16). This finding is in line with previous literature on earnings tests and actuarial adjustment rates (see Chapter 4 of this dissertation). Households, therefore, react strongly to the change in incentives of the pension system by adjusting their retirement behavior accordingly.

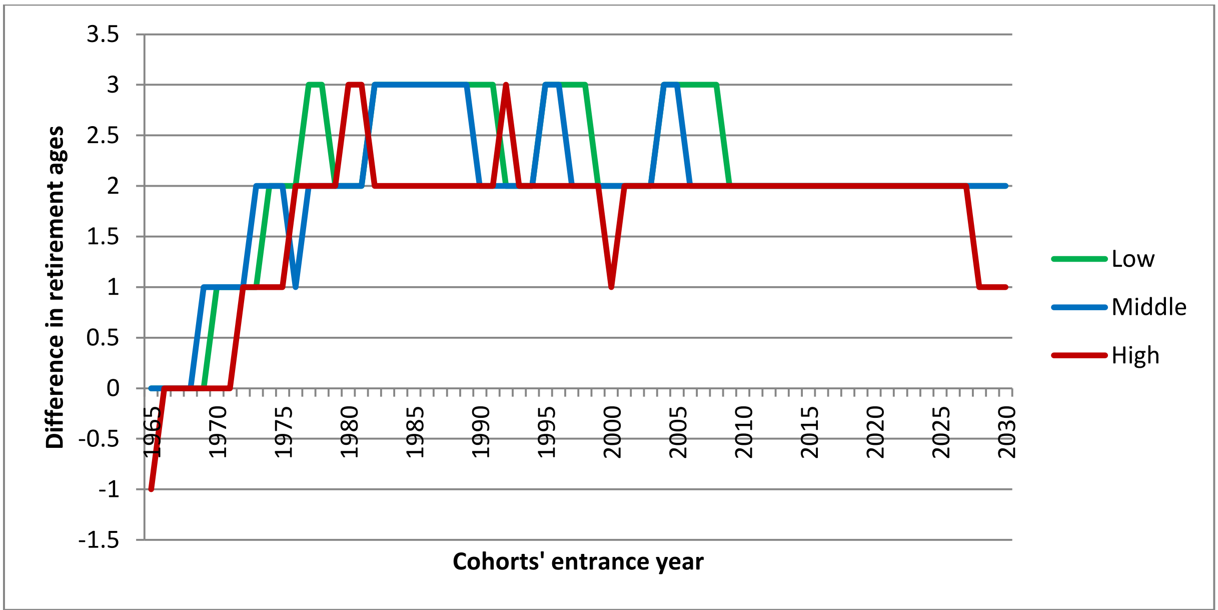
Figure 3.15: Retirement ages



Source: own calculations.

To see this more precisely, Figure 3.16 shows the difference in retirement ages between the reform and the baseline scenario for every skill group. As Figure 3.16 reveals, households generally retire 2-3 years later in this alternative scenario. Only the highest skill group postpones retirement by less than 2 years because it already retires at higher ages in the baseline scenario.

Figure 3.16: Retirement ages (differences)

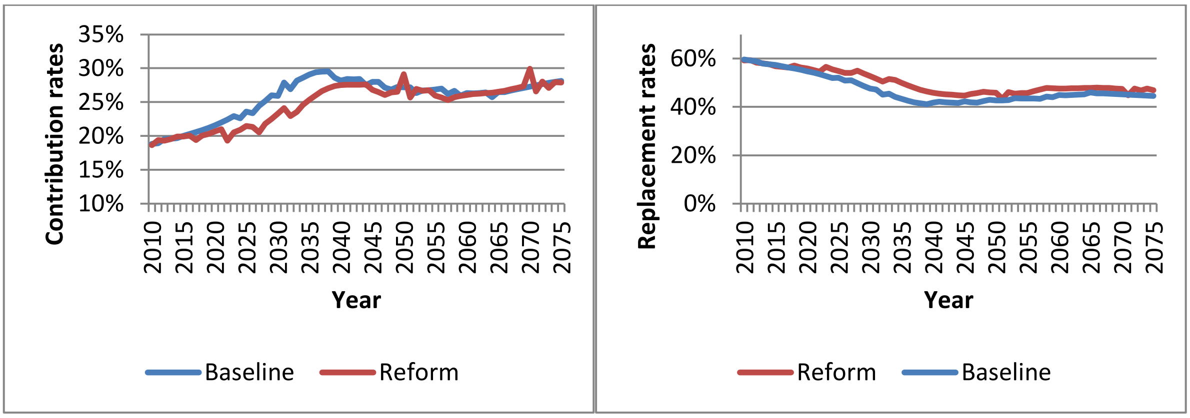


Source: own calculations.

Figure 3.17 (left) displays the evolution of the contribution rates in the baseline scenario and in the case with 6.3% deductions (Reform). Higher adjustment rates clearly lower the contribution rates relative to the baseline scenario by about 2 p.p. in the mid-term. On the one hand, this can be explained by the later retirement of households, which relaxes the budget equation of the PAYG pension system since there are fewer pensioners at every point in time. On the other hand, households that might still retire early receive much lower pension benefits due to a higher penalty that decreases total pension expenditures.

In the long-term, differences in contribution rates are almost non-existent because the advantages for the system from later retirement ages are overcome by higher adjustment rates, which increase payments to retirees and the burden on the system.

Figure 3.17: Contribution rates and replacement rates

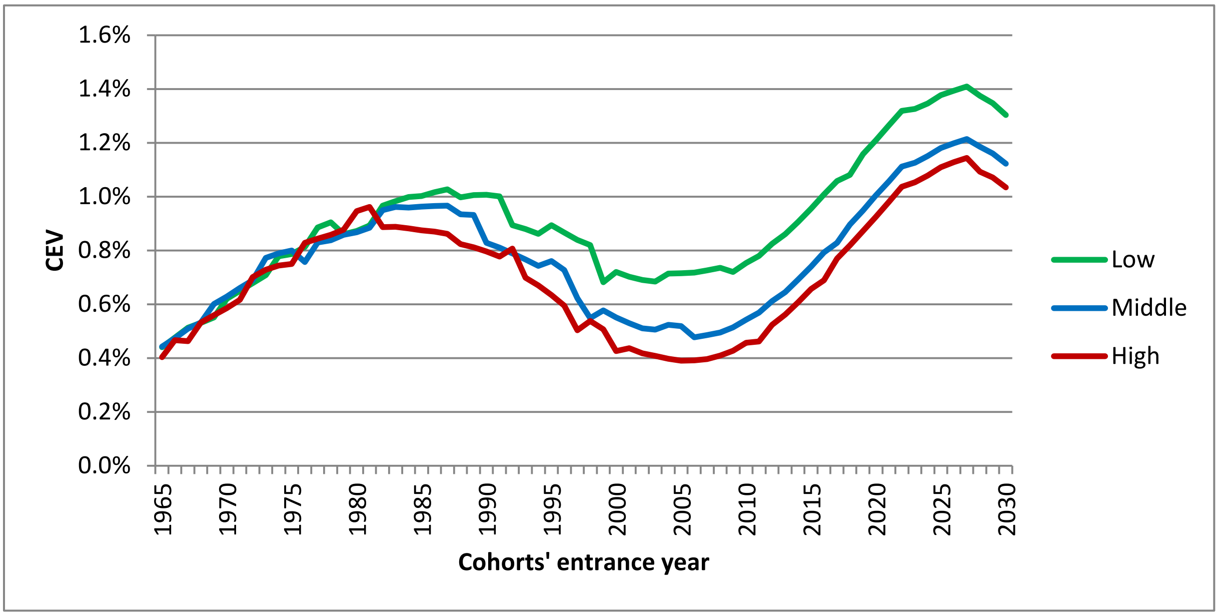


Source: own calculations.

The same argument holds for the replacement rate (see Figure 3.17, right), which is now slightly higher. Note that individual pensions are substantially higher than in the baseline scenario since households work longer and, hence, have the right to higher pension benefits. Figure 3.17, however, depicts the evolution of the aggregate replacement rate, b_{t+1}, expressed in equation (3.13).

In addition to a more sustainable public pension system after the reform, lifetime utility of households is also higher in the reform case. Looking at welfare implications in detail, Figure 3.18 reveals that households are better off in the reform scenario than in the baseline case by up to 1.4%. This means that one would have to give them 1.4% of aggregate lifetime consumption in the baseline scenario to make them indifferent to the reform case. This maximum value holds for cohorts entering the labor market around the year 2028 since they fully profit from lower contributions and a higher replacement rate. Earlier cohorts profit less since they are only influenced by the reform during part of their lives.

Figure 3.18: Consumption equivalent variation



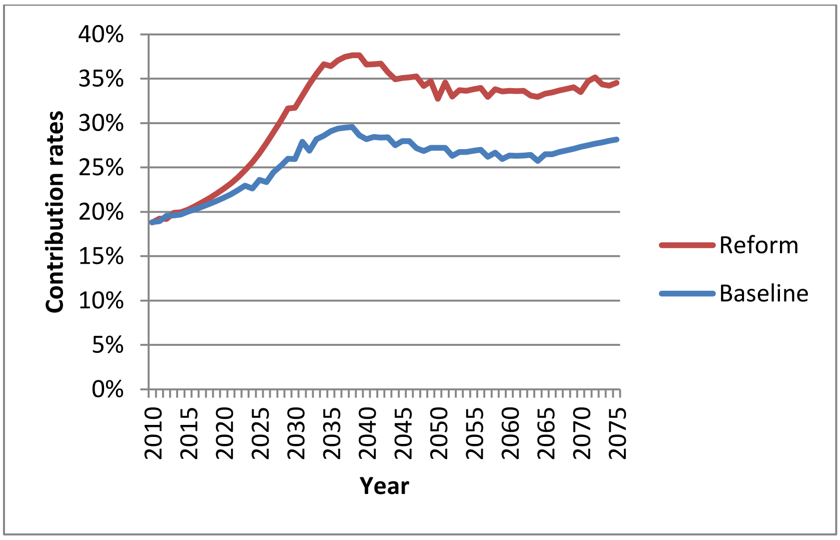
Source: own calculations.

Furthermore, high skill groups entering the labor market after 1980 seem to profit less from the higher adjustment rates than their low skill counterparts. The reason stems from the fact that younger low skilled cohorts retire much earlier than the statutory eligibility age. Therefore, they are punished more by higher deductions than their high skill counterparts, who always retire late. For cohorts entering the labor market in later years, this negative effect for low skill groups diminishes because even these cohorts start to retire later (general upward trend in retirement ages). From this point onward, low skill households profit more from the reform than high skill groups. And the benefit will again be more than proportional because the increase in their pension benefits represents a proportionally larger increase in income than for the high skilled. This gap in CEVs will contribute to a substantial decrease in the inequality gap between groups.

3.4.5 Effects of a political backlash reform

The presence of a hybrid DB/DC mechanism leads to an automated adjustment of pension benefits to demographic trends and the evolution in wage growth (see equation (3.13)), as described in detail above. The aim is to make the PAYG pension system more sustainable by sharing the burden of an aging population between generations without requiring politics to constantly intervene. As can be seen above in equation (3.13), the aging of the population leads to a fall in the replacement rate. In politics, this circumstance is sometimes seen as worrisome because it is feared that pension benefits will not suffice to finance a minimum standard of living for specific population groups. Therefore, there are recurring policy proposals to hold the replacement rate constant, which implicitly means to return to a defined benefit regime. This can be understood as a political backlash to previous reforms, which aimed to make pension systems more sustainable. Instead, the main focus is the income and well-being of older people. In order to study these proposals and understand the long-run effects, we simulate a reform proposal that holds the replacement rate constant from the year 2017 onward until 2045. To set the replacement rate constant means to let the contribution rates adjust endogenously to finance the PAYG pension system. After 2045, we assume that the original replacement rate following equation (3.13) will be in place again.

Figure 3.19: Contribution rates

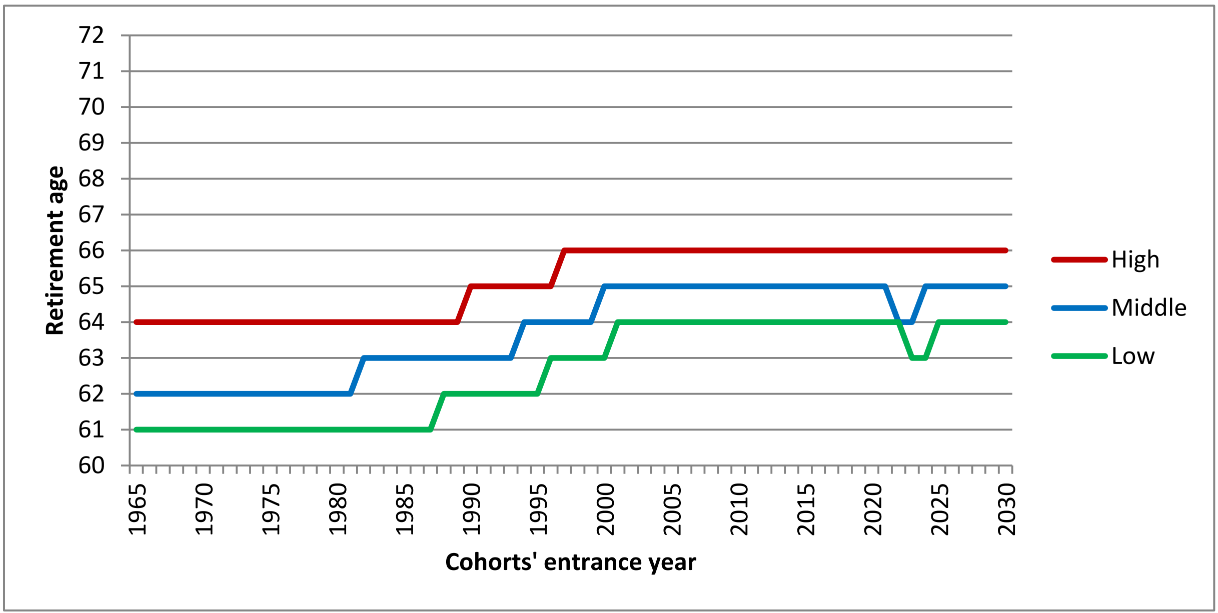


Source: own calculations.

Figure 3.19 compares the contribution rates under a regime with a replacement rate in place (baseline) and a regime with a constant replacement rate (reform). The difference is striking. While contribution rates to the pension system stabilize in the long run around 27% in the baseline case, they do so around 34% in the reform scenario and stay at this elevated level afterwards. This pronounced difference in contributions has major implications on labor supply and especially on retirement ages (see Figure 3.20).

Indeed, the major observation is that agents always retire earlier in the reform scenario. This effect is amplified for younger cohorts since they are affected more by the reform. There are two arguments that explain this behavior. First, because of the elevated contribution rates, households want to leave the pension system by retiring earlier. Second, they can afford to do so since pension benefits are larger due to a high replacement rate. This creates a vicious circle that reinforces the impact of the reform. A fixed replacement rate implies increasing contribution rates due to population aging. Households change their retirement decision and retire earlier (see Figure 3.20 and Figure 3.21). The lower number of contributors to the PAYG pension system again leads to a further rise in the contribution rate to balance the system, which starts another circle until the equilibrium is reached. As a consequence, households retire substantially earlier.

Figure 3.20: Retirement ages



Source: own calculations.

Figure 3.21 shows the difference in retirement ages for different cohorts and skill groups between the reform and the baseline scenario. Negative values mean that retirement ages are lower in the reform than in the baseline scenario.

Figure 3.21: Retirement ages (differences)

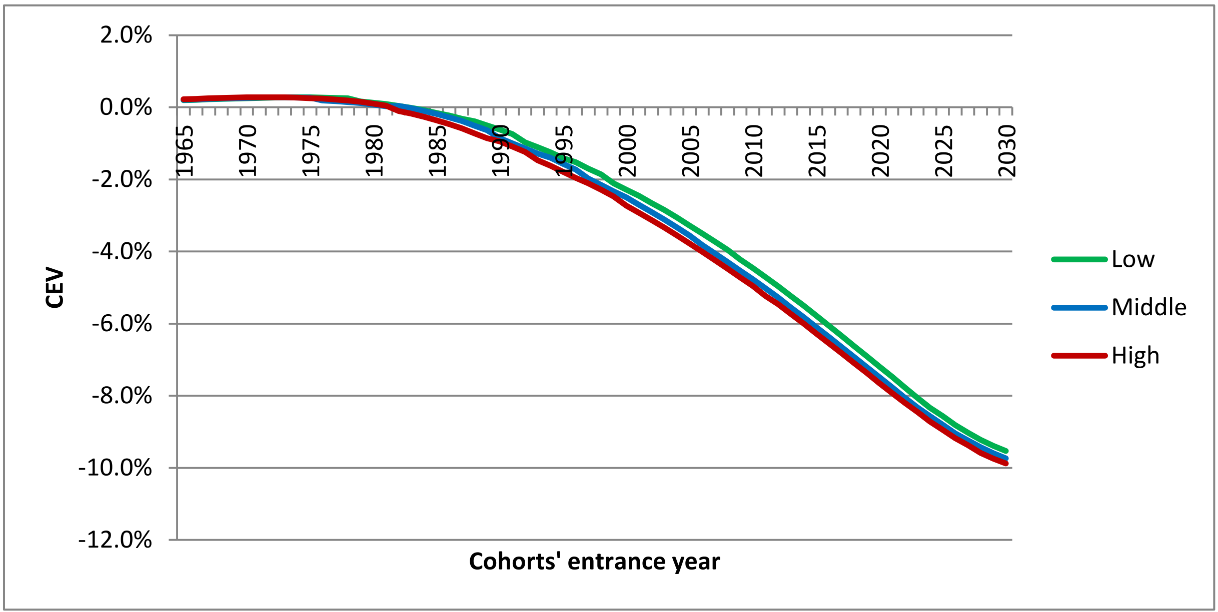
Source: own calculations.

It shows that the effect is more pronounced for the middle and highest skill group. Since we do not allow for retirement earlier than the age of 60, low skill groups, which already retire early in the baseline case, are constrained in their retirement decision. Higher skill groups, which generally retire later, however, can adjust their retirement ages accordingly since they are less restricted in the baseline scenario.

The question that arises is which cohort benefits/suffers the most from the hypothetical reform. Figure 3.22 displays the CEV for different cohorts.

Cohorts entering the labor market in early years gain from this reform since they receive higher pension benefits without paying higher contributions. This shows that the effects of policies directed toward older voters have a significant impact on intergenerational inequality of transfers. The main price paid for these actions is a significant decrease in the comparative welfare of the young generations that will have to contribute much more to guarantee the sustainability of the system. In fact, cohorts entering in later years are always much worse off. Those entering in 2030 are 10% worse off than their counterparts in the baseline scenario in terms of lifetime consumption. In short, and not surprisingly, younger cohorts, who have to finance the reform, are the biggest losers.

Figure 3.22: Consumption equivalent variation



Source: own calculations.

Examining the distributional effects reveals that the highest skill group is slightly more harmed by the reform. Elevated contribution rates are harmful for all groups and incentivize them to retire earlier. However, the welfare impact is larger for the high skill group because these individuals have a higher loss from earnings. They relinquish higher wages in later stages in life for a pension and at the same time this pension is calculated with a lower adjustment factor. In contrast, low skilled individuals have to relinquish a lower wage and receive a pension that is calculated for an adjustment factor that is already smaller than one. According to our results, the former effect is stronger than the latter and therefore we see that the low skilled group loses slightly less welfare than the high skilled. This implies that the inequality gap between groups tends to contract, leading to greater welfare equality between them, although on a much lower welfare level.

3.4.6 Reform comparisons

According to the previous results, this section provides a unified overview of the previous reform proposals and ranks them according to different outcome variables. The findings for the reform where the statutory eligibility age is increased to 67 and the actuarial neutral reform are in line with previous research. As a contribution of this chapter, our model allows for a unified framework to compare different reform proposals and provides valuable policy recommendations. Table 3.4 summarizes and compares the effects of each reform with the benchmark scenario. For retirement ages and CEVs, cohorts entering the labor market between 1995 and 2005 are considered as examples. The columns “Retirement ages” and “Gap in CEVs” give the maximum and minimum differences in retirement ages and gaps in CEVs across skill groups between the reform and baseline scenarios, respectively. The column “Utility” shows the range of the 10 year averages for the three skill groups. For the contribution and replacement rates, we compare the 10 year averages for the time range 2040-2050. These later years are chosen because they correspond to the years when the 1995-2005 cohorts retire.

When looking at the decisions on retirement ages, the 2:1 reform scenario exhibits the largest impact (2-3 years later retirement). This reform is followed by the actuarial neutral reform with around 1-3 years of postponed retirement and the 67 reform by 1 year. A negative change of 1 year can be observed in the constant replacement rate reform.

Table 3.4: Summary results

Reform proposal	Retirement ages	Utility (CEV in %)	Gap in CEVs between the lowest and highest group (in p.p.)	Contribution rates (in p.p.)	Replacement rates (in p.p.)
Increase of SEA to 67	0 to 1	0.8 to 0.9	-0.0 to 0.1	-2.0	1.5
Actuarial neutral	1 to 3	0.5 to 0.8	0.2 to 0.3	-0.5	3.4
2:1 reform	2 to 3	1.5 to 1.7	0.1 to 0.2	-3.5	3.0
Constant replacement rate	-1 to 0	-2.3 to -2.7	0.4 to 0.5	7.5	-

Note: ***Time range*** with respect to cohorts' entry years: 1995-2005. ***Time range***: 2040-2050.

Source: own calculations.

Interpreting lower contribution rates and a higher replacement rate as measures of sustainability of the public pension system, the following picture emerges: The 2:1 reform shows the largest fall in contribution rates (-3.5 p.p.) followed by the 67 reform (-2.0 p.p.) and the actuarial neutral reform (-0.5 p.p.). The largest rise in replacement rate can be found in the actuarial neutral reform (3.4 p.p.) and the 2:1 reform (3.0 p.p.). The 67 reform still achieves an increase of 1.5 p.p. Only the reform proposal which holds the replacement rate constant severely harms the public pension system through soaring contribution rates of 7.5 p.p. Therefore, in terms of sustainability, the 2:1 reform is the most beneficial reform proposal, whereas holding the replacement rate constant is the most harmful one.

The main mechanism that drives our welfare results are contribution rates: as soon as a reform leads to declining contribution rates as a direct effect, this diminishes the labor disincentives of working. As a consequence, agents are less constrained and work more which further drives down the contribution rates. In this sense, some reforms potentially have larger welfare effects. In terms of the CEV, the 2:1 reform is again the most beneficial reform. Here, agents are up to 1.7% better off. This reform is followed by the 67 reform (up to 0.9%) and the actuarial neutral reform (up to 0.8%). The reform that keeps the replacement rate constant is again the most damaging one: Agents are up to 2.7% worse off than in the baseline scenario.

All these reforms have consequences for the inequality between skill groups. The inequality tends to shrink in all scenarios except for the first reform scenario (increase of SEA to 67).

Paradoxically, the one with the highest equality gains is the one that in welfare level terms leaves everyone worse off (constant replacement rate reform). Excluding this reform, we observe that the actuarial neutral reform is the one contributing the most for equality. The 2:1 reform follows closely but it cannot be forgotten that for cohorts in the long run this effect fades out. The 67 reform has almost no impact on inequality. Consequently, the former two reforms would be the ones to be considered when the main target of policy is to decrease inequality.

3.5 Performance of reforms under different macroeconomic regimes

After examining the impact of each reform independently and looking at its effects, we test how these same reforms would perform under different macroeconomic regimes. The main objective is to observe whether each reform has a similar or very different behavior according to the macroeconomic environment in which they are implemented. Therefore, we choose a low interest rate and low growth regime, since our benchmark regime is in line with the macroeconomic setting that has been observed in the last decades in several countries. Since the financial crisis and the slowdown in technology growth in the last few years have affected several developed countries, it is important to test if the impact of the reforms would survive under these conditions. Overall, we can be confident in knowing the impact of these reforms for each of these regimes, which reassures the worthiness of implementing some of these reforms. At the same time, other reforms that have a significant negative impact both in the sustainability of pension systems and in the welfare of individuals should be avoided.

3.5.1 Low-interest-rate regime

The world interest rates have been decreasing in recent years due to the expansionary monetary policy of central banks. Especially in the Euro-zone, the decrease has been very pronounced and real interest rates are currently close to zero or even negative for some countries. This development certainly has impacts on capital income of savers and triggers changes in saving decisions of households. In order to simulate such a regime of low interest rates, we introduce a wedge between the marginal product of capital and real interest rates in our model. Still, we want interest rates to be connected to capital productivity and its general evolution. Therefore, we introduce a wedge that is modeled as a fraction of the marginal product of capital. Another interpretation could be a linear capital tax of 26.4%, as is assumed in Fehr et al. (2013). This tax will drive a wedge between the marginal productivity of capital and the interest rate perceived by the households. To mimic the developments in interest rates since the recent financial crisis, we assume that the wedge increases linearly during the period 2008-2016 and stays at this level afterwards.

In general equilibrium, several effects are at work. As a first round effect, agents reduce their savings due to lower returns on savings. This, in turn, reduces the capital stock, which is the sum of aggregate savings (in this closed economy setting). Holding labor constant, a smaller capital stock implies a higher marginal productivity of capital. This increases the net interest rate, namely the one perceived by the households. In general equilibrium, this effect leads to the outcome that the net interest rate is only slightly different from the case without a wedge. However, it is important to note that aggregate savings are substantially lower than in the benchmark scenario. This observation again has consequences on retirement decisions.

Table 3.5 evaluates, parallel to Table 3.4, the reforms described in previous chapters under this low interest regime. It compares the reform scenario vis-à-vis its baseline scenario. Note that we cannot directly compare Tables 3.4 and 3.5 in level terms. Instead, we will emphasize the degree of impact and how each reform performs and ranks in terms of the specific variables of interest in the analysis. In Table 3.5 it is important to remember that, contrary to the benchmark regime, all scenarios exhibit lower interest rates.

Table 3.5: Low interest rates

Reform proposal	**Retirement ages**	**Utility (CEV in %)**	**Gap in CEVs between the lowest and highest group (in p.p.)**	**Contribution rates (in p.p.)**	**Replacement rates (in p.p.)**
Increase of SEA to 67	-1 to 2	0.1	-0.1 to 0.2	-2.0	1.5
Actuarial neutral	1 to 4	-0.2 to 0.2	0.2 to 0.5	-0.6	2.6
2:1 reform	1 to 3	0.8 to 1.0	0.2 to 0.4	-3.4	2.8
Constant replacement rate	-2 to 0	-3.0 to -3.5	0.5 to 0.6	7.3	-

Note: ***Time range*** with respect to cohorts' entry years: 1995-2005. ***Time range***: 2040-2050.

Source: own calculations.

As a general outcome, households react stronger in their retirement behavior under the low-interest-rate regime: the variation in retirement age is higher for all reforms in both positive and negative directions. For instance, households retire up to 4 years later when the 2:1 reform is implemented, while before it was at most 3 years later. As a result, the relative ranking of reforms slightly changes since now the actuarial neutral and the 2:1 reform have a similar impact on retirement behavior.

Contribution rates react similarly to the regime with high interest rates. Changes in replacement rates, in contrast, are smaller than before. This is due to the lower growth of wages under the low-interest-rate regime. In contrast to the benchmark regime, the 2:1 reform now leads to the highest relative change in replacement rates as compared to the actuarial neutral reform, which previously showed the highest relative increase. Since households benefit from a similar relative reduction in contribution rates as in the high interest rate regime and the rise in replacement rates is relatively lower, the gains from reforms in terms of welfare will be lower. In terms of welfare gains, the relative ranking between reforms remains the same as in the benchmark regime.

Concerning the gap in CEVs, representing how households benefit differently from reforms, we observe a general increase and variation for all reforms. This means that low skilled households benefit disproportionally more from reforms under the low interest rate than in the high interest rate regime. This stems from higher relative gains in income due to the increase in the extensive margin of labor supply. Since low skilled households have lower income compared to the high skilled households, any additional gain in work income from reforms leads to a disproportional increase in consumption and welfare in comparison to the high skilled. This effect is strengthened when interest rates are lower because capital gains are smaller in this regime and any marginal increase in labor income is more beneficial for low skilled households than for the high skilled counterparts.

3.5.2 Low growth of technology regime

The possibility that developed countries are entering an age of low technological and economic growth has been advanced over the last decade. The so called secular stagnation will prevail in the next decades and developed economies will face the slowest growth rates of the last half century, according to Gordon (2014) and Fernald (2015). This, of course, brings more challenges to pension systems and to their reforms, as the effects may differ in intensity and rank differently between reforms.

In order to simulate such an environment of low economic growth, we define a lower growth rate of technology that will affect production as well as wages and capital rates of return. Therefore, labor productivity growth is set to $g = 0.5\%$, a very low growth environment in comparison with our benchmark case where $g = 1.5\%$. Compared to the benchmark regime, in general equilibrium, several effects are at work. As a first round effect, ceteris paribus, lower technology growth produces lower output. This will produce feedback effects that lead agents to work more hours to earn more and will also increase savings in order to raise capital and, hence, production. This increases the capital stock relative to output, which is the sum of aggregate savings (in this closed economy setting). Raising capital stocks will reduce returns on capital and improve returns to labor in our model.

Note that individuals, when planning their life-cycle decisions, already take into account that this low growth setting will remain over time. This, of course, influences the comparisons of reforms to the baseline case (low growth environment and no reform), since a low growth perspective will be a consideration of the decisions of agents. Namely, individuals tend to retire on average one year later compared to the benchmark environment (for some cohorts, decisions remain equal), although the net effect on contribution rates and replacement rates tends to be quite constant between environments. Individuals make the decision to retire later due to the need of compensating for lower interest rates that affect consumption and welfare levels. These effects have to be taken into account when observing the effects of each reform. As stated above, we cannot directly compare Tables 3.5 and 3.6 in level terms, so instead we will emphasize the degree of impact of each reform.

A change in regime that results from changes in technological growth must only have level effects on our outcomes since technological growth should not impact the decision of households. As an overall inspection of the results (see Table 3.6), the impact of each reform on several variables is identical to the ones observed in the high growth regime (benchmark regime), confirming our expectations. Therefore, we find that the effects of the implementation of all reforms on the pension system leads to a similar variation of retirement ages. As for pension system components, the actuarial neutral reform produces a slight increase in replacement rates, which is responsible for a higher increase in welfare for this reform. The other reforms show equal findings to the high growth regime. Concerning contribution rates, only the increase of the statutory eligibility age to 67 produces a less positive impact of the reform. This is mirrored by the welfare gains, which are lower in comparison to the high growth regime. All other reforms do not affect contribution rates in a way that is different from the benchmark regime. Consequently, the same holds for welfare increases and gaps in CEVs between skill groups.

Table 3.6: Low technological growth

Reform proposal	Retirement ages	Utility (CEV in %)	Gap in CEVs between the lowest and highest group (in p.p.)	Contribution rates (in p.p.)	Replacement rates (in p.p.)
Increase of SEA to 67	0 to 1	0.7	-0.1 to 0.1	-1.8	1.5
Actuarial neutral	1 to 3	1.3 to 1.5	0.1 to 0.3	-0.5	3.7
2:1 reform	1 to 3	1.5 to 1.6	0.1 to 0.2	-3.5	3.1
Constant replacement rate	-1 to 0	-2.2 to -2.6	0.3 to 0.5	7.5	-

Note: ***Time range*** with respect to cohorts' entry years: 1995-2005. ***Time range***: 2040-2050.

Source: own calculations.

3.6 Conclusion

How to reform the pension system has been debated in the last decades. In order to keep the finances of the pension system sustainable, many policy proposals have been presented that essentially focus on creating incentives for working longer and introducing measures to reduce the expenses and increase revenues of the pension system. This has led to the introduction of several reforms that focus on changing basic mechanisms of the pension system. However, sustainability should not be the only goal but instead must be put into perspective together with the well-being of all generations alive and yet to come. In response to this, we contribute to the literature a comparison between different policy reforms and examine their impact on the sustainability of the pension system considering at the same time individuals' welfare.

When evaluating each of the reforms, household behavioral feedback effects of each reform and realistic life-cycle components have been taken into consideration. Namely, important backlash effects on labor supply and endogenous retirement decisions have a significant impact on the final outcomes of each reform. All together, we learned that introducing a continuous rule (2:1) that automatically changes the statutory eligibility age according to the evolution of the life expectancy has the most beneficial effects in terms of our evaluation measures. It is the one that dampens the rise in contribution rates through an extended working life the most and simultaneously reduces the welfare gap between the skill groups vis-à-vis the baseline scenario while also substantially increasing the welfare of all individuals. In comparison to this reform, a simple increase of the statutory eligibility age to 67 falls behind in terms of effectiveness, since not only are the effects temporary, but the magnitude is not enough to cope with the forces of population aging on the sustainability of the pension system in the long term. The 2:1 reform is closely followed by the reform which raises adjustment rates close to their actuarial neutral values. Here, households indeed work longer, taking pressure off the pension system's budget equation. This reform actually has the highest effect on replacement rates, but it falls behind the 2:1 reform in all other evaluation measures. Still, the welfare gap between skill groups is reduced substantially compared to the baseline scenario and welfare improves significantly. The last reform, in contrast, lacks effectiveness. Although the goal of keeping the replacement rate constant in order to avoid poverty among the low skilled is reached (lower welfare gap between the skill groups vis-à-vis baseline scenario), it comes at a large cost. Mounting contribution rates, necessary to finance the system, harm labor supply (earlier retirement ages) and the welfare of the youngest generations. Our results are robust with respect to differing growth and interest rate regimes representing current macroeconomic tendencies. While for a low growth scenario essentially no differences in our reform evaluation emerge, under a low interest rate regime reform effects are larger.

In conclusion, our study sheds some light on the interaction of pension reforms, labor supply reactions to them, and the macroeconomic environment. Incentives created by the pension system are discussed in detail to understand the mechanisms through which reforms affect people's labor supply and savings behavior. Results suggest that it is essential for researchers and policy makers to understand the incentives created by the pension system and reactions of households to changes in those incentives. Actual retirement behavior is indeed a key variable for evaluating the suitability of reforms to insure the sustainability of pension systems. Possible feedback effects also have to be considered to avoid imbalances in the pension system and an underestimation of the quantitative effects of pension reforms.

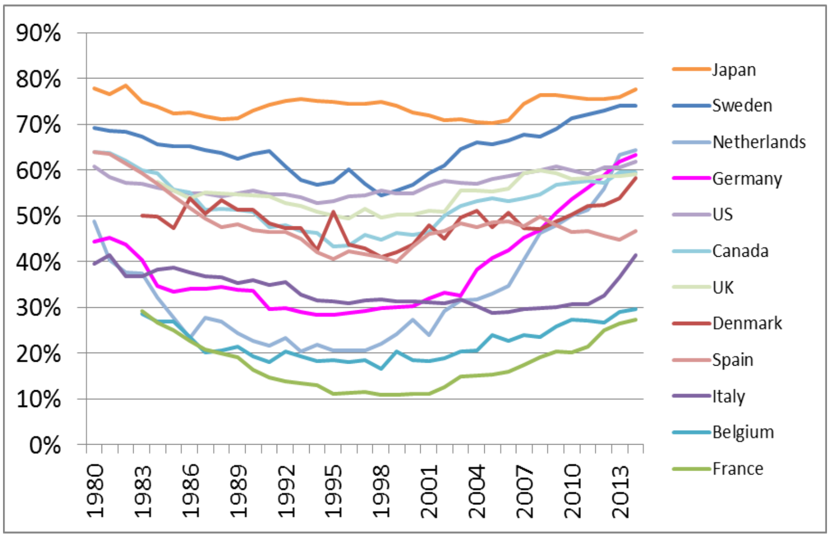
4. Earnings test, non-actuarial adjustments and flexible retirement

This chapter was written in co-authorship with Axel Börsch-Supan and Duarte Nuno Leite.

4.1 Introduction

Living longer is a great achievement of modern societies but has posed major challenges to policy makers as they struggle to keep the social security systems sustainable. As a consequence, much attention has been given to labor supply at older ages since working longer helps to decrease a pension system's dependency ratio. Many countries have introduced gradual increases of the statutory eligibility age and shut down pathways to early retirement. This has, among other factors (Coile, et al., 2018), led to a striking reversal around the year 2000 of the long-term trend to ever earlier retirement observed since the 1970s (Figure 4.1).

Figure 4.1: Labor force participation among men 60-64



Source: (OECD, 2017)

Nevertheless, the percentage of individuals who retire early is still large, regardless of the statutory eligibility age implemented. Except for Sweden, all European countries depicted in Figure 4.1 feature less than 65% labor force participation among men aged 60-64. In France, Belgium, Italy and Spain the majority of men in this age range have already retired. In Germany, which has experienced the strongest reversal in labor force participation, the actual average retirement age is about 62.1 years, more than 3 years earlier than the current statutory eligibility age which is 65 years and 3 months (Börsch-Supan, et al., 2018c; OECD, 2015). This observation is in line with the many incentives left which create early retirement, in particular earnings tests and less than actuarial adjustment factors to the benefits claiming age.

In addition, backlashes against further reforms have become very large. Increasing the eligibility age for public pensions and increasing the penalties for early retirement are especially unpopular policies. Politicians consider them as the "third rail in politics", referring to the high-voltage rail in the subway which gives a fatal jolt to those who touch it (Safire, 2007; Lynch & Myrskyl, 2009). Some countries have even introduced new pathways to early retirement (e.g. Germany) and re-instated earlier eligibility ages for women (e.g. Poland).

As a substitute for increasing the eligibility age and the penalties for early retirement, "flexibility reforms" have become a favorable policy (Graf, et al., 2011; Huber, et al., 2016; Sonnet, et al., 2014; Börsch-Supan, et al., 2018c). They introduce partial retirement, a combination of part-time work and partial pension benefit receipt by relaxing constraints such as earnings tests which often impose very tight maximum hours constraints on working after the earliest eligibility age for public pensions.

While "flexibility" sounds desirable and abolishing constraints has intuitive appeal to policy makers and the populace in general, this chapter argues that such reforms may backfire. We show with a general life-cycle model that abolishing an earnings test as part of a "flexibility reform" may create more labor supply but at the same time, will reduce the average claiming age when adjustments remain less than actuarial, thereby worsening rather than improving the sustainability of public pension systems.

The key element of flexibility reforms is the abolishment of an existing earnings test. Earnings tests are a specific form of means-testing and impose an upper limit on earnings while receiving a pension. In their most stringent form, earnings tests force workers to exit the labor market when claiming a pension. In contrast, without an earnings test, workers could claim their benefits and continue working, thus potentially increasing labor supply. Earnings tests have been abolished in a few countries (e.g. in the US, Canada and the UK) quite some time ago. Norway has been the most recent European country to follow their example. Table 4.1, however, shows that many European countries still have earnings tests for individuals who retire before the SEA, e.g. France or Germany, with different limits and different rules (Social Security Administration, 2014).

Table 4.1 Adjustments to retirement age and earnings tests across selected countries

	Adjustment rate	Earnings test
Australia	–[5]	Pension is means tested against any income above AUD 4,200/7,500 p.a. (singles/couples); 50% withdrawal rate;
Austria	4.20%	Before SEA: when earnings are above a ceiling of 290 € per month, the pension is fully withdrawn; After SEA: no limit
Belgium	–[6]	Before SEA: when annual earnings are above 7,793€ (single) or 11,689 € (dependent child) per year, the pension is reduced by the amount that exceeds the limit. If annual earnings are 25% above the limit, the pension is fully withdrawn for as long as the additional income is higher than the ceiling; After SEA: when earnings are above 22,509 € (single) or 27,379 € (dependent child) per year, the pension is reduced by the amount that exceeds the limit. If annual earnings are 25% above the limit, the pension is fully withdrawn for as long as the additional income is higher than the ceiling. For a retiree older than 65 with at least 42 years of contribution, the ceiling is lifted entirely
Canada	0.60%	No limit
Denmark	–[7]	Before SEA: no public pension receipt possible, therefore no conflict between public pension benefits and additional income; After SEA: full basic pension (795€ per month or 9,540€ per year, which is equivalent to around 17% of average earnings) is reduced at a rate of 30% against earned income, if work income exceeds 40,518€ per year (approx. ¾ of average earnings)
Finland	4.80%	No limit
France	5.00%	No limit for full pension recipients; workers are eligible for full public pension benefits if they fulfil either both a minimum contributory record (in 2014: 41.25 years for people born in 1953) and the minimum legal pension age (61 years and two months) or the age of 66 years and two months
Germany	3.60%	Before SEA: for drawing full pension payments the limit is one-seventh of the reference base (i.e. 3,060€ per year or 255€ per month respectively); for drawing a partial pension the ceiling is dependent of the partial pension level, i.e. 1,483€ per month (1/3 partial pension), 1,112€ per month (1/2 partial pension), 741€ per month (2/3 partial pension), multiplied with the individual earnings points in the year before pension claiming; After SEA: no limit
Italy	1-2%	No limit

[5] In Australia, there are no adjustment rates implemented.

[6] In Belgium, there is no actuarial reduction in the pension calculation in case of early retirement. However, the pension of the early retirees can be incomplete if they have worked less than 45 years.

[7] In Denmark, early claiming of pension benefits is not possible.

Japan	8.40%	Up to age 69. Threshold differs for ages 60–64 and 65–69; marginal withdrawal rate is 50%.
Netherlands	_[8]	Before SEA: no public pension receipt possible, therefore no conflict between public pension benefits and additional income; After SEA: no ceiling on additional earnings for public pension recipients
New Zealand	_[9]	No limit
Norway	3.8-4.7%	No limit
Spain	2-3%/6.5%-8%	Until 2013 work and pension were incompatible except under the partial retirement program.
Sweden	4.1-4.7%	No limit
UK	5.40%	No limit
US	5.0-6.67%	Limits between 62 and SEA; after SEA: no limits

Sources: Queisser & Whitehouse (2006), Blundell et al. (2017) and Börsch-Supan et al. (2018c).

Table 4.1 also shows how diverse and relatively small adjustment factors are between countries. These adjustment factors link the pension benefit to the age at which individuals begin claiming pension benefits. They are crucial elements of a pension system to understand the beneficial or harmful effects of flexibility reforms since they reduce benefits by a certain percentage ("adjustment rate") when an individual claims pension benefits earlier than the statutory eligibility age, and increase benefits when claiming benefits is postponed after the statutory eligibility age. If an individual's choice of claiming age should be neutral to the sustainability of the pension system, these adjustment factors must be actuarially neutral, i.e., they should equalize the present discounted value of pension benefits across all permissible claiming ages. Depending on age and life expectancy, actuarial adjustment rates are between 6.5 and 8 percent (Börsch-Supan, 2004; Werding, 2007; Werding, 2012; Gasche, 2012b; OECD, 2015; Queisser & Whitehouse, 2006). In most European countries, however, they are substantially lower (Table 4.1).

This chapter employs a life-cycle model of rational consumption and labor supply choices in order to study the interaction between earnings tests and actuarial adjustments during the window of retirement when workers are allowed to choose their retirement age.[10] A key feature of our model

[8] In the Netherlands, it is not possible to claim public pensions before the SEA. Early retirement is financed either by private savings or by occupational pensions.

[9] In New Zealand, there are no adjustment rates implemented.

[10] In this paper, we do not take into account time inconsistent decision making. See our concluding sections and Börsch-Supan et al. (2016b) which provides a discussion and models designed for this case. Time inconsistent behavior will strengthen our results about early claiming since time inconsistent individuals tend to prefer receiving benefits as soon as possible. We also abstract from other behavioral mechanisms such as norms and anchoring because our focus is on the incentives created by adjustment factors and earning tests.

is that households may decide separately on their claiming age R and their exit age from the labor force X $(R \gtreqless X)$, subject to the rules and parameters of the pension system. The main aim of the chapter is to study the reaction of these two potentially separate ages R and X to the parameters of the pension system and other determinants driving the retirement decision. Among the parameters of the pension system, we focus on the adjustment factors which link the pension benefit to the chosen claiming age. Other determinants influencing the retirement behavior include declining health, declining productivity, increasing appreciation of leisure versus consumption, and fixed costs of working.

Our contribution to the literature combines four aspects. First, we model the three decisions: to claim benefits, to choose working hours (intensive margin of labor supply) and to exit the labor force (extensive margin) as separate decisions in a unified life-cycle framework. This is crucial in order to understand partial retirement. Second, we offer several alternative mechanisms that create the abrupt jump in the hours' supply to zero when exiting the labor force, including a minimum hours constraint generated by fixed time costs of working. This is important in order to understand the incentives to keep on working. Third, we do not restrict our analysis to the effects of abolishing an earnings test on labor supply but also predict the implications for the financial sustainability of a prototypical public pay-as-you-go pension system. Fourth, we extend this analysis from the actuarially neutral case to the case of distortive adjustment factors which are more typical for the pension systems in Europe as compared to the US. Taken together, these four aspects are essential to better understand in which institutional setting a reform towards more flexibility will not only boost labor supply but also strengthen the financial sustainability of pension systems.

We show that the difference between exit and claiming age strongly depends on the preference for consumption versus leisure and can become very large. This is in line with previous literature and our intuition on how workers tend to react to stimuli that affect their preferences for consumption, leisure and savings. There are, however, also interaction effects that are more complex and not covered by the existing literature. Most importantly, the difference between exit and claiming age strongly depends on the actuarial neutrality of the pension system. We show, for instance, that abolishing an earnings test will reduce the average claiming age when adjustments are less than actuarial, hence worsening rather than improving the sustainability of public pension systems. This effect is not compensated by the increase in labor supply.

Our model provides a unified framework which nests and explains a host of empirical findings which have been provided by the literature. There is a large empirical literature which has concentrated its efforts on identifying the effects of the abolishment of earnings tests on labor supply. Studies such as Friedberg (2000), Tran (2002), Gustman & Steinmeier (2008), Michaud (2008), Haider & Loughran (2008), Friedberg & Webb (2009) and Engelhardt & Kumar (2009) for the US, Baker & Benjamin (1999) for Canada, Disney & Smith (2002) for the UK, Shimizutani & Oshio (2013) for Japan, Brinch et al. (2012)and Hernæs & Jia (2013) for Norway show that the abolishment of an earnings test has led to an increase in labor supply.

There is a substantial body of evidence showing that smaller than actuarially neutral adjustments exert large incentives to claim benefits earlier than the statutory eligibility age and that this has significantly contributed to the early retirement visible in Figure 4.1 (Gruber & Wise, 1999; Gruber & Wise, 2005; Blöndal & Scarpetta, 1999; Börsch-Supan, 2000).

Our model is in the tradition of several theoretical models that have studied the abolishment of the earnings test in the Anglo-Saxon countries on labor supply (Gustman & Steinmeier, 2008; French, 2005; Benítez-Silva & Heiland, 2007; Michaud, 2008; Fehr & Uhde, 2014; Kudrna & Woodland, 2011). With one exception, these papers do not address the implications for the financial sustainability of the public pay-as-you-go pension systems and they take place in an actuarially neutral pension system.

The closest paper to ours is Gustman & Steinmeier (2008) which models the distinction between claiming and exiting the labor force in a very rich dynamic programming model. This model includes heterogeneity of workers' preferences and job characteristics in order to obtain a good fit to US data. While Gustman & Steinmeier (2008) implicitly consider the parameters of the US Social Security system, they do not vary them except for the abolishment of the earnings test. Hence, their analysis refers to a largely actuarial neutral institutional environment which is in stark contrast to the situation in Europe.

Regarding the claiming decision, Gustman & Steinmeier (2008) show that the abolishment of the earnings test increases the share of married men who claim their benefits by about 10% between the early and normal retirement age. Gruber & Orszag (2003), Song (2004) and Song & Manchester (2007) also find evidence that loosening the earnings test accelerates the claiming of benefits among the eligible population.[11]

Regarding labor supply, many papers claim that the increase in labor supply due to the abolishment of an earnings test stems mostly from the intensive margin, i.e., the decision of working more hours than before, e.g. Disney & Smith (2002), Engelhardt & Kumar (2009), Friedberg (2000), Song (2002), Tran (2002), Hernæs et al. (2016) or Hernæs & Jia (2013). Others find that the positive effect is mainly generated on the extensive margin, i.e., by an increase in labor force participation, e.g. Baker & Benjamin (1999), Tran (2002), Engelhardt & Kumar

[11] Michaud (2008) finds no significant evidence on an impact on the claiming age after the elimination of earnings tests.

(2009), Hernæs et al. (2016), Hernæs & Jia (2013), Michaud (2008), Friedberg & Webb (2009).[12] Our theoretical model is designed to distinguish between the two margins.

Our study is also related to the literature about means-testing pension benefits against assets (Bütler, et al., 2016; Chomik, et al., 2015; Fehr & Uhde, 2014; Woodland, 2016). In contrast to our study which investigates earnings tests, these studies concentrate on wealth tests when applying for pension benefits. More specifically, Kudrna & Woodland (2011) and Tran & Woodland (2014) focus on the Australian superannuation scheme and examine the impact of means-testing on the incentives of individuals to save and work, on government financial commitments and on the distributional effects on the welfare of individuals.

Finally, our study also relates to the literature on minimum hours constraints (Gustman & Steinmeier, 2004a; Gielen, 2009). We generate such a constraint through fixed time costs of working.

The chapter is organized as follows. In Section 4.2, we present our model. Section 4.3 describes the calibration strategy and our computational solution method. The analysis of our results and sensitivity analyses are presented in Section 4.4. It includes a prototypical "flexibility reform" which looks promising from a political point of view but is likely to fail in securing the sustainability of a pay-as-you-go pension system. Section 4.5 concludes the chapter.

4.2 The model

Since we want to focus on the households' labor supply decisions in a complex pension system, we will operate in a partial equilibrium framework in which wages and interest rates are exogenously fixed.[13] Our model can be thought of as the household sector plus the pension system in the well-known general equilibrium framework developed by Auerbach & Kotlikoff (1987). Regarding the household model, we need to extend this typical neoclassical set-up by an endogenous retirement decision (extensive margin: labor force participation) in addition to the choice of labor supply (intensive margin: working hours). Regarding the pension system, we need additional detail by modeling earnings tests and adjustment factors as bonuses for late retirement and penalties for early retirement. Since the main goal of our study is to explain the mechanism

[12] Song (2004), Song & Manchester (2007) and Gruber & Orszag (2003) find no significant effects of the abolishment of the earnings test on employment and/or hours worked in the US.

[13] We will thus disregard the general equilibrium effects of abolishing an earnings test on wages and interest rates. Woodland (2016) provides a general equilibrium analysis of means testing and other forms of taxation. While the wage effects are small, the interest rate effects are larger but not in the focus of this labor-supply oriented paper.

and reaction of individuals to earnings tests and different adjustment factors, we abstain from any distributional considerations, e.g. regarding differences by gender, occupational groups or any other differentiable forms between individuals.

4.2.1 Household consumption and leisure

We begin with the traditional set-up of how households choose between consumption and leisure. Households of age j gain utility from consumption c_j and leisure l_j according to a CES-type per-period utility function given by

$$u(c_j, l_j) = \frac{1}{1-\theta}\left[c_j^{\phi_j} l_j^{1-\phi_j}\right]^{1-\theta}, \tag{4.1}$$

where ϕ_j denotes the utility weight of consumption versus leisure and can be modeled as age-dependent (see Section 4.3.2). Risk aversion is described by the parameter θ.

Households are neoclassical life-cyclers with perfect foresight. They solve a von Neumann-Morgenstern expected utility maximization program over the entire life-cycle which lasts for a maximum of J years. The life-time maximization problem of a cohort is therefore given by

$$max \ \sum_{j=1}^{J} \beta^{j-1} \sigma_j \, u(c_j, l_j), \tag{4.2}$$

where β is the pure time discount factor, $\beta = \frac{1}{1+\rho}$. In addition to pure discounting, households discount future utility with their unconditional survival probability, σ_j, expressing the uncertainty about the time of death. We do not include intended bequests in our model and assume that accidental bequests resulting from premature death are taxed away by the government at a confiscatory rate and used for otherwise neutral government consumption.

The household's disposable non-asset income y_j is

$$y_j = h_j w_j (1 - \tau) + p_R, \tag{4.3}$$

which has two components. The first term of the right-hand side reflects net labor income which is the number of hours, h_j, times the hourly wage, w_j, net of the contribution to the pension system at rate, τ. The second term denotes pension income, p_R. Pension benefits and contributions will be defined by equations (4.9) and (4.12) further below.

Denoting total assets by a_j, maximization of the household's intertemporal utility is subject to a dynamic budget constraint given by

$$a_{j+1} = a_j(1 + r) + y_j - c_j. \tag{4.4}$$

In this traditional set-up, labor supply (working hours) may decline at the intensive margin if the parameters in the utility function change. There is, however, no sudden retirement (withdrawal from the labor force at the extensive margin). Retirement is typically assumed to be exogenously dictated by a mandatory retirement age R at which individuals must stop working and will begin receiving pension benefits. This implies that $p_j = 0$ for $j \leq R$ and $h_j = 0$ for $j>R$ in equation (4.3). We will deviate from this traditional set-up in the following section.[14]

4.2.2 The retirement decision

Modern pension systems deviate from this rigid set-up. First, most pension systems have a window of retirement defined by an earliest and a latest eligibility age $R_E \leq \overline{R} \leq R_L$ which bracket the statutory or "normal" eligibility age $\overline{R}$. Workers have the choice to retire within this window which we need to model. Second, "flexibility reforms" permit combinations of work and pension benefit receipt both before and after the statutory eligibility age. In this case, "retire" refers to two separate decisions, namely to stop working at age X and to begin receiving pension benefits at age R. Both decisions are influenced by common determinants such as institutional parameters and the individual's preferences. Earnings tests and mandatory retirement may enforce $R = X$. In other institutional settings, however, R may be earlier or later than X. If workers have saved sufficiently, they may want to stop working before they receive pension benefits ($X<R$). In turn, many retirees want to continue some limited engagement with their work place ($R<X$). We therefore need to model two separate decisions – claiming benefits and exiting the labor force – in a life-cycle setting.

The decision to begin claiming benefits at age R is heavily influenced by the parameters of the pension system. This will be described in the Subsection 4.2.3. Modeling the decision to leave the labor force completely at age X, the extensive margin of labor supply, is more difficult. Common sense tells us that the choice of the labor force exit age X is mainly driven by the aging process

[14] Our model does not include liquidity constraints for the sake of simplicity and clarity. The influence of imperfect capital markets on retirement and claiming choices is complex and the subject of another paper in preparation.

which is characterized by declining productivity, declining health, increasing value of leisure, and/or a combination thereof. Since these are on average continuous and slow-moving processes, the sudden downward jump in labor supply associated with the labor market exit requires an additional mechanism such as a fixed cost of working which makes it unattractive to supply small amounts of labor.

We offer several mechanisms to model the sudden jump in labor supply associated with exiting the labor force. First, productivity may rise to a peak well before retirement and then decline with age. In a neo-classical world, hourly wages then evolve as

$$w_j = \bar{w}\varepsilon_j, \tag{4.5}$$

where ε_j is age-specific labor productivity. As ε_j declines, individuals receive lower wages and reduce their labor supply.

Second, the value of leisure relative to consumption may increase with age. This is expressed by a decrease of the parameter ϕ_j in the utility function (4.1) with age. Accordingly, the household weighs consumption less in the later, rather than the earlier, stages of life. The opposite evolution applies to leisure. In response, individuals will reduce their labor supply in later ages.

Third, time costs of work $\vartheta(h_j, j)$ may increase with age. These time costs represent the effect of declining health on the disutility of work (Börsch-Supan & Stahl, 1991). This effect may be non-linear, increasing with the number of hours worked:

$$\vartheta(h_j, j) = \chi_j \left(1 - \frac{1}{(1+h_j)^{\xi}}\right), \tag{4.6}$$

where χ_j increases with age (i.e., worsening health). We insert these costs of work into the household's decision program by linking leisure and work hours following French (2005):

$$l_{t,j} = 1 - h_j - \vartheta(h_j, j). \tag{4.7}$$

Since the labor supply of households is bound by $0 \leq h_{t,j} \leq 1$, the non-negativity condition drives individuals to stop working. As soon as $\vartheta(h_j, j) > 1 - h_j$, workers will exit the labor force at a well-defined exit age X.

These three mechanisms are likely to work in parallel. Unfortunately, there is little solid evidence for their quantification. While there is plenty of quantifiable evidence that health declines with age, there is little evidence of how to translate declining health into related time costs of work (the $\vartheta(h_j, j)$ function) or a shift in the labor-leisure tradeoff (the decrease of ϕ_j). The evidence on productivity decline is also mixed. While aggregate studies show rising and then declining productivity with age (e.g. Altig et al. (2001)), micro-econometric estimates show flat age-productivity profiles in the relevant age range $R_E \leq \overline{R} \leq R_L$ (Göbel & Zwick, 2009; Börsch-Supan & Weiss, 2016). Our approach is therefore to define synthetic age profiles of ϕ_j, ε_j and χ_j which represent a benchmark case plus an upper and lower bound for each mechanism. We will then map out all combinations and check the robustness of the key results. The parameters of ϕ_j, ε_j and χ_j will be chosen in the calibration process to ensure that labor force exit falls into the retirement window $[R_E, R_L]$ for the benchmark case. This will be detailed in Subsection 4.3.2 below.

4.2.3 The pension system

The institutional background for the claiming and labor market exit decision is a contributory PAYG system which promises defined benefits that are strictly earnings-related. This corresponds to the pension systems in the large Continental European countries, e.g. France, Germany and Italy.[15] In a first setting, contributions are due until *R*-1, pension benefits are paid from the claiming age *R* onwards. We will slightly modify this setting in Subsection 4.4.2 when we study a prototypical flexibility reform. We model the relation between earnings and benefits in the form of earnings points. In each working year, earnings points reflect the labor income position of a worker at age i relative to the average earnings $\overline{wh}$. Earnings points are accumulated during the entire work life:

$$s_R = \sum_{j=1}^{R} \frac{w_j h_j}{\overline{wh}} \, . \tag{4.8}$$

Life-time earnings points depend on the claiming age, the hours of work supplied (intensive and extensive margin) and their valuation (hourly wage). Pension benefits p_R for an individual claiming benefits at age *R* are given by three multiplicative components:

$$p_R = \bar{q} \; s_R \; \omega_R \qquad \text{for } R \geq R_E. \tag{4.9}$$

$\bar{q}$ is the base pension amount for one earnings point when a worker is claiming at the statutory

[15] These countries have large PAYG systems while the role of fully-funded occupational and private pensions is still fairly limited. We therefore do not model 2nd and 3rd pillar pensions in this paper.

eligibility age $\overline{R}$; s_R are the accumlated earnings points according to (4.8); finally, ω_R is an adjustment factor which links pension benefits to the actual claiming age R.

Adjustment factor ω_R is actuarially neutral if the present discounted value of participating in the pension scheme is independent of the benefit claiming age R: [16]

$$PDV_t(R) = \sum_{j=R+1}^{\infty} \bar{q}\, s_R\, \omega_R\, \sigma_{t+j,j} \left(\frac{1}{1+r}\right)^j - \sum_{j=0}^{R} \tau_{t+j} w_{t+j}\, \sigma_{t+j,j} \left(\frac{1}{1+r}\right)^j \quad (4.10)$$
$$= \text{constant for all } R \in [R_E, R_L].$$

The resulting actuarially neutral adjustment factors are a function of the assumed interest rate, r, and the survival probabilities, σ_j. Pension systems providing flat benefits independent of the individual claiming age (i.e., $\omega_R = 1$ for all R) are not actuarially neutral since they redistribute income from late retirees to early retirees who receive the same benefit over a longer time, thereby creating particularly strong incentives for workers to claim early. As we have seen in Table 4.1, many countries feature adjustment factors that are constant over a large range of claiming ages R and are lower than actuarially neutral.[17]

We therefore model this adjustment in a linear fashion where the steepness of the adjustment is driven by a single actuarial adjustment rate, ω[18]. If the household claims its pension at the statutory eligibility age $\overline{R}$, there is no deduction or premium, ω_R=1. For one year of earlier claiming, benefits are reduced by ω percent while benefits are increased by ω percent for one year of later claiming[19]

$$\omega_R = 1 + \left(R - \overline{R}\right)\omega. \quad (4.11)$$

The decision to begin claiming benefits at age R is heavily influenced by the size of the actuarial adjustment rate, ω. If ω is very small, rational individuals will choose R=R_E. If ω is very large, rational individuals will choose R=R_L. If ω is actuarially neutral, individuals are indifferent when

[16] See Queisser & Whitehouse (2006) for a detailed discussion on this definition.

[17] The actuarial neutral adjustment rate at age 65 is about 6.3% for the average of France, Germany and Italy underlying the calibration described in Section 4.3.3.

[18] Following the terminology in the literature, we use the term “actuarial adjustment“ independently of whether the adjustment is actually neutral.

[19] Some countries have two adjustment rates: ω_{ER} for retirement before the statutory “normal retirement age” and ω_{LR} for retirement thereafter. Adjustment factors are only one way to link pension benefits to the claiming age. It fits well with earnings point, notional defined contribution and similar pension systems. Other mechanisms include age-varying benefit accrual rates.

to claim and R is not well defined.

The contribution rate to the system, τ, is computed to balance the PAYG system. Revenues are the product of the contribution rate τ and the wage bill, $\sum_{j=1}^{R-1} w_j h_j NW_j$, where the number of workers of age j is denoted by NW_j. Expenditures are the sum of the products of pension benefits p_j and number of pensioners NP_j. The budget-balancing contribution rate is thus given by

$$\tau = \sum_{j=1}^{R} w_j h_j NW_j \,/\, \sum_{j=R+1}^{J} p_R NP_j. \tag{4.12}$$

4.3 Partial equilibrium and calibration

4.3.1 Computational algorithm

The optimal paths of consumption and labor supply (average hours worked) are computed using the algorithm developed by Ludwig (2007) which is a further development of the procedures initially proposed by Auerbach & Kotlikoff (1987). The life-cycle of a household ranges from the entrance in the labor market at age 15 until a maximum of 100 years. The solution of the life-cycle optimization is solved recursively by taking initial guesses for variables at last age and policy variables. Then, the model is solved backwards using recursive methods by applying first order methods and appropriately handling the constraints. Decisions of individuals are computed yielding the new values for aggregate variables. This procedure delivers new guesses for the vectors of consumption, hours worked, claiming age, labor force exit age, assets and the new contribution rate. Following this, we update the initial (old) guesses and repeat the same method until we reach convergence of the model towards the partial equilibrium. This equilibrium is achieved when the initial guesses and the final new values for aggregate variables have sufficiently converged.

Labor costs – here modeled as time costs – depend on hours worked and tend to increase with age as they simulate the burden of older workers to remain in the labor market. We loop forward in order to calculate savings and assets applying the budget constraint (4.4). Labor market exit age is simply the age at which the hours worked reach zero. We constrain the exit age to be at most age 85. We do not allow the household to re-enter the labor market.

The endogenous decision of retirement (claiming age) is a second step of the algorithm step. To solve it and calculate the pension claiming age, we use an outer loop that searches the claiming age which maximizes the household's utility, taking into account the adjustment factors that provide incentives for earlier or later claiming. In the earnings test scenario, hours are set to zero after claiming for pensions and the claiming age coincides with the labor market exit age. If there is no earnings test, we allow the decision on hours worked to be independent of the optimal claiming age *R*.

4.3.2 Calibration

The benchmark case of the model is calibrated such that claiming and exit ages correspond roughly to the values observed in the large Continental European countries such as France, Germany and Italy for the cohorts retiring about now. This was around 65 years for men and 63 years for women in 2014 (OECD, 2015), associated with relatively low actuarial adjustment rates ω of about 3.5% to 4% per year which are common in these countries. In our policy experiments, the outcomes of different pension system parameters also relate to these early baby boomer cohorts.

We use the average mortality rates across the EU countries from 1960 until 2014 as reported by Eurostat (2016). The main behavioral parameters are summarized in Table 4.2 and chosen by reference to other studies. The sensitivity of our results to the choice of these parameters is studied in Subsection 4.4.4.

Table 4.2: Parameter calibration

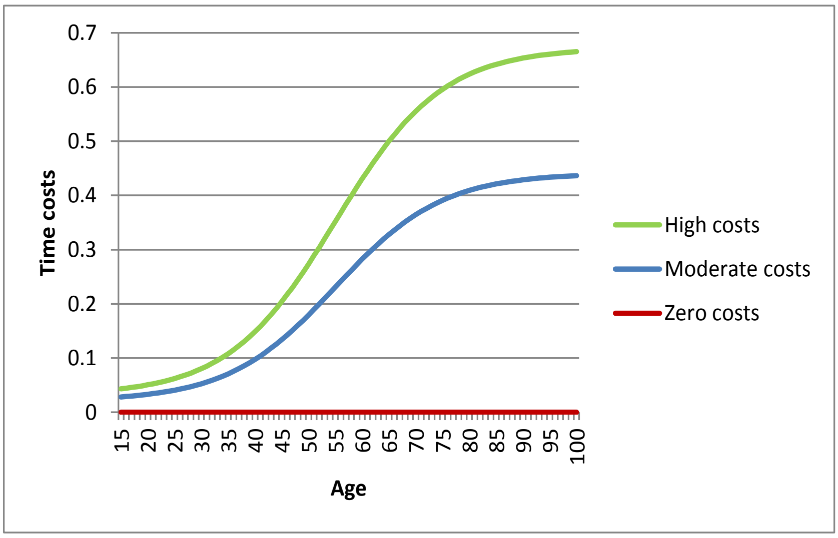
Parameter	Values
Discount rate (ρ)	0.02
Risk preference (θ)	2
Consumption weight (ϕ_j)	[0.55; 0.65]
Interest rate (r)	0.04
Cost function parameter (ξ)	15
Age dependent maximal attained cost – at age 80 (χ_j)	0.41
Earliest claiming age (R_E)	60
Latest claiming age (R_L)	72
Replacement rate at age 65 ($\bar{q}$)	0.6
Actuarial adjustment rates (ω)	[0%: 7%]

The discount rate ρ is assumed to be 0.02 (Frederick, et al., 2002), smaller than the interest rate r_t of 4% (i.e., more patient households). The risk preference parameter θ is assumed to be 2, which makes the household slightly risk averse and lies in the middle of estimates in the literature – between 1 and 5 – (Bansal & Yaron, 2004; Browning, et al., 1999; Cecchetti, et al., 2000). The weight of consumption in the utility function, ϕ_j, ranges between 0.55 and 0.65 (French, 2005). Its dependence on age will be specified below (Figure 4.4).

We set the retirement window from $R_E = 60$ until $R_L = 72$. Age 60 is the earliest eligibility age in many countries (OECD, 2015). While there is no corresponding value for Continental European countries, we assume 72 as the latest possible claiming age in accordance with US Social Security regulations. We set the base pension amount $\bar{q}$ such that the replacement rate is 60% at the statutory eligibility age. This value is close to the average replacement rate across the three large aging countries in Continental Europe (France, Germany and Italy). Depending on the policy experiment, we assume different values for the actuarial adjustment rates ranging from ω =0% to ω =6.3% (see equation (4.11)).

We calibrate the three aging mechanism described in Subsection 4.2.2 such that the claiming age for the benchmark case is within the retirement window. First, fixed costs are assumed to have two components: χ_j, which is age-dependent, and the ratio $\frac{\chi_j}{(1+h_j)^{\xi}}$. We assume that χ_j linearly increases over time until a maximum value of 41% of total time available for the household when reaching age 80. At the highest possible claiming age, costs can reach around 37% of total time available, which is normalized to 1. The age profile of this cost function for $h_j = 1$ is shown in Figure 4.2 (moderate scenario).

Figure 4.2: Time costs of working



Source: own calculations. Note that this figure displays fixed costs functions over age for $h_j = 1$.

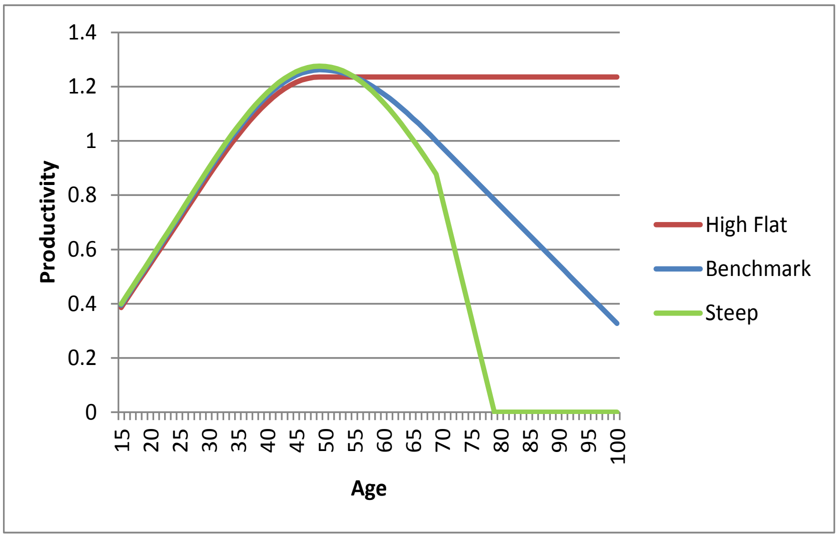
However, since they depend also on hours worked, costs never reach such high values. Due to the ratio in the cost function, the calibrated value of $\xi = 15$, and the decisions of households on leisure and consumption, the cost function will never attain the maximum cost value at any age but will asymptotically approach it for higher working hours.[20] As an alternative scenario (see Subsection 4.4.3), we also consider a cost profile that increases to a maximum value of 62% of total time available (high costs scenario in Figure 4.2).

Second, we define life-course productivity profile ε_j. The steepest case is based on the procedures developed by Altig et al. (2001) and Fullerton & Rogers (1993) and is adapted to Germany where suitable panel data is available. We use all waves from 1984 until 2013 of the GSOEP and calculate the productivity profile according to:

$$\varepsilon_j = e^{\zeta_0 + (g+\zeta_1)j + \zeta_2 j^2 + \zeta_3 j^3}, \tag{4.13}$$

where j stands for age and g is the constant rate of technological progress. The ζ coefficients are calculated according to the following procedure (Altig, et al., 2001). First, hourly wages are regressed on fixed-effect dummies, age-cubed and interactions between age, age-squared and other demographic variables. Second, the coefficients obtained from the previous regression are used to generate predicted life-cycle wage profiles. The coefficients of equation (4.13) are estimated from the simulated data. The resulting productivity profile ε_j is used in equation (4.5) to determine individual life-cycle wage profile. It is depicted in Figure 4.3.

Figure 4.3: Different age productivity profiles



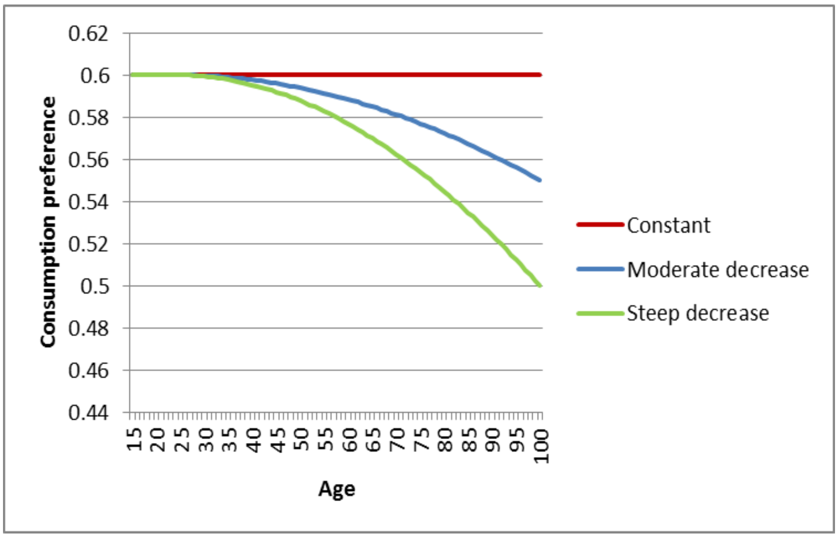
Source: own calculations.

[20] Note that with a value of ξ=15, the cost function quickly approaches zero when hours worked are small. We use this shape of the cost function to avoid discrete jumps in fixed costs at $h_j = 0$. Instead, the function smooths the costs function for values of hours worked close to zero. These assumptions of fixed costs lead to a more realistic hours profile and of course, they also shape retirement decisions of households – this is discussed in the sensitivity analysis in Subsection 4.4.3.

As an alternative productivity scenario, we assume a profile, in which productivity increases with age until it stabilizes after reaching the maximum productivity around age 50. Our benchmark scenario is a compromise between these two profiles.

The third aging mechanism is declining preferences of consumption, see Figure 4.4. These profiles range from constant preferences to steep decreasing ones. The decline can be of 0.05 (moderate decrease) or 0.10 (steep decrease). For instance, in the case of initial preferences of 0.6, we assume that they could decrease until reaching values between 0.55 or 0.5 at the end of life. This assumption is independent of productivity, meaning that we would either have declining productivity profiles or declining preferences of consumption to mimic the aging process.

Figure 4.4: Decreasing weight on consumption



Source: own calculations.

4.4 Results

We structure our results in four subsections. First, we discuss the benchmark case in detail (Subsection 4.4.1). It shows that abolishing an earnings test may undermine the financial sustainability of a PAYG pension system rather than strengthening it. Subsection 4.4.2 shows that the same conclusion holds for some forms of "flexibility reforms" in Europe and the US. We then investigate the sensitivity of our results. Subsection 4.4.3 combines alternative specifications of the retirement mechanisms defined at the end of the preceding section while Subsection 4.4.4 investigates the sensitivity of our results with respect to other key model parameters in Table 4.2.

In each subsection, our focus is on the interaction between earnings tests and actuarial adjustments. The figures and tables shown have therefore two dimensions: whether the pension system imposes a strict earnings test or not, and how large the actuarial adjustment rates are, ranging from 0% to 6.3% per year earlier or later than the statutory eligibility age. The figures and tables then show the resulting claiming and labor force exit ages (which coincide in the case of a strict earnings test).

With respect to the earnings test, we study three scenarios:

- *Strict earnings test:* the pension system rules out any additional earnings after claiming pension benefits such that individuals have to exit the labor force after claiming a pension. Labor supply is therefore zero after claiming age;
- *No earnings test:* the pension system permits any amount of additional earnings and individuals can choose different claiming and exit ages. After the claiming age, neither are contributions due nor will the individual accumulate earnings points. Equation (4.8) applies for the actual claiming age R;
- *Flexibility reform:* The no earnings test scenario is modified in Subsection 4.4.2 with respect to the latter rule: contributions are due on earnings also after claiming age and earnings points can be accumulated after claiming age. Equations (4.8) and (4.12) are re-defined as follows: earnings points are given by $s_R = \sum_{j=1}^{X} \frac{w_j h_j}{\overline{wh}}$, where X is the labor force exit age, and contribution rates are given by $\tau = \sum_{j=1}^{X} w_j h_j NW_j \,/\, \sum_{j=X+1}^{J} p_R NP_j$.

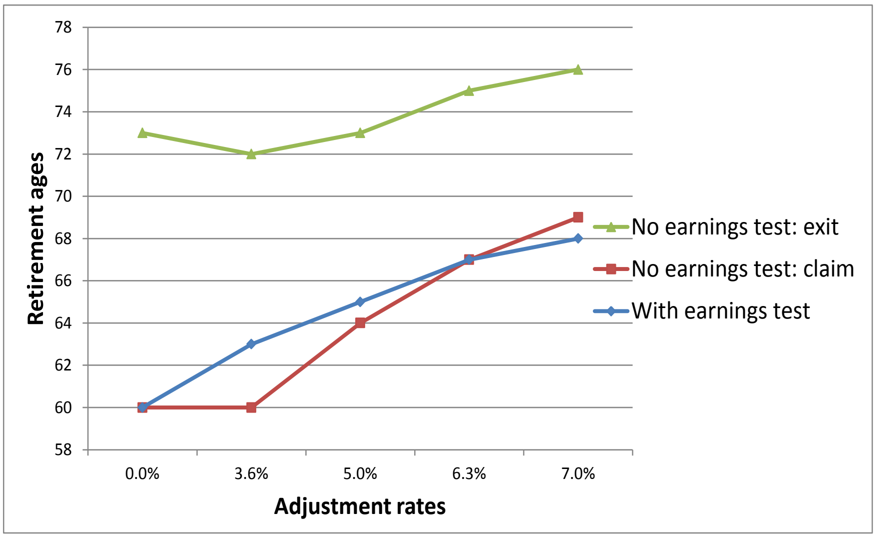
4.4.1 Analysis of the benchmark case

The benchmark case is defined by moderate time costs of working as depicted in Figure 4.2, an age-productivity profile that mildly declines in later stages of life as depicted in Figure 4.3 and a moderately decreasing weight of consumption in the utility function starting at $\phi = 0.6$ as depicted in Figure 4.4.

Figure 4.5 provides a general overview of our main results based on this benchmark case. It shows that the benefit claiming and labor market exit ages are very different depending on the maintenance or abolishment of an earnings test. For low actuarial adjustment rates (i.e., below actuarial values), this difference is particularly large. If an earnings test is imposed and actuarial adjustment rates are small but positive, individuals exit the labor market early but claim benefits later than in the no earnings test scenario. As actuarial adjustment rates increase, the gap decreases. The two lines intersect for actuarially neutral adjustment rates. In conclusion, less than actuarially neutral adjustment rates create incentives for early claiming/retirement. This is a well-known result (Gruber & Wise, 1999). Early claiming leads to more years of benefits to be paid by the system which threatens its sustainability.

The key point of our analysis is that abolishing an earnings test is not a substitute for making adjustment factors neutral. If moving from an earnings test system to a no earnings test system should have the aim of maintaining the same age of retirement/claiming as previously and additionally increase labor supply, it fails to achieve that aim as long as adjustment factors are too small. The aim is achieved only when the pension system also introduces at least actuarially neutral adjustment factors. As Figure 4.5 shows, imposing or not imposing an earnings test will not influence the choice of claiming age if the adjustment rate is actuarially neutral but increase labor force participation, hence also increasing the sustainability of pension systems.

Figure 4.5: Retirement decisions with and without earnings test



Source: own calculations.

Tables 4.3 to 4.5 depict in a more detailed way the main results summarized in Figure 4.5. Table 4.3 shows retirement decisions for the earnings test scenario depending on actuarial adjustment rates and preferences for consumption over leisure, whereas Table 4.4 and Table 4.5 show the choices of the benefit claiming age and the labor force exit age in absence of an earnings test, respectively. As noted earlier we refer to “retirement age” when X=R and distinguish “claiming age” from “labor market exit age” otherwise.

In the earnings test scenario (Table 4.3), low actuarial adjustment rates, ω, create early retirement choices. Since claiming age and exit age are equal, individuals tend to retire even before the statutory eligibility age in a pension system when actuarial adjustment rates are low. Actuarial adjustment rates of 0% induce, independently of the value assumed for preferences for consumption, claiming at the earliest possible age – here age 60. The reason is that there are no financial penalties for early claiming at all. For $\omega = 3.6\%$ and ϕ = 0.55/0.60, the resulting claiming ages are 61/63, respectively. These are the retirement ages observed in the German data which may serve as a benchmark for the effects of abolishing an earnings test. For $\omega \geq 5\%$, Table 4.3 shows relatively late claiming ages of 67 and later monotonically increasing with the magnitude of the actuarial adjustment rates and the associated penalties for early retirement/premia for later claiming, respectively. Table 4.3 shows that individuals react very sensitively to the actuarial adjustment rates, especially when the weight of consumption in the utility function is high.

Table 4.3: Claiming age *R* as a function of actuarial adjustment – earnings test

	Actuarial adjustment rate (ω)				
Initial level of utility weight of consumption ($\boldsymbol{\phi}$)	**0%**	**3.6%**	**5%**	**6.3%**	**7%**
Low (0.55)	60	61	64	68	69
Middle (0.60)	60	63	65	67	68
High (0.65)	60	64	67	68	69

Source: own calculations.

If there is no earnings test, claiming age R (Table 4.4) and labor market exit age X (Table 4.5) differ. For low values of the actuarial adjustment rate $\omega \leq 3.6\%$, workers' claiming age is earlier than in the scenario with an earnings test (around age 60) because the longer period of retirement is not penalized by sufficiently low benefits. In fact, early claiming is even more extreme than in the earnings test case since claiming is detached from exit from work force. Hence, decisions on claiming are mainly dependent on the financial incentives created by the penalties/premia generated by the actuarial adjustment rates and are less dependent on the consumption/leisure trade-off. If actuarial adjustment rate become large ($\omega > 5\%$), workers shift their claiming age to very late ages around 67-70 in order to benefit from higher pension payments. The optimal claiming age depends on ω_R relative to the discount rate including mortality risk.

Table 4.4: Claiming age *R* as a function of actuarial adjustment – no earnings test

	Actuarial adjustment rate (ω)				
Initial level of utility weight of consumption (ϕ)	**0%**	**3.6%**	**5%**	**6.3%**	**7%**
Low (0.55)	60	60	65	69	69
Middle (0.60)	60	60	64	67	69
High (0.65)	60	60	65	68	70

Source: own calculations.

Regarding exit age decisions, households work until the utility from consumption is dominated by the utility of leisure and labor costs. As Table 4.5 shows, labor force exit age *X* is decoupled from the benefit claiming age *R* in Table 4.4. Exit ages are mostly higher than claiming age, which means that workers request their pension benefits but keep working for some more years before exiting the labor market. The duration of labor supply beyond claiming age strongly depends on the preference for consumption, expressed by the parameter ϕ. The higher the preference for consumption, the longer workers remain in the labor force. Moreover, it depends on total income (wages plus pensions). The higher the preference for consumption, the longer individuals work and receive wages along with pensions.

Table 4.5: Exit age *X* as a function of actuarial adjustment – no earnings test

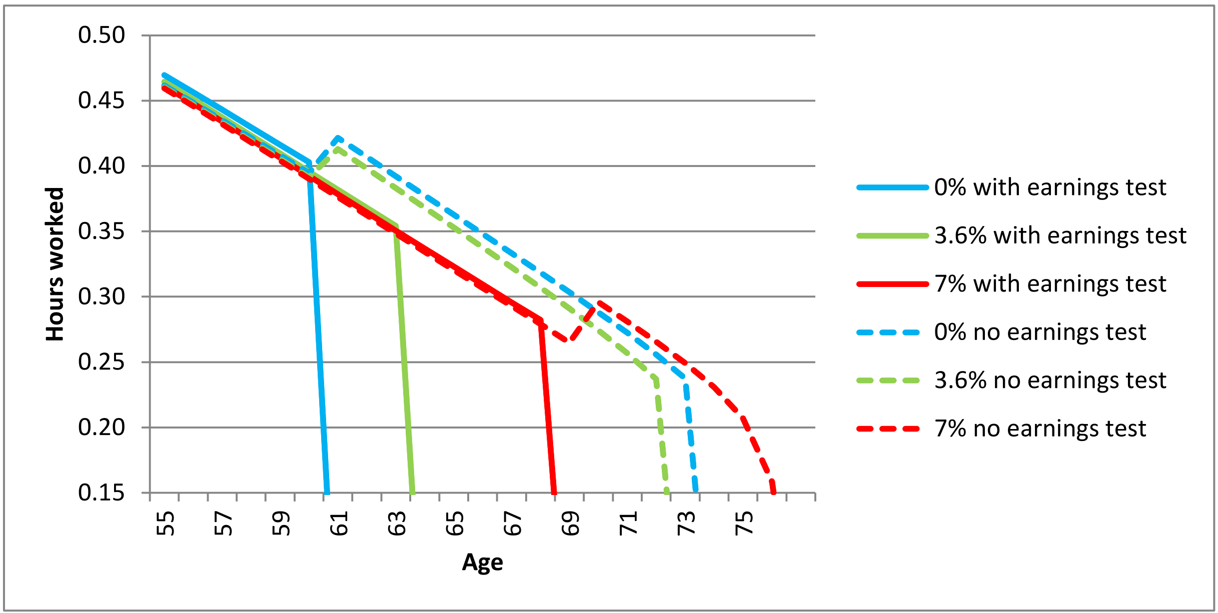
	Actuarial adjustment rate (ω)				
Initial level of utility weight of consumption (ϕ)	**0%**	**3.6%**	**5%**	**6.3%**	**7%**
Low (0.55)	69	69	70	67	67
Middle (0.60)	73	72	73	75	76
High (0.65)	85	79	79	85	85

Source: own calculations.

The difference between claiming and exit ages diminishes with increasing actuarial adjustment rates which results from labor costs and decreasing consumption preferences with age. Otherwise, the impact of the actuarial adjustment rates on exit ages has no general pattern since exit ages are only indirectly affected by them. This is in stark contrast to claiming ages which are directly dependent on the actuarial adjustment rates.

Figure 4.5 and the subsequent tables have shown claiming and labor force exit ages. They represent the extensive margins of labor supply. We now turn to the intensive margin (hours worked if participating, Figure 4.6). The product of both margins (total labor volume) is a key variable for a PAYG system since it directly determines a country's overall wage bill from which proportional contributions are paid.

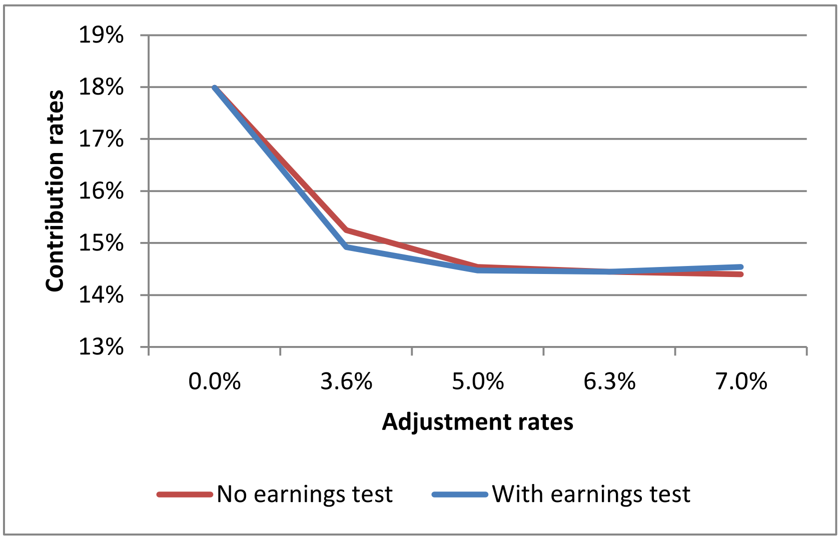
Figure 4.6: Labor supply for different adjustment rates with and without earnings test



Source: own calculations.

Figure 4.6 shows that abolishing an earnings test has positive impacts on total labor volume in terms of both margins. Labor force exit ages are shifted to older ages and hours are increased relative to the scenarios with an earnings test imposed. It would be premature, however, to conclude that this higher labor volume helps to stabilize the PAYG-DB pension system by reducing the costs of the system. We measure the system's costs conveniently and intuitively by the level of contribution rates. Since contribution rates balance the budget in the PAYG-DB pension system, their changes measure the impact of policy changes on the costs of the pensions system. As we have seen in Figure 4.5, claiming age decreases when the adjustments rates are smaller than actuarially neutral. This increases pension expenditures and thus contribution rates. The combined effect is show in Figure 4.7. It shows that contribution rates are higher after the abolishment of an earnings test for low actuarial adjustment rates and decrease only for actuarial adjustment rates that are actuarially neutral (around 6.3%) or higher.

Figure 4.7: Contribution rates with and without earnings test



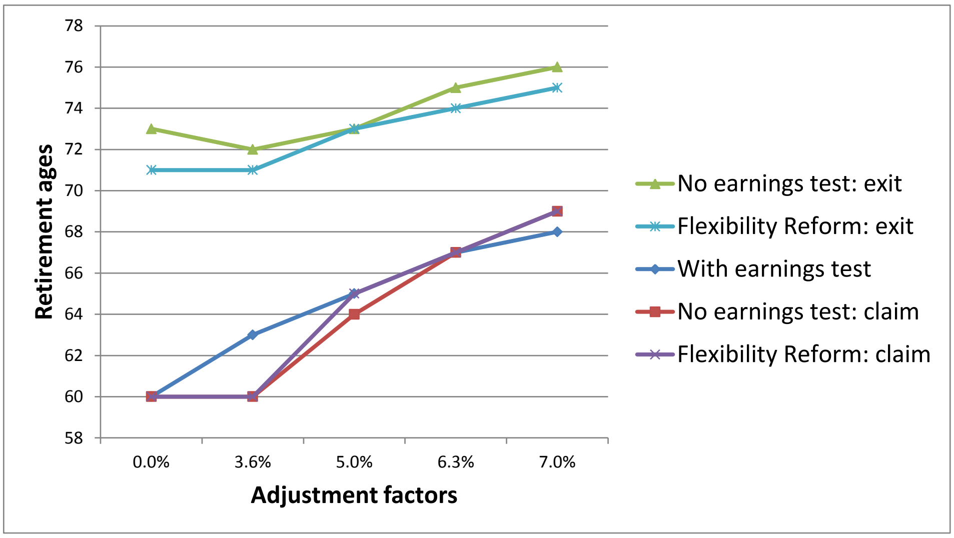
Source: own calculations.

4.4.2 Flexibility reform and partial retirement

Some recent "flexibility reforms" and "partial retirement" proposals entail a slightly modified scenario of how benefits are calculated when individuals keep working after having claimed pension benefits. Examples are the abolition of the earnings test in 2000 in the US (Social Security Administration, 2008) and the proposal for a "*Flexi-Rente*" announced by the German government (Bundesgesetzblatt, 2016). These reforms abolish the strict earnings test but depart from the scenario presented in the previous subsection by collecting pension points after claiming pensions which is not permitted in traditional systems without an earnings test. This modification allows individuals to increase their pension benefits after claiming. On the one hand, this creates even larger incentives to work longer since besides receiving wages individuals also receive higher pension benefits in the end – a double incentive. On the other hand, however, net wages are lower due to contributions to the pension system.

While the double incentive has an intuitive appeal to many policy makers, this subsection shows that these proposals have the same negative impact on claiming ages and sustainability of the pension system when they are applied to the existing public pension system with less than actuarially neutral adjustment factors. Figure 4.8 parallels Figure 4.5 and provides an overview of the results based on the same benchmark parameters as in the preceding subsection.

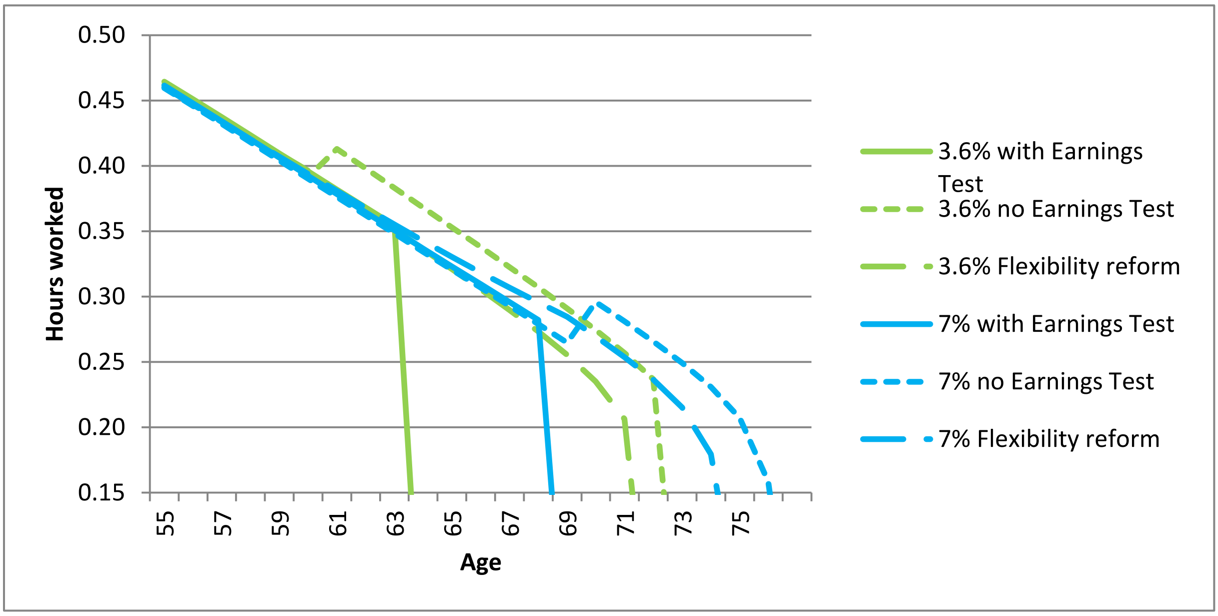
Figure 4.8: Retirement decisions under a flexibility reform



Source: own calculations.

The flexibility-reform in Figure 4.8 generates slightly later claiming ages but earlier labor force exit ages compared with the abolishment of the earnings test depicted in Figure 4.5. At the same time, individuals also work less intensively under a flexibility reform compared to the traditional scenario without an earnings test (Figure 4.9).

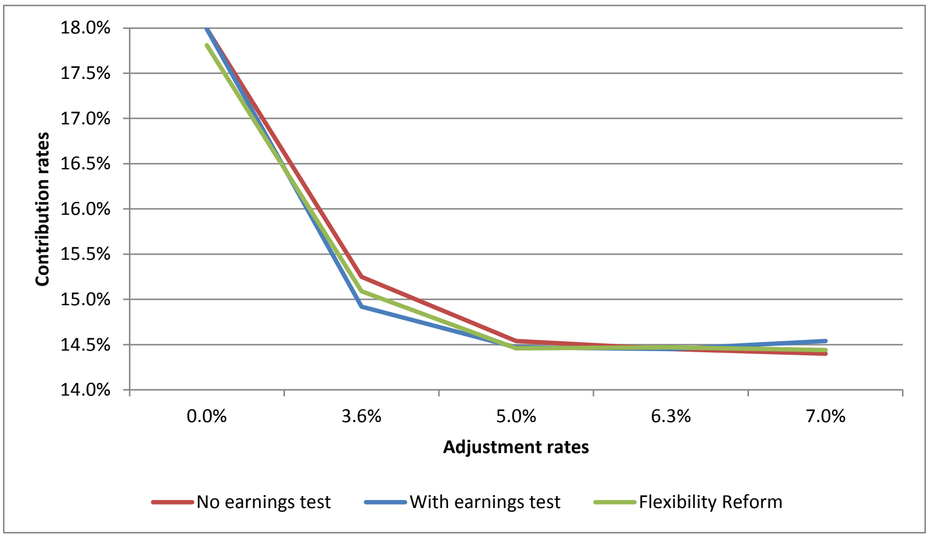
Figure 4.9: Labor supply under a flexibility reform



Source: own calculations.

The total effect on the pension system is shown in Figure 4.10 in terms of the contribution rate. It is in between the two cases shown in the preceding subsection (earnings test imposed and traditional scenario without an earnings test). The contribution rate is slightly lower after a flexibility reform than after simply abolishing an earnings test if the adjustment rates are lower than actuarially neutral. This poses incentives for earlier claiming in order to benefit from higher net wages after claiming. In turn, the higher total income (wages and pensions) changes the labor/leisure trade-off and makes workers leave the labor force earlier than in the straight no-earnings test scenario. The pension system faces two opposite effects. On the one hand, after claiming, workers can still contribute to the pension system through more contributions until later in life which increases receipts to the system. On the other hand, the pension claims of retirees will be higher which increases expenditures. If adjustment rates are actuarially neutral, there is no effect on the contribution rate. If they are higher than actuarially neutral, contributions rates are slightly higher than in the traditional scenario without an earnings test since the costs of the additional pension benefits outweigh the additional contributions.

Figure 4.10: Contribution rates under a flexibility reform



Source: own calculations.

In summary, keeping contributions active when working even after claiming benefits as part of a flexibility reform is less harmful in terms of the financial sustainability to the simple abolishment of an earnings test when adjustment rates are less than actuarially neutral – but the effect on the financial sustainability is still negative. As was the case for the simple abolishment of an earnings test, a flexibility reform is not a substitute for making adjustment rates actuarially neutral.

4.4.3 Sensitivity to alternative retirement mechanisms

This subsection investigates whether these harmful effects occur also under different assumptions about the aging process of which we have no good evidence. We simulate systematically all non-benchmark assumptions presented in Subsection 4.3.2 and show that they yield similar behavior of individuals when faced with the abolishment of an earnings test. Since the flexibility reform presented in the preceding subsection is an intermediate case, we only show the difference between the more extreme cases of Subsection 4.4.1.

We separate the sensitivity analyses into two sets of scenarios. The first set changes the assumptions on the evolution of productivity during the life-cycle under different fixed costs profiles, representing higher or lower effects of declining health on the disutility of work (Table 4.6). The second set examines different age-dependent preferences on consumption and leisure under different fixed costs profiles (Table 4.7). We start by comparing vertically the different productivity scenarios (see light grey boxes in Table 4.6, results displayed in Figure 4.11). We then compare scenarios horizontally (dark grey boxes in Table 4.6, results displayed in Figure 4.12). Finally, we compare vertically the different preference scenarios (see light grey boxes in Table 4.7, results displayed in Figure 13). The more extreme scenarios are relegated to Appendix A.

Table 4.6: Scenarios with different productivity profiles and fixed cost levels

Productivity	Time costs of working		
	Zero	**Moderate**	**High**
Flat	Appendix A	Figure 4.11	Appendix A
Moderate	see Figure 4.12	Benchmark in Section 4.4.1	Figure 4.12
Steep	Appendix A	Figure 4.11	Appendix A

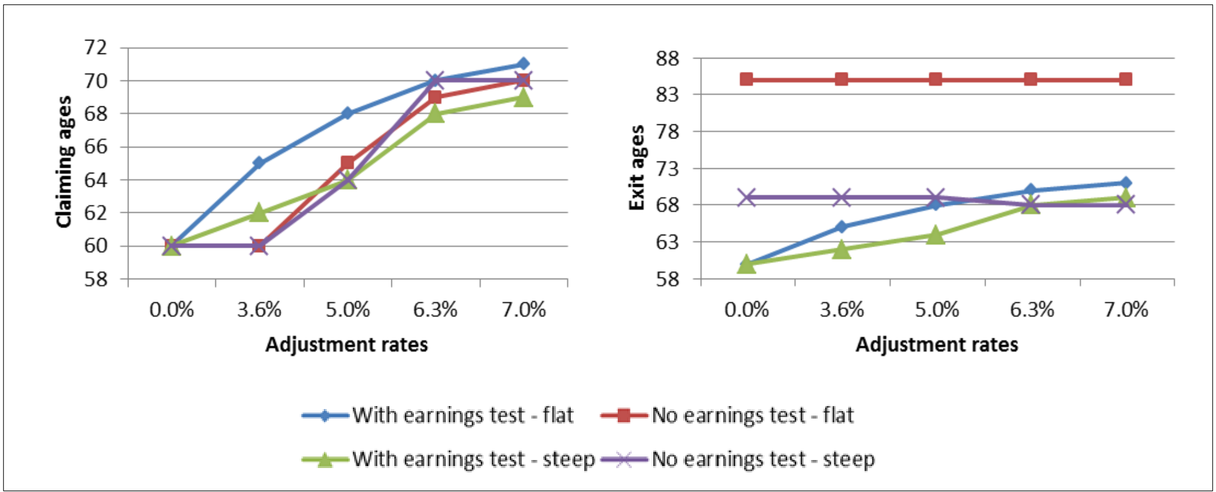
Table 4.7: Scenarios with different consumption preferences and fixed cost levels

Consumption preferences	Time costs of working		
	Zero	**Moderate**	**High**
Flat	Appendix A	Figure 4.13	Appendix A
Moderate	Figure 4.12	Benchmark in Section 4.4.1	Figure 4.12
Steep	Appendix A	Figure 4.13	Appendix A

The first set of sensitivity analyses addresses the different productivity profiles (flat and steep decline). As referred to in Subsection 4.3.2, different strands of literature show that productivity may present different shapes with age. Börsch-Supan & Weiss (2016) show that productivity tends to not decrease with age. This profile is presented as the flat productivity profile. The other two experiments refer to the estimated benchmark productivity profile and to an even steeper productivity profile ("steep decrease") where the decline on productivity is stronger after age 50 (Figure 4.3 in Subsection 4.3.2).

Figure 4.11 shows that the abolishment of an earnings test with less than actuarial neutral adjustment rates leads to large differences in claiming ages between scenarios with and without an earnings test. Under a flat or steep declining productivity profile and for low actuarial adjustment rates, the claiming age is always higher in the earnings test scenario than in the no earnings test scenario (except for actuarial adjustment rates of 0% since the incentives for very low values lead to the earliest possible claiming age).

Figure 4.11: Claiming and exit ages with and without earnings test (different productivity profiles)



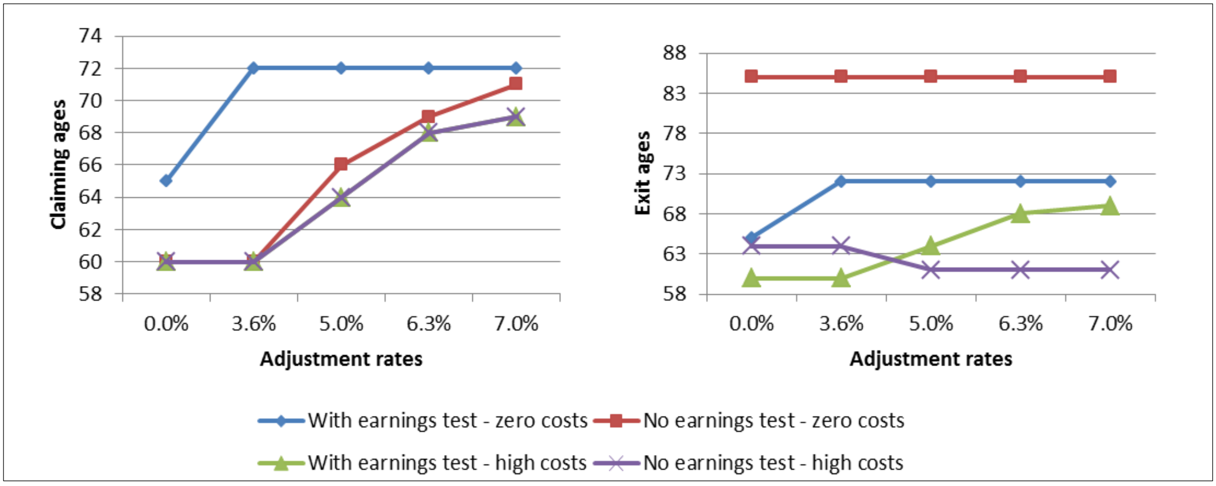
Source: own calculations.

These outcomes are in accordance with the benchmark scenario and support the claim that individuals tend to claim earlier under the no earnings test scenario when adjustment factors are not actuarially neutral. Only for very high actuarial adjustment rates, this pattern turns around and claiming ages in the no earnings test scenario are equal or higher than in the earnings test case. As can be seen in Figure 4.11, this happens in the steep scenario with actuarial adjustment rates of 5%. In the flat-productivity simulation, this intersection occurs only for very high actuarial adjustment rates. For the flat productivity profile, individuals exit the labor force very late in life because of the constant, high wages at older ages that incentivize individuals to work longer.

When analyzing the effect of different fixed cost profiles on the outcomes of the model

(Figure 4.2), we again obtain the same patterns as we did in the benchmark case. For fixed costs equal to zero ("zero costs"), the differences in claiming ages are large: individuals claim much earlier in the scenario without an earnings test. The intersection occurs, again, only for very high actuarial adjustment rates. In the case of high fixed costs ("high costs"), exit and claiming ages are identical.

Figure 4.12: Claiming and exit ages with and without earnings test (different fixed costs profiles)



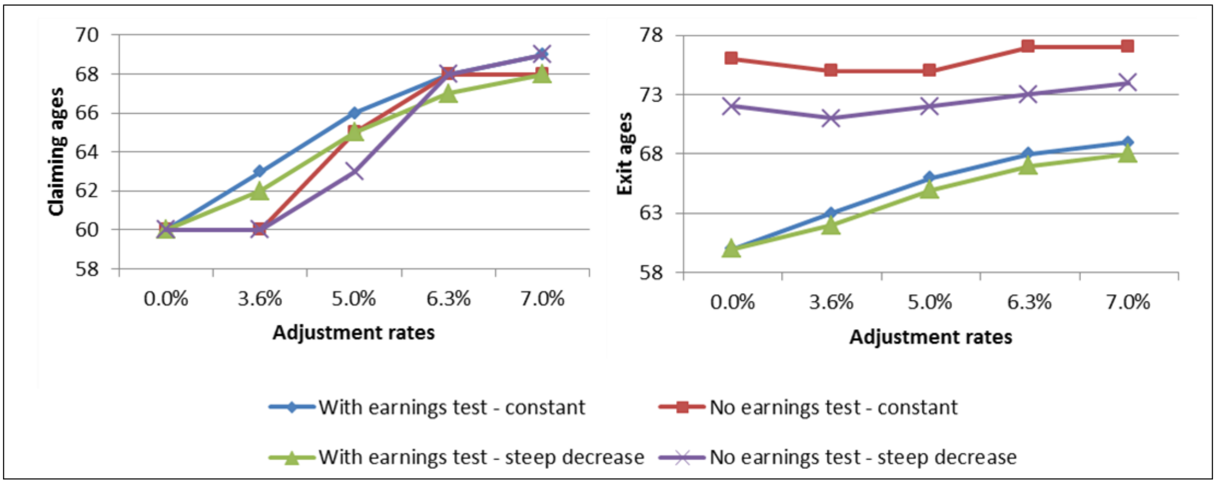
Source: own calculations.

Two main types of labor force exit behavior are observed when no earnings tests are imposed. While fixed costs of zero lead to very late exit ages, high fixed costs lead to early exit ages. For the highest fixed costs considered (62% of total available time), exit ages become substantially lower (age 61/64) because decreasing health conditions represented by the fixed costs of work force workers to exit the labor market much earlier. In some cases, workers even exit labor force before claiming their pensions. These individuals finance their retirement consumption temporarily with the savings which they have accumulated during their working lives.

Claiming ages in the earnings test scenario are quite sensitive to the fixed costs of working. This is not the case for claiming ages when no earnings tests are in place. Claiming ages remain relatively stable whereas the corresponding exit ages decline substantially. This can lead to some very particular cases where the claiming age after flexibilization is higher than the claiming age before flexibilization. However, this is a very specific situation which results from the higher sensitivity of individuals under an earnings test to fixed costs. This happens because individuals do not have as much degrees of freedom as they had when no earnings test was imposed. We conclude from this analysis that individuals released from the restriction of an earning test first prefer to reduce the number of years in the labor force and change their claiming age only when necessary.

We now turn to Figure 4.13 and the third alternative to model the aging process, namely different trajectories of how the relative preference for leisure versus consumption increases with age, modelled by a declining ϕ_j in the utility function (4.1). Fixed costs and productivity are set to the benchmark values, i.e. fixed costs are 41% of total available time and productivity is assumed to decline moderately after age 50. We compare the two extreme cases presented in Figure 4.4 of Subsection 4.3.2. The first case entails constant preferences during the life-cycle while the second case comprises a decrease that is steeper than in the benchmark case. As it was the case in our earlier sensitivity analyses, claiming ages decrease when abolishing an earnings test and the adjustment rates are not actuarially neutral. These results do not change qualitatively when different slopes of increasing leisure preferences are assumed. In the case of a steep decrease, the intersection takes place between actuarial adjustment rates of 5% and 6.3% (Figure 4.13). When preferences are flat, the intersection occurs for an actuarial adjustment rate of 6.3%. Exit ages are also affected by the abolishment of an earnings test, being considerably later than before, as it would be expected. Figure 4.13 shows that this effect is slightly larger when preferences are constant over the life course than with steeply increasing preferences for leisure, again in line with intuition.

Figure 4.13: Claiming and exit age decisions with and without earnings test (different consumption preferences)



Source: own calculations.

In summary, this subsection has shown that the patterns of outcomes and the main messages are preserved when more extreme assumptions about the process of aging and the mechanisms for retirement are assumed.

4.4.4 Sensitivity to other model parameters

As explained in Subsection 4.3.2, our calibration roughly targeted the actual average age of labor market exit in the large Continental European countries. In this section, we investigate how our results change if different preference and rate price parameters are chosen. We focus on the outcomes of retirement decisions for actuarial adjustment rates of 0%, 3.6%, and 7%.

The first part of the analyses assumes that households are less risk averse, namely $\theta = 1$ rather than $\theta = 2$. Individuals are less concerned about large income shocks and therefore save less. Results are shown in Table 4.8. Retirement ages under an earnings test are usually lower for all consumption preferences and actuarial adjustment rates. For values close to the actuarially neutral adjustment rate, the claiming age is equal or slightly higher than the retirement age under earnings tests. The predictions regarding the impact of the abolishment of an earnings test on individuals' behavior remain unchanged to the benchmark case.

Table 4.8: Sensitivity analysis for $\boldsymbol{\theta}$=1 and r=4% and ρ=2%

	Earnings test			No earnings test (Claim)			No earnings test (Exit)		
	Actuarial adjustment rate (ω)			Actuarial adjustment rate (ω)			Actuarial adjustment rate (ω)		
Utility weight of consumption ($\boldsymbol{\phi}$)	**0%**	**3.6%**	**7.0%**	**0%**	**3.6%**	**7.0%**	**0%**	**3.6%**	**7.0%**
Low (0.55)	60	60	69	60	66	69	66	62	59
Middle (0.60)	60	60	69	60	60	69	69	68	62
High (0.65)	60	61	69	60	60	72	71	71	70

Source: own calculations.

Table 4.9 shows the sensitivity to our assumptions regarding interest rates. A lower interest rate makes individuals work longer in order to compensate for the loss of interest income from their savings. They will therefore retire much later even when an earnings test is implemented. With a low non-actuarially neutral adjustment rate, an earnings test yields very early retirement. Abolishing the earnings test makes most individuals claim their pension earlier, but at the same time they leave the labor force later than in our main scenario in Subsection 4.4.1. These results might be interpreted as an indication of the younger generations' behavior if current low interest rates were to persist in the long run.

Table 4.9: Sensitivity analysis for θ=2 and r =3% and ρ=2%

	Earnings test			No earnings test (Claim)			No earnings test (Exit)		
	Actuarial adjustment rate (ω)			Actuarial adjustment rate (ω)			Actuarial adjustment rate (ω)		
Utility weight of consumption (ϕ)	**0%**	**3.6%**	**7.0%**	**0%**	**3.6%**	**7.0%**	**0%**	**3.6%**	**7.0%**
Low (0.55)	60	64	70	60	62	72	76	75	85
Middle (0.60)	60	66	71	60	62	72	85	85	85
High (0.65)	60	67	72	60	63	72	85	85	85

Source: own calculations.

For a higher interest rate, we can observe the same results (Table 4.10). The patterns observed in the benchmark case now occur already for lower actuarial adjustment rates. For instance, for initial values of consumption preferences of 0.6, abolishing an earnings test no longer leads to earlier claiming ages for an actuarial adjustment rate of 3.6%. This means that the actuarial adjustment rate which equates the claiming ages in the two types of pension systems is now lower than in the benchmark case.

The exit age is also slightly lower than in the benchmark case. This is due to higher returns on savings that can make up for lower number of years at work force.

Table 4.10: Sensitivity analysis for θ=2 and r =5% and ρ=2%

	Earnings test			No earnings test (Claim)			No earnings test (Exit)		
	Actuarial adjustment rate (ω)			Actuarial adjustment rate (ω)			Actuarial adjustment rate (ω)		
Utility weight of consumption (ϕ)	**0%**	**3.6%**	**7.0%**	**0%**	**3.6%**	**7.0%**	**0%**	**3.6%**	**7.0%**
Low (0.55)	60	60	67	60	60	67	66	65	63
Middle (0.60)	60	60	67	60	60	68	69	69	66
High (0.65)	60	62	67	60	60	68	60	60	67

Source: own calculations.

In summary, the central conclusions drawn in the benchmark case also hold if different preference and cost parameters are assumed. For lower than actuarially neutral adjustment rates, workers tend to claim their pension earlier rather than later when an earnings test is abolished, worsening the financial sustainability rather than improving it. Exit ages, however, will occur later in life, increasing total labor volume.

4.5 Conclusions

Increasing dependency ratios in aging societies pose a threat to the financial sustainability of pension systems. Policy makers have faced this challenge with several reforms. Among them, increasing the statutory eligibility age is effective but very unpopular. Alternative reforms, particularly if sold to the public under the label of increasing flexibility, are more popular. It is essential to understand how these measures affect labor supply and retirement behavior. These behavioral effects are complex since flexibilization drives a wedge between claiming pension benefits and exiting the labor force. In the best case, more labor supply creates additional resources to finance the pension system; in the worst case, however, such "flexibility reforms" do harm to the sustainability of pension systems because the added flexibility allows individuals to claim pension benefits earlier. It is thus crucial to take behavioral reactions into account.

In order to shed some light on this topic, we built a life-cycle model of saving and labor supply under a PAYG pension system that allowed us to study the incentive effects of a pension system on three distinctive decisions of workers: when to claim benefits, how many hours to work (intensive margin) and when to exit the labor force (extensive margin). Several key parameters shape these decisions, mainly institutional parameters such as the adjustment factors to the actual claiming age and the existence of an earnings test, and preference parameters such as the consumption/leisure trade-off, which may change with age.

Workers tend to exit early from the labor force when an earnings test is enforced. Lifting this restriction appears to be a good way to keep older workers in the labor force and make pension systems more sustainable. The key result of this chapter is that this aim is achieved if and only if adjustment factors are actuarially neutral. This result also holds when individuals who keep working after claiming benefits continue to contribute to the pension system with associated benefit increases. This is the case for some flexibility reforms which have actually been enacted, e.g. in Germany and the US. If pension benefits are not actuarially neutrally linked to the claiming age, abolishing an earnings test is indeed harmful to the financial sustainability of a pension system.

These conclusions are derived from a theoretical model. Like any model, one may criticize its underlying assumptions, specifications and parameter choices. We have performed a series of sensitivity analyses to ascertain that results are robust under different parameter choices and alternative specifications of the retirement mechanism. The results are also corroborated by the few empirical studies on recent flexibility reforms (Graf, et al., 2011; Huber, et al., 2016; Börsch-Supan, et al., 2015a; Börsch-Supan, et al., 2015c; Börsch-Supan, et al., 2018c). They also explain the results from the much larger empirical literature on the abolishment of the earnings tests in the

US, Canada and the UK.

Our predictions can intuitively be understood as follows. If there is no earnings test, the decisions of when to claim a pension and when to exit the labor force ages are detached. The decision to claim a pension is essentially driven by the adjustment factors which balance additional contributions to be paid by individuals with additional pension benefits later on. Low adjustment factors create incentives for workers to claim early. This incentive is strengthened once the earnings test has been abolished because individuals can now combine their pension benefit with additional wage income. Early claiming, however, means additional years of benefits that have to be financed by the pension system, threatening its sustainability.

The gap between claiming and labor force exit age shrinks with higher adjustment factors. If they are actuarially neutral, having or not having an earnings test will not influence the decision on claiming age but will provide higher labor supply until later in life. Only in this case, abolishing an earnings test meets the aim of policy makers to strengthen the financial sustainability of a pension system.

Abolishing an earnings test must therefore be carefully contemplated by policy makers. Understanding the interplay of the benefit computation with the claiming age is essential to avoid worsening the financial sustainability of pension systems. Flexibility per se is no substitute to fixing a pension system that creates early retirement incentives due to adjustment factors that are lower than actuarially neutral.

Permitting workers to keep contributing to the system in order to earn additional earnings points leads to less harm done to the pension system than simply abolishing the earnings test. The key condition for actually improving the financial sustainability, however, is again an actuarially neutral linkage between benefits and claiming age.

As always, models abstract from many aspects of real life. Hence, several caveats apply. Our model refers to the typical 1st pillar PAYG systems in Continental Europe. We therefore do not include in our model fully-funded 2nd and 3rd pillar pensions. Especially occupational pensions based on defined benefits create their own strong retirement incentives. They differ between professions and need to be accounted for in empirical work, see e.g. the studies in Gruber & Wise (2004). Many of their incentives are analogous to the effects described in this chapter.

Another issue is heterogeneity. Individuals may differ in their time preference and life expectancy, and thus react differently to the incentives created by homogenous adjustment factors and earnings tests. Examples are differences across cohorts and between women and men. Qualitatively, however, our results would remain.

As already mentioned, our modelling approach is based on fully rational individuals, abstracting from behavioral mechanisms such as those created by time inconsistent decision making. Such behavior would strengthen our key result of earlier claiming under low actuarial adjustments since time inconsistent individuals prefer receiving benefits as soon as possible.

Norms and anchoring mechanisms, in turn, will reduce the short-run elasticity with respect to law changes such as the abolishment of earnings tests. Norms or anchoring are therefore likely to weaken our results but will not influence the direction of our predicted effects.

5. Who cares about the day after tomorrow? Pension issues when households are time inconsistent

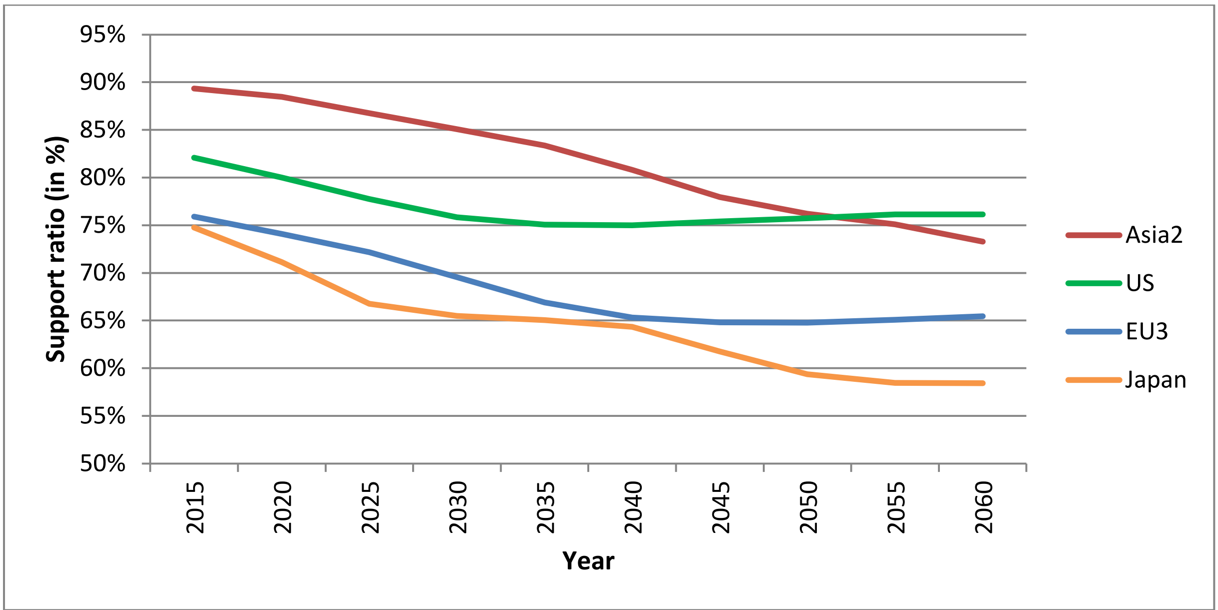
This chapter was written in co-authorship with Axel Börsch-Supan and Duarte Nuno Leite.

5.1 Introduction

The uncertain future of public and private pension systems is a topic of high priority and large controversy. The pressures on pension systems are particularly pronounced in Europe and Asia – in Europe, because the number of retirees per number of workers is already very high and still increasing until about 2050, and in Asia, because the speed of population aging is so fast. This strain will affect all types of pension systems, whether they are pay-as-you-go, fully-funded, defined benefit, or defined contribution, albeit to a different extent.

Figure 5.1 shows the demographic pressure, expressed by the support ratio – the number of working age individuals, defined as ages 15-64, divided by total population size – for the four countries/country groups which will be the focus of this chapter.

Figure 5.1: Support ratio in the US, EU and Asia



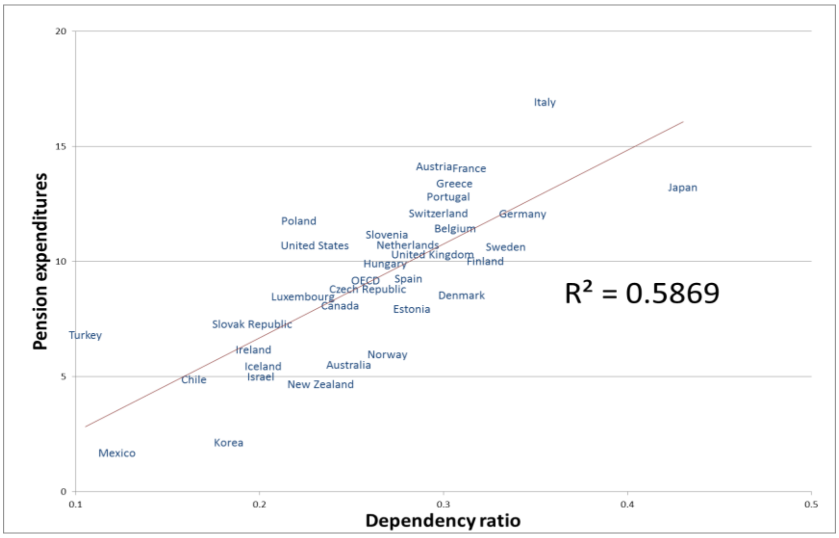
Source: EU3 and US: Human Mortality Database (2016). Japan and Asia2: United Nations (2012) Population Trends. Support ratio is population age 15-64 divided by total population size.

Japan features the most progressed aging process in the world and it has a large PAYG-financed public pension system. EU3 represents the three largest countries of Continental Europe – France, Germany and Italy. These countries have also substantially aged and have similarly large public

PAYG pension systems as Japan. In contrast, the US has a much smaller Social Security system and a much less pronounced population aging process. Finally, Asia2 denotes the two countries with the largest population in Asia, China and India, which have very small pension systems and are still young, but will face a very fast aging process in the future. After 2050, the Asia2 countries will actually have a lower support ratio than the US (as shown in Figure 5.1). These international differences in the demographic development have important economic implications as they may induce capital and labor movements between faster and slower aging countries (Brooks, 2003; Fehr, et al., 2003; Domeij & Floden, 2006; Attanasio, et al., 2007; Börsch-Supan, et al., 2006) which in turn have implications for national pension systems.

A large number of older individuals per working age population in a country exert pressures on the economy of a country since pension expenditures demand a high share of GDP. The alignment between the extent of population aging and pension expenditures, however, is far from perfect (Figure 5.2). Most European countries have pension expenditures significantly above the regression line (Italy, Austria, France, Poland), while most Asian countries have much smaller pension systems relative to their demographic status (Japan, Korea, Australia, New Zealand). This is mainly due to the many design differences between national pension systems. When studying the impact of population aging on pension expenditures, particularly in an internationally comparative context, it is therefore important to take account not only of international differences in demography but also these design differences.

Figure 5.2: Pension expenditures (percent of GDP) by old-age dependency ratio



Source: OECD (2015). Old-age dependency ratio is population age 65+ divided by population of age 15-64 (2013 data). Public and private pension expenditures are share of GDP (2012 data).

In order to do so, pension economics has traditionally employed formal models based on individuals in overlapping generations who think in a life-cycle context with perfect foresight, full information and in a time-consistent manner (Feldstein & Samwick, 1998; Auerbach & Kotlikoff, 1987). There is, however, a large body of evidence indicating that individuals fail to make decisions in a time-consistent manner, lack full information and are much more present-oriented than assumed in the perfect foresight life-cycle model. Opinions among citizens range from complete ignorance about how serious the challenges are to the equally faulty belief that pension systems are doomed to a complete failure (Boeri, et al., 2002; Boeri, et al., 2001; Walker, et al., 2014).

In many countries, one can also observe the widespread failure to provide sufficiently early and consistently for retirement income in the sense that such saving is sufficient to offset actual and future benefit cuts (Börsch-Supan et al. (2015b), Börsch-Supan et al. (2016a) for Germany; Knoef et al. (2016) for Netherlands, and Crawford & O'Dea, (2012) for the UK). In the US, such under-saving for retirement has received widespread attention (Poterba, et al., 2012; Repetto, et al., 1998; Madrian & Shea, 2001).

Individuals seem to realize these failures – but too late. Börsch-Supan et al. (2016b) conducted an Internet survey among individuals aged 60 and older. The results of the survey show a substantial prevalence of regret over previous saving decisions. 60% of the respondents wished that they had saved more when they were younger. High demand for commitment devices, even when they are costly, provides more evidence to this finding (Rabin, 2013a; Rabin, 2013b; Ashraf, et al., 2006; Beshears, et al., 2011).

In order to tackle this evidence, several strands in the literature emerged. A first strand enriches the neoclassical textbook model of time-consistent households by elements that justify the existence of a public pension system. Such elements include poverty alleviation and longevity risks (Börsch-Supan, et al., 2016b), income risks, market failures and information costs (Chan & Stevens, 2008; Bucher-Koenen & Lusardi, 2011; Lusardi & Mitchell, 2014; Lusardi & Mitchell, 2011; Lusardi, et al., 2017).

This chapter focusses on a second strand of research which more radically replaces the neoclassical paradigm with models of time-inconsistent behavior (Thaler, 1994; Laibson, 1998; Laibson, 1997; Angeletos, et al., 2001; Choi, et al., 2002; Rabin, 2013a; Rabin, 2013b; Della Vigna & Malmendier, 2006). There are several avenues to model imperfect household decisions, such as myopia, present bias and procrastination, each of which carries different implications for social insurance and population aging. These modeling approaches are by no means new (Strotz, 1956; Phelps & Pollak, 1968; Pollak, 1968; Thaler & Shefrin, 1981) but have only found widespread attention when they were applied to retirement saving in the US (Laibson, 1998; Laibson, 1997; Madrian & Shea, 2001).

This chapter is concerned with the implications of such time-inconsistent behavior for pension policy. Moreover, it adds the international context to the analysis. It constructs and calibrates– to our knowledge – the first multi-country model of procrastinating households (Section 5.2) in order to shed light on several aspects of pension economics and pension policy when the traditional assumptions do not hold. There are a handful of macroeconomic models with time-inconsistent agents in a one-country setting, and there are many models and papers about international capital flows and population aging, but the combination is novel and does deliver new insights, especially in the asymmetric cases: for some countries it is actually advantageous to deviate from the neoclassical path.[21] Our model is designed to shed light on the global interactions among three traits that characterize a country: the share of procrastinators, the speed and extent of population aging and the size of an existing PAYG-DB pension system.

We focus on three questions which are particularly relevant for the quickly aging Asian economies:

- What are the consequences of procrastination for pay-as-you-go, fully-funded pension systems and their relative weights in the typical mixed pension systems (Section 5.3)?
- Where will retirement savings be invested in a globally linked world with very different shares of procrastinating households and what does this mean for the national pension systems (Section 5.4)?
- How large are global spillover effects of pension reforms in one region for the other regions in the world (Section 5.5)?

Section 5.6 summarizes our main conclusions. The interaction effects of the share of procrastinators, especially in asymmetric situations in which one country group has a different share of procrastinators than another country group, with the size of the pension system and the speed and extent of the aging processes are complex and large, often yielding counterintuitive results. First, since the volume of savings for old-age provision is substantially lower in a world with many short-sighted households, interest rates are higher and wages lower. This increases contribution rates to PAYG-DB pension systems but nevertheless shifts the relative merits of mandatory PAYG-DB systems versus voluntary FF pension systems towards PAYG. Second, international capital flows are lower when households are procrastinating since they are saving less, but these effects are asymmetric and depend, in a complex and highly non-linear way, on

[21] Examples for one-country OLG-models with procrastinating households are Imrohoroglu et al. (2003) and Fehr et al. (2008). Models describing population aging and international capital flows are discussed in Subsection 5.2.2.

demography and pension systems. Third, parametric pension reforms in one part of the world will have global spillover effects. Changes in key labor market parameters, especially retirement age, in Europe would also improve the sustainability of pension systems and economic growth in Asia pointing to the important role of international policy coordination. This role becomes even more important when the extent of time-inconsistent behavior is different across countries.

5.2 Theoretical framework

Departure for our model is the insight stressed in the introduction that the effects of demographic change on pension systems, their design and individual saving behavior strongly interact in a global context. On the one hand, the provision of social insurance reduces risks for households which may be hard, or even impossible, to cover on an individual basis. On the other hand, it reduces the need for private savings to provide for old-age consumption and may thus reduce the level of productive capital in an economy. Population aging tends to sharpen this trade-off. International movements especially of capital, in turn, may alleviate the demographic pressures since retirement savings of households in quickly aging countries can be invested in countries with a more advantageous demography.

This section provides a model of how these trade-offs and alleviating mechanisms work under the assumption that households fail to plan ahead. Does this assumption fundamentally change how these trade-offs and alleviating mechanisms are affected by population aging versus the traditional model of perfect foresight and time-consistency? This section also sheds new light on some of the key controversies among economists interested in saving behavior and social insurance (see Section 3). Being the result of aggregate private savings decisions, capital flows are also strongly influenced by imperfect household decisions, which will be examined in Sections 5.3 and 5.4.

Subsection 5.2.1 describes household behavior. Subsection 5.2.2 will then embed this household module into a multi-country model of the four countries/regions (Japan, China & India, France & Germany & Italy, USA) introduced in Figure 5.1, characterized by very different demographic developments and different mixtures of PAYG and FF pension systems.

5.2.1 Household behavior

5.2.1.1 A generalized model of consumption, saving and labor supply

A first and very simple way to model the failure to plan ahead is to extend the neoclassical model by assuming that welfare evaluation is still following a time-consistent perfect-foresight program, although the actual decision function is subjected to individual short-sightedness. This will be the basic building block on households' behavior that will be later integrated into the general equilibrium model. Household i at time t receives utility from consumption $c_{t,j}$ and leisure $1 - h_{t,j}$, where $h_{t,j}$ is the time spent working. The most conventional specification is a per-period utility function given by

$$u(c_{t,j}, 1 - h_{t,j}) = \frac{1}{1-\theta}[c_{t,j}{}^{\phi}(1 - h_{t,j})^{1-\phi}]^{1-\theta}, \tag{5.1}$$

where risk aversion and intertemporal substitution are jointly described by the single parameter θ while ϕ denotes the utility weight of consumption versus leisure. The household solves a utility maximization program over the entire life-cycle, such that the maximization problem of a cohort born in period t at $j=0$ is given by

$$max\{u(c_{t,0}, 1 - h_{t,0}) + \delta \sum_{j=1}^{J} \beta^j \sigma_{t+j,j} u(c_{t+j,j}, 1 - h_{t+j,j})\}. \tag{5.2}$$

There are three different elements of discounting the future utility from consumption and leisure. First, β represents the pure time discount factor

$$\beta = 1/(1 + \rho). \tag{5.3}$$

Second, households discount future utility with their unconditional survival probability, $\sigma_{t,j}$, expressing the uncertainty about the time of death.

Third, the parameter $0 \leq \delta \leq 1$ defines the degree of short-sightedness or present bias. At one extreme, $\delta = 0$. In this case, the household is totally myopic and disregards all future utility. At the other extreme, $\delta = 1$, we are back to the neoclassical model of time-consistent behavior. In the intermediate cases, future utility is discounted more than exponentially relative to present utility.

Populations may not be homogenous in their degree of short-sightedness or present bias. In some applications, we will divide the population into two groups: γ is the share of households who have present bias ($\delta < 1$) while 1-γ of the population plans and behaves in a time-consistent manner.

We do not include intended bequests in our model and assume that accidental bequests resulting from premature death are taxed away by the government at a confiscatory rate and used for otherwise neutral government consumption.

Households earn an age-specific labor income $h_{t,j}w_{t,j}$ until retirement age R (where $w_{t,j}$ denotes the hourly wage) and may then receive a public pension, $p_{t,j}$, which is financed by a contribution proportional to the labor income at rate τ_t. Hence, current disposable non-asset income $y_{t,j}$ is

$$y_{t,j} = \lambda h_{t,j} w_{t,j}(1-\tau_t) + (1-\lambda) p_{t,j}, \tag{5.4}$$

where λ=1 for $j=0,\dots,R$ and λ=0 for $j \geq R+1$.

Denoting total assets by $a_{t,j}$, maximization of the household's intertemporal utility is subject to a dynamic budget constraint given by

$$a_{t+1,j+1} = a_{t,j}(1+r_t) + s_{t,j}, \tag{5.5}$$

where discretionary saving, $s_{t,j}$, is defined as

$$s_{t,j} = y_{t,j} - c_{t,j}. \tag{5.6}$$

5.2.1.2 Procrastinating households

Myopia ($\delta = 0$) in equation (5.2)) is an extreme assumption. A milder deviation from the perfect-foresight life-cycle model is self-control problems. The key assumption is that households plan according to the life-cycle model but then fail to execute their plan, e.g., by procrastinating the decision to set up and pay into a retirement savings account.

Procrastinating behavior is modeled as a continuing game between the current and future self, where the immediate future is discounted more strongly relative to the present than two equally distant events further in the future (Thaler & Shefrin, 1981). The model has three main features: (a) the addition of a present bias parameter δ which discounts the immediate future additionally to the standard discount factor β and mimics hyperbolic discounting, (b) the distinction between the present bias δ of the current self from the belief about the present bias of the future self, denoted by $\hat{\delta}$, and consequently, (c) the distinction between actual consumption behavior $c_{t,j}$ from beliefs about future consumption behavior $\hat{c}_{t+1,j+1}$. The notion of different "selves" with changing preferences allows us to model different features of individuals and how saving and consumption behavior changes due to these characteristics and the sequence of these "selves" with conflicting preferences and future beliefs. Since the behavior of these households moves away from the traditional assumptions, but still stems from such causes as monetary or psychic costs of decision making, we always refer to these households as time-inconsistent. In specifying future beliefs, according to O'Donoghue & Rabin (1999), it is possible to distinguish between "naïve" and "sophisticated" hyperbolic households. They only differ in their own perception of future preferences. While the naïve households believe that their future selves will behave in a time-consistent manner although they have consistently violated this belief in the past, i.e. $\hat{\delta} = 1$, the more sophisticated households correctly foresee that their future selves will also behave in a time-inconsistent way, i.e. $\hat{\delta} = \delta < 1$. Therefore, sophisticated households seek to overcome this misbehavior by constraining their future consumption. We therefore avoid terms such as “rational” and “irrational” behavior.

The current self at age *j* maximizes the objective function

$$max\{u(c_{t,j}) + \delta\beta\sigma_{t+1,j+1}\hat{V}(z_{t+1,j+1})\} \tag{5.7}$$

by choosing current consumption, $c_{t,j}$, subject to the budget constraint (equation (5.5)) and his beliefs $\hat{V}(z_{t+1,j+1})$ about the behavior of his future selves for the future state $z_{t+1,j+1}$. The value function $\hat{V}(z_{t,j})$ for future beliefs is computed recursively by

$$\hat{V}(z_{t,j}) = u(\hat{c}_{t,j}) + \beta\sigma_{t+1,j+1}\hat{V}(z_{t+1,j+1}). \tag{5.8}$$

Note that the present bias δ of the current self does not appear in the value computation. His future self who is at age *j* + 1 will maximize

$$max\ \{u(\hat{c}_{t+1,j+1}) + \hat{\delta}\beta\sigma_{t+2,j+2}\hat{V}(z_{t+2,j+2})\} \tag{5.9}$$

by choosing future consumption $\hat{c}_{t+1,j+1}$, where δ is replaced by $\hat{\delta}$ compared to (5.7). Finally, welfare is computed based on the actual behavior of households

$$\hat{V}(z_{t,j}) = u(c_{t,j}) + \beta\sigma_{t+1,j+1}\hat{V}(z_{t+1,j+1}). \tag{5.10}$$

Preferences are time-inconsistent because the present bias parameters δ and $\hat{\delta}$ appear in the decision problems (5.7) and (5.9) but not in the calculation of the value functions (5.8) and (5.10). Sophisticated hyperbolic consumers (where $\delta = \hat{\delta} < 1$) behave differently compared to time-consistent consumers (where $\delta = \hat{\delta} = 1$). For naïve hyperbolic consumers (where $\delta < \hat{\delta} = 1$), however, the decision rules and the respective value functions of current and future selves do not coincide (Fehr, et al., 2008; Imrohoroglu, et al., 2003).

Equations (5.7) to (5.10), jointly with equations (5.1) to (5.6), solve the household model and constitute the household module of the general equilibrium model presented in the next section. We first set $\delta = 1$ and apply the dynamic budget constraint (equation (5.5)), but do not impose a borrowing constraint. We then deviate from this neoclassical set-up and model households which are time-inconsistent due to present bias and procrastination as described in equations (5.7) through (5.10).

5.2.2 The international macroeconomic perspective

We now leave the microeconomic perspective and take the view of international macroeconomics. An important argument in favor of FF pension systems for countries with a strongly aging population is that the assets can be invested in countries which have a less pronounced aging process, while PAYG pension systems depend on the size and productivity of the domestic work force. Earlier research has demonstrated the beneficial effects of such international diversification (Reisen, 2000; Rios-Rull, 2001; Brooks, 2003; Attanasio, et al., 2007; Börsch-Supan & Ludwig, 2013; Börsch-Supan & Ludwig, 2010; Attanasio, et al., 2016; Börsch-Supan & Ludwig, 2009; Börsch-Supan, et al., 2006). This section investigates whether these results also hold when households are time-inconsistent. Specifically, we simulate the size of capital flows and welfare when the share of time-inconsistent households differs between the capital exporting and the capital importing countries. We employ several variants of CGE models with an OLG structure that permits a quantitative assessment of capital flows and their welfare implications.

We do not model frictions to the capital market and allow for free capital flows across countries. This assumption appears to contradict the seminal work by Feldstein & Horioka (1980) who found a strong positive correlation between a country's investments and savings (for OECD countries), which was interpreted by the literature as evidence for lower than perfect capital mobility between countries. Contradicting conventional wisdom about free international capital flows, Obstfeld & Rogoff (2000) called this finding "The Feldstein-Horioka Puzzle" and included it in their list of the six major puzzles in international macroeconomics. A large number of follow-up literatures tried to explain this observation. According to Coakley et al. (1998) and Apergis & Tsoumas (2009), the majority of studies in modern literature find theoretical or econometric explanations for this effect, implying that Feldstein and Horioka's puzzle does not collide with the free capital flow hypothesis. This chapter adds another explanation for relatively small international capital flows which is based on myopic behavior and/or procrastination.

The following subsections describe the multi-country macroeconomic model. It uses the building blocks from Subsection 5.2.1 and closes the model with a simple production sector. We then compute the general equilibrium for the four countries/country groups introduced in Figure 5.1 with three dimensions of international exchange: First, there is trade in the goods and services produced by each country. Second, there are corresponding capital flows between countries. Saving and investment decisions are governed by a common global interest rate which, via international capital flows, equalizes the return to capital across countries. Assets held by households in a country are therefore not necessarily equal to the domestic capital stock in that country, nor does saving necessarily equal investment in a single country. Third, there is migration which we will treat as exogenous such that the international equilibrium is uniquely defined by the world interest rate.

5.2.2.1 Demography

Demography is described by the initial size of each cohort and the survival of that cohort. In the notation below, we abstract from migration although in our simulations we add the historical average of net migration as a constant to population size. Let $N_{t,j}$ denote the number of individuals of age j at time t. They were born in year $c = t\text{-}j$ and are the survivors of the original birth cohort $N_{c,0}$:

$$N_{t,j} = N_{c,0}\sigma_{t,j}. \tag{5.11}$$

Here, $\sigma_{t,j}$ denotes the unconditional probability to survive until age j which will be in year t. The original cohort size for cohort c depends on the fertility of women aged k at time $c = t\text{-}j$:

$$N_{c,0} = \sum_{k=0}^{\infty} f_{c,k} N_{c,k} \ . \tag{5.12}$$

Population aging has therefore three demographic components which differ significantly across countries: past and future increases of longevity, expressed by $\sigma_{t,j}$; the historical transition from baby boom to baby bust expressed by past changes of $f_{c,k}$; and fertility below replacement in many countries expressed by current and future low levels of $f_{c,k}$.

We treat all three demographic forces as exogenous. The actual data are the medium variants of the long-term population forecasts provided by the Human Mortality Database (EU3 and US) and the 2012 UN Population Trends (Japan and Asia2). Households are the decision units. They enter economic life at an age which we denote by j=0 and have a finite life span defined by the high mortality at very old age. This generates the OLG structure of the CGE model which is essential for modeling pension issues.

5.2.2.2 Pension system

The next building block is the PAYG-DB pension system. Revenue in year t is the product of the contribution rate τ_t, the average labor income $h_{t,j}w_{t,j}$ and the number of workers NW_t defined as

$$NW_t = \sum_{j=0}^{R} N_{t,j}, \tag{5.13}$$

where R denotes the retirement age. Expenditure in year t is the product of the average pension benefit p_t and the number of pensioners NP_t, defined as

$$NP_t = \sum_{j=R+1}^{\infty} N_{t,j}. \tag{5.14}$$

This results in the PAYG budget equation

$$\tau_t w_t h_{t,j} NW_t = p_t NP_t. \tag{5.15}$$

The PAYG system is of the defined benefit type where a cohort of retirees is promised a pension benefit p_t defined by a replacement rate q_0 which relates pensions to the net wage but is independent from the demographic and macroeconomic environment

$$p_t = q_0 w_t (1 - \tau_t). \tag{5.16}$$

The contribution rate to the system must then be adjusted up or down to keep the PAYG-DB system balanced such that current workers cover the demographic risk for the benefit of the retirees

$$\tau_t = q_0 NP_t / (q_0 NP_t + h_{t,j} NW_t). \tag{5.17}$$

As described in the introduction, the size of the PAYG-DB pension systems is very different across the four countries/country groups. Table 5.1 shows this, expressed as the replacement rate q_0:

Table 5.1: Replacement rate of PAYG-DB pension systems

France	60%
Germany	60%
Italy	70%
Japan	60%
US	30%
China	10%
India	10%

The internal rate of return of a PAYG-DB pension system is calculated by setting the expected present discounted value of the life-time contributions paid by a cohort *c* equal to the expected present discounted value of the life-time pension benefits received by that cohort

$$\sum_{j=0}^{R} \tau_{c+j} w_{c+j} \sigma_{c+j,j} (1/(1+irr_c))^j = \sum_{j=R+1}^{\infty} p_{c+j} \sigma_{c+j,j} (1/(1+irr_c))^j \, . \qquad (5.18)$$

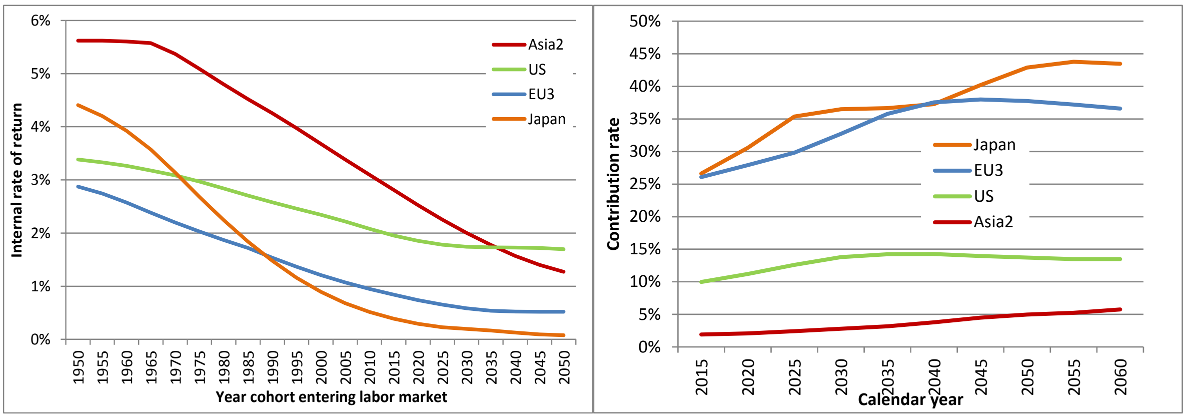
If wages grow at a constant rate g, if the relative number of workers grows at a constant rate n and if pensions are set according to the DB rule, equation (5.16), then the internal rate of return of the PAYG-DB system is roughly equal to the growth rate of the labor force n plus the growth rate of wages g experienced during the lifespan of this cohort

$$irr = g + n. \qquad (5.19)$$

Figure 5.3 shows the burden of the large PAYG-DB systems due to the aging process in two metrics, the internal rate of return and the equilibrium contribution rate. The large and negative growth rate of the labor force n in Japan is reflected in the fast decrease of the Japanese internal rate of return of the PAYG-DB system. It also decreases quickly in China and India, due to the rapid decline in their support ratios. The internal rate of return stabilizes in the EU3 countries for cohorts entering the labor market after about 2035. The internal rate of return in Japan becomes very low but increases for cohorts entering the labor market after about 2050. Contribution rates are plotted by calendar year and show similar trends. The levels, however, reflect the very different replacement rates of the pension systems (Table 5.1).

Figure 5.3: The impact of population aging on PAYG-DB pension systems

Internal rate of return | Contribution rate



Source: own calculations.

5.2.2.3 Production sector

The final building block which closes the CGE model is the production sector of country i. It consists of a representative firm that uses a Cobb-Douglas production function given by

$$Y_{t,i} = F\left(A_{t,i}, K_{t,i}, L_{t,i}\right) = K_{t,i}^{\alpha}(A_{t,i}L_{t,i})^{1-\alpha}, \quad (5.20)$$

where $K_{t,i}$ denotes the capital stock and $L_{t,i}$ is the aggregate labor volume in country *i* at time *t*. α denotes the capital share (set to 33%) and $A_{t,i}$ the technology level of country *i* which is assumed to grow at an exogenous rate g and is also assumed to be equal (1.5% p.a.) for all countries.[22] The initial technology levels $A_{t,i}$ are calibrated to reflect GDP per capita at the year 2005 and we use the US technology level as the benchmark, see Table 5.2:

Table 5.2: Initial technology levels (calibrated for 2005)

France	0.93
Germany	0.96
Italy	0.62
Japan	1.33
US	1.00
China	0.025
India	0.017

The firm's problem is static such that wages and the rate of return rates are given by

$$w_{t,i} = A_{t,i}(1-\alpha)k_t^{\alpha}, \quad (5.21)$$

$$r_t = \alpha k_t^{\alpha-1} - \Delta, \quad (5.22)$$

where k_t is the capital stock per productivity weighted unit of labor and Δ is the depreciation rate of productive capital, set to 5%.

5.2.2.4 General equilibrium

The solution of the CGE model is given by a set of equilibrium conditions. The outcome variables are sequences of disaggregate variables on the household level $\{c_{t,j,i}, h_{t,j,i}, a_{t,j,i}\}$, sequences of aggregate quantities $\{C_{t,i}, L_{t,i}, K_{t,i}\}$ and prices for labor $\{w_{t,i}, \tau_{t,i}\}$ on the country level, where the difference between the net and the gross wage is defined by the contribution rate to the pension system, and a sequence of interest rates $\{r_t\}$ on the global level. Given the initial capital stocks $K_{0,i}$ in each country, the general equilibrium of the world economy is obtained when households maximize their life-time utility subject to the constraints given by the two model variants, factor

[22] Börsch-Supan & Ludwig (2009) show the effect of different growth rates on returns. In this paper, we want to focus on the joint effects of demography and pension systems and therefore keep productivity growth fixed at a common level.

prices equal their marginal productivities, the PAYG-DB pension systems satisfy the balancing condition, and all markets clear in every country and every period

$$L_{t,i} = \sum_{j=0}^{J} h_{t,j,i} N_{t,j,i} \text{ for all } t,i\ , \tag{5.23}$$

$$\sum_{i=1}^{I} K_{t+1,i} = \sum_{i=1}^{I} \sum_{j=0}^{J} a_{t+1,j+1,i}\, N_{t,j,i}\ , \tag{5.24}$$

$$\sum_{i=1}^{I} \sum_{j=0}^{J} c_{t,j,i}\, N_{t,j,i} + \sum_{i=1}^{I} K_{t+1,i} = \sum_{i=1}^{I} K_{t,i}^{\alpha} (A_{t,i} L_{t,i})^{1-\alpha} - (1-\Delta) \sum_{i=1}^{I} K_{t,i}. \tag{5.25}$$

This CGE model has to be solved numerically. The algorithm searches for equilibrium paths of consumption, hours worked, capital to output ratios and, in case there are social security systems, pension contribution rates in each country. We determine the equilibrium path of the OLG model by using the modified Gauss-Seidel iteration as described in Ludwig (2007). The solution of the life-cycle optimization is solved recursively by taking initial guesses for consumption at last age. Then, the model is solved using recursive methods on first order conditions, taking into account the logic of time-inconsistent behavior described in Subsection 5.2.1, and appropriately handling the constraints of the model described above. This procedure delivers guesses for the vectors of consumption and hours worked. We then calculate savings and assets, applying the budget constraint (5.5). The consumption profile including consumption at last age is then updated. This procedure is repeated until consumption and the hours profile converge. Our time line has four periods: a phase-in period, a calibration period, a projection period, and a phase-out period. First, we start calculations 110 years before the calibration period begins with the assumption of an "artificial" initial steady state in 1850. The time period between 1960 and 2005 is then used as calibration period in order to determine the structural parameters of the model. Our projections run from 2015 until 2060.[23]

The life-span of the household is assumed to be 100 years. The household enters the labor market at age 15. The structural parameters of the household model are chosen with reference to other studies. Table 5.3 gives an overview.

[23] For technical reasons, the model then runs further during a transition to a steady-state population in 2150 and an additional 100-year period until the model reaches its final steady state in 2250.

Table 5.3: Parameter calibration

Parameter	Values
Discount rate (ρ)	0.01
Risk preference (θ)	2
Consumption preferences (ϕ)	0.6
Degree of present bias (δ)	0.7
Share of present biased households (γ)	[0%-100%]
Capital share in production (α)	0.33
Depreciation rate of capital (Δ)	0.05
Growth rate of labor productivity (g)	0.015

The discount rate ρ is set to 0.02 (see overview by Frederick et al. (2002)). The risk preference parameter θ is assumed to be 2 which makes the household slightly risk averse and lies in the middle of estimates in the literature (see overview by Bansal & Yaron (2004) and Browning et al. (1999)).

5.3 Implications of time inconsistency for pension systems

This section analyzes how standard insights of pension economics change when households are myopic or procrastinating rather than time-inconsistent. For analytical reasons, the setting is national but we point out how different pension system designs and demographic contexts affect our conclusions. Section 5.4 then introduces feedback effects in an international setting, in particular when the extent of time-inconsistency differs across countries.

5.3.1 Myopic households

It is insightful to begin with the extreme case of complete myopia in which households focus on current utility only and ignore future utility. They therefore do not anticipate retirement and do not save. Without a pension system, they would suffer from starvation once deteriorating health forces them to retire. A mandatory pension system, whether PAYG or FF, DB or DC, thus has large beneficial effects. As opposed to the life-cycle model, a mandatory pension system has no negative incentive effects in this model (e.g., crowding out and moral hazard) since these myopic households would not save under any circumstance. Population aging will increase the financial volume of the pension system but there are no policy implications to be drawn as preventing starvation is indispensable. This arguably extreme example shows that welfare and policy implications are radically different from the perfect-foresight case.

More realistically, different degrees of myopia prevail among households, and a more relevant question is not whether to have a mandatory pension system at all but whether a mandatory PAYG-DB system (such as the US Social Security system or the Bismarckian systems in Continental Europe and Japan) is preferable to a FF system of voluntary savings (such as IRAs and 401k plan in the US or the German Riester pension plans). Models with heterogeneous households are instructive in this case because they demonstrate the trade-off between social protection and economic efficiency. In order to keep things transparent, assume a population with two types of households: a fraction γ of households is myopic; the other households are time-consistent. While a PAYG-DB pension system is beneficial for the myopic households as argued above, this is different for the time-consistent households because they have to co-finance the pensions of the myopic households, which reduces their utility. Moreover, the PAYG-DB system will crowd out private saving which may earn a higher rate of return (Feldstein, 1985).

Whether a PAYG-DB pension system is preferable to a FF system for society as a whole therefore depends on γ and the difference between the market interest rate *r* and the internal rate of return, *irr,* which are, in turn, functions of the extent of population aging (Figure 5.3). If the share of myopic households is large, a mandatory PAYG-DB system is always beneficial, even for quickly aging countries with very low internal rates of return. The opposite is the case for a large share of time-consistent households and a mild aging process.[24]

5.3.2 Procrastinating households

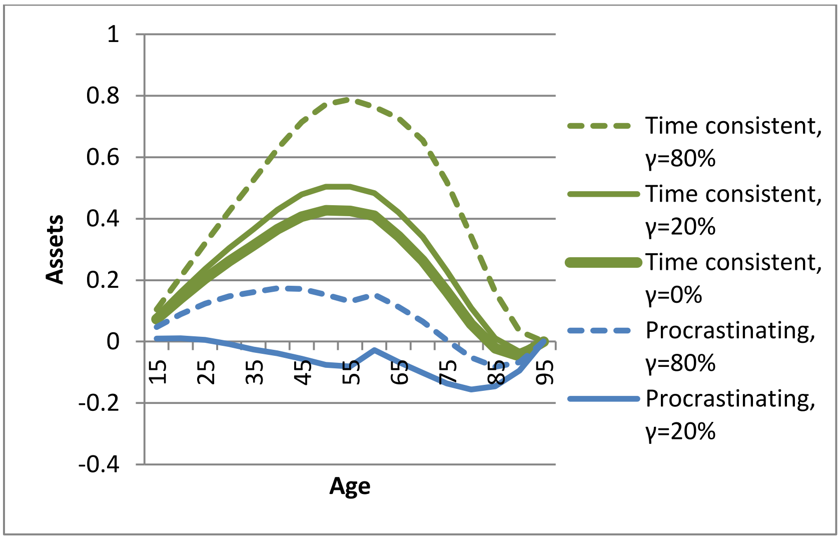
The case is more complex in a general equilibrium model with a share, γ, of procrastinating households. As is well known, these households exhibit overconsumption in the beginning of their life-cycle relative to time-consistent households at the expense of lower consumption later in life and therefore save much less than time-consistent households. They also have a more tilted life-course trajectory of labor supply than time-consistent households. Depending on the share of procrastinating households, γ, both behaviors change the general equilibrium outcome of interest rates and wages (with repercussions on individual behavior) relative to the traditional case. This in turn affects the contribution rate and the internal rate of return of a PAYG-DB pension system as well as the accumulated assets in a FF system. Finally, the relative advantage of a PAYG-DB versus a FF pension system depends on the share of procrastinating households.

As a starting point, Figure 5.4 depicts the trajectory of accumulated assets for different shares of procrastinating households, γ. It shows the familiar result that procrastinating households save less

[24] Börsch-Supan et al. (2016b) provide a formal treatment.

than time-consistent households (blue lines vs. green lines).[25] More importantly, this figure also shows that both types of households save more with a higher share of procrastinating households. This effect is substantial and shows how important it is to model general equilibrium effects.

Figure 5.4: Life-cycle asset holdings – different shares of procrastinating households

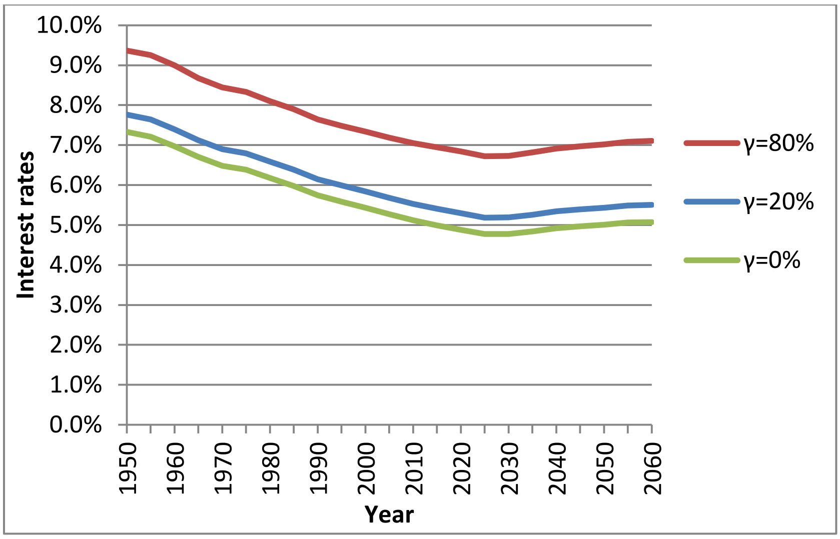


Source: own calculations. This graph refers to the US. Results for the other countries are qualitatively similar.

Lower savings lead in equilibrium to a lower capital stock and, consequently, to a higher rate of return to productive capital, *r*. This is shown below in Figure 5.5. For an 80% share of procrastinating households interest rates are higher by about 2 percentage points in comparison to an economy with time-consistent households. The difference depends on two parameters, the extent of overconsumption by procrastinating households, δ, which we keep fixed at 0.7, see Table 5.3, and the share of procrastinating households, γ. Two observations are important. On the one hand, the difference between an economy with 80% procrastinating households and the traditional case is quantitatively large. On the other hand, population aging affects the return to productive capital similarly in all three cases depicted in Figure 5.5. Notably, there is no "asset meltdown" in the sense that returns become negative due to population aging (Poterba, 2001; Rios-Rull, 2001).

[25] Especially procrastinating households borrow against future income. We decided not to impose a borrowing constraint because it complicates the numerical solution which is impractical for the large number of scenarios computed in this paper. For the baseline scenario, imposing a borrowing constraint does not change the results on capital flows, hours worked, consumption and welfare in a substantive way.

Figure 5.5: Rate of return to productive capital



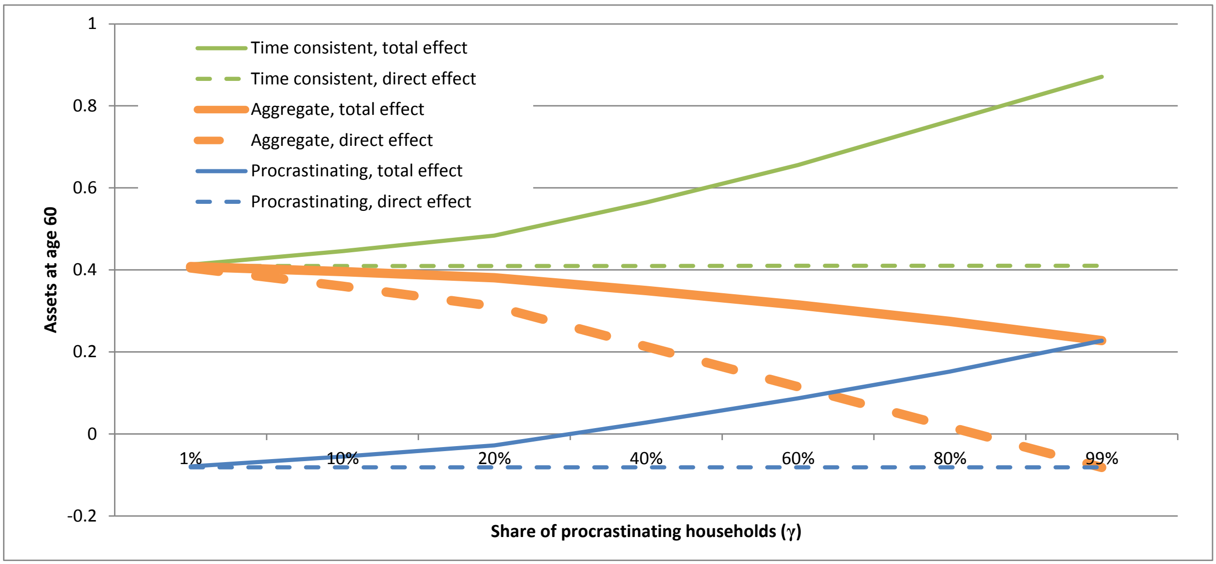
Source: own calculations.

The general equilibrium effect of higher interest rates with a higher share of procrastinating households does not offset the direct effect of lower saving behavior. This is shown in Figure 5.6 which depicts assets holdings at old age (age 60) for an increasing share of procrastinating households as we go from the left to right, distinguishing between time-consistent households, procrastinating households and the average household in this economy (weighted by the shares of time-consistent and procrastinating households). It also distinguishes between the partial equilibrium (direct) and the general equilibrium (total) effects.

The partial equilibrium effect is the direct behavioral effect and abstracts from feedback effects on interest rates and wages by holding them constant between the scenarios in Figure 5.6. It is independent from the share of procrastinating households in the economy. Time-consistent households have accumulated higher savings at the time before retirement than their procrastinating counterparts.

The total effect includes all direct and feedback effects modeled in our general equilibrium setting. Savings at old age are substantially higher in the general equilibrium setting due to the higher interest rates which incentivize savings in our model. This effect becomes stronger for a higher share of procrastinating households because the interest rate effect is not linear. In addition, time-consistent households profit more from the total effect than procrastinating households. This is due to higher savings of the former compared to overconsumption and undersaving of the latter. In the aggregate (thick lines; measuring total assets as weighted mean of assets held by time-consistent and procrastinating households), the interest effect compensates about two thirds of the direct effect. This is an important result if one wishes to base a part or even the entire pension system on voluntary savings.

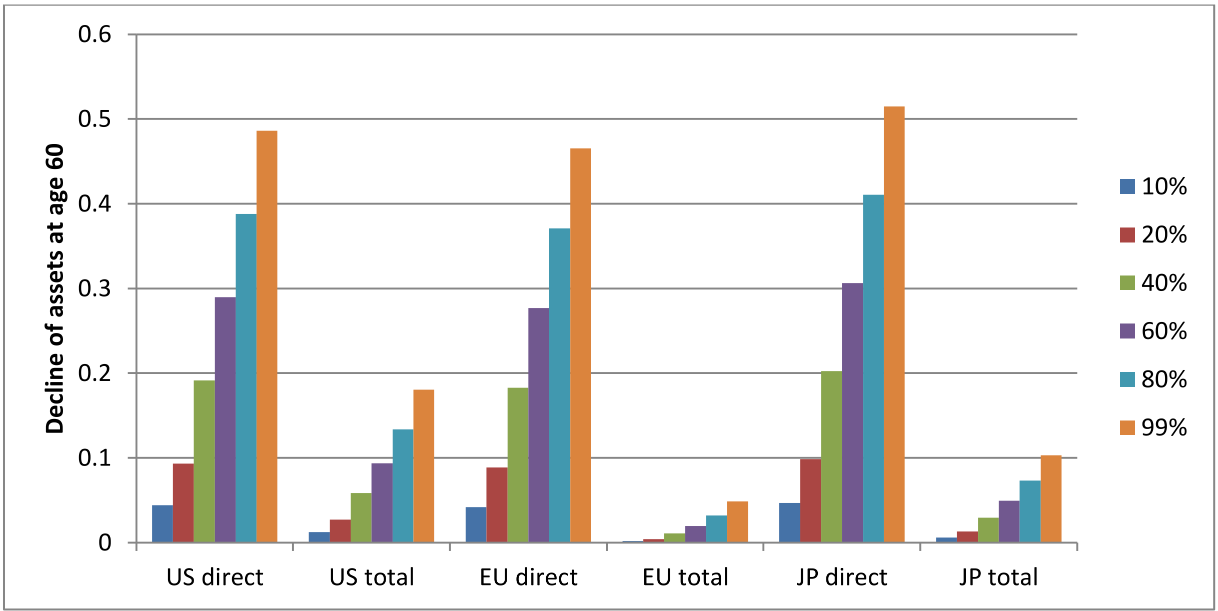
Figure 5.6: Economy-wide accumulated assets



Source: own calculations. This graph refers to the US. Results for the other countries are qualitatively similar.

Figures 5.4 and 5.6 represent the US case; the other countries/country groups show qualitatively similar patterns. The relative size of the direct and the general equilibrium effects, however, are quite different. This is summarized in Figure 5.7.

Figure 5.7: Decline of economy-wide assets with higher share of procrastinating households



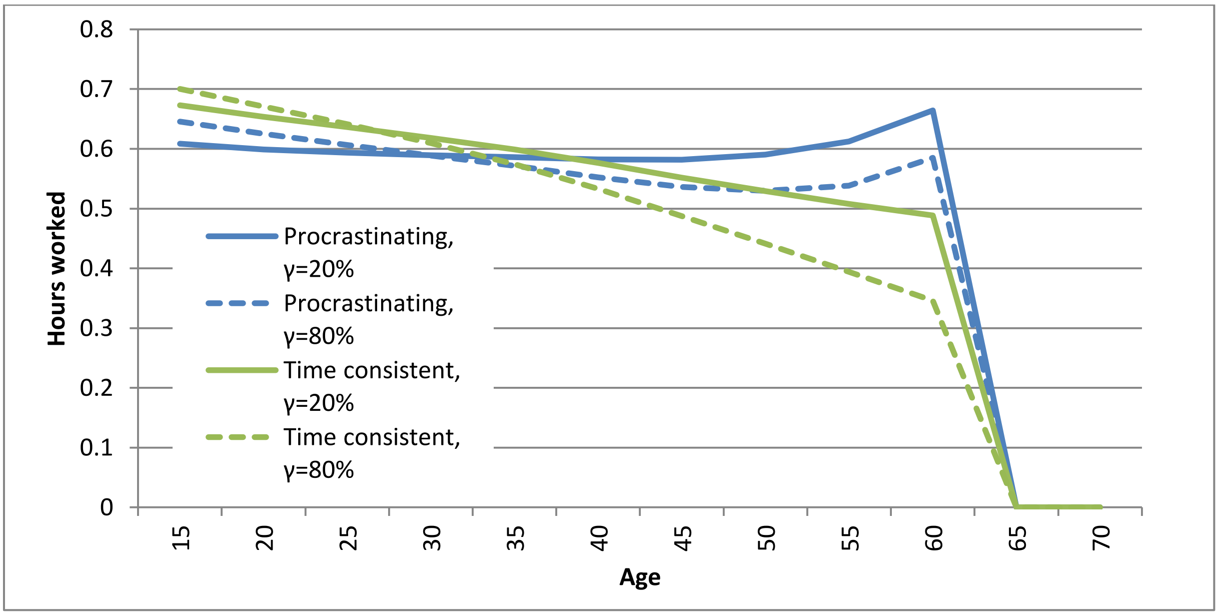
Source: own calculations.

The general equilibrium effects, mainly working through the interest rate channel, generate total effects which are much larger in Japan and the EU. This reflects the further progression of aging and the larger size of the PAYG-DB systems in Japan and the EU which lead to lower levels of aggregate saving and higher interest rates.

Procrastinating households also exhibit a very different labor supply behavior than their time-consistent counterparts (Figure 5.8). They supply fewer hours of work when they are young but more than compensate this when they are older. This overcompensation can be seen by comparing the areas between the blue and the green hours' profiles of time-consistent and procrastinating households. This relative difference between time-consistent and procrastinating households holds for both scenarios (high and low share of procrastinating households, indicated by the dashed and solid lines) and corresponds to the direct (or partial equilibrium) effect that is generated by the different labor supply behaviors.

In addition, however, there are again strong general equilibrium effects. They are reflected in the difference between the solid and the dashed lines in Figure 5.8. Even though procrastinating households work more during their lifetime than their time-consistent counterparts, total average labour supply decreases. This stems from the fact that savings and, accordingly, the capital stock are lower in an economy with a higher share of procrastinating households. Consequently, labor is less productive.

Figure 5.8: Labor supply over the life-cycle

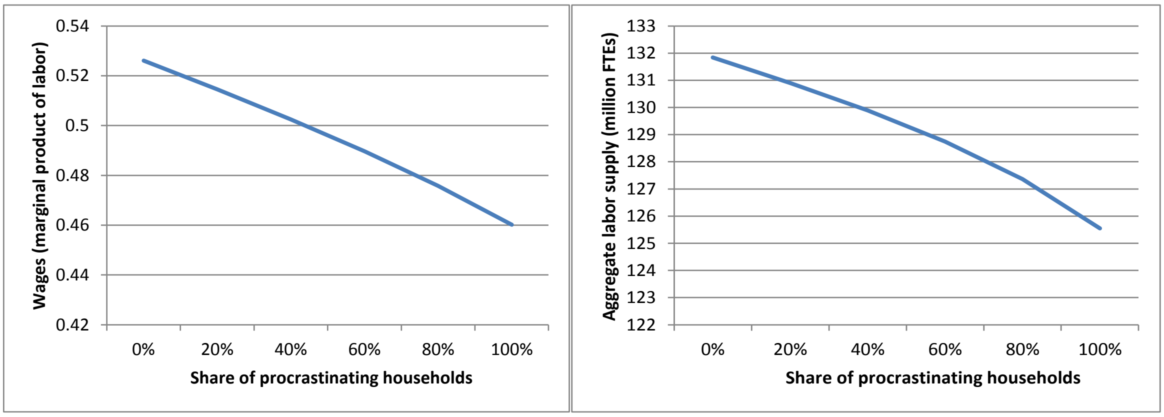


Source: own calculations. This graph refers to the US. Results for the other countries are qualitatively similar.

This translates in lower wages (Figure 5.9, left panel) which have negative incentive effects on households' labor supply and thus drive total labor supply in the economy down (Figure 5.9, right panel).

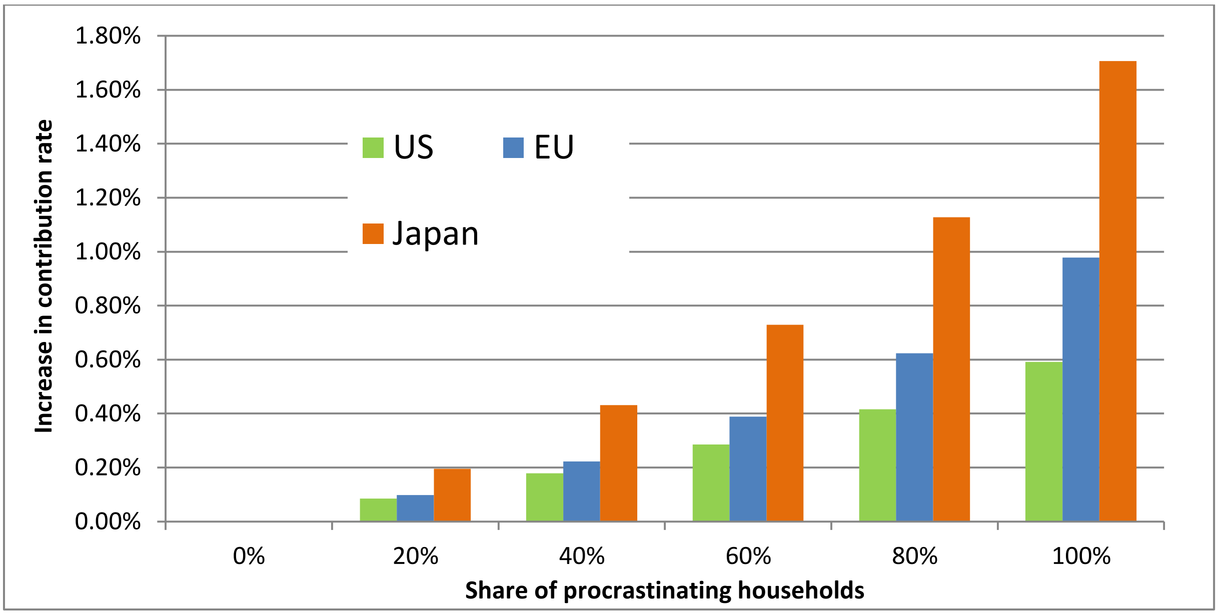
Figure 5.9: Wages and aggregate labor supply for different shares of procrastinating households

Wages (marginal product of labor) Aggregate labor supply (million FTEs)



Source: own calculations. This graph refers to the US. Results for the other countries are qualitatively similar.

Figure 5.10: Increase in contribution rate to PAYG-DB pension system as a function of the share of procrastinating households



Source: own calculations.

Since an economy with more procrastinating households provides less hours of work, they also contribute less to a PAYG-DB pension system and contributions must rise in order to balance the pension system according to equation (5.17). Figure 5.10 depicts the increase in the contribution rate relative to an economy with time-consistent households. This increase is not identical across countries. This is due to the size of the pension system and their corresponding level of contribution rates which in turn reflects the different replacement rates and the different aging processes in these three countries. For Japan and the EU with a very high level of contribution rates, the effect of higher shares of procrastinating households is much stronger than in the US because labor supply is already reduced in Japan and the EU due to their high contribution rates.

Finally, the extent of present bias in an economy with procrastinating households changes the weights in the perennial debate whether a mandatory PAYG-DB or a voluntary FF pension system based on private savings provides higher welfare. As already pointed out in Subsection 5.3.1, totally myopic households benefit from a mandatory PAYG-DB system because they would starve at old age due to their lack of savings in a voluntary FF system. This argument also holds in an economy with procrastinating households, although in a more subtle way. Figure 5.11 presents the threshold internal rates of return for which households with a specific type have higher welfare under a PAYG-DB system than under a voluntary FF system. Household types are time-consistent, sophisticated procrastinators and naïve procrastinators, each distinguished by their extent of present bias, δ, according to equation (5.2). Welfare is measured as the consumption-equivalent variation relative to a situation in which a PAYG-DB system delivers an internal rate of return of 3%.

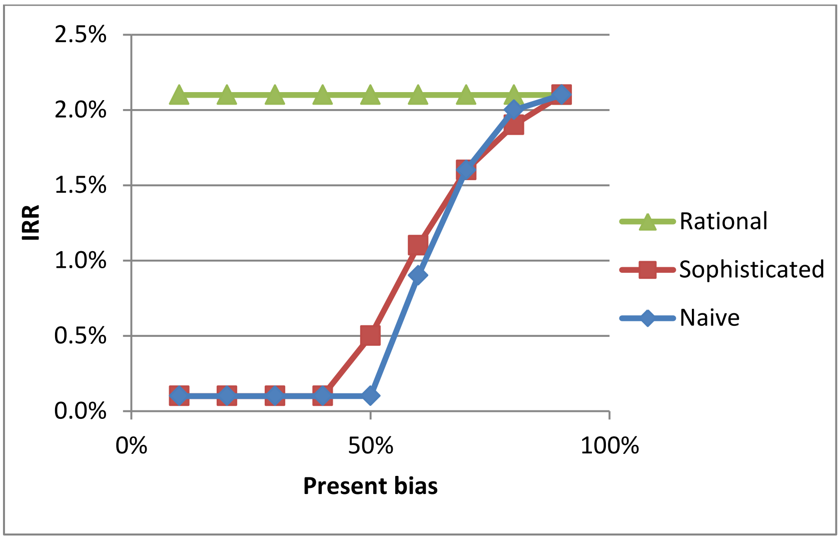
Time-consistent households would be better off in a mandatory PAYG-DB system only if this system were to deliver an internal rate of return of at least 2.1%.[26] Procrastinating households save less and suffer from substantially lower consumption in old age. They are therefore better off in a mandated PAYG-DB system even if this system delivers much lower internal rates of return than in a voluntary FF system. One may identify this difference with the value of the mandatory PAYG-DB system as a commitment device.[27] Sophisticated procrastinators tend to require higher internal rates of return because they are less time-inconsistent than naïve procrastinators. For lower degrees of present bias, sophisticated and naive procrastinators have similar internal rates of

[26] The difference to 3% is explained by the insurance against longevity included in a mandatory PAYG-DB system as opposed to voluntary savings in an IRA or 401k plan, cf. Börsch-Supan et al. (2016b).

[27] A mandatory FF system with mandatory annuitization would provide an even higher welfare if it could be introduced without transition costs. This, however, is an unrealistic option in countries with an already established PAYG system such as the US, Japan and the large Continental European countries.

return thresholds because the behavior of both types tends to become similar when the present bias is low.

Figure 5.11: Relative advantage of PAYG vs FF



Source: own calculations.

5.4 International diversification and its implications

The accumulated assets characterized in the previous section are invested internationally. This section models how these retirement savings are distributed across the four countries/country groups introduced in Figure 5.1 in the course of population aging, how this changes with the share of procrastinating households, and how this affects pension systems, consumption per capita and the welfare of cohorts. As we will see, the effects are particularly strong and interesting when the share of time-inconsistent households is different across countries. This may reflect less international differences in short-sightedness than difference in traditions, rules and institutions which provide commitment devices that lead to more time-consistent behavior. We therefore do not take the share of procrastinators in an economy and their short-sightedness strictly literally; it may as well describe the dearth of commitment devices which force or nudge individuals in a behavior resembling perfect foresight.

As described in Subsection 5.2.2, saving and investment decisions are governed by a common global interest rate which, via international capital flows, equalizes the return to capital across countries. Assets held by households in a country are therefore not necessarily equal to the domestic capital stock in that country, nor does saving necessarily equal investment in a single country. The net position of country i at time t is calculated as

$$NP_{t,i} = \sum_{j=1}^{\infty} a_{j,t,i} - K_{t,i}, \quad (5.26)$$

where $a_{j,t,i}$ denotes assets owned by households in country i which are invested in country j at time t and $K_{t,i}$ is the domestic capital stock. Net international capital flows from a country to all other countries are computed as the change in a country's net position which equals the difference between saving and investment

$$ncf_{t,i} = NP_{t,i} - NP_{t-1,i} = SAV_{t,i} - INV_{t,i},$$

$$\text{where } SAV_{t,i} = \sum_{j=1}^{\infty} a_{j,t,i} - \sum_{j=1}^{\infty} a_{j,t-1,i} \text{ and } INV_{t,i} = K_{t,i} - K_{t-1,i}\,. \quad (5.27)$$

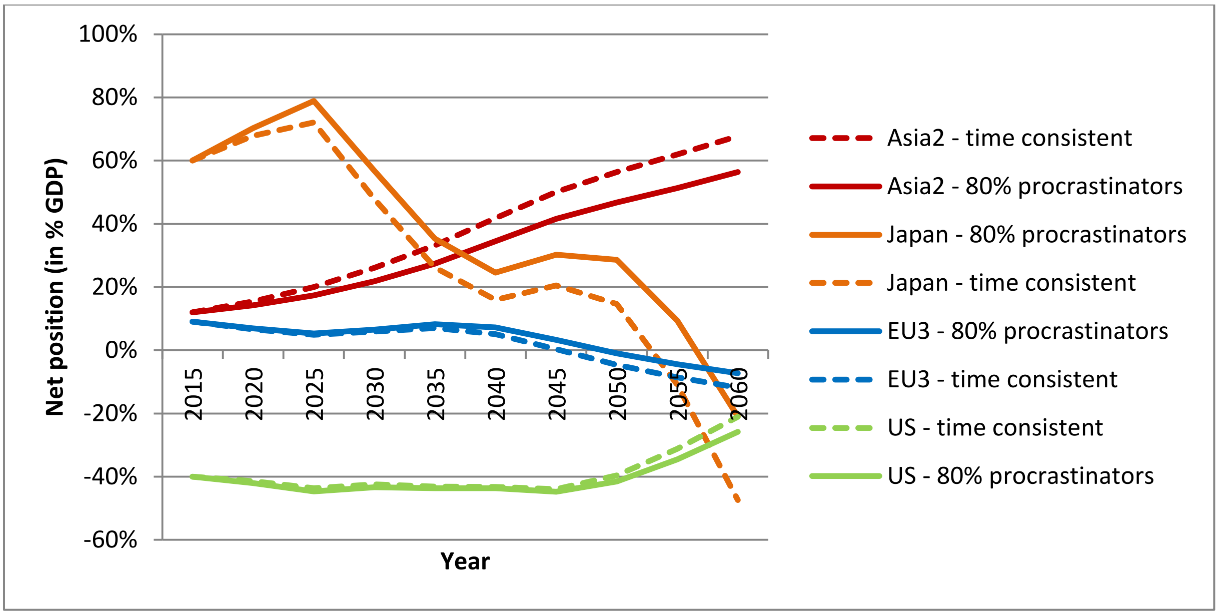
Our model thus does not explain gross flows from one country into another country and therefore also not the portfolio shares of gross foreign direct investments or what is commonly referred to as foreign direct investments.

5.4.1 International diversification when all countries have the same share of procrastinators

Figure 5.12 depicts the net position of the four countries/country groups and how they change in the course of population aging. In addition, Figure 5.12 shows the difference between the assumption that these four economies consist of time-consistent households (solid lines) and the assumption that 80% of the households in these four economies are procrastinators with a present bias parameter δ = 0.7 (dashed lines).

Japan has large capital outflows which will increase its net position to a first peak around 2025. With the retirement of the early baby boomers, some of that capital is repatriated; hence, Japan's net position will decline until the savings of the secondary baby boom are invested abroad, slightly increasing Japan's net position again. When also these savings will be repatriated, Japan's net position will strongly decline and even become negative. The EU3 countries have a later baby boom and thus a later repatriation phase. They also start from a much lower level of outflows. China and India follow a path of steadily increasing investments abroad, while the US with its large GDP receives the foreign investments. This role is strongly declining in the period after 2045 when Europe and Japan repatriate their assets.

Figure 5.12: Net position

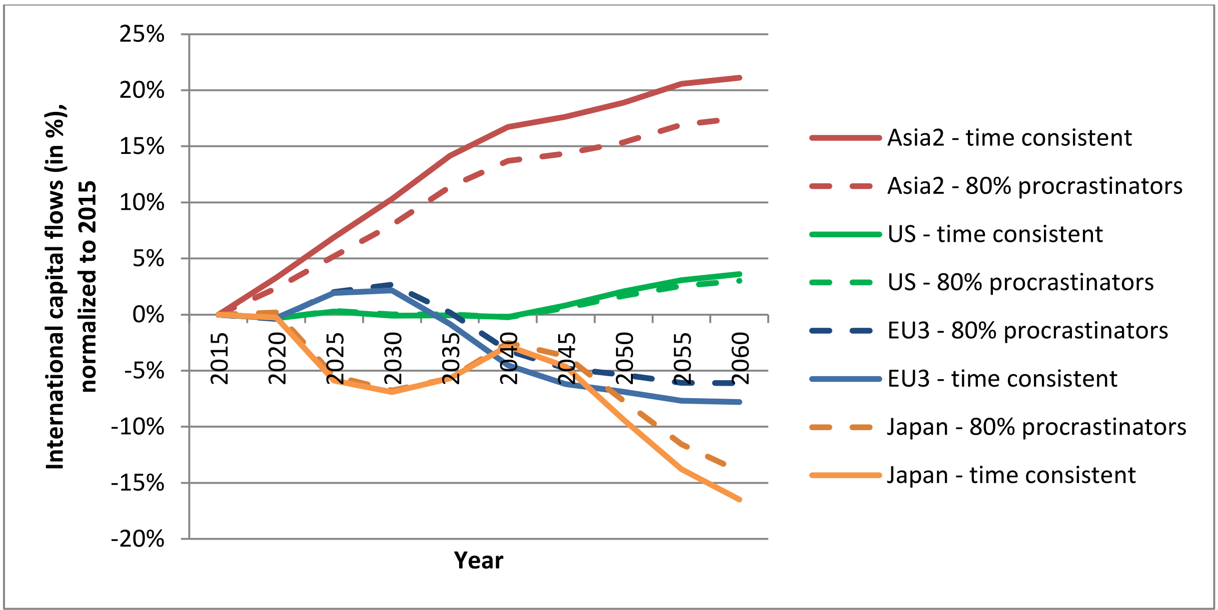


Source: own calculations.

This pattern is qualitatively similar under both behavioral assumptions, time-consistency and procrastination. However, the direction and the extent of the differences between the two behavioral assumptions vary strongly across countries/country groups. Japan and the EU3 countries actually strengthen their net position when more households are procrastinators, while the net position of China and India will weaken. The reason is the interaction with the PAYG-DB pension systems. First, since procrastinating households save substantially less, international capital flows are generally smaller than in the situation with time-consistent households, see Figure 5.13[28]. Both outflows and inflows will increase less as population aging advances. In this figure, all capital flows are normalized to begin with zero in 2015 in order to isolate the difference between time-consistent and procrastinating households regarding the effect of population aging on capital flows. This normalization removes the differences in the levels of the net positions between the model with time-consistent households and the model with procrastinating households. The large Asian countries will experience ever growing outflows in the time range presented while the US has more inflows of capital and will only face growing outflows later on when it starts to age more quickly than currently. EU and Japan exhibit the same wide swings which we have already seen in Figure 5.12 reflecting the aging of the primary and secondary baby booms.

[28] An exception is EU3 between 2020 and 2035 due to the accelerating aging process.

Figure 5.13: International capital flows, normalized to 2015=0%



Source: own calculations.

5.4.2 International diversification with asymmetric shares of procrastinating households

Some of these effects become much larger when the share of procrastinating households is asymmetric across countries. In addition to the two symmetric scenarios,

(a) all households in all countries are time-consistent, and

(b) in all countries, 80% of households procrastinate with a present bias parameter $\delta = 0.7$,

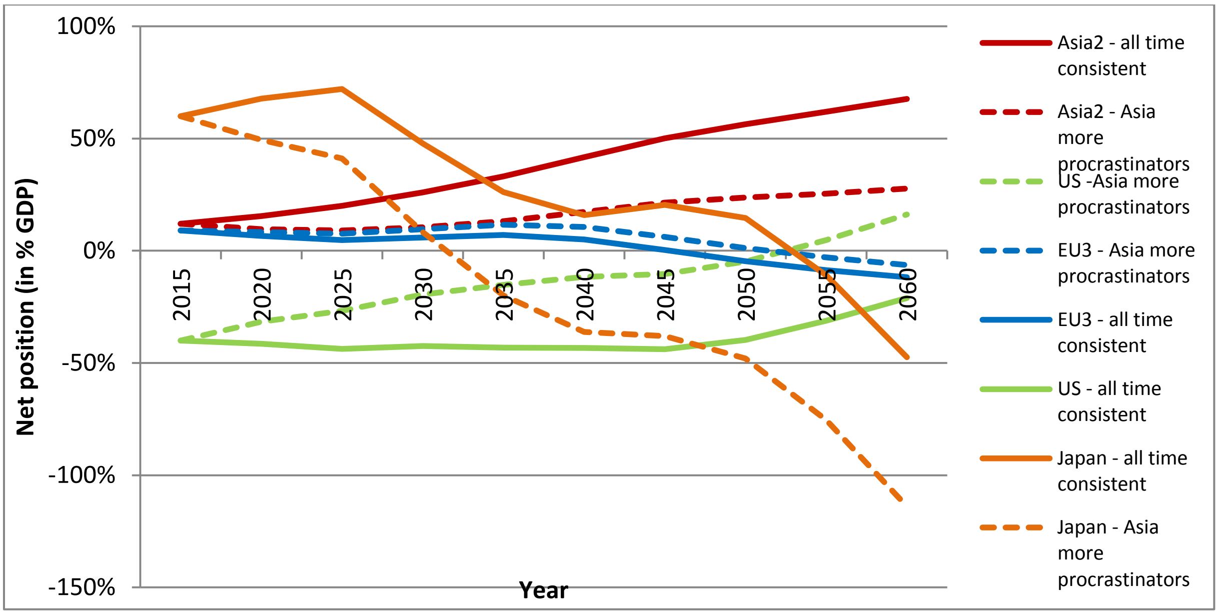
we now model two additional asymmetric scenarios:

(c) the Asian countries (Japan, China and India) have a share of 80% procrastinating households while this share is only 20% in all other countries/country groups, and

(d) the EU3 countries (France, Germany and Italy) have a share of 80% procrastinating households while this share is only 20% in all other countries/country groups.

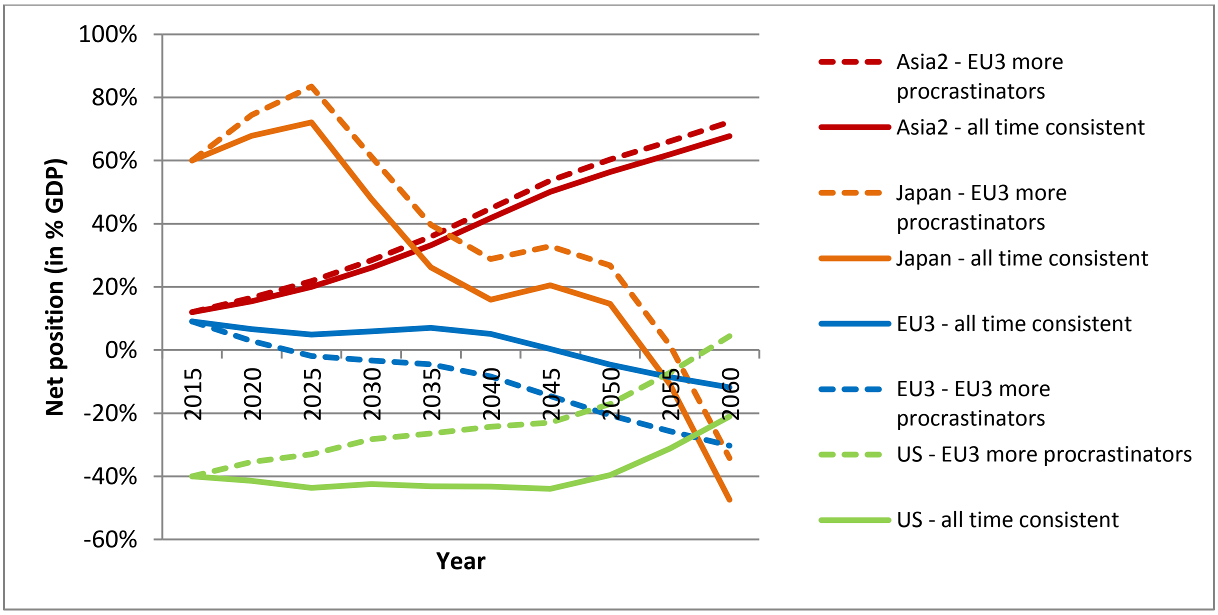
Figures 5.14 and 5.15 present the resulting net positions for the two asymmetric scenarios with the time-consistent scenario as a reference.

Figure 5.14: Net positions when Asia has a higher share of procrastinating households



Source: own calculations.

Figure 5.15: Net positions when EU3 has a higher share of procrastinating households



Source: own calculations.

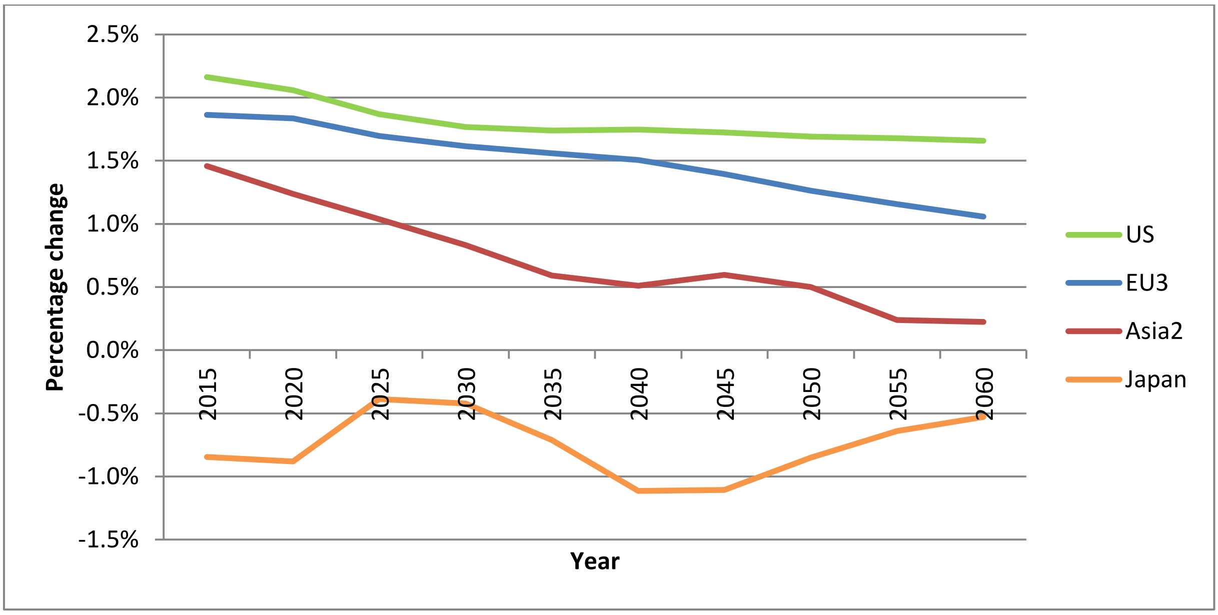
Since households who are time-consistent save dramatically more than procrastinating households, the capital flows react very sensitively to asymmetric shares of procrastinating households. When Asia or the EU3 countries save relatively little due to their high share of procrastinating households, the US assumes the role of a capital exporting nation while the EU3 and Japan, the countries with the fastest aging process, will have negative capital flows (increasing inflows) due to their high share of procrastinating households with very little saving and their large PAYG-DB pension systems.

5.4.3 Implications for pension systems

As we have seen in Figure 5.10, contribution rates are substantially higher than in the time-consistent case if a country has a large share of procrastinating households. This is due to the increase of interest rates relative to wages which generates negative incentives to work which lead to lower labor supply and, subsequently, higher contribution rates in order to keep a balanced pension system's budget. This effect is much more complex when the shares of procrastinating households differ across countries.

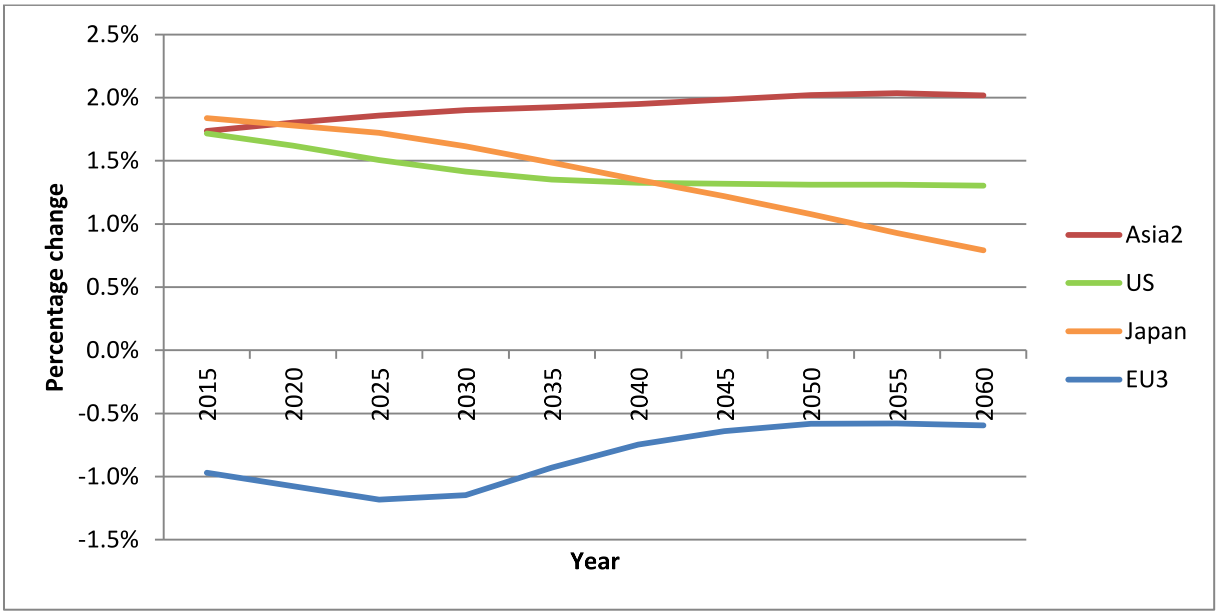
Figures 5.16 and 5.17 show the percentage changes in contribution rates relative to the scenario with all time-consistent households. The two scenarios with asymmetrical shares of procrastinating households are the same as described in the previous subsection.

Figure 5.16: Effect on contribution rates if Asia has a higher share of procrastinating households (change relative to time-consistent scenario)



Source: own calculations.

Figure 5.17: Effect on contribution rates if EU3 has a higher share of procrastinating households (change relative to time-consistent scenario)



Source: own calculations.

Generally speaking, while contribution rates increase in all countries due to population aging, countries with a large share of procrastinating households have a smaller increase of their contribution rates than countries with a smaller share of procrastinating individuals. These are Japan, China and India in Figure 5.16 and the EU3 countries in Figure 5.17. At first sight, this appears to contradict the results depicted in Figure 5.10. However, the relation between contribution rate to a PAYG-DB pension system, the world interest rate and share of procrastinators is more complex due to counter-effects in the countries with a high share of procrastinating households. Since these households tend to overconsume and work less in the first years of their lives, they have to work more hours later on. Depending on the population structure of each country, this labor-supply behavior of procrastinating individuals can have either a strengthening or a weakening effect on the change in contribution rates. The effects are especially large with an older age structure, i.e., more people close to retirement. If the population is composed mainly of younger people, the effects are weaker. Therefore, in relatively old countries such as Japan and EU3, the overall effect of having procrastinating households leads to lower contribution rates as compared to the time-consistent scenario (e.g., Japan in Figure 5.16 and EU3 in Figure 5.17). For relatively young economies, like China, India and the US, the interest rate effect dominates. In these countries, having an asymmetrically larger share of procrastinating households does therefore not lead to lower contribution rates (e.g., Asia2 in Figure 5.16).

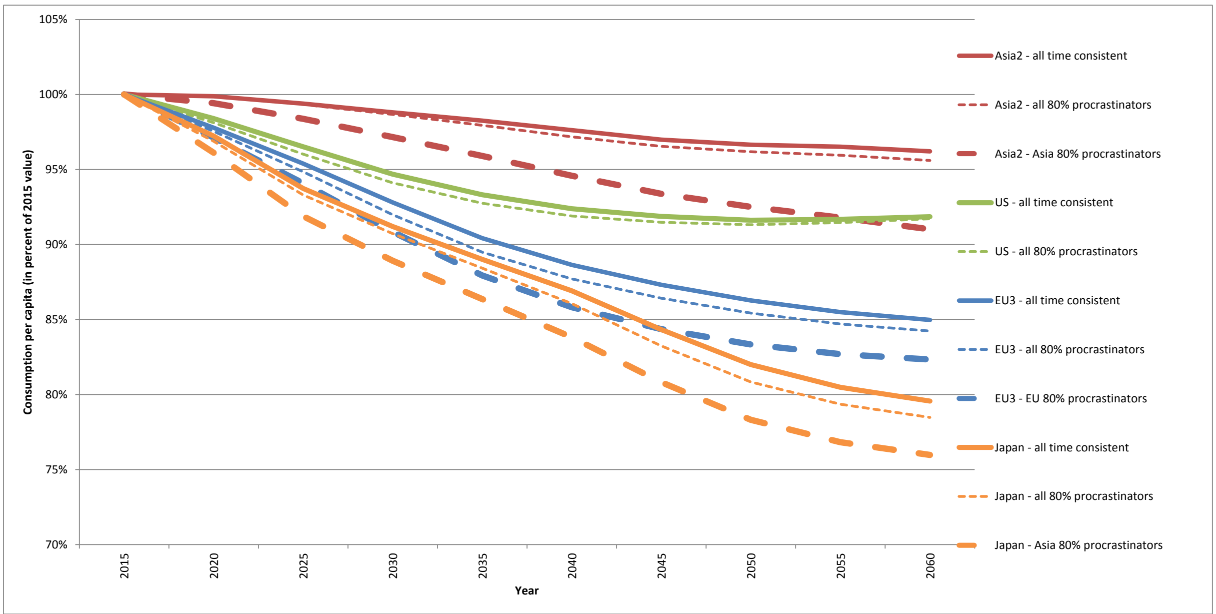
The presence of procrastinating households has thus quite complex implications on PAYG-DB pension systems. They are dependent on many factors, namely the population structure, the degree of present bias and the share of procrastinating households, all of which differ across countries. In a world where procrastination is equally distributed across countries, PAYG-DB pensions systems are always negatively affected in form of increasing contribution rates. If only some countries have a greater share of procrastinating households, this could even mean an advantage for the pension system since contribution rates could be lower and/or increase more slowly. Whether there is such an advantage, however, depends on the specific population structure of each country.

5.4.4 Implications for per capita consumption

As a first step in understanding whether procrastination makes people better off in a world, in which countries may have different degrees of procrastination, we look at the development of per capita consumption. We distinguish the same scenarios as described at the outset of Subsection 5.4.2. In all scenarios, consumption per capita declines due to population aging.

Figure 5.18 shows the trajectories 2015-2060, Figure 5.19 focuses on the decline from 2015 to 2040. The implications of procrastination for per-capita consumption are relatively small when the extent of procrastination is symmetric across all countries, see the difference between the thin broken and the solid lines in Figure 5.18.

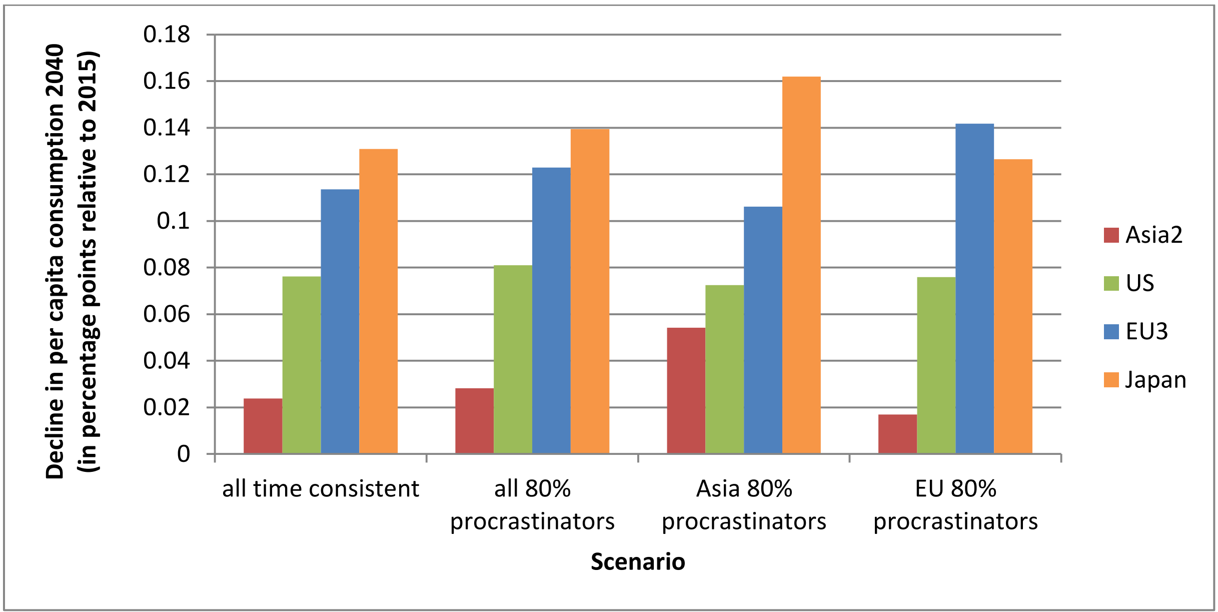
Figure 5.18: Consumption per capita with different and asymmetric shares of procrastinating households



Source: own calculations.

They are, however, quite substantial in the asymmetric cases in which procrastination is concentrated in the own country (thick dashed lines in Figure 5.18). An example is the case of Asia2 (red thick dashed line). If the share of procrastinators is 80% in Asia but in the other countries only 20%, then the decline in per capita consumption would be around 5 percentage points in 2040 (see Figures 5.18 and 5.19). During the time range presented in Figure 5.18, this corresponds to a decreasing trajectory of consumption per capita which is steeper than in the symmetric case (red thin dashed line).

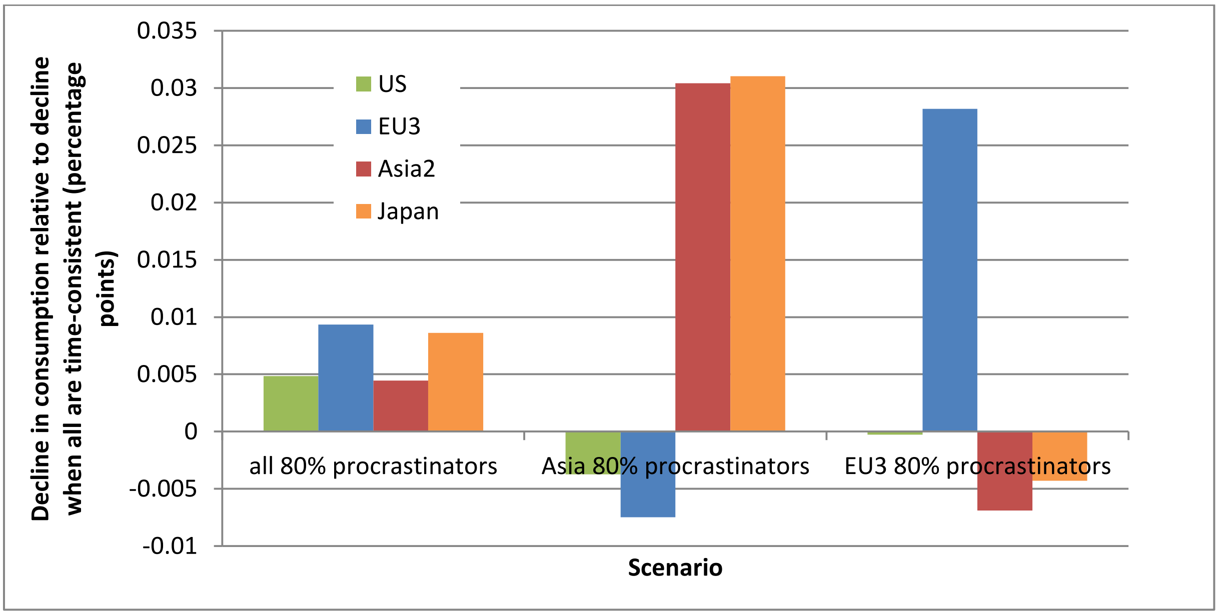
Figure 5.19: Decline of per capita consumption from 2015 to 2040



Source: own calculations.

In fact, in the asymmetric cases, consumption per capita in the countries with a high share of procrastinators declines much faster with population aging than in the scenario with time-consistent households. This is shown more distinctly in Figure 5.20. In the other countries, however, the decline is in some cases even smaller than in the time-consistent scenario in spite of a 20% share of procrastinating households. This shows again that the effects of procrastination are complex when the share of procrastination varies across countries. The reason behind this larger decline when the majority of households are procrastinating is the balance between higher returns on savings (via interest rate) but lower savings due to present bias. Procrastinating households save less and although consumption may increase via higher consumption shares, the interest rate effect is diluted. Hence, households accumulated fewer assets which could benefit from a higher rate of return.

Figure 5.20: Decline in per capita consumption 2040 versus 2015 that is due to procrastination

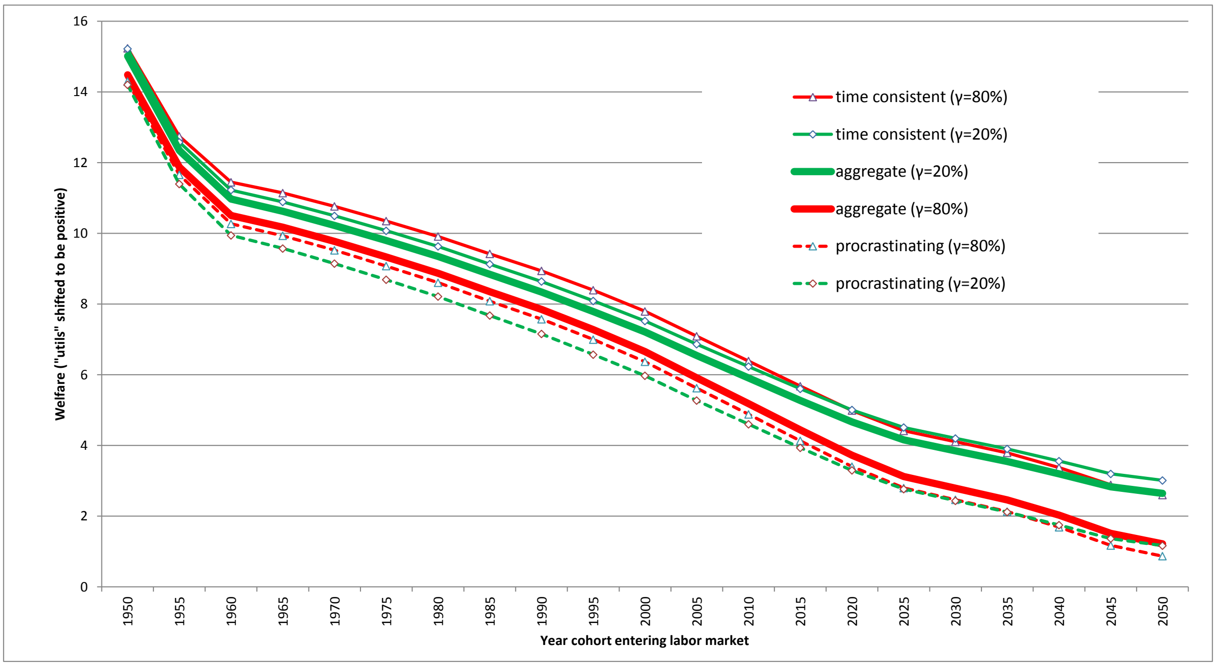


Source: own calculations.

5.4.5 Implications for the welfare of cohorts

Higher consumption per capita at a given point in time does not imply higher welfare for all individuals. This has two reasons. First, welfare includes not only the utility from consumption but also from leisure. Second, consumption per capita at a given point in time aggregates over the different cohorts living at this point of time. This subsection therefore investigates the welfare gains or losses for individual cohorts due to a higher share of procrastinators. Figure 5.21 shows the trajectories of life-time welfare under two scenarios, an economy in which the share of procrastinating households, γ, is low (20%), and an economy where it is high (80%). Time is indicated by the year in which each cohort of households enters the labor market. The figure distinguishes between time-consistent (thin solid line) and procrastinating households (thin broken line). Aggregate welfare (thick line) is weighted by the share of each household type. Figure 5.21 takes the case of Japan as an example.

Figure 5.21: Trajectory of welfare if share of procrastinating households is low or high



Source: own calculations.

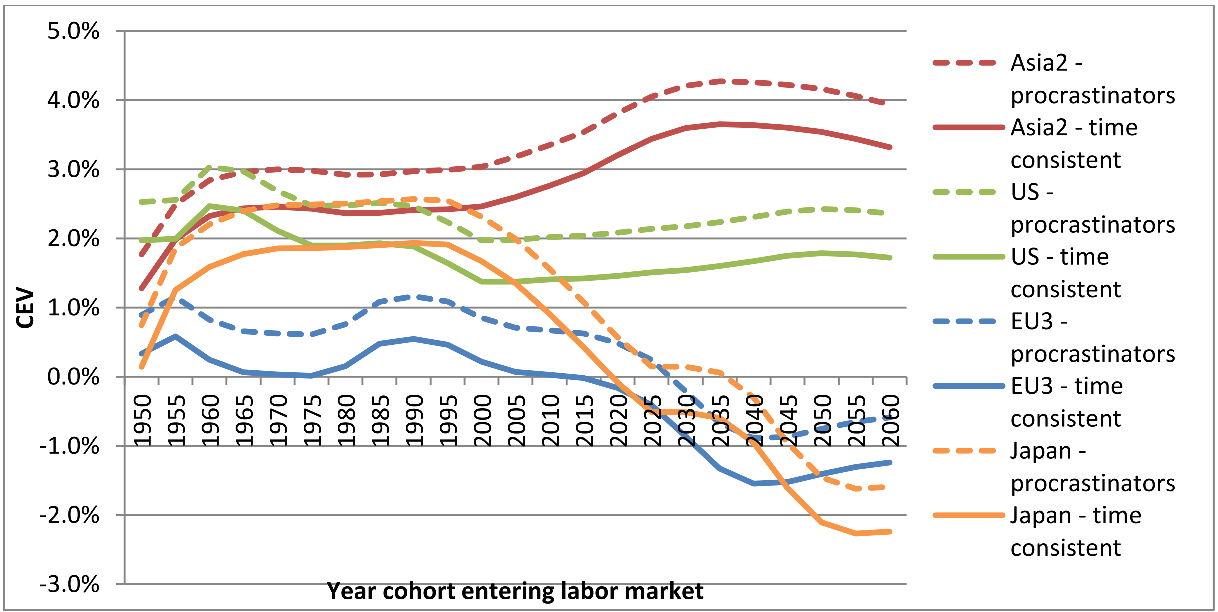
Figure 5.21 permits several conclusions. First, as we know from Subsection 5.2.1.2, time-consistent households enjoy higher life-time welfare than procrastinating households. Second, as we know from the internal rates of return and the rise of contribution rates visible in Figure 5.3, younger cohorts are worse off as population aging progresses. Third, aggregate welfare is higher in an economy with a relatively low share of procrastinators. The trajectories for each homogenous household type are more complex. For the cohorts entering the labor market until about now, each household type is better off living in an economy with a high share of procrastinators. For later cohorts, however, the opposite is the case.

Measuring welfare in utility units has the advantage of an intuitive interpretation but suffers from the fact that utility has arbitrary units. Figure 5.22 expresses the differential effects therefore as the life-time CEV of a cohort of a specific type, either time-consistent or procrastinating. Since we cannot compare different types of individuals, there are separate lines for time-consistent households (solid) and procrastinating households (dashed). Units are in percent of life-time consumption. The reference scenario is an economy with 20% procrastinating households. A positive value means that households of a cohort entering the labor market at the given time must receive the indicated percentage of life-time consumption to be as well off as the alternative scenario in which a much higher share of households are procrastinating. If the CEV is positive, households in the alternative scenario are therefore better off than in the reference scenario.

For example, in 2015 one has to pay 3% of life-time consumption to time-consistent households in the Asia2 countries, assuming that the share of procrastinating households takes the reference value of 20%, to make them as well off as in the alternative situation in which 80% of households are procrastinating. In turn, a future Japanese procrastinating household entering the labor market in 2050 prefers a situation with a small share of procrastinating households as we have already pointed out in Figure 5.21.

Note that we do not argue that time consistent households are worse off than procrastinating households. We state that welfare differences between procrastinating households in different scenarios increase more than differences between welfare of time consistent individuals in the same scenarios. As we have shown in Figure 5.21, time-consistent individuals have higher welfare than procrastinating households in the different scenarios.

Figure 5.22: Welfare gains and losses due to a higher share of procrastinating households



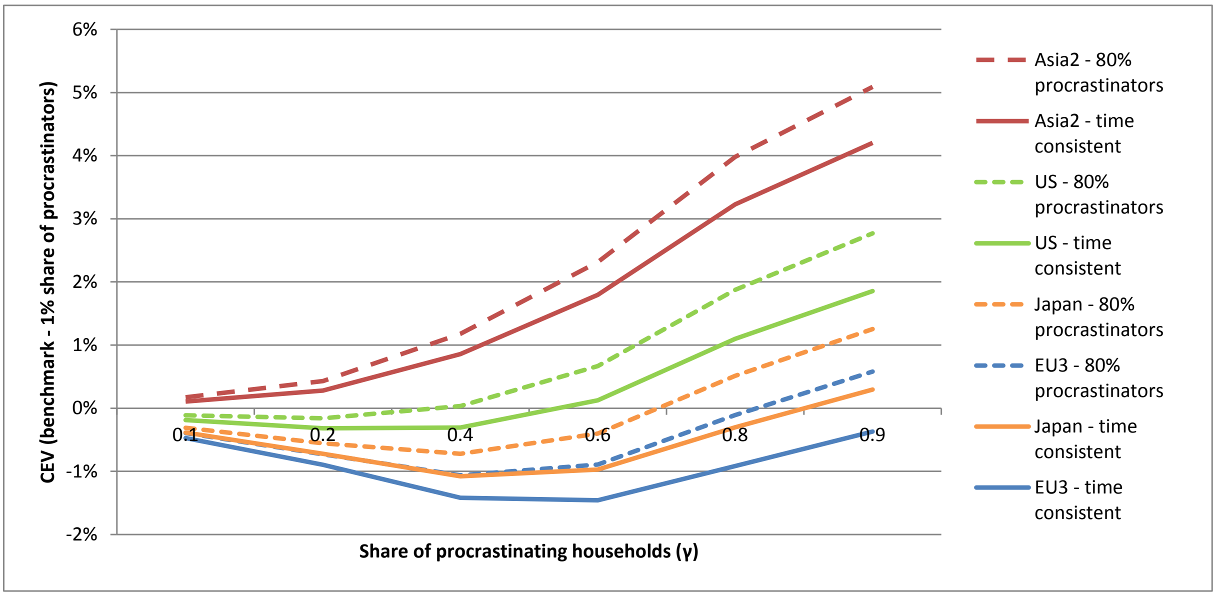
Source: own calculations.

In general, all types of households are better off in terms of consumption equivalent variation under the higher share of procrastinating households in the economy. Some exceptions are Japan and the EU3 countries where cohorts entering the labor market after about 2020 are worse off when there is a higher share of procrastinating households. In Figure 5.21, this was indicated by the crossing of the respective trajectories.

There are several mechanisms explaining these results. First, the interest rate is higher under a higher share of procrastinating households than in the case of a lower share, therefore individuals profit from higher interest rates when they have sizeable private savings. Hence, especially countries with smaller pension systems benefit more from higher returns on savings because individuals save mostly privately for retirement. This explains mainly the outcomes for China, India and the US. Moreover, the pattern of welfare over time, measured as consumption equivalent variation, interacts with demographics. In both scenarios, countries with large pension systems have intrinsically higher contribution rates which suffer from a larger increase over time compared to contribution rates in countries with small pension systems. Most importantly, contribution rates are higher when the share of procrastinating households is large. Moreover, this difference even increases over time. Figure 5.22 shows that until around 2020 the higher interest rate effect dominates the effect of higher contribution rates. After 2020, the contribution rates effect becomes the dominant effect which decreases welfare for later cohorts. This explains why cohorts entering the labor market after 2020 can be worse off in the scenario with a high share of procrastinating households.

The relation between welfare and the share of procrastinating households is complex and not linear. Figure 5.23 compares welfare of both procrastinating households and time-consistent counterparts as a function of the share of procrastinators. The consumption equivalent variation is relative to an economy with a very small, but still positive share of time-consistent households. Taking again the example of procrastinating households in Asia2 who live in an economy with 1% procrastinators, one would need to give these households around 5% more lifetime consumption to make them indifferent to the situation with a share of 90% procrastinators.

Figure 5.23: CEV comparison between shares of procrastinating households



Source: own calculations.

In the other countries, especially the EU3 and Japan, initial increases of the share of procrastinating households have a negative effect on welfare. This stems from the large sizes of their pension systems that lead individuals to borrow more during their life-cycle and therefore are penalized by higher interest on their debt. However, for some higher shares of procrastinating households there is an inversion point where the negative impact dilutes and welfare impacts become positive or close to positive (time-consistent households in the EU). This happens mainly due to the interest rate effect and life-cycle behavior of individuals. A higher share of procrastinating households increases interest rates. However, at the same time there is still too much borrowing which hinders the positive effect that higher savings could have on savings. Therefore, only when interest rates are high enough, households can profit from large savings and interest that yields from them. The same argument regarding size of pension systems and interest rates applies between countries. Therefore, households in countries with smaller pension systems profit more than households in countries with large pension systems.

5.5 Global spillover effects of pension and labor market reform

In the aging countries of Asia and Europe, pension and labor market reforms have been on the agenda since the 1990s in order to increase labor supply and to reduce the tax and contribution burden to the younger generation. Börsch-Supan & Ludwig (2009) have shown that such reforms have not only effects on the reforming country itself but also beneficial spillover effects to other countries. This section investigates whether these spillover effects also hold, or even are strengthened, when households are present biased. This is a salient and important topic because it strengthens the case for international policy coordination, e.g., via institutions such as the Group of Twenty (G20). This section uses a prototypical reform package in the EU3 countries as an example and investigates the spillover effects on Japan, the Asia2 countries and the US.

5.5.1 The reform package in Europe and its direct effects

The prototypical reform package is composed of four elements that are motivated by historical interventions in the EU. The key parameters to be changed are:

- An increase in the retirement age by 2 years;
- A decrease in the job entry age by 2 years;
- Convergence of female labor force participation to 90 percent of the rate for men;
- A reduction in unemployment to 4 percent.

All four parametric reform steps will together be phased in linearly between 2005 and 2050 in our EU3 model economies.

We assume that labor supply is exogenous and abstract from "backlash" effects described in Chapter 2 of this dissertation. Hence, the reforms increase labor supply to their full extent. Still, "backlash" effects from endogenous labor supply reactions are interesting when evaluating pension reforms. Addressing this, Chapter 6 of this dissertation will allow for behavioral reactions of labor supply of present-biased households and focus on them in more detail when evaluating various pension reforms. Except these differences in assumptions on labor supply behavior, the set-up in this section is the one of Section 5.3 with the four countries/country groups US, EU3, Japan and Asia2.

These four reform elements are motivated by the corresponding historical reform steps:

- The German parliament decided in 2007 to gradually increase the statutory eligibility age from 65 to 67 years until the year 2029. The French government increased the pensionable age of 60 to 62 in 2010. In Italy, the Monti-government 2011-2013 abolished several labor market restrictions and advanced the scheduled increase of the retirement age and abolished several pathways to early retirement.
- The change in the high school and university system all across the EU starting in 2001 (the so-called Bologna process) is expected to decrease duration in schooling by about 2 years.
- All three EU3 countries have experienced a strong increase in female labor force participation, partially due to improvements of the ability to combine job and family.
- In Germany, the so-called Hartz reforms announced in 2002 have dramatically reduced unemployment to a level which may be regarded as the long-term stable rate of unemployment.

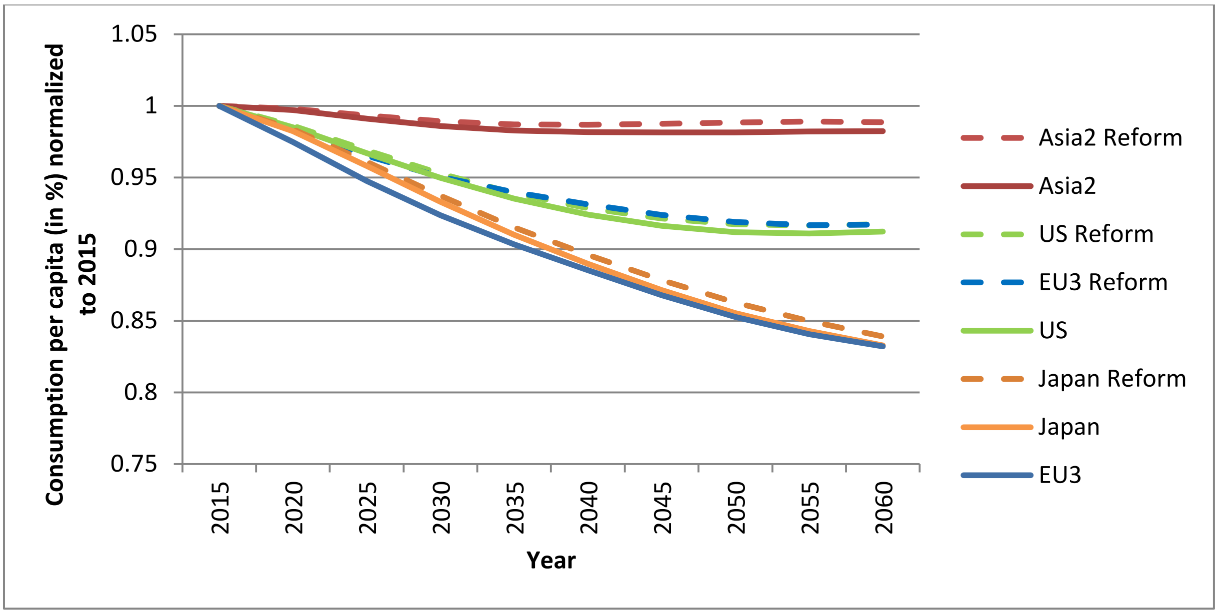
The effects of this reform package have been predicted using a similar model as the one described in Section 5.3 in Chapter 2 of this dissertation for an economy with time-consistent households. They can be summarized as follows.

First, the decline in the total labor volume due to population aging in the EU3 economies is offset by more than a half through the labor supply reform. This has beneficial effects for contribution rates to the PAYG-DB pension systems in Europe. Since there is more labor supply in the economy, contribution rates to the PAYG-DB pension system at the peak of population aging around the year 2040 about 2.8 percentage points lower in the reform case than in a scenario without a reform.

Second, higher labor supply increases saving and investment, leading to an increase in the domestic capital stock relative to the baseline scenario without reform. Since both factors of production increase, the percentage effect of the reform package on GDP per capita is larger than the increase in employment. Since increasing labor also increases aggregate savings, some households' savings flow from the aging EU3 countries abroad. This is the reason for the global spillovers to be discussed in the following subsection.

Third, the reform package leads to an increase in the market interest rate because every unit of capital is getting more productive when more labor becomes available (Table 5.4). The higher interest rate is beneficial for savers and allows them to increase their consumption further. This is shown in Figure 5.24 where the thick lines represent EU3. Solid lines are pre-reform while broken lines are after the labor supply reform. Rather than declining by 17%, consumption per capita only declines by about 8%. The reform thus offsets about half of population aging.

Figure 5.24: Reform effects on consumption per capita, all time-consistent



Source: own calculations.

In spite of the financial crisis since 2008, these predictions are largely in line with the actual development in Germany experienced so far where the reform package has been realized to a large extent. Specifically, labor supply has increased, unemployment declined to a historical low, contributions rates to the German PAYG-DB could be stabilized, and GDP and consumption per capita have been increasing at a moderate but steady pace in spite of rapid population aging due to the current effects of the baby boom-baby bust transition.

5.5.2 Global spillover effects on Asia and the US

Global spillover effects work through the interest rate channel: a higher labor force in Europe increases the world interest rate because every unit of capital is getting more productive when there is more labor input (Table 5.4). The higher interest rate, in turn, generates higher GDP per capita also in the other countries which in turn increases consumption per capita. These spillover effects to the other countries – here measured in terms of consumption per capita – are small but visible in Figure 5.24. Table 5.4 shows that they are largest for Japan where they amount to about two thirds of a percentage point of annual consumption in 2040.

This interest-rate effect interacts with the share of procrastinators households in an economy. The presence of procrastinating consumers increases the interest rate further because of lower savings at all times. Figure 5.25 shows this interaction for three scenarios: the symmetric scenario in which EU3 and the Asian countries Japan, China and India have a share of 80% procrastinating households, and two asymmetric scenarios in which one country group has a higher share of procrastinators (80%) than the other country groups (20%). As a reference, the first line of Table 5.4 reports the case of time-consistent households in all countries.

The interaction of reform and procrastination changes the paths of consumption in a similar way as we have seen in Figure 5.20. The spillover effects are largest in the asymmetric scenario in which the EU3 has the highest share of procrastinating households. This is due to the large PAYG-DB pension systems in the EU3 countries which make pension and labor market reform particularly effective in the presence of procrastinating households.

Regarding life-time welfare across cohorts, the qualitative pattern is common for all above-mentioned scenarios with different shares of procrastinating households and similar to what we have observed in Subsection 5.4.4. While consumption per capita increases for the average household, cohorts entering the labor market before 2005 are better off than in the scenario without a labor market-reform; cohorts entering afterwards are slightly worse off. The reason is the increase of the interest rate due to the reform. Cohorts that are already old and possess much savings profit a lot from a higher interest rate; young cohorts who may even go into debt are worse off if they face a higher interest rate early in life.

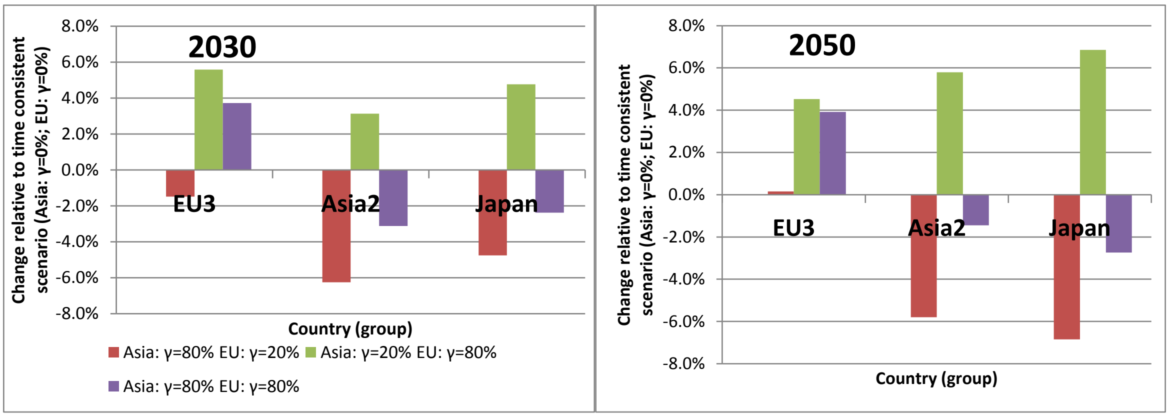
Table 5.4: Reform effects on interest rate and consumption per capita

	Year 2030				
	Effect on interest rate	Effect on consumption per capita			
		EU3	Asia2	Japan	US
Asia γ=0%, EU γ=0%	0.079	2.69%	0.32%	0.42%	0.30%
Asia γ=80%, EU γ=20%	0.081	2.65%	0.30%	0.40%	0.33%
Asia γ=20%, EU γ=80%	0.086	2.84%	0.33%	0.44%	0.32%
Asia γ=80%, EU γ=80%	0.087	2.79%	0.31%	0.41%	0.34%

	Year 2050				
	Effect on interest rate	Effect on consumption per capita			
		EU3	Asia2	Japan	US
Asia γ=0%, EU γ=0%	0.064	6.63%	0.69%	0.73%	0.56%
Asia γ=80%, EU γ=20%	0.065	6.64%	0.65%	0.68%	0.57%
Asia γ=20%, EU γ=80%	0.080	6.93%	0.73%	0.78%	0.58%
Asia γ=80%, EU γ=80%	0.078	6.89%	0.68%	0.71%	0.59%

Source: own calculations.

Figure 5.25: Differential effect relative to time-consistent scenario



Source: own calculations.

5.6 Conclusions

Economics has traditionally guided pension policy with the help of formal models based on individuals who think in a life-cycle context with perfect foresight, full information and in a time-consistent manner, often in a single-country economy. This chapter sheds light on several aspects of pension economics when these behavioral assumptions do not hold and when the macroeconomic development takes place in a globalized economy. For this purpose, we construct and calibrate – to our knowledge – the first multi-country model of procrastinating households.

Our focus is on the interaction between the share of procrastinators in a country, the speed and extent of population aging, and the size of an existing PAYG-DB pension system.

We do not take the share of procrastinators in an economy and their short-sightedness strictly literally. It may as well describe the dearth of commitment devices which have been created by traditions, rules and institutions and force or nudge individuals in a behavior resembling perfect foresight. This point is especially important when we consider different shares of procrastinators across countries or regions.

We focus on three aspects which are particularly relevant for the quickly aging Asian economies: What are the consequences for the balance between pay-as-you-go and fully-funded pension systems? Where will retirement savings be invested in a globally linked world with very different pension systems and demographics? How large are global spillover effects of pension reforms in one region for the other regions in the world? Regarding the first aspect, it is well-known that savings are substantially lower if a substantial fraction of households is myopic or procrastinating with hyperbolic time preferences. Moreover, the life-cycle trajectory of labor supply changes. Both together have repercussions on the world interest rate and national wages, affecting the relative merits of PAYG versus FF pension systems. Contribution rates to PAYG-DB systems rise with a higher share of procrastinating households in an economy. This is particularly pronounced for Japan. Nevertheless, PAYG-DB systems provide higher welfare in this case due to the low consumption in old age that can be financed by the relatively low savings that procrastinating households accumulate in a FF system based on voluntary saving.

It is important to note from a policy point of view that we do not compare a mandatory PAYG system with a mandatory FF system. Rather, we compare the merits of a stylized PAYG-DB pension system that is typical for many large industrialized countries (Japan, US, Continental Europe) with voluntary saving instruments such as IRAs or 401k plans in the US or the Riester pensions in Germany. Regarding the second aspect, international capital flows are generally lower if households are procrastinating since they are saving dramatically less. This general pattern, however, does not hold once population processes are very different across countries. Matters are even more complex when the share of procrastinators across countries or regions differs. While contribution rates to PAYG-DB pension systems generally increase with the share of procrastinators, countries with a high share of procrastinators and a large PAYG-DB pension system may have a slower increase of the contribution rate than in a time-consistent scenario if the labor supply effects dominate the effects generated by a higher world interest rate. The point of policy relevance here is that reforms which change a PAYG-DB pension systems in ways that increase the self-commitment of individuals to save (in an extreme case: a transition to a fully-funded system) must be carefully evaluated in the context of the potentially asymmetric shares of procrastinating households in a globally linked economy.

International capital flows in a world with asymmetric shares of procrastinators also affect welfare. First, time-consistent households enjoy higher life-time welfare than procrastinating households. Second, younger cohorts will have lower life-time welfare than older cohorts due to the population aging progress. Third, aggregate welfare is higher in an economy with a relatively low share of procrastinators. These are well-known results. The trajectories for each homogenous household type are more complex. For the cohorts entering the labor market until about now, each household type is better off living in an economy with a high share of procrastinators. For later cohorts, however, the opposite is the case. This holds especially for young households in Japan.

Regarding the third and final aspect of this chapter, parametric labor market and pension reforms in one part of the world (Europe) have global spillover effects through the global interest rate. Changes in key labor market and pension parameters, especially retirement age, in Europe also improve the sustainability of pension systems and economic growth in Asia. This is a salient and important point because it strengthens the case for international policy coordination, e.g., via institutions such as the Group of Twenty (G20). Spillover effects are largest in the asymmetric scenario in which the EU3 has the highest share of procrastinating households. This is due to the large PAYG-DB pension systems in the EU3 countries which make pension and labor market reform particularly effective in the presence of procrastinating households.

6. Evaluating pension reforms and labor supply under time-(in)consistency

This chapter was written in single authorship.

6.1 Introduction

Population aging poses a threat to the social security systems of many countries. Facing this challenge, policy makers are suggesting numerous reform proposals with the goal of maintaining the sustainability of social security systems. At this point, suitable economic models are required to simulate these reform proposals and evaluate their impact on the behavior of individuals and, consequently, the sustainability of pension systems. Traditionally, this task has been carried out using models incorporating life-cycle behavior and assuming that households make decisions within a framework of time-consistency (Auerbach & Kotlikoff, 1987; Feldstein & Samwick, 1998). Model outcomes, and, therefore, policy recommendations, strongly depend on this assumption. However, empirical studies on choice behavior (e.g. Chan (2017); Read & van Leeuwen (1998)) reveal that individuals fail to commit to their decisions and previous choices often get reversed. In response to this drawback, this chapter relaxes the classical assumption of time-consistent behavior when evaluating pension reform policies.

The behavior of procrastination for retirement saving has been studied by a large strand of literature (Laibson, 1997; Laibson, 1998; Madrian & Shea, 2001). These models are able to capture a number of behavioral regularities found in empirical studies which cannot be explained with standard exponential discounting[29]. The main focus of many of these analyses is on the procrastination of consumption behavior and savings decisions. Extending on this, other authors have also included the decision on labor supply and leisure as an additional dimension in their models (see, e.g., Imrohoroglu et al. (2003); Petersen (2004); Kaplow (2015b); Kaplow (2015a); Dupas et al. (2016)). However, a detailed investigation of life-cycle labor supply behavior in large-scale macroeconomic models has not yet been carried out. To address this gap, this chapter concentrates on the full life-cycle labor supply behavior in a large-scale macroeconomic model with hyperbolically and exponentially discounting households. In order to investigate the differences in labor supply behavior between time-consistent and present-biased households closely, the model assumes two different kinds of households inhabiting the economy: those who can perfectly plan their future and carry out these plans (time-consistent households) and those

[29] See, for instance, Park & Feigenbaum (2018) who discuss the advantages of optimization subject to bounded rationality for receiving realistic consumption profiles in life-cycle models when there are pension systems.

who fail to do so (time-inconsistent or present-biased households) because they do not execute their original plans.

Endogenous labor supply reactions to policy reforms are important as they can create effects in the aftermath of the reform that are difficult to foresee. At this point, it is crucial to understand that time-consistent and time-inconsistent behavior of households might imply a different evaluation of policy reforms. Macroeconomic feedback effects from policy changes can be substantial and surprising (see Chapters 2 and 3 of this dissertation). In order to account for this, the two different life-cycle models described above are embedded in an overlapping generations setting. Furthermore, a simple firm sector is assumed to mimic the impact of changing savings and labor decisions on prices for capital and labor. The public pension system is established as a pay-as-you-go system with obligatory contributions from labor income and a mandatory (forced) retirement age. Therefore, it is assumed that the household leaves the labor market at the time of claiming pension benefits. Since this chapter abstracts from endogenous retirement decisions and focuses on labor supply of the working population, reforms regarding the statutory eligibility age are treated as reforms affecting the mandatory retirement age. Finally, several characteristics about life-cycle profiles of wages and mortality rates, which are realistic for both types of households, are added to the model in order to allow for a more accurate evaluation of reforms.

Various single model components mentioned earlier have already been used in economic literature. Fehr et al. (2008) and Imrohoroglu et al. (2003), for instance, use a framework with time-inconsistent households to evaluate efficiency gains when eliminating a public PAYG pension system. In doing so, Fehr et al. (2008) find a positive role of social security in Germany, especially for present-biased households, due to the insurance against mortality risk and the presence of a commitment device. Imrohoroglu et al. (2003) conclude that corresponding welfare findings depend on the degree of time inconsistency. While the aforementioned studies compare two points in time, this chapter will focus on the entire transition path of demographic change and its interaction with reform policies and labor supply behavior of time-consistent and present-biased households. This allows me to distinguish which generations profit or suffer from reforms and how these results differ between the types of households, which is not possible in a two-point-in-time comparison.

The work by Petersen (2004) discusses whether findings about tax policies derived under exponential discounting still hold under models with hyperbolic discounters. His main finding is ambiguous: if preferences are sufficiently close to hyperbolic discounting, tax policy conclusions change. However, this result is again carried out by focusing on steady-state comparisons and neglects demographic transition, which could influence conclusions. The behavior of myopic agents is also investigated by Kaplow (2015b). He focuses on the implications of social security and capital taxation. His findings are ambiguous: whether labor supply increases or decreases under taxation depends on the individual's utility function. However, and similar to the previously mentioned literature, his life-cycle model incorporates two periods which allows for a gross analysis of labor supply behavior. To account for more complex dissimilarities in (labor supply) behavior, this chapter applies a considerably more refined life-cycle model embedded in an OLG structure simulated on a yearly basis.

In sum, while the aforementioned literature allows for a rough assessment of labor supply, this chapter will model a more fine-grained life-cycle behavior on a yearly basis to investigate various reform proposals. There is very little literature (Fehr, et al., 2008; van de Ven & Weale, 2010) using similarly detailed household models on hyperbolic discounting. The two studies mentioned focus on the justification for the existence of PAYG pension systems as a measure to address under-saving by households, which is not the idea of this chapter. Furthermore, while Section 5.5 in Chapter 5 of this dissertation does not permit endogenous labor supply reactions when evaluating a prototypical reform package, this study explicitly allows for "backlash" effects from labor supply in response to various pension reforms taking into account differing labor supply behavior between time-consistent and present-biased households. This chapter is therefore the first to investigate a new set of current pension reform proposals using such a detailed model while explicitly taking into account life-cycle labor supply behavior. In that way, it is possible to challenge sophisticated results from purely rational models that address pension reforms. Furthermore, a special focus in the analysis is laid on labor supply, which is usually modeled, if at all, in the background but not explicitly discussed. In addition, the present model framework incorporates both time-consistent and inconsistent households, allowing for a direct comparison of the two modeling approaches within the same framework, which is essential to understanding the underlying labor supply behavior. In a more in-depth analysis, these two types of households are enriched with realistic life-cycle profiles for wages and mortality rates in Section 6.6.

As a first step, two baseline models are simulated: one is inhabited by time-consistent households and resembles the vast majority of literature when evaluating pension reforms. The second is populated by 50% time-consistent and 50% present-biased households[30]. As expected, present-biased households generally work more to make up for the over-consumption that occurs during

[30] Note that it is not claimed that 50% of the actual population consists of present-biased households. Instead, it is important that both types of households live in this economy, irrespective of the exact share. Empirical studies (e.g. see Chan (2017), Haan et al. (2017)) find that most individuals behave time-inconsistently in their labor supply behavior at some degree and that there is clearly heterogeneity. In this study, this continuum is simplified in two types of households with 50% being fully rational and 50% being present-biased.

early life. However, when observing consumption per capita (p.c.), present-biased households are hit more severely by an aging population than their time-consistent counterparts, the reason for this being the systematic under-saving of present-biased households such that assets cannot serve as a buffer against the negative consequences of demographic change.

The first pension reform, which studies an increase of the retirement age from 65 to 67, and the second reform, which connects the retirement age to life expectancy, are simulated for both model versions and compared to their respective baseline scenarios. The major finding here is that within the 50%/50% model version, present-biased households react more strongly to these two reforms than their time-consistent counterparts. While time-consistent households only react sluggishly in their labor supply to these pension reforms, present-biased households follow the evolution of the mandatory retirement age more closely. This is mostly due to the fact that they appreciate the possibility of working longer since they over-consumed during large parts of their lives. This stronger responsiveness to reform policies of present-biased agents is confirmed empirically by Chan (2017) for the case of tax reforms. However, when taking into account endogenous adjustments of factor prices, aggregate labor supply changes less in this model version, which, consequently, affects the pension system. Therefore, positive effects from such reforms for pension systems are dampened when taking into account time-inconsistency. In terms of household welfare, the reforms are beneficial for both types of households. However, the positive effect is substantially larger for present-biased households. As a consequence, neglecting the possibility that some households might act in a time-inconsistent manner underestimates the positive effects of welfare of these kinds of pension reforms.

The third reform simulation evaluates a proposal that is often put forward to avoid old age poverty: freezing the current levels of replacement rates and therefore returning to a DB pension regime. As a result, the contribution rate to the PAYG pension system has to increase more to guarantee the funding of the pension system. This, in turn, poses negative labor incentives on labor supply. It is found that aggregate labor supply is harmed more in the model that is populated by 50% present-biased households. As a consequence, the increase in contribution rates over time due to population aging is much more severe in this model than in the model version that is inhabited only by time-consistent households. Therefore, a model that does not take into account time-inconsistent behavior would underestimate the negative incentive and feedback effects for pension systems arising from such a reform proposal. In terms of welfare losses, however, the conventional model with time-consistent households would overestimate the negative impact of this reform proposal.

In a sensitivity analysis, these findings also hold when the share of present-biased households differs from 50% in the economy. Furthermore, when controlling for more realistic profiles of income and mortality rates, the relative order mostly persists. Quantitative differences, however, might change slightly. The same holds in an alternative regime with low interest rates, which is also investigated in a sensitivity analysis. In sum, while differences on the individual level might seem large between both model versions, macro-variables like contribution rates and factor prices do not differ much.

The structure of the chapter is as follows. Section 6.2 describes the model set-up and derives the life-cycle framework of time-consistent and inconsistent households. In the subsequent section, the solution and calibration method is shown. Before turning to the general equilibrium model, Section 6.4 illustrates findings from the household model using a partial equilibrium framework. Section 6.5 discusses the baseline model and evaluates three reform proposals. A sensitivity analysis with respect to alternative shares of present-biased households in the economy, different income profiles and mortality rates for both types of households, and a low interest rate regime is performed in Section 6.6. The final section concludes.

6.2 The model components

6.2.1 Household model

In the following sections, the household problem is discussed. It is derived such that the standard classical life-cycle model with time-consistent behavior poses a special case. The general idea when modeling procrastination lies on the idea that households plan according to the life-cycle model with perfect foresight but then fail to execute their original plan, e.g. by consuming too much early in life. Time-inconsistent behavior has been the subject of research in many studies (Thaler, 1994; Laibson, 1997; Laibson, 1998; Angeletos, et al., 2001; Choi, et al., 2002; Rabin, 2013a; Rabin, 2013b; Della Vigna & Malmendier, 2006).

6.2.1.1 The general life-cycle model

The general life-cycle model looks as follows: the household at time t and age j receives utility from consumption $c_{t,j}$ and leisure $1 - h_{t,j}$, where $h_{t,j}$ is time spent working and total time is normalized to 1. The per-period utility function is

$$u(c_{t,j}, 1-h_{t,j}) = \frac{1}{1-\theta}[c_{t,j}{}^{\phi}(1-h_{t,j})^{1-\phi}]^{1-\theta}, \tag{6.1}$$

where θ describes risk aversion and intertemporal substitution. ϕ denotes the relative weight of consumption versus leisure in the utility function. The household maximizes utility over the entire life-cycle. Accordingly, the problem of the household born in period *t* is

$$max\{u(c_{t,0}, 1-h_{t,0}) + \delta \sum_{j=1}^{J} \beta^j \, \sigma_{t+j,j} u(c_{t+j,j}, 1-h_{t+j,j})\}. \tag{6.2}$$

As can be seen in the second term of equation (6.2), there are three factors for discounting the future per period utility. First, β is the pure time discount factor with

$$\beta = 1/(1+\rho), \tag{6.3}$$

where ρ is the annual discount rate. The second discount factor is the cohort- and age-specific unconditional survival probability, $\sigma_{t,j}$. The third factor, δ, defines the degree of present-bias. If $\delta = 1$, the problem is identical to the neoclassical model of time-consistent behavior. If $0 \leq \delta < 1$, future utility is additionally discounted and the problem is enriched with a quasi-hyperbolic discounting setting. Lower values of δ denote a higher degree of shortsightedness. This will be discussed intensively in Subsection 6.2.1.2.

Households receive age-specific labor income $h_{t,j}w_{t,j}$ until retirement age *R* depending on their choice of labor supply, $h_{t,j}$. Note that this setting does not include a modelling of unemployment since it implicitly assumes that everyone is employed. After the mandatory retirement age, *R*, households receive pension benefits, $p_{t,j}$. Accordingly, the budget constraint is given by

$$a_{t+1,j+1} = a_{t,j}(1-r_t) + h_{t,j}w_{t,j}(1-\tau_t) + p_{t,j} - c_{t,j}, \tag{6.4}$$

where asset holdings at the beginning of period *t* are denoted by $a_{t,j}$. Note that there are no intended bequests. For simplicity, bequests resulting from premature death are taxed away by the government at a confiscatory rate and used for otherwise neutral government consumption.

6.2.1.2 The different selves[31]

Strotz (1956), Phelps & Pollak (1968) and Pollak (1968) advanced the first theoretical frameworks on hyperbolic discounting. Later, it was refined by Thaler & Shefrin (1981) and popularized by Laibson (1997) and (1998). Time-inconsistent behavior is usually modeled as a struggle between the current and future self. Thus, the immediate future is discounted more strongly relative to the present than two equally distant events further in the future. As was already mentioned in Subsection 6.2.1.1, an additional present-bias discount factor, δ, is added to the maximization problem (see equation (6.2)). It discounts the immediate future in addition to the standard discount factor β and mimics hyperbolic discounting. True hyperbolic discounting would assume that the distance in discounting between two future periods continuously increases as the periods move closer to the present. However, quasi-hyperbolic discounting, as applied here, assumes discontinuously higher discounting to the first prospective period, which is modeled by the parameter δ. It is further characterized by the distinction between the present-bias, δ, of the current self from the belief about the present-bias of the future self, denoted by $\hat{\delta}$. As a consequence, actual consumption $c_{t,j}$ and labor supply $h_{t,j}$ are distinguished from beliefs about future consumption $\hat{c}_{j+1}$ and labor supply $\hat{h}_{j+1}$. In terms of beliefs, according to O'Donoghue & Rabin (1999), it is possible to distinguish between "naïve" and "sophisticated" present-biased households. While naïve households believe that their future selves will behave time-consistently and will not deviate from their original plans ($\hat{\delta} = 1$), sophisticated households foresee that they will behave time inconsistently in the future ($\hat{\delta} = \delta < 1$).

The present self at age *j* maximizes the objective function

$$max\{u(c_{t,j}, 1 - h_{t,j}) + \delta\beta\sigma_{t+1,j+1}\hat{V}(z_{t+1,j+1})\} \tag{6.5}$$

by choosing consumption $c_{t,j}$ and labor $h_{t,j}$ subject to (6.4) and its beliefs, $\hat{V}(z_{t+1,j+1})$, about the behavior of its future selves for the future state $z_{t+1,j+1}$. The value function $\hat{V}(z_{t,j})$ is calculated recursively by

$$\hat{V}(z_{t,j}) = u(\hat{c}_{t,j}, 1 - \hat{h}_{t,j}) + \beta\sigma_{t+1,j+1}\hat{V}(z_{t+1,j+1}). \tag{6.6}$$

Note that the parameter δ of the current self does not appear when calculating the value function (6.6). The future self at age *j+1* will maximize

[31] This section draws from Subsection 5.2.1.2 of this dissertation.

$$max\ \{u(\hat{c}_{t+1,j+1}, 1 - \hat{h}_{t+1,j+1}) + \hat{\delta}\beta\sigma_{t+2,j+2}\hat{V}(z_{t+2,j+2})\} \tag{6.7}$$

by optimizing on future consumption $\hat{c}_{t+1,j+1}$ and labor $\hat{h}_{t+1,j+1}$. Note that future beliefs about the present-bias, $\hat{\delta}$, are essential here, which is different to δ in (6.5). Finally, the value function is calculated using actual optimal consumption and labor

$$\hat{V}(z_{t,j}) = u(c_{t,j}, 1 - h_{t,j}) + \beta\sigma_{t+1,j+1}\hat{V}(z_{t+1,j+1}). \tag{6.8}$$

As can be seen, preferences are time-inconsistent because the present-bias parameters δ and $\hat{\delta}$ appear in the maximization (6.5) and (6.7) but not in the calculation of the value functions (6.6) and (6.8). As a consequence, sophisticated time-inconsistent households ($\delta = \hat{\delta} < 1$) behave differently compared to time-consistent households ($\delta = \hat{\delta} = 1$). The decision rules of naïve time-inconsistent households ($\delta < 1 = \hat{\delta}$), however, and the value functions of current and future selves do not coincide (see also Fehr et al. (2008) and Imrohoroglu et al. (2003)).

Under logarithmic utility, the solutions for sophisticated and naïve consumers coincide (Zhang, 2013). For reasons of presentation, results for sophisticated households are shown in this chapter since the basic outcome of this chapter is not dependent on household type (Chapter 5 of this dissertation). The difference in behavior between time-consistent and time-inconsistent households is accordingly more pronounced and interesting than between sophisticated and naïve households when evaluating pension reforms. Furthermore, empirical studies (e.g. Chan (2017)) reveal that most people are aware of the fact that they behave in a time-inconsistent manner, which speaks more toward the sophisticated type of individual.

6.2.2 The pension system

The pension system is modeled in an abstract and simple way to account for various national pension systems. The public pension scheme is a PAYG system which requires a balanced budget in every year, t. Contributions to the public pension system are mandatory. They consist of the product of the contribution rate, τ_t, age-specific income $h_{t,j}w_{t,j}$ and the number of workers $\sum_{j=1}^{R} N_{t,j}$, where R denotes the mandatory retirement age and $N_{t,j}$ the size of cohort aged j at time t. If applied, age-dependent wage is defined by $w_{t,j} = \varepsilon_j w_t$, where ε_j denotes age-dependent productivity. Pension expenditures are the sum of the product of the pension benefits p_t and cohort size $N_{t,j}$ over ages $R + 1$ and older. Accordingly, the yearly pension budget equation is given by

$$\tau_t w_t \sum_{j=1}^{R} \varepsilon_j h_{t,j} N_{t,j} = \sum_{j=R+1}^{J} p_t N_{t,j}. \tag{6.9}$$

An optimal decision on retirement ages does not take place since the focus of this study is on the working population. It is further assumed that the household leaves the labor market at the time of claiming pension benefits at age R. The PAYG system is, by default, a hybrid DB/DC- system: pension benefits, p_t, are defined by a replacement rate, b_t, of net-wages, $w_t(1-\tau_{t,i})$

$$p_t = b_t w_t(1-\tau_{t,i})\ . \tag{6.10}$$

The factor b_t scales the pension benefits up or down according to changes in wages and demographics over time and is given by

$$b_t = b_{t-1} * \frac{w_{t-1}(1-\tau_{t-1})}{w_{t-2}(1-\tau_{t-2})} * \left(\frac{RQ_{t-2}}{RQ_{t-1}}\right)^{\mu}, \tag{6.11}$$

where RQ_t is the ratio of the number of retirees to the number of contributors. As a consequence, b_t decreases when net wages decrease and RQ_t increases over time. The second effect is especially pronounced when the population ages. As Börsch-Supan et al. (2016b) state, the parameter μ in equation (6.11) can be interpreted as a political compromise between current voters' preferences and the financial sustainability of the pension system. Accordingly, the parameter captures the intergenerational distribution of the demographic risk generated by population aging: setting $\mu = 0$ stabilizes the replacement rate of pension benefits to the older generation while $\mu = 1$ stabilizes the contribution rate of the younger generation.

6.2.3 Production sector

The production of output, Y_t, takes place in a representative firm. This firm produces according to a production technology, which is described by a Cobb-Douglas production function. The capital stock, K_t, (consisting of aggregate savings of both type of households) and aggregate effective labor supply, $L_{t,i}$, (consisting of aggregate labor supply of both types of households) serve as inputs

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}, \tag{6.12}$$

where A_t is labor augmenting technology growing at rate g_t. α denotes the capital share in the economy. Due to the perfect market setting, production factors earn their marginal product, i.e. the wage, w_t, and interest rate, r_t, are given by

$$w_t = A_t(1-\alpha)k_t^{\alpha}, \quad (6.13)$$

$$r_t = \alpha k_t^{\alpha-1} - \Delta\ , \quad (6.14)$$

where k_t denotes the capital stock per efficient unit of labor ($K_t/(A_t L_t)$) and Δ is the yearly depreciation rate of capital. Calibrated parameter values are described in Section 6.3.

6.2.4 Demography

Demography is characterized by the size of each cohort, $N_{t,j}$, the conditional survival rate of that cohort, $\varphi_{t,j}$, and migration. All three demographic aspects are treated as exogenous, i.e. a decision that might influence these components does not take place within the model framework. The size of population at age *j* in period *t* is given by

$$N_{t+1,j+1} = N_{t,j}\varphi_{t,j}. \quad (6.15)$$

The number of people in cohort *c* at time *0* depends on the fertility of women aged *k* at time *c=t-j*:

$$N_{c,0} = \sum_{k=0}^{\infty} f_{c,k} N_{c,k}. \quad (6.16)$$

Population aging can be described by the evolution of the two variables $\varphi_{t,j}$ and $f_{c,k}$ over time. Past, current, and potential future increases in longevity of people is expressed by higher values of $\varphi_{t,j}$. The shift from baby-boom to baby-bust is described by past changes of fertility, $f_{c,k}$. Fertility below the replacement level, which is currently true for several countries, is modelled by current and future low levels of $f_{c,k}$. Since it gives a good example for an aging country, German data is chosen to simulate the model. Data on cohort size, age distributions, and projections for fertility, mortality, and migration are taken from the middle scenario of the Human Mortality Database (2016). Life expectancies, which will be necessary for computing the evolution of retirement ages in the 2:1 reform, are computed from life tables also provided by this source.

6.3 Calibration and solution method

The household lives 100 years and enters the labor market at age 15. It is constantly employed until mandatory retirement (no unemployment possible). The parameter values (Table (6.1)) are chosen to achieve calibration targets and are in range with other studies.

Table 6.1: Parameter calibration

Parameter	Values
Discount rate (ρ)	0.01
Risk preference (θ)	2
Consumption weight (ϕ)	0.65
Initial steady state “Sustainability Factor”	0.6
Demographic risk sharing (μ)	0.25
Capital share in production (α)	0.33
Growth rate of labor productivity (g)	0.015
Depreciation rate of capital (Δ)	0.05
Quasi-hyperbolic discount factor (δ)	0.7

Calibration is carried out such that selected simulated moments of the model (in the year 2017) match their empirical counterparts in the data. The target for the capital-output ratio is 2.79 (see European Commission (2018) for Germany), which is achieved in the baseline scenario (2.77) by setting the discount rate, ρ, to a value of 0.01 (Frederick, et al., 2002). Average annual hours worked per person employed in Germany (see European Commission (2018)) are also achieved for 2017. The parameter describing risk preferences, θ, is set to 2, which makes the household risk averse and lies in the middle of estimates (Bansal & Yaron, 2004; Browning, et al., 1999). The relative weight of consumption in the utility function, ϕ, is 0.65 (e.g. French (2005)). The capital share α in the economy equals 0.33 and annual growth rate of productivity 1.5%. The depreciation rate of capital is 5% per year. The initial steady state of the “Sustainability Factor” is 60% and adjusts afterwards according to equation (6.11). The parameter μ which captures the intergenerational distribution of the demographic risk generated by population aging is set to 0.25 in accordance with German legislation. To additionally discount the near future due to quasi-hyperbolic discounting, the factor δ is set to 0.7.

The CGE model is solved using numerical methods. The equilibrium of the OLG model is identified by using the modified Gauss-Seidel iteration (Ludwig, 2007). The algorithm searches for equilibrium paths of consumption and hours worked in a series of inner loops. The solution of the life-cycle optimization is carried out by taking initial guesses for consumption at last age, J. Next, the model is solved recursively using value function iterations and first order conditions. For present-biased households, the special logic of time-inconsistent behavior described in Subsection 6.2.1.2 is taken into account. This procedure delivers first guesses for consumption and corresponding hours worked. Then, the procedure loops forward in order to calculate savings and assets, applying the budget constraint (6.4). The consumption profile, including consumption at last age, is updated such that discounted life-time income corresponds to discounted life-time consumption. This technique is repeated until consumption and the hours profile converge. The household is not allowed to exit the labor market at its own decision but is constantly employed from age 15 until retirement, i.e. no corner solutions in leisure emerge. Note that a borrowing constraint is not in place. This leads to the outcome that policy functions are linear in wealth. After mandatory retirement, the household problem is a pure consumption decision problem since the household does not take into account labor decisions in the optimization problem. After the convergence of these inner loops, asset holdings and hours worked of all types of households and cohorts alive at a given year t are aggregated to receive the capital stock K_t and aggregate labor supply, L_t. Applying equations (6.13) and (6.14), the wage and interest rate can be updated.

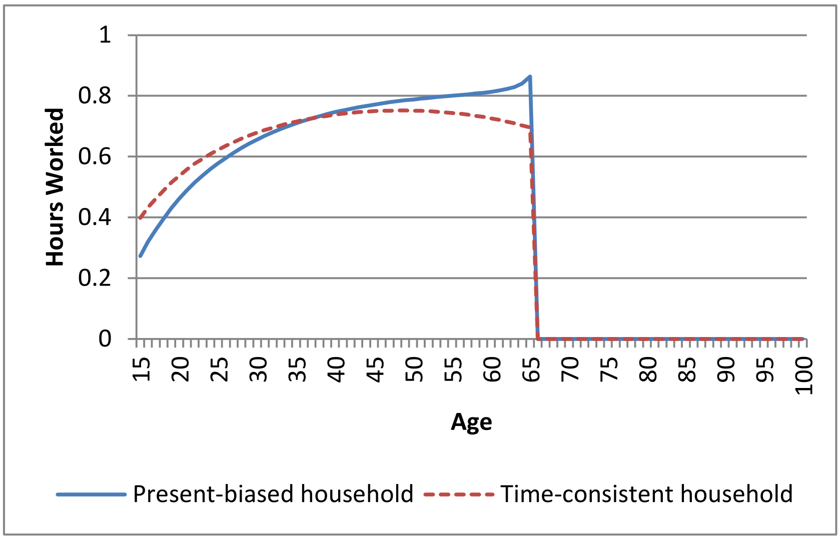
6.4 Partial model results

Before proceeding to the baseline scenario and comparing simulations of the full model, which incorporates a firm sector and a PAYG pension system, life-cycle profiles of the two types of households are discussed in this section to develop a better understanding of the underlying mechanisms. To abstract from transitional and feedback effects from macro variables at this initial stage, an analysis of the two types of households is conducted in a partial equilibrium setting, i.e. without a production sector in place. This implies a fixed wage and interest rate[32]. Savings for old age are assumed to work through private assets, i.e. a public PAYG pension system is not in place in this exercise. Instead, the current setting resembles a fully-funded, voluntary pension system. Note that retirement is mandatory at age 65 since this study abstracts from retirement decisions. Figure 6.1 shows the life-cycle labor supply of a time-consistent and a present-biased household, which both enter the labor market in the year 2017.

The differences between the two hours profiles are clearly visible. While the hours profile of the time-consistent household displays a hump-shaped pattern, the present-biased household's profile shows a constantly increasing pattern. Accordingly, the present-biased household's profile starts at a lower level than the time-consistent household's labor supply. This under-employment early in life is a direct result from impatience, which is in agreement with empirical and theoretical behavioral findings (see, for instance, Augenblick et al. (2015), Fang & Silverman (2009) and van de Ven & Weale (2010)).

[32] The wage is normalized to 1 and a yearly interest rate of 6% per year is assumed. The other parameters correspond to the values described in the calibration section above.

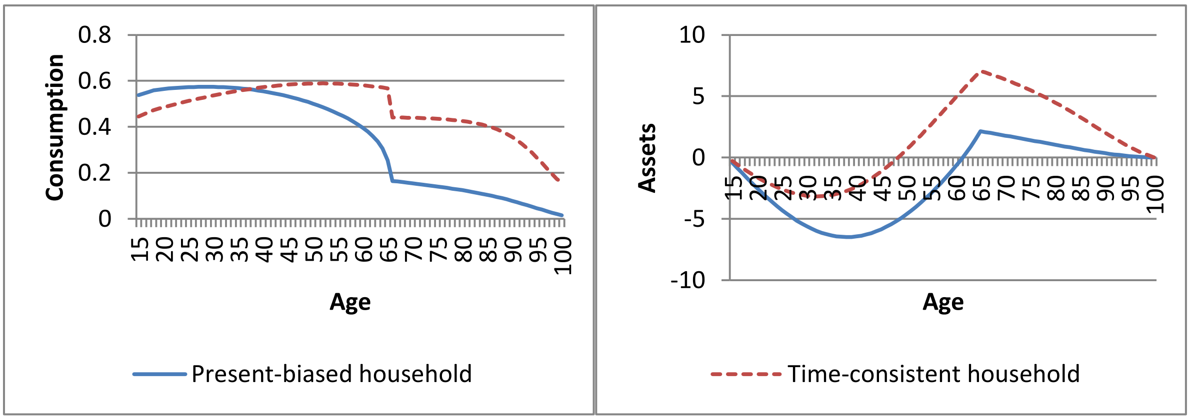
Figure 6.1: Hours profile



Source: own calculations.

Since leisure and consumption are the two goods that the household receives utility from, it over-consumes in these two goods early in life due to present-bias. This can also be seen in the consumption profile in Figure 6.2 (left), which shows the corresponding consumption and savings profiles.

Figure 6.2: Consumption and asset profiles



Source: own calculations.

Because of impatience, the present-biased household also desires to consume consumption goods earlier rather than later. Therefore, the household consumes more (Figure 6.2, left) and works too little (Figure 6.1) compared to the time-consistent household early in life. The corresponding savings (Figure 6.2, right) are much lower for the present-biased household than for its time-consistent counterpart[33].

This lack of accumulating savings during early working life comes at a cost later: due to the missing assets, and, therefore, capital income from these assets, the present-biased household is forced to decrease its consumption and work more to make up for this circumstance in the course of its life. Therefore, the hours and consumption profiles of the present-biased and time-consistent households cross in mid-life. During higher ages, the patterns are reversed: the time-consistent household can afford a higher consumption and works less while the present-biased household is forced to substantially reduce consumption and work more to make up for the debt from over-consumption earlier in life (see Figure 6.2, right). In other words, the time-consistent household can smooth consumption over its life-cycle.

Interestingly, just before the mandatory retirement age, there is a peak in labor supply of the present-biased household while the time-consistent household slightly reduces working hours in view of retirement. This over-employment comes from the fact that the present-biased household realizes too late that its working life is coming to an end. As a consequence, especially during the ages just before retirement, the difference in labor supply is striking and will generally lead to the outcome that aggregate life-cycle labor supply of the present-biased household is larger than that of its time-consistent counterpart. However, this augmented labor supply is not enough to overcome losses in life-time consumption possibilities. Since the present-biased household is so heavily indebted during most of its working life, the loss of asset income is larger than the gain in labor income. Therefore, the present-biased household has to decrease consumption substantially after retirement (see Figure 6.2, left). This lower level of life-time consumption of present-biased households, their under-saving, and especially their augmented labor supply, will have consequences in the full model, which will be discussed in the next section.

6.5 Results

As the previous section revealed, there are substantial differences in life-cycle behavior between time-consistent and present-biased households, especially concerning labor supply. Therefore, it is essential to re-evaluate current pension reform proposals using both types of economic agents and

[33] Note that there is no borrowing constraint in the life-cycle model. Accordingly, present-biased households can borrow early in life to finance their over-consumption while also working less. Imposing a borrowing constraint for present-biased households, however, complicates behavioral predictions since they constitute a commitment device, which is beyond the scope of this paper. Imposing commitment devices would indeed make behavior of the two types of households more similar.

challenge the derivations from standard economic literature. In doing so, differing individual behavior between households will alter macroeconomic variables, which will again have feedback effects on individual behavior, which constitutes one of the contributions of this chapter. Therefore, this section will turn from the microeconomic to the macroeconomic view and apply a full general equilibrium model.

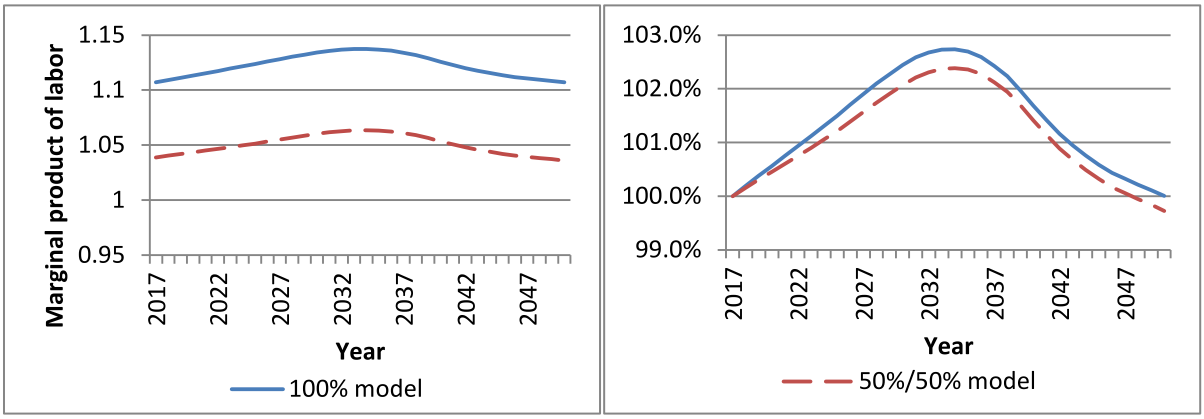
6.5.1 Baseline results

Before studying pension reform scenarios and divergent labor market behaviors of time-consistent and inconsistent households, two model versions are introduced. Both are calibrated with the parameters described in Section 6.3 and differ in the share of time-inconsistent households. In the first version, all households are time-consistent, which resembles the neoclassical case and has often been studied (see also Chapter 2 of this dissertation). The second version contains 50% time-consistent households and 50% present-biased households. Both versions will be simulated for the baseline scenario as well as for all pension reform scenarios studied. The rationale for simulating two model versions is twofold: first, it allows for studying the effect of ignoring present-biased households in economic models when comparing the two model versions (50%/50% vs. 100% model version). The main difference here will be the divergent behavior of macroeconomic variables not only like interest rates and wages, but also contribution rates. Second, present-biased and time-consistent households' behavior can be compared within the same model with identical macroeconomic conditions in the 50%/50% model version. This makes it possible to compare reforms in a "standard" model that only includes time-consistent households (100% model) to an alternative model also inhabited with present-biased households (50%/50% model version). The only force that changes over time in this subsection is demography in the background of the model[34].

Figure 6.3 depicts the resulting wages for both model versions. Note that interest rates would show the inverse behavior (see equations (6.13) and (6.14)).

[34] Note that a "sustainability factor" (see equation (6.11)) is in place from the year 2004 onward and the mandatory retirement age is 65 in the baseline scenario.

Figure 6.3: Marginal product of labor (wages)

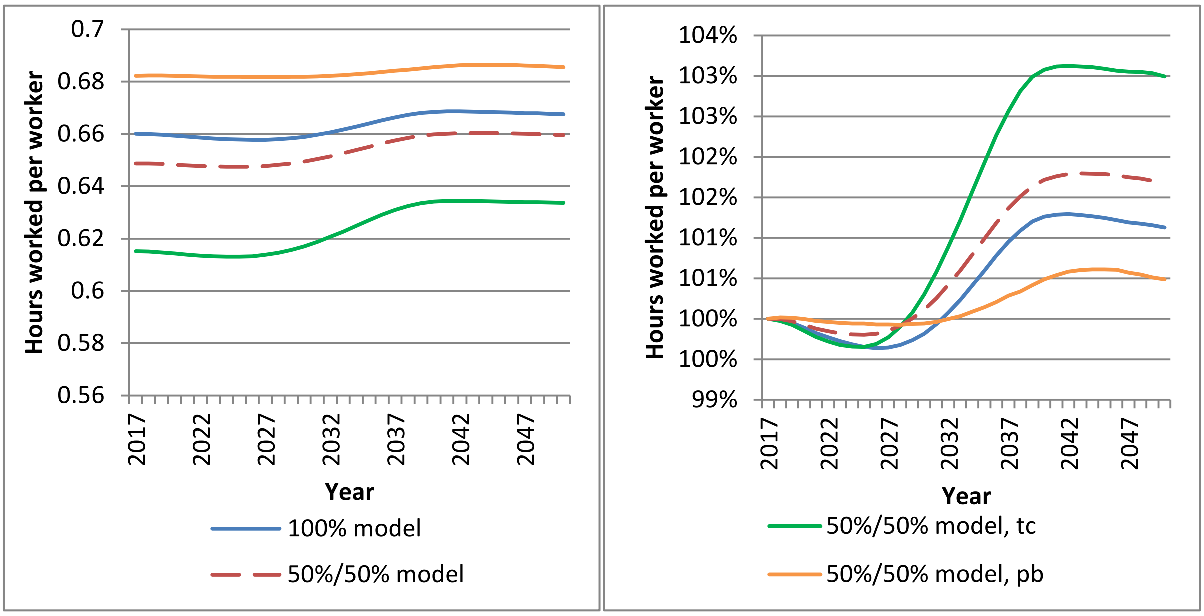


Source: own calculations. While the figure on the right reveals differences in levels, the curves on the left are normalized to 100% in 2017 such that changes in trends are visible.

As a first outcome, there is an inverse u-shaped pattern in wage. Interest rates, in contrast, move in the opposite direction (u-shaped, not shown). This general pattern in both model versions can be explained by demographics: in early years, there is still the phenomenon of elevated savings since large cohorts (baby-boomers) save large amounts of assets to finance retirement. This increases the economy's capital stock which drives down the price for capital, namely, interest rates. For wages, the opposite argument holds. In later years, when these large cohorts start retiring and dissaving, the trend turns around and interest rates start increasing while wages decrease.

Looking at differences between the two baseline model versions, wages are higher in levels in the case with 100% time-consistent households (Figure 6.3, left). This is because rational households, compared to their present-biased counterparts, generally save more for retirement (see findings in the household model in Section 6.4), which increases the capital stock and, consequently, wages. At the same time, these higher individual savings produce larger fluctuations in the capital stock which, in turn, leads to more pronounced reactions of wages and interest rates (Figure 6.3, right). Accordingly, in the model version with 50% present-biased households, this observed pattern is smoother. Since households procrastinate, the resulting increase in the capital stock is smaller and, therefore, wages stay lower and interest rates higher. When consuming their savings at old ages, this pattern will turn around in both cases. Since the increase in savings was larger in the model version with 100% time-consistent households, the dissaving is also larger than in the scenario with 50% time-inconsistent households.

Figure 6.4: Labor



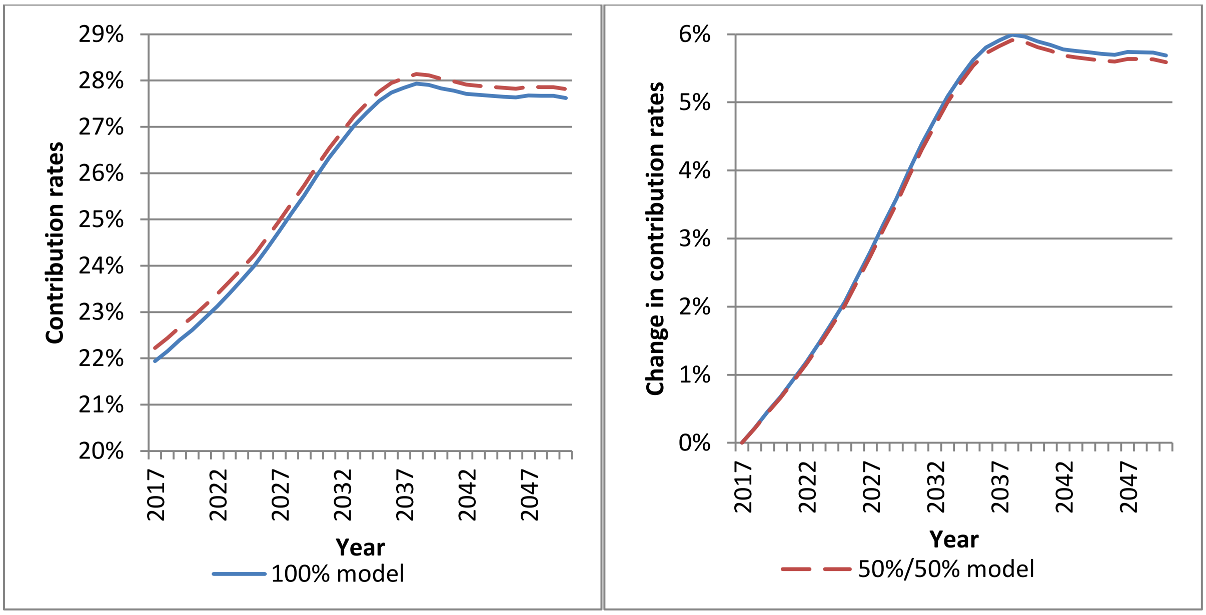
Source: own calculations. Note that the graphs show the average value over all cohorts at a point in time displayed on the x-axis. The right part shows the changes in hours worked normalized to 100% in the year 2017.

Figure 6.4 displays the evolution of hours worked per worker in the economy over time. They generally increase over time, which is similar for both model versions. Furthermore, in levels (see Figure 6.4, left), average labor supply is lower in the 50%/50% model version. This is due to lower wages relative to interest rates which stems from the smaller capital stock in this version of the model (see Figure 6.3, right). When comparing both types of households within the 50%/50% version (i.e. same wage for both types of households), present-biased households supply more labor in levels than their time-consistent counterparts (Figure 6.4, left). This result stems from the time-inconsistent behavior, which was explained in Section 6.4: since time-inconsistent households over-consume when young, they have to work more to finance retirement.

The reason for the general rise in hours worked per worker is the increasing wages (see Figure 6.3, right). However, these gains in labor per worker differ between model versions and types of households: labor increases less strongly in the 100% than in the 50%/50% model version. This comes from the higher level of aggregate labor supply in the 100% model version. Since time-consistent households already work a lot and are consequently closer to the maximum labor constraint, they react less strongly to changes in labor incentives, i.e. wages. A similar argument holds when comparing both types of households within the 50%/50% model version: here, time-consistent households are especially likely to increase their labor supply. This is due to the very low level of labor for time-consistent households in the 50%/50% model version, allowing them to react more strongly to changes in wages.

Note that the analysis of labor supply has concentrated on the hours worked per worker. Due to the retirement of large cohorts during this time, aggregated labor supply shows a clear negative trend, which is mirrored in contributions to the pension system. Figure 6.5 shows contribution rates for the 100% and 50%/50% model versions.

Figure 6.5: Contribution rates



Source: own calculations. The graph on the left displays the absolute value while the graph on the right shows changes in percentage points (p.p.).

As a first finding, contribution rates are generally higher in levels in the model with 50% present-biased households (see Figure 6.5, left). This is because aggregate labor supply is higher in the 100% model version due to higher wages (see Figure 6.4, left)[35]. More importantly, the increase in contribution rates over time (Figure 6.5, right) is smaller in the 50%/50% model version than in the standard model with only time-consistent households. This is the mirror image of labor supply trends displayed in Figure 6.4 (right): due to the stronger reaction to wage changes of aggregate labor supply in the 50%/50% model version, contribution rates do not have to rise as strongly in order to balance the pension system.

Yet, consequences for the pension system are not the only dimension worth investigating. When taking consumption p.c. as a gross approximation for welfare of households, it is generally lower in levels in the model with 50% present-biased households (see Figure B.6.1 in Appendix B). This is because of the non-optimal behavior of time-inconsistent households: even though they work

[35] This is in line with previous research that finds that PAYG-DB pension systems are negatively affected in form of increasing contribution rates when procrastination is equally distributed across countries (see Chapter 5 of this dissertation).

more on average, their lack of savings and, therefore, capital income, lowers consumption. In addition, the decrease in consumption is larger in the 50%/50% model version. This is because of the presence of time-inconsistent households: the stronger decrease in consumption of present-biased households also makes the average consumption in the 50%/50% model version decline faster.

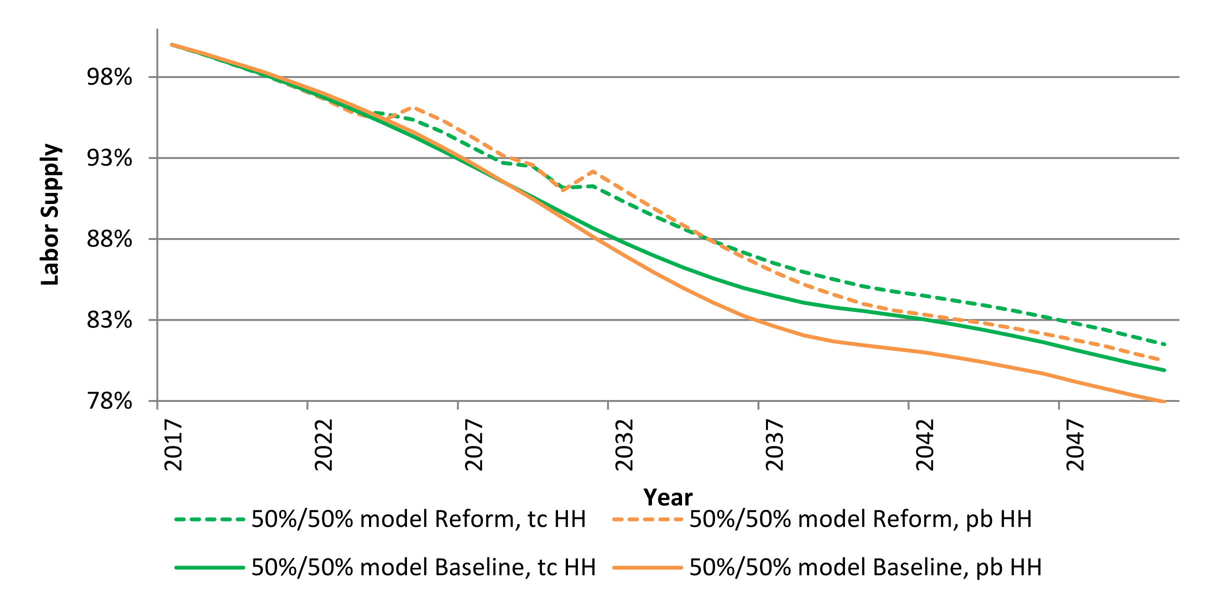
As an interim result, when evaluating the effects of aging without a policy reform, one has to be aware that a model with only time-consistent households slightly overestimates the negative effects of aging on labor supply and, consequently, on the pension system. This is mostly due to changes in macro-variables and different reactions of economic agents. The question arises whether implications from reform evaluations also change when including hyperbolically discounting agents in the model, which is the aim of the following analysis.

6.5.2 Increasing the retirement age

In order to make public pension systems more sustainable, increasing contributions to the PAYG system by activating more labor can be a helpful solution (see Chapter 2 of this dissertation). To incentivize people to work longer at older ages, many countries have increased (and are still increasing) their statutory eligibility ages at which people can retire without deductions. Similar to the evolution in other countries, the statutory eligibility age in Germany, for instance, has been gradually rising from age 65 to 67 since the year 2012 and will until the year 2029. In this section, this reform is implemented by increasing the retirement age in the model framework. Note that, since this chapter abstracts from endogenous retirement decisions, an increase of the mandatory retirement age is modeled because there is no statutory eligibility age with corresponding deductions.

The reform indeed has a substantial impact on labor supply for both types of households. Figure 6.6 disentangles aggregate labor supply and differentiates between the labor supplies of the two types of households within the 50%/50% model version. Comparing each type of household’s labor supply reaction to the reform within the 50%/50% model version, there is an important finding: present-biased households increase labor supply more than time-consistent households (difference in orange lines (present-biased) vs. green lines (time-consistent), see Figure 6.6).

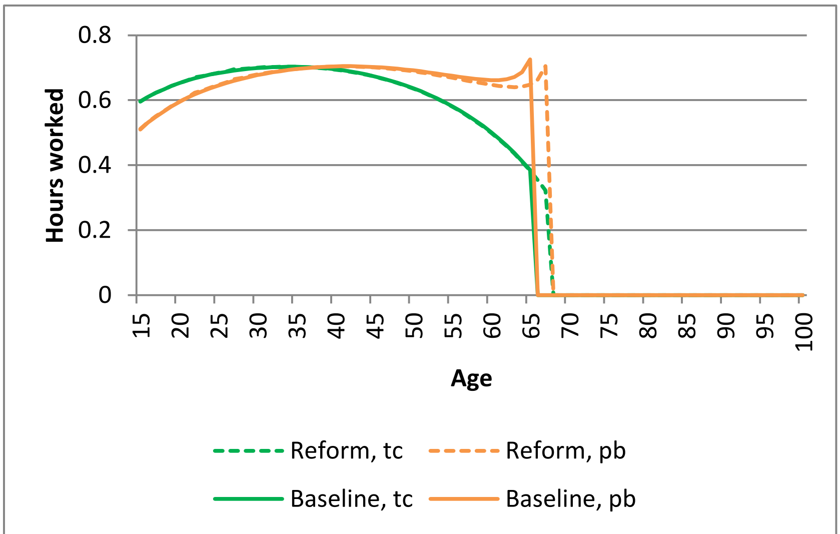
Figure 6.6: Labor supply of different households



Source: own calculations. The graphs show aggregate labor supply of all cohorts alive at a specific point in time displayed on the horizontal axis. Hereby, the two groups of time-consistent (green) and present-biased (orange) households are differentiated. Baseline results are depicted in solid, reform results in dashed lines. Values are normalized to 100% in the year 2017.

The reason for this difference stems from different life-cycle profiles of hours worked between the two types of households. Figure 6.7 pictures this argument using life-cycle hours profiles for cohorts that enter the labor market in 2017.

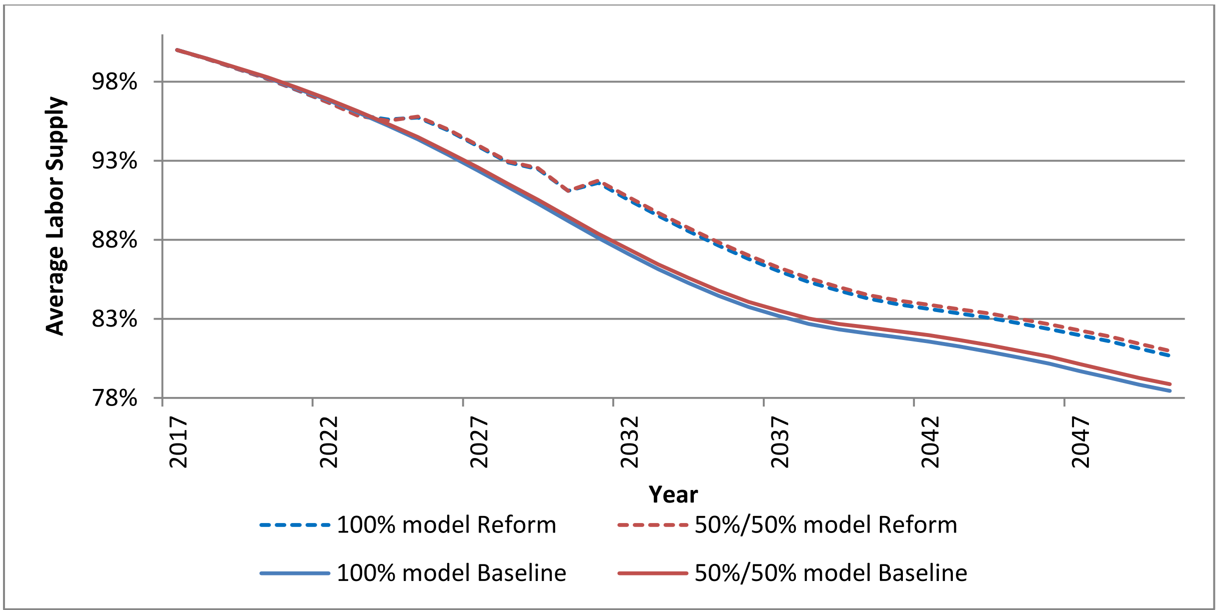
Figure 6.7: Life-cycle hours profiles



Source: own calculations.

Thus, time-consistent households react less substantially to the change in the mandatory retirement age. In fact, both types of households extend working time until the new retirement age on the extensive margin. However, since time-consistent households already reduce labor supply on the intensive margin before retirement, the additional working time due to the increase in working years for these types is relatively small. At the same time, the reduction of working hours on the intensive margin during younger ages is relatively small compared to the extension of working years. As a consequence, labor supply of time-consistent households changes less due to the pension reform, while present-biased individuals react more strongly to this reform. As was explained in Section 6.4, present-biased individuals increase working hours just before retirement. For them, too, the reduction of labor supply on the intensive margin is negligible compared to the increase on the extensive margin. In other words, since labor supply shows an upward trend at higher ages for present-biased households, the total increase in labor volume is larger for these households. All in all, time-inconsistent households seem to react stronger to the reform, which feeds through to aggregate labor supply as displayed in Figure 6.6. However, this conclusion is only true within the 50%/50% model version. When extending the analysis to the macro level and taking into account different wages and interest rates, this message changes.

Figure 6.8: Aggregate labor

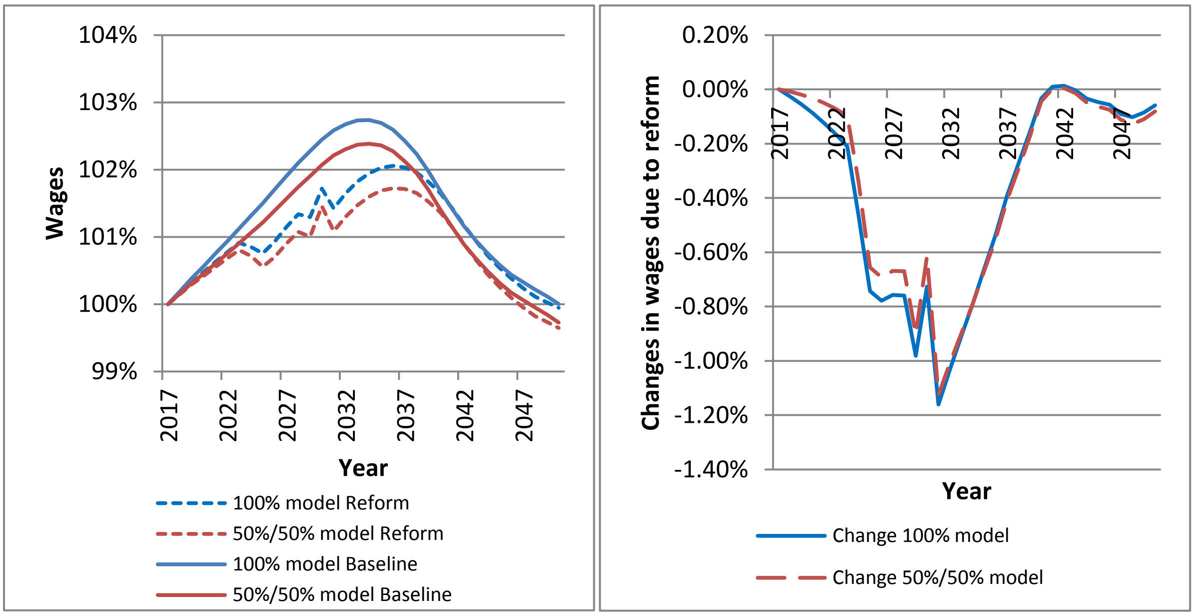


Source: own calculations.

Aggregated labor of both types of households over time is depicted in Figure 6.8 for the baseline and reform scenario and for the 100% time-consistent and 50%/50% model versions. Indeed, and this is the target of the reform, an increase of retirement ages dampens negative demographic effects on aggregate labor volume: both model versions show a substantially smaller decline in labor supply by the year 2050.

Furthermore, the reform has a slightly larger positive impact on aggregate labor supply in the 100% time-consistent model version than in the model that also incorporates present-biased households (the gap between red lines is smaller than between blue lines). This is due to the larger reaction of wages in the 100% model version, which delivers incentives for labor supply. This argument is depicted in Figure 6.9. The first observation is the more pronounced decrease in wages due to the reform, which can be explained by the rise of aggregate labor volume in the aftermath of the reform: if aggregate labor increases, its marginal product, namely wage, decreases. Importantly, wages (and interest rates) react stronger in the 100% model version due to the reform (see graph on the right in Figure 6.9, which shows changes in wages due to the reform). This is because of higher aggregate savings in the 100% model version (see life-cycle savings in Figure 6.2): a given increase in absolute labor supply due to the increase in the retirement age has a larger impact on the marginal product of labor when the complementary capital stock is higher – as it is the case in the 100% model version. In the long run, however, this effect fades out and wages of both model versions move in parallel (see Figure 6.9, right).

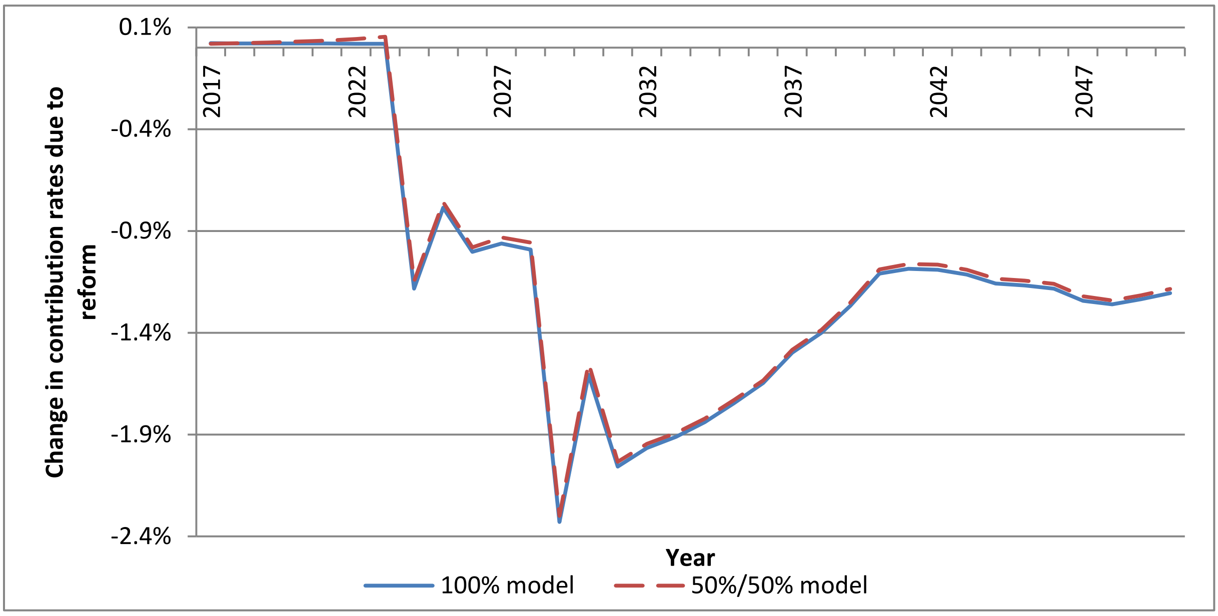
Figure 6.9: Wages



Source: own calculations. Wages are normalized to 100% in 2017 in the left graph. The right graph shows the difference between the reform and the baseline scenario (reform minus baseline) of the graph on the left.

In general, due to the retirement of large cohorts, pension benefits paid to pensioners increase during the projection period. Because of this increase and the simultaneously decreasing labor volume, the contribution rate has to rise in order to balance the PAYG pension system. However, due to augmented labor volume in the aftermath of the reform as depicted in Figure 6.8, contribution rates have to increase slightly less. The difference in contribution rates between the reform and the baseline scenario is depicted in Figure 6.10. Not too surprisingly, the reform leads to lower contribution rates compared to the baseline scenario by up to 2.4 p.p..

Figure 6.10: Change in contribution rates



Source: own calculations.

As a direct result of a less pronounced reaction of aggregate labor supply as depicted in Figure 6.8, the effect of the reform is smaller in the model version with 50% present-biased households. However, this result is very small in terms of contribution rates. Still, a conventional model with only time-consistent households would slightly overestimate the positive effect of the reform on the pension system.

From the viewpoint of households, the picture looks different: in terms of consumption p.c., two findings can be derived (Figure B.6.2 in Appendix B). First, the reform is generally beneficial in both models, which is in line with previous findings (see Chapter 3 of this dissertation). The economic stimulus that comes from additional labor supply and lower contribution rates to the pension system arrives at consumption p.c.. Second, and more importantly, omitting present-biased households in models that evaluate pension reforms potentially underestimates the positive effect of pension reforms in terms of consumption p.c. for different types of individuals. The explanation for this finding can be derived from Figure B.6.3, which disentangles consumption p.c. for each household type. The reform raises consumption p.c. much more for present-biased households than for time-consistent households. The reason for this is found in different labor supply behavior: present-biased households increase labor more than their time-consistent counterparts after the reform.

Refining the concept of welfare, an additional analysis of the reform in terms of CEV is essential (Figure B.6.4 in Appendix B). This concept allows for the comparison of utility levels between scenarios measured in percent of life-time consumption. A positive number indicates that one would have to give the household a certain percentage of its life-time income in the baseline scenario such that it is as well off as in the reform scenario. In other words: reforms make the household better off when the numbers are positive. Confirming the results on consumption p.c., the reform makes households much better off. Importantly, both types of households in the 50%/50% are better off than the time-consistent household in the 100% model version (1.8% and 1.1% of life-time income versus 0.9% for those cohorts entering the labor market in the year 2020). Therefore, the 100% model version would underestimate welfare consequences of such a pension reform. Within the 50%/50% model version, it becomes clear that the present-biased household is much better off than its time-consistent counterpart. This is due to the stronger reactions in labor supply and consumption p.c. of the present-biased household in the aftermath of the reform as explained above.

6.5.3 The 2:1 reform

Aging, as one of the main driving force of imbalances of PAYG pension systems, is caused by increasing life expectancies and low fertility rates. However, success of pension reforms often turns out to be only temporary until the previous imbalances that were meant to be taken care of emerge again since life expectancy is still increasing. That is why an increase in the statutory eligibility age today to 67 (see Subsection 6.5.2) would soon lead to the same problems for pension systems. A possible solution for avoiding recurring discussions, which was previously presented by Börsch-Supan (2007), offers a systematic rule that could be understood by any citizen and that accommodates changes in demographic dynamics. This rule, called the “2:1 rule”, says that sufficient increases in life expectancy of individuals should be compensated by increases in the statutory eligibility age on a proportional basis. This comes from the thought that, since an individual works approximately two thirds of its life, an increase of 3 years in life expectancy should result in an increase of 2 years of working time and 1 year in retirement – the 2:1 rule. In order to implement this rule in this model framework, a benchmark life expectancy age of cohorts retiring in 2017 is defined. From this year on, any cohort whose life expectancy exceeds 1.5 years from the benchmark will face an increase in the statutory eligibility age of 1 year. This life expectancy will be the new benchmark and, later on, any other cohort with 1.5 years more of life expectancy will face another increase in the statutory eligibility age by one year. In this section, this reform proposal is now simulated by increasing the mandatory retirement age according to the 2:1 rule described above. The detailed development of retirement ages is displayed in Table 6.2.

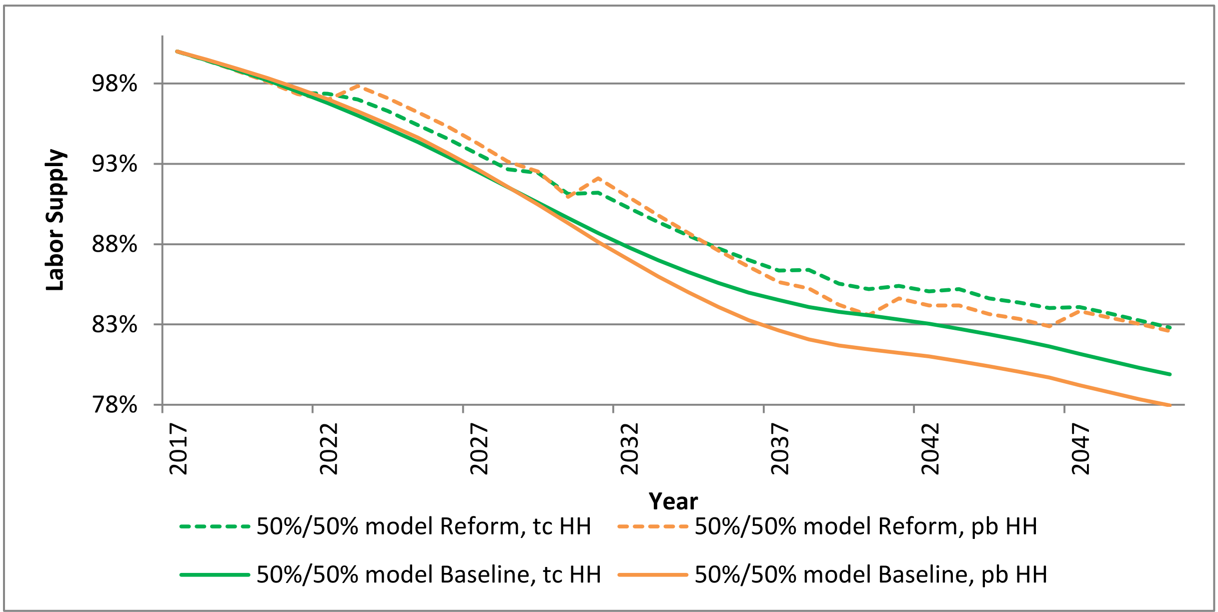
Table 6.2: Evolution of retirement ages

Years	Retirement age
2017-2021	65
2022-2028	66
2029-2037	67
2038-2042	68
2043-2051	69
2052 - onwards	70

Source: own calculations using data from the Human Mortality Database (2016), middle scenario.

Within the 50%/50% model version, there is a clearly larger increase of labor supply of present-biased households in the aftermath of the reform compared to their time-consistent counterparts (see Figure 6.11).

Figure 6.11: Labor supply of different households

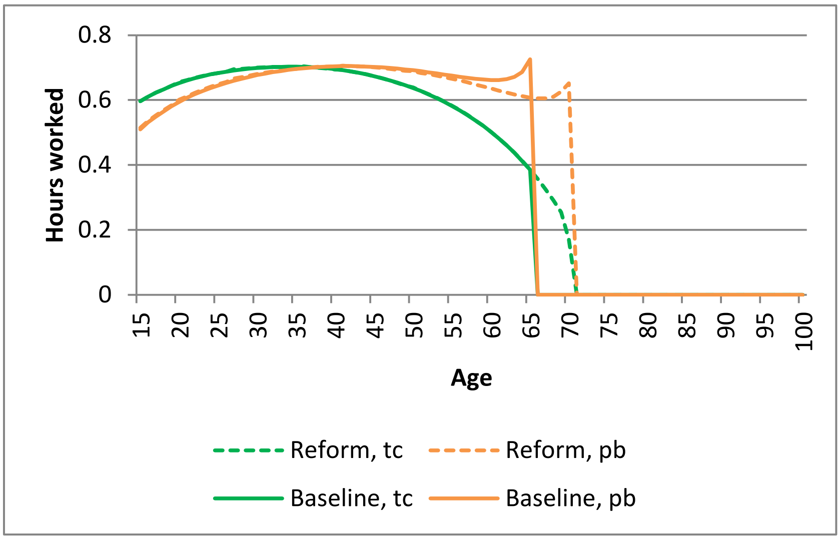


Source: own calculations.

The difference between labor supply of present-biased households in the reform case and in the baseline scenario (orange lines) is substantially larger than the respective labor supply of time-consistent households (green lines). Thus, the reform leads to a narrowing in labor supply development of both types of households due to high retirement ages (the gap between dotted lines is substantially smaller than between solid lines).

This can be explained by divergent life-cycle labor decisions, which are depicted in Figure 6.12 for the 50%/50% model version. As expected, the differences between the reform and the baseline scenario are now much more pronounced than in the 67 reform scenario. Present-biased households work until the mandatory retirement age of 70 while time-consistent households reduce their working hours almost to zero just before retirement. On the intensive margin, households slightly reduce their working hours, which can be seen for present-biased households in the peak in working hours just before retirement. The time-consistent household, in contrast, only slightly decreases its intensive working hours. However, it becomes clear that total labor supply, i.e. the product of intensive working hours and the length of working time, increases substantially more for present-biased than for time-consistent households. To see this, one has to compare the areas between the green lines (time-consistent) and orange lines (present-biased).

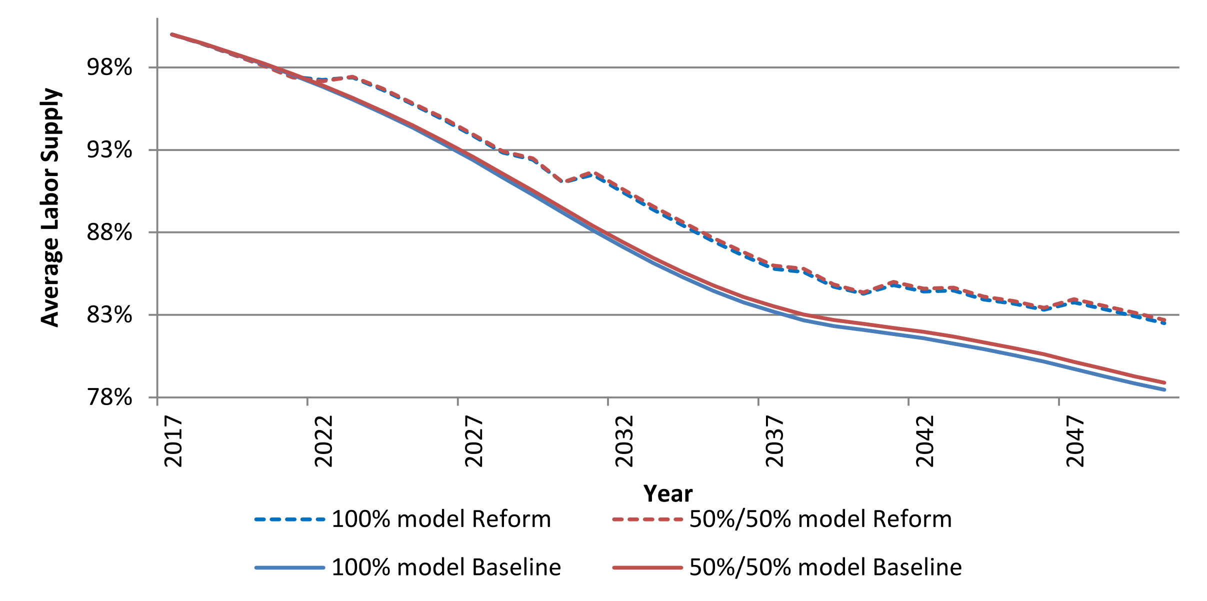
Figure 6.12: Life-cycle hours profiles



Source: own calculations.

Comparing both versions of the model and thus allowing for different factor prices, aggregate labor supply in the economy over time is displayed in Figure 6.13 for the 2:1 reform scenario and the baseline scenario. Again, the reform meets its goals and generally increases labor supply compared to a scenario without such a reform.

Figure 6.13: Aggregate labor

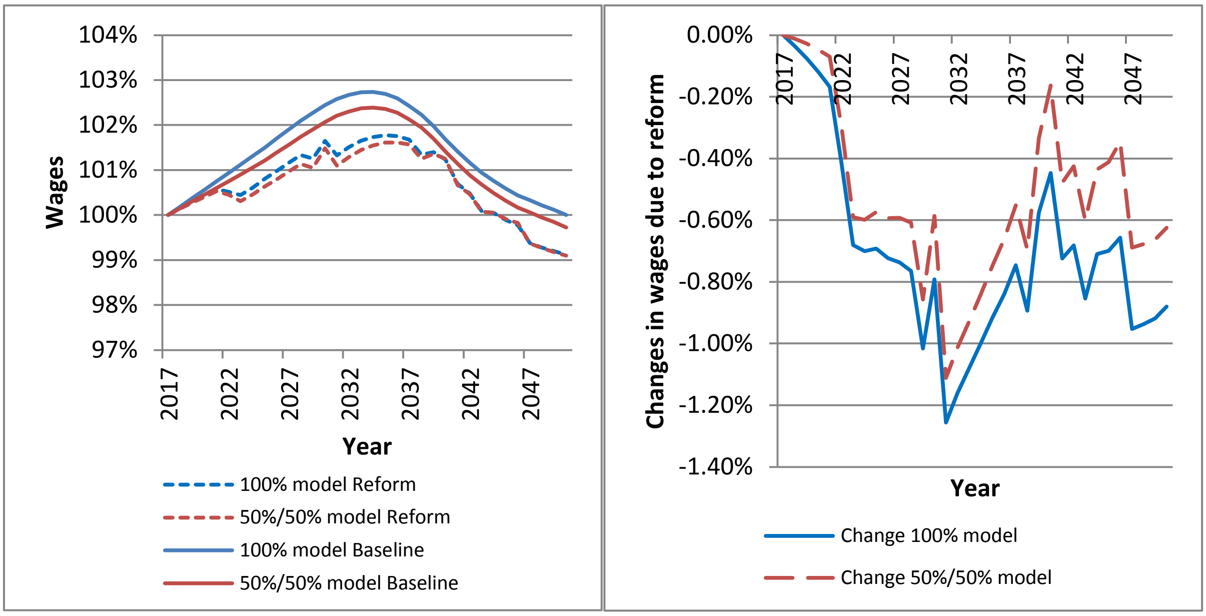


Source: own calculations.

However, in the long-run, labor supply stabilizes at 83% rather than 81% as was the case in the previous reform. This is due to the larger increase in retirement ages. As before, in a model with present-biased households (difference in red lines), the reform has a smaller positive impact on aggregate labor supply in the 50%/50% model version than in the model that only incorporates time-consistent households (difference in blue lines). This is due to the substantially larger negative reaction of wages due to the reform: Figure 6.14 shows these wages for the reform scenario. One can recognize two differences to the previous reform scenario. First, changes are substantially larger than before. This is straight forward given that the retirement age increases by up to 5 years from 2052 onwards.

Second, and more interestingly, the observed pattern does not narrow with time as was the case in the previous reform scenario. Accordingly, long-run wages remain below their baseline levels for a sustained period of time. This will have some further implications on labor supply behavior of households. Similar to the previous reform scenario, the reaction of wages in the aftermath of the reform is larger in the 100% than in the 50%/50% model version. While there is still a substantial gap between both model versions in the baseline scenario than in the previous reform scenario, the development of wages is now closer to the reform scenario for both model versions (see Figure 6.14, left). The 2:1 reform, therefore, leads to a more parallel evolution of macroeconomic aggregates for both model versions over time than in the baseline scenario, which stems from high retirement ages.

Figure 6.14: Wages

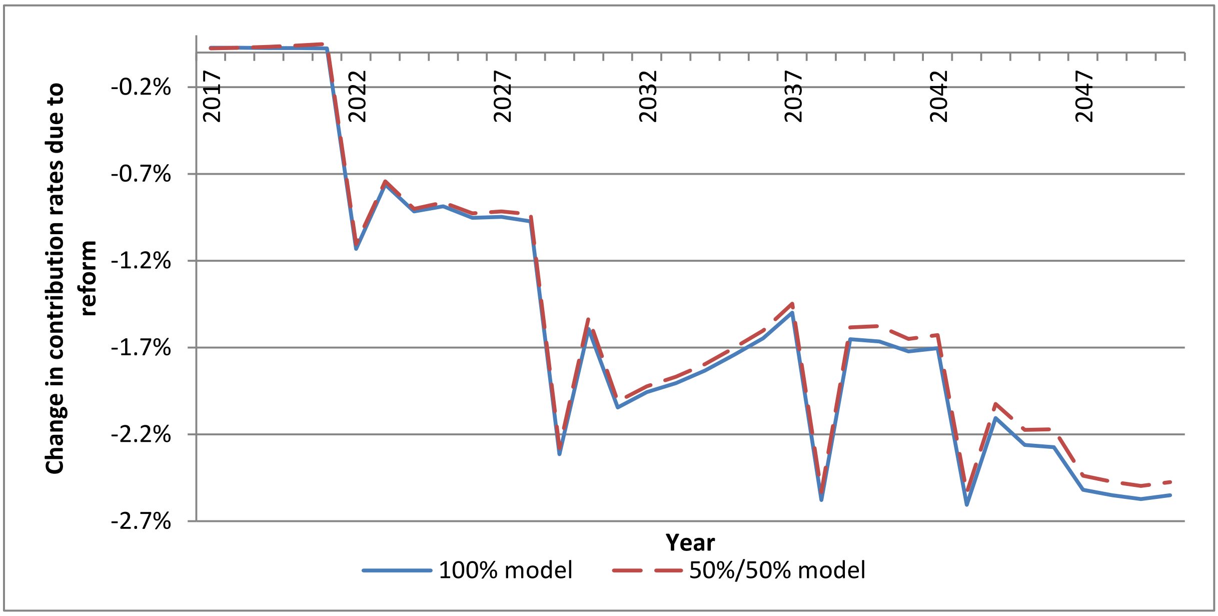


Source: own calculations. Wages are normalized to 100% in 2017 in the left graph. The right graph shows the difference between the reform and the baseline scenario (reform minus baseline) of the graph on the left.

Because of augmented labor volume in the aftermath of the 2:1 reform as depicted in Figure 6.13, contribution rates increase less than in the baseline scenario. The difference in contribution rates between the reform and the baseline scenario is depicted in Figure 6.15. This time, the reform leads to lower contribution rates compared to the baseline scenario by up to 2.7 p.p.. In contrast to the 67 reform depicted in Figure 6.10, under the 2:1 reform, the effect does not fade out over time but rather rates stay at low levels for a prolonged period of time.

Figure 6.15 also reveals that the effect of the reform on contribution rates is smaller in the model version with 50% present-biased households, this being a direct result from different labor supply reactions as depicted in Figure 6.13. For the 2:1 reform, however, this result is larger in terms of contribution rates than was the case in the previous section and is thus not negligible. The 100% time-consistent model version would accordingly lead to an overestimation with respect to consequences for the pension system.

Figure 6.15: Contribution rates



Source: own calculations.

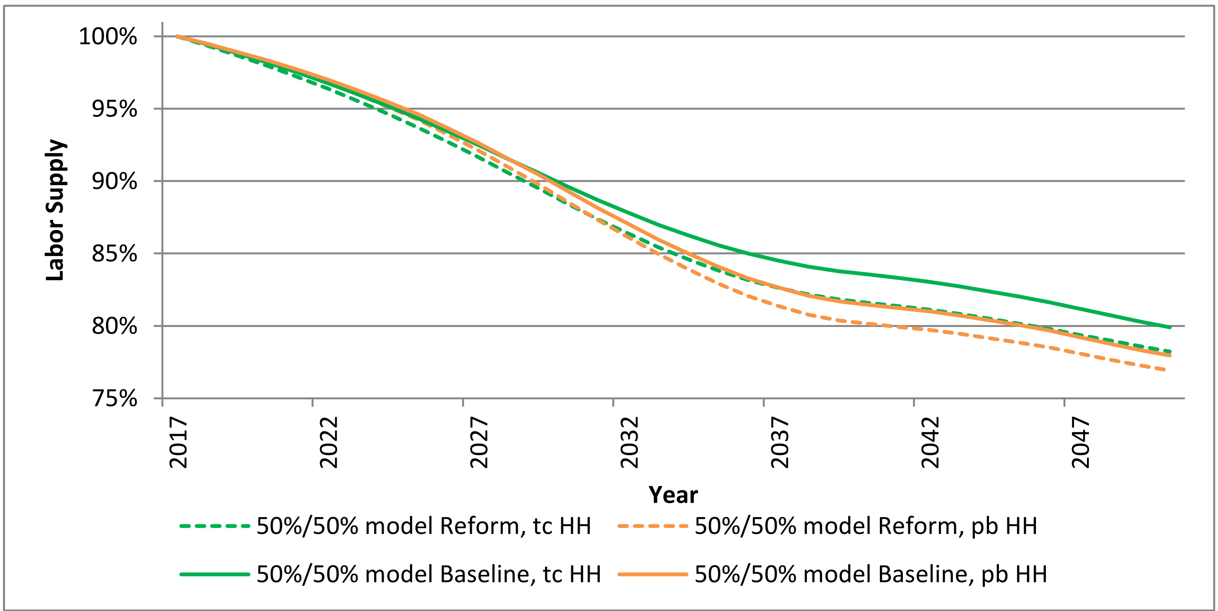
For households, the situation again looks different: in terms of consumption p.c. (Figure B.6.5 in Appendix B), the 2:1 reform offsets much of the decrease due to aging. This result has been found in previous work using models consisting of only time-consistent households (Chapter 3 of this dissertation). The main message here, which becomes even more pronounced than in the previous reform scenario, is that the inclusion of present-biased households in the analysis shows a much larger effect of the reform in a model with 50% present-biased households than in a model without present-biased households in terms of consumption p.c.. Models consisting of only time-consistent households, therefore, underestimate the beneficial effects of such reforms.

A more elaborate welfare analysis in terms of CEV (Figure B.6.7 in Appendix B) delivers a similar picture as in the previous section and confirms the results for consumption p.c.. However, welfare gains are increasing for a much longer time. While the CEVs only reach values of 1.4% for the cohort entering in 2020 for time-consistent households in the 100% model version, the time-consistent household in the 50%/50% model version profits by 1.6% and the present-biased household by 3.3%. This is again due to stronger reactions in labor supply of the present-biased household in the aftermath of the reform. In conclusion, the 100% model version would again underestimate welfare consequences of the 2:1 pension reform. The underestimation of the reform effect is substantially larger for the 2:1 reform scenario than for the 67 reform scenario in the previous section. Consequently, the error of omitting the behavior of present-biased households is therefore not negligible for this reform proposal.

6.5.4 Hybrid DB/DC vs DB

As described in Subsection 6.2.2, the hybrid DB/DC mechanism in the baseline scenario leads to an automatized adjustment of pension benefits to demographic trends and the evolution of wage growth (see equation (6.14)). The aim of this "sustainability factor" is to make PAYG pension systems more sustainable by sharing the burden of an aging population between generations without requiring politicians and scholars to constantly intervene. In politics, this circumstance is sometimes seen as worrisome because it is feared that pension benefits will not be sufficient in financing a minimum standard of living for specific population groups. Therefore, there are recurring policy proposals to hold the replacement rate constant which means returning to a defined benefit regime. In order to study these proposals, a reform proposal that holds the replacement rate constant from the year 2017 onward until 2045 is simulated. To set the replacement rate constant means that the contribution rates have to adjust endogenously to finance the PAYG pension system. After 2045, the "sustainability factor" is assumed to adjust again according to equation (6.14). Figure 6.16 shows the resulting labor supply of the different types of households within the 50%/50% model for this reform simulation.

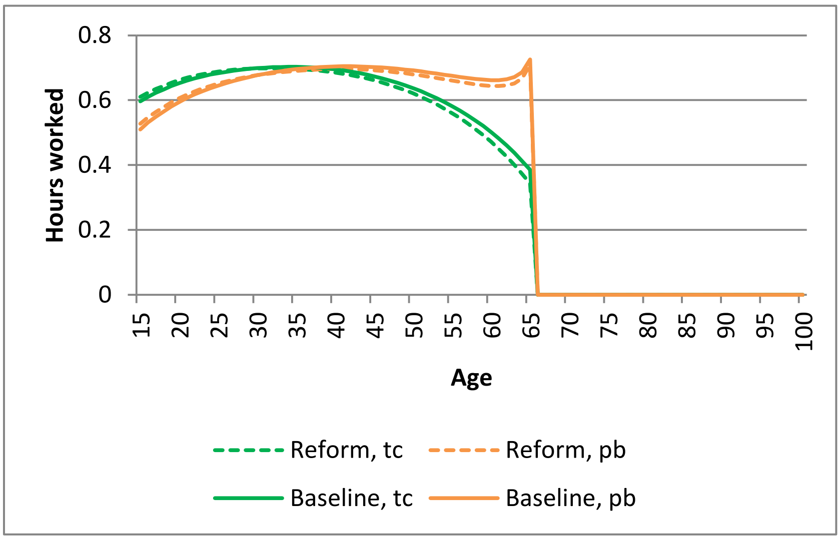
Figure 6.16: Labor supply of different households



Source own calculations.

In contrast to the two previously examined reforms, the negative reaction of labor supply due to this reform is larger for time-consistent than for the present-biased households (the gap between green lines is visibly larger than between orange lines). This surprising outcome comes from the strong increase of contribution rates in the aftermath of the reform. Time-consistent households react more strongly to these labor dis-incentives. Present-biased households, in contrast, react more sluggishly to these incentives since they have to make up for the over-consumption and under-employment during their early stages of life – independently from changes in labor incentives (i.e. increasing contribution rates). Complementing the picture on labor supply of the two types of households, Figure 6.17 depicts the life-cycle profiles of hours worked.

Figure 6.17: Life-cycle hours profiles

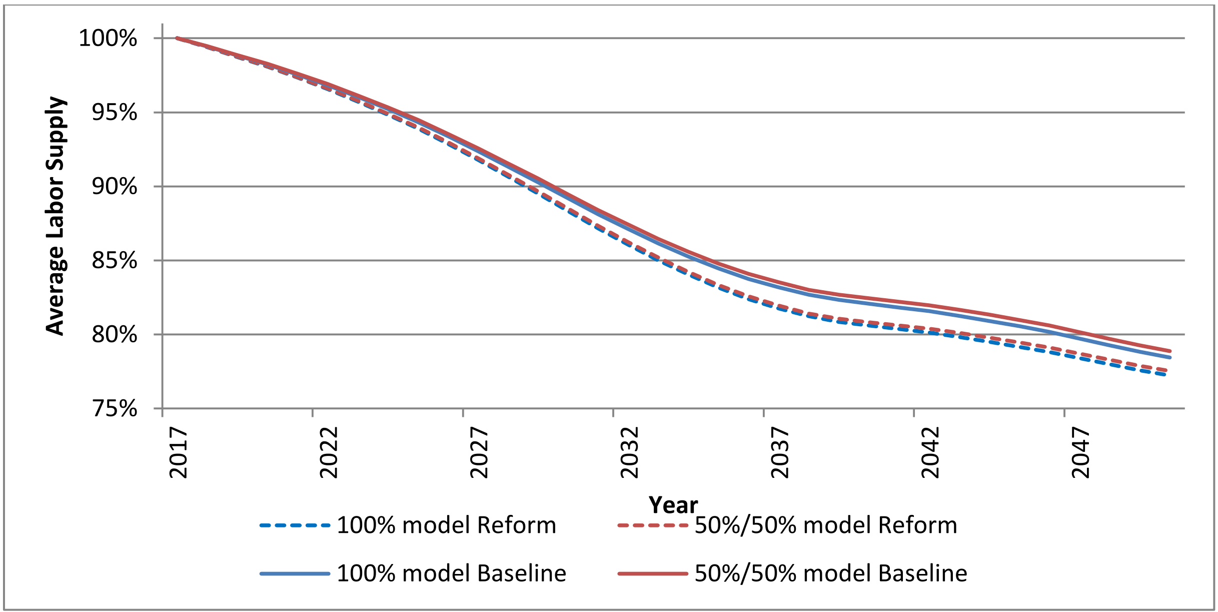


Source: own calculations.

Again, it becomes clear that higher contribution rates are harmful for the labor supply of both model versions: in the reform case (dotted lines), hours worked are almost always below the solid lines (baseline). Only during young ages, when the reform has not yet settled in, labor supply is slightly higher. Time-consistent individuals reduce their labor supply more substantially. Present-biased households also reduce hours worked but to a lesser extent. This is because, especially in later stages of their life, they have to make up for their over-consumption earlier in life. Accordingly, they react less strongly to changes in labor incentives before retirement. This explains why the decrease in hours is larger for time-consistent than present-biased households, as depicted in Figure 6.16.

When comparing both model variants, Figure 6.18 suggests that the decrease in aggregate labor supply due to higher contribution rates is larger in both reform scenarios than in the corresponding baseline scenarios. This is due to the large increase in contribution rates and its corresponding labor supply distortions mentioned earlier.

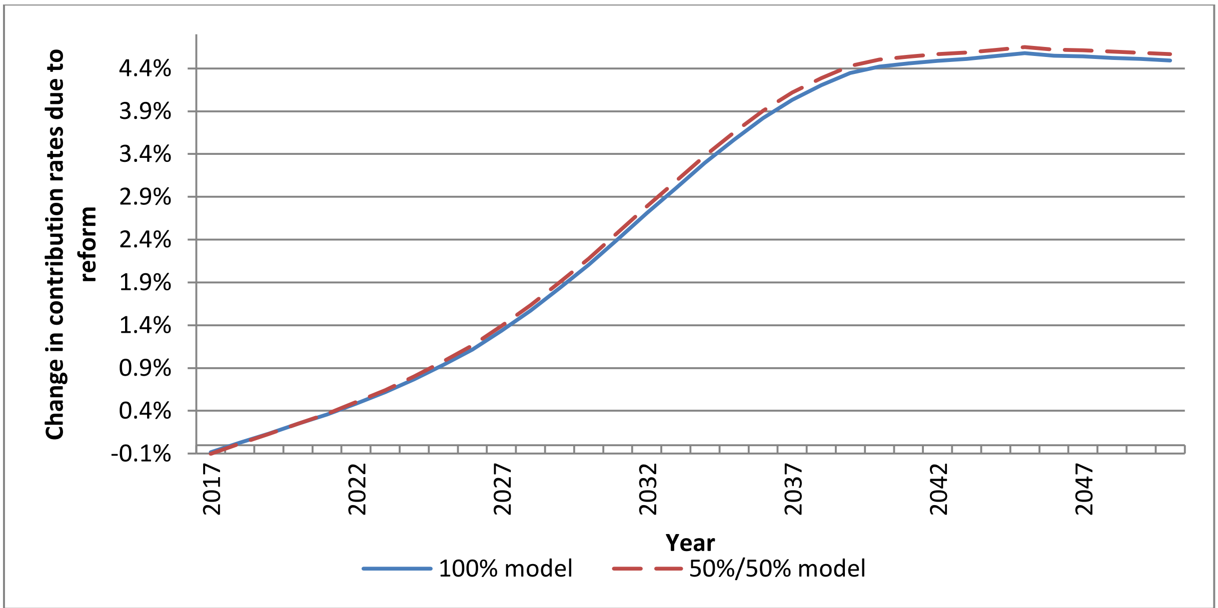
Figure 6.18: Average labor



Source: own calculations.

Interestingly, this decrease is higher in the 50%/50% model version than in the model with 100% time-consistent individuals (the difference between the red dotted line and red solid line is larger than the gap between the corresponding blue lines). This is due to higher labor dis-incentives stemming from the reform: the level of contribution rates is already higher in the 50/50% model version for the baseline case since aggregate labor supply is lower (see findings on baseline labor supply in levels, Figure 6.4, left).

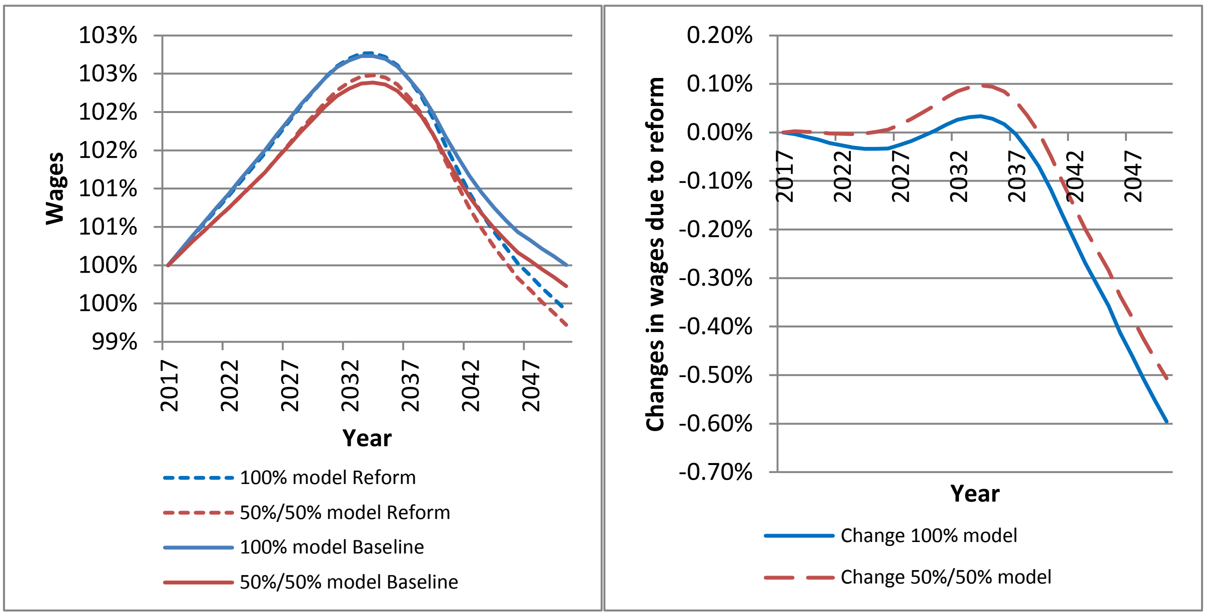
Figure 6.19: Contribution rates



Source: own calculations.

Holding the "sustainability factor" constant induces contribution rates to rise in order to balance the PAYG system. As described, labor supply decreases due to lower net wages. Since the level of labor supply is lower and contribution rates are higher in the 50%/50% model version (see Figure 6.19), contribution rates also increase more strongly in the 50%/50% model version due to the reform, which leads to a larger decrease of aggregate labor supply (Figure 6.18). This happens despite the smaller, more negative reaction of wages in the aftermath of the reform in the 100% model version (see Figure 6.20).

Figure 6.20: Wages



Source: own calculations. Wages are normalized to 100% in 2017 in the left graph. The right graph shows the difference between the reform and the baseline scenario (reform minus baseline) of the graph on the left.

Figure 6.20 displays the resulting wages over time. Wages increase more in the reform scenario than in the baseline scenario. In the long-run, this pattern turns around and wages decrease more strongly in the reform scenario. The reason for this general evolution can be implicitly derived from Figure 6.19. When the replacement rate is fixed in the reform scenario, contribution rates have to adjust to balance the budget of the PAYG pension system. The resulting increasing contribution rates, however, constitute negative labor incentives and harm labor supply more in the reform than in the baseline case. Hence, aggregate labor supply and, importantly, savings in the economy are smaller in the reform scenarios. Under a resulting smaller capital stock, changes in demographics hit the marginal product of labor (i.e. wages) more severely compared to the baseline case (see Figure 6.20, left). Therefore, amplitudes due to aging are larger in the reform scenario.

All in all, one can conclude at this point that the conventional model with only time-consistent households slightly underestimates the effect of this reform proposal on pension systems. However, this time it underestimates the negative impact.

Turning the focus from pension systems towards households, consumption p.c. (Figure B.6.8) decreases more after the reform in the 50%/50% than in the 100% time-consistent model version. This is due to the larger reduction in average working hours (see Figure 6.18) and lower savings in this model. One can conclude that, this time measured in terms of consumption p.c., a standard model with 100% time-consistent individuals underestimates the negative impact of such a reform proposal. Within the 50%/50% model version (Figure B.6.9), the decrease in consumption p.c. is more dramatic for the present-biased than for the time-consistent household. This results from two opposing effects: first, the time-consistent household reduces working hours more than the present-biased one. As a consequence, labor income is slightly more reduced for this individual. However, this effect is rather small compared to the second effect: due to over-consumption, savings of the present biased household are lower compared to its time-consistent counterpart and the household is at the same time hit more severely by the reform (lower net wage). Therefore, the present-biased household loses capital income from savings.

Finally, a refined welfare comparison in terms of CEVs (Figure B.6.10 in Appendix B) delivers some surprising results. After gains in utility due to higher replacement rates for older cohorts, utility losses from higher contributions outweigh these gains very quickly. Interestingly, time-consistent households in the 100% model version show the strongest declines in utility: cohorts entering the labor market in 2020 are up to 4.0% worse off in terms of life-time consumption due to the reform. The same cohorts of time-consistent (-3.6%) and present-biased (-3.4%) households in the 50%/50% model version are also substantially worse off than before but still better off than the household in the 100% model version. The reason why present-biased households are better off within the 50%/50% model version than their time-consistent counterparts is that they profit more from fixed high replacement rates because of their low retirement savings. Furthermore, the time-consistent household in the 100% model version is hit more by the reform due to the lower level of interest rates prevailing in this model version, which comes from the larger capital stock. Therefore, households suffer more from increases in contribution rates (see Figure 6.19) because private savings for retirement also delivers less capital income. In conclusion, in terms of CEV, the model version with 100% time-consistent households would overestimate negative welfare effects due to the reform, while measures like consumption p.c. would underestimate the consequences.

6.6 Sensitivity analysis

6.6.1 Different share of time-inconsistent households

The main analysis of the chapter assumed a share of 50% present-biased households within the economy. Note, however, that it is not claimed that 50% of the actual population literally consists of present-biased households. Instead, the important message is that both types of households potentially exist in this economy irrespective of the exact share. Empirical studies (e.g. Chan (2017) and Haan et al. (2017)) find that most individuals behave time-inconsistently in their labor supply behavior at some degree and that there is some heterogeneity among this group. So far, this continuum was simplified as two types of households with 50% being fully rational and 50% being present-biased. In this section, by following the finding that most individuals behave time-inconsistently, the share of present-biased households is set to 80%. In this way, the impact of the behavior of present-biased households on macroeconomic variables like wages and interest rates will be even larger since their share in the economy is larger.

Table 6.3: Results with an 80% share of present-biased households

	Gap in labor p.c.		Contr. rates		Welfare (CEVs)		
	100 % model	80%/20% model	100 % model	80%/20% model	T.-c. in 100% model	T.-c. in 80%/20% model	P.-b. in 80%/20% model
67 reform	2.23	1.96	-1.21	-1.16	0.95	1.83	1.25
2:1 reform	4.04	3.58	-2.55	-2.41	1.36	3.09	1.65
DB reform	-1.22	-1.52	4.49	4.68	-3.99	-3.14	-3.34

Source: own calculations. “67 reform” shows the reform which increases the retirement age from 65 to 67, while “2:1 reform” describes the reform proposal which increases the retirement age in parallel to the development in life expectancies. “DB reform” holds the “sustainability factor” constant and therefore mimics a return to a defined benefit regime. “Gap in labor p.c.” gives the percentage gap between aggregate labor supply between the respective reform scenario and the baseline scenario. The same applies for “Gap in cons. p.c.”. Welfare in CEVs compares the gain in life-time consumption due to the respective reform for the types of households. All numbers for the first to measures are from the year 2050. For cohort measures (right three columns on the right), the cohort entering in 2020 is taken as an example.

Table 6.3 gives some idea as to how the core measures change due to the reforms in a scenario with an 80% share of present-biased households. The corresponding table for the main analysis can be found for comparison in Appendix B (see Table B.6.1). In general, a higher share of present-biased households in the economy means lower wages and higher interest rates (in levels) due to lower aggregate savings (see Chapter 5 of this dissertation). As already discussed in Section 6.5.1, amplitudes of wage and interest rate developments over time are smaller when there are present-biased households. Accordingly, amplitudes are even smaller when the share of time-inconsistent household rises. As a consequence, wages increase and interest rates decrease less strongly in the aftermath of the 67 and 2:1 reforms. Due to the smaller increase in wages, we can observe a lower rise in labor p.c. (first column of Table 6.3). In response to this, the positive effect of the reform in terms of contribution rates is slightly smaller. While the contribution rate had to rise by 1.19 p.p. less due to the reform, this number is now reduced to 1.16 p.p., which widens the gap in comparison to the 100% model version. Accordingly, the higher the relative share of present-biased households, the smaller the positive reform effect on the pension system.

However, in terms of welfare for households, the picture looks different: CEVs for all types of households are higher. The order between households stays the same compared to the main analysis of the chapter. This increase in CEVs is due to a simultaneously larger increase in consumption and a lower increase in labor supply (and therefore a larger rise in leisure). This higher increase in consumption p.c. stems from present-biased households who increase consumption more in the 67 and 2:1 reforms (see Figures 6.11 and 6.17) and present-biased households constitute a larger share of the economy in the new scenario. This is in line with Chapter 5 of this dissertationn which uses a model without labor supply behavior. Intuitively, however, the gap to the 100% time-consistent model version becomes larger as the share of present-biased households increases. Within the 50%/50% model version, the gap between the two types of households in terms of CEVs narrows because present-biased households can profit more from higher prevailing interest rates.

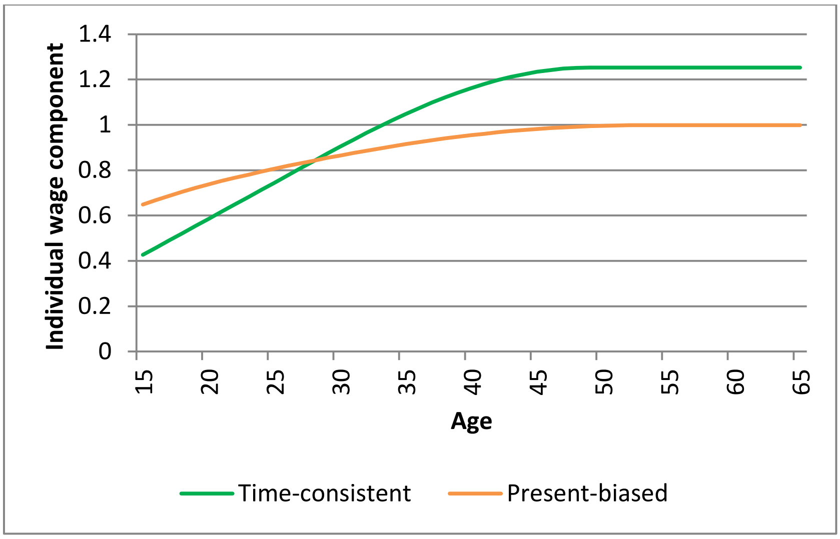
In general, under a higher share of present-biased households, contribution rates are generally higher (due to lower labor p.c. in levels – see Figure 6.4). Interestingly, in the aftermath of the DB reform, they also increase more, widening the gap to the 100% model version. Therefore, labor supply p.c. decreases more strongly than in the benchmark model in the main analysis. This larger decrease in labor p.c. also harms consumption p.c. more strongly. In terms of welfare (CEV), households still lose substantially due to the reform and its labor dis-incentives. However, this loss is smaller since higher prevailing interest rates (lower capital stock) buffer the negative effects stemming from the reform. The order between the different households and models in terms of CEVs stays the same as in the main analysis. For the differences between households in terms of CEVs, the same findings hold as in the first two reform scenarios.

6.6.2 Differing income (education) profiles

The central idea of the main analysis of the chapter is to evaluate how results derived from purely rational models with only time-consistent households change when including present-biased households into the analysis. The implicit assumption has so far been that the two types of households earn the same hourly wage. In other words, education was held constant for both types, the idea being to extract the pure difference in outcomes due to another model set-up. Legitimately, the question arises whether the assumption of equal education profiles is realistic for both types of households. Intuitively, impatient (present-biased) individuals would rather invest less time in formal education in the beginning of their life and earn money to be able to consume more. Patient individuals are expected to invest more time in their education in order to increase their income in the future. Indeed, empirical literature finds evidence that lower income groups reveal higher degrees of impatience (see, e.g., Hausman (1979) and Lawrance (1991)), hinting that less patient individuals invest less in education and therefore reach lower income levels. In an empirical study, Paserman (2008) even concludes that the degree of hyperbolic discounting is substantially high for low wage workers. In order to evaluate how the inclusion of different education profiles between both types of household affect previous findings, Figure 6.21 introduces two artificial wage profiles matching the results of previously mentioned studies. Therefore, the wage profile of the present-biased households is assumed to be flatter than the one of the time-consistent household. Importantly, the increase in wages is substantially larger for time-consistent households, which is due to higher investments in education during early life-time. As a result, time-consistent households earn substantially higher wages at older ages than their present-biased counterparts[36]. Note that both model versions are simulated using the new wage profiles. For the 100% time-consistent model version, only the steep profile is applied.

[36] Wage profiles are often found to be hump-shaped (Altig, et al., 2001; French, 2005; Huggett, et al., 2011). However, as Casanova (2013) argues, these profiles usually stem from "pooling observations of full- and part-time workers." When only full-time workers are considered, wage-age profiles found to be flat during later ages. This point is also discussed by French (2005) finding a hump-shaped pattern of hourly wage profiles. When controlling for part-time work and considering full-time workers in his regressions, he finds flat wage-age profiles for later ages. This is consistent with studies that show that there is no decreasing labor productivity at higher ages (Börsch-Supan & Weiss, 2016). Therefore, I assume wage profiles that do not decline in old age, but rather stay constant after reaching the maximum.

Figure 6.21: Individual wage component for different households



Source: own calculations.

The introduction of the new wage profiles has several general equilibrium effects: the steep wage profile of time-consistent households leads to lower income during young ages. Accordingly, savings for retirement are taken care of when wages are higher later in life. Therefore, aggregate savings in the economy are lower. A lower capital stock, in turn, decreases wages and increases interest rates with its consequences on labor supply.

As Table 6.4 reveals, the increase in aggregate labor supply p.c. between the reform scenario and the baseline scenario is larger in the aftermath of the 67 and 2:1 reforms for both model versions compared to the main analysis (Table C.7.1), the reason being the lower wage due to the smaller capital stock. The labor volume is increased relatively more by the reform of retirement ages since it was at a lower level before the reform. This bigger expansion of aggregate labor volume is beneficial for the PAYG pension system and allows the contribution rate to fall more severely by roughly 0.2 p.p. for the 67 reform and 0.5 p.p. for the 2:1 reform vis-à-vis the baseline scenario in the main analysis. As a further consequence of this, the gap between the 50%/50% and the 100% model version slightly widens.

In terms of welfare for households, both types profit from new income profiles since aggregate labor and consumption react more strongly due to the 67 and 2:1 reforms. Therefore, both types of households profit more from higher labor volume and lower contribution rates in the aftermath of the reform. Still, time-consistent households in the 50%/50% model version profit disproportionally more, widening the gap between both types of households. This is because time-consistent households receive higher wages later in life. Therefore, the extension of working life by several years under both reforms leads to larger income gains for this type of household.

Table 6.4: Results with different income profiles

	Gap in labor p.c.		Contr. rates		Welfare (CEVs)		
	100 % model	50%/50% model	100 % model	50%/50% model	T.-c. in 100% model	T.-c. in 50%/50% model	P.-b. in 50%/50% model
67 reform	3.25	2.99	-1.41	-1.37	1.18	2.36	1.38
2:1 reform	6.27	5.81	-3.04	-2.92	2.04	4.52	2.30
DB reform	-1.22	-1.51	4.41	4.59	-3.82	-2.26	-3.71

Source: own calculations. "67 reform" shows the reform which increases the retirement age from 65 to 67, while "2:1 reform" describes the reform proposal which increases the retirement age in parallel to the development in life expectancies. "DB reform" holds the "sustainability factor" constant and therefore mimics a return to a defined benefit regime. "Gap in labor p.c." gives the percentage gap between aggregate labor supply between the respective reform scenario and the baseline scenario. "Contr. rates" indicates the change in contribution rates in p.p.. Welfare in CEVs compares the gain in life-time consumption due to the respective reform for the types of households. All numbers for the first to measures are from the year 2050. For cohort measures (right three columns on the right), the cohort entering in 2020 is taken as an example.

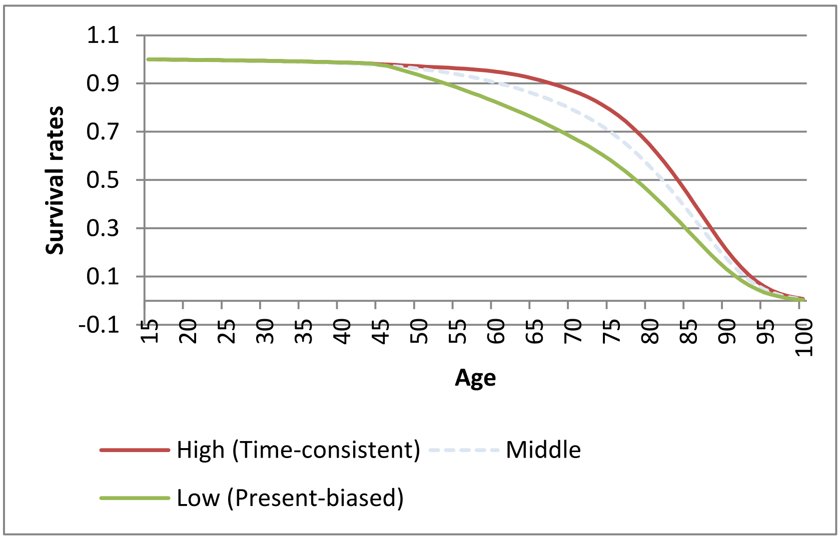
In the aftermath of the reform that holds the "sustainability factor" constant (DB reform), labor supply p.c. (and consumption p.c.) reacts more negatively in the 50%/50% model version. As a result, the gap between both model versions widens. The introduction of flatter profiles in the 50%/50% model version leads to relatively higher savings compared to the 100% model version vis-à-vis the analysis in the main part of the chapter. Therefore, the widening gap in wages and interest rates is responsible for different developments in labor p.c.. This is the same argument as in Subsection 6.6.1: due to the lower capital stock and higher interest rates prevailing in the 100% model version, the loss is smaller because this effect buffers the negative effect stemming from the reform. Due to this, contribution rates to the PAYG pension system have to increase slightly more than in the main analysis, widening the gap between model versions very slightly.

Interestingly, in terms of CEVs, present-biased households are worse off (more negative) and time-consistent households are better off (less negative) than in in the main analysis. As a consequence, the gap between the two types of households within the 50%/50% model version widens due to different income profiles. The reason behind this widening effect is the larger increase in contribution rates due to the reform in this alternative scenario: it hits households more who work more early in life.

6.6.3 Differing mortality rates

After studying the impact of different income groups on outcomes, the question arises whether these income groups, which can also be interpreted as skill groups, come along with different mortality rates. Several studies (see, e.g., Deaton & Paxson, (2001), Reil-Held, (2000) and Lutz et al., (1998)) find that mortality rates are higher for less educated/lower income groups. Concentrating on the case of three skill groups, Danish data, for instance, (Kallestrup-Lamb & Rosenskjold, 2017) suggests that there is a gap in life expectancy of two years between the middle and high income/wealth groups and a gap of 4-4.5 years between the low and middle groups. Reproducing these aforementioned gaps in life expectancy, survival rates for the EU28 countries (Eurostat, 2010) are adjusted such that they fit the observed gaps in life expectancies. These estimates of the unconditional survival rates, $\sigma_{t,j}$, for the three skill groups are shown in Figure 6.22.

Figure 6.22: Unconditional survival rates



Source: Eurostat (2010), Kallestrup-Lamb & Rosenskjold, (2017).

As an additional experiment, the high and low skill group profiles for survival rates (omitting the middle skill group) will be linked to the time-consistent and present-biased households, respectively, and used in equation (6.2) to discount future utility in addition to pure time discounting. Table 6.5 shows the corresponding simulation results.

Table 6.5: Results with different mortality rates

	Gap in labor p.c.		Contr. rates		Welfare (CEVs)		
	100 % model	50%/50% model	100 % model	50%/50% model	T.-c. in 100% model	T.-c. in 50%/50% model	P.-b. in 50%/50% model
67 reform	2.23	2.13	-1.21	-1.19	0.95	1.78	1.14
2:1 reform	4.04	3.87	-2.55	-2.49	1.36	3.23	1.65
DB reform	-1.22	-1.29	4.49	4.52	-3.99	-3.51	-3.49

Source: own calculations. "67 reform" shows the reform which increases the retirement age from 65 to 67, while "2:1 reform" describes the reform proposal which increases the retirement age in parallel to the development in life expectancies. "DB reform" holds the "sustainability factor" constant and therefore mimics a return to a defined benefit regime. "Gap in labor p.c." gives the percentage gap between aggregate labor supply between the respective reform scenario and the baseline scenario. "Contr. rates" indicates the change in contribution rates in p.p.. Welfare in CEVs compares the gain in life-time consumption due to the respective reform for the types of households. All numbers for the first to measures are from the year 2050. For cohort measures (right three columns on the right), the cohort entering in 2020 is taken as an example.

In general, higher mortality rates go along with lower life-expectancy and lower survival rates during older ages for time-consistent households. Present-biased households enjoy less time in retirement since they face a lower life-expectancy and lower survival rates during old ages. It is assumed that 50% of all births are time-consistent and 50% present-biased individuals. Due to different mortality rates, present-biased households die earlier than time-consistent households. As a consequence, the relative share between the two types of households changes as time passes, which will have implications for average measures in the economy.

In the aftermath of the 67 and 2:1 reforms, labor supply p.c. reacts more strongly under the new mortality rates. The results of the 50%/50% model are now closer to the effect in the 100% model version. This is intuitive because present-biased households die earlier and labor supply behavior now more closely resembles the 100% model version. Correspondingly, the gap between contribution rates between the 100% and the 50%/50% model version narrows to 0.02 p.p. for the 67 reform and to 0.06 for the 2:1 reform scenario, therefore becoming almost negligible.

In the new alternative scenario, welfare changes for households are lower for time-consistent and slightly higher for present-biased households, narrowing the gap between them. The reason can be directly derived from different mortality rates: by spending many years in retirement (baseline scenario), time-consistent households profit more because they live longer and receive pension benefits for a longer time. Due to the reforms, the relative time spent in retirement is shortened. This especially hits time-consistent households. Present-biased households, in contrast, profit more because they die earlier and do not spend as much time in retirement in the first place. They mainly profit from lower contribution rates during working ages due to the reform.

For the DB reform, the opposite holds: labor supply p.c. decreases less strongly. The explanation behind this is the narrowing gap between the 100% model and 50%/50% model version because present-biased households die earlier while time-consistent ones survive, which increases the share of time-consistent households in the economy. This again feeds through to contribution rates, which now react almost identically in both model versions.

In terms of welfare, time-consistent households suffer more strongly from the reform than in the main analysis while, for present-biased households, the opposite holds. Importantly, the relative order between the two types of households turns around. This is due to the higher life-expectancy of time-consistent households. As a consequence, they profit more from higher replacement rates, which is why their welfare increases more. Present-biased households do not profit as much from higher replacement rates because they die earlier and suffer from rising contribution rates during working ages.

6.6.4 Low interest rate regime

In recent years, interest rates have been decreasing due to the expansionary monetary policy of central banks. This development certainly has impacts on capital income of savers and triggers changes in saving and labor supply behavior of households. In order to simulate such a regime of low interest rates, a wedge of 26.4% between the marginal product of capital (gross interest rate) and interest rates perceived by the households (net interest rate) is introduced. In that way, interest rates are still connected to capital productivity and its general evolution due to demographic change. Another interpretation is a linear capital tax as is assumed in Fehr et al. (2013). Table 6.6 illustrates the simulation outcomes. Note that next to the 50%/50% model version, the 100% model scenario was simulated under the new interest rate regime, too.

Table 6.6: Results with different interest rates

	Gap in labor p.c.		Contr. rates		Welfare (CEVs)		
	100 % model	50%/50% model	100 % model	50%/50% model	T.-c. in 100% model	T.-c. in 50%/50% model	P.-b. in 50%/50% model
67 reform	2.29	2.16	-1.23	-1.20	0.87	1.78	1.10
2:1 reform	4.15	3.93	-2.60	-2.52	1.23	3.25	1.58
DB reform	-1.17	-1.29	4.41	4.49	-4.07	-3.42	-3.66

Source: own calculations. "67 reform" shows the reform which increases the retirement age from 65 to 67, while "2:1 reform" describes the reform proposal which increases the retirement age in parallel to the development in life expectancies. "DB reform" holds the "sustainability factor" constant and therefore mimics a return to a defined benefit regime. "Gap in labor p.c." gives the percentage gap between aggregate labor supply between the respective reform scenario and the baseline scenario. "Contr. rates" indicates the change in contribution rates in p.p.. Welfare in CEVs compares the gain in life-time consumption due to the respective reform for the types of households. All numbers for the first to measures are from the year 2050. For cohort measures (right three columns on the right), the cohort entering in 2020 is taken as an example.

In general equilibrium, several effects are at work. First, both types of households reduce their savings due to lower returns on savings. This, in turn, reduces the capital stock in the economy, which is the sum of aggregate savings. Holding labor constant, a smaller capital stock implies a higher marginal productivity of capital. This again increases the interest rate. In general equilibrium, this effect leads to the outcome that the net interest rate is only slightly lower than in the case without a wedge. However, it is important to note that aggregate savings are substantially lower than in the main analysis. Due to the lower capital stock, the marginal product of labor, namely wage, is lower, too. All in all, the wedge causes a smaller capital stock associated with lower wages and lower net interest rates (higher gross interest rates).

Under the new regime, interest rates decrease slightly more and wages increase slightly more over time than in the main analysis. In the aftermath of the 67 and 2:1 reforms, however, differences between the reform and baseline scenario are basically identical for interest rates and wages (not shown). Supporting the robustness of the results from the main part of the chapter, the relative order between the 50%/50% and 100% model version does not change. However, quantitative effects for both models can be found. Both reforms of retirement ages (67 and 2:1 reforms) affect labor supply p.c. more strongly due to a lower capital stock, wages, and interest rates. The reason is that the increase in retirement ages due to the reforms increases aggregate labor supply disproportionally. In response, contribution rates can decrease more strongly in the aftermath of the reforms (see second column in Table 6.6). The gap between the contribution rates of the two model versions, however, stays constant at 0.03 p.p. and 0.08 p.p. for the 67 and 2:1 reform, respectively.

In terms of welfare, CEVs are generally smaller than before. This is because of the lower capital stock due to lower savings: a given reform in labor supply is less beneficial when the complementary production factor is smaller. The gap in CEVs between the 50%/50% and the 100% model version, however, slightly increases as well as the gap between the types of households within the 50%/50% model version. These changes are very small and the relative order between the types of households and models stays as it was. A lower capital stock with lower wages and net interest rates, therefore, amplifies the differences between types of households and model versions.

In the reform scenario that holds the "sustainability factor" constant (DB reform), labor supply p.c. now reacts less negatively. This means more work and less leisure relative to the main analysis. As a consequence, contribution rates have to increase less in order to balance the system. The gap between the rise in contribution rates of both model versions stays constant at 0.08 p.p., as was already the case for the previous two reform scenarios.

Welfare measured in CEVs is also harmed more. This is the opposite effect that was explained in Subsection 6.6.1: lower prevailing interest rates cannot serve as a buffer for the harming effect stemming from the reform. Consequently, the gap in CEVs between the 50%/50% and the 100% model version slightly increases as well as the gap between the types of households within the 50%/50% model version.

6.7 Conclusion

The aim of this chapter is to investigate whether conclusions from evaluating pension reforms using purely time-consistent agent models still hold under the assumption of time-inconsistent agents. For this purpose, two detailed life-cycle models of household behavior containing a consumption/savings and a labor/leisure decision for time-consistent and present-biased households are included in a large scale OLG framework. A PAYG pension system is modeled that is subject to several reform simulations. A special focus is laid on different labor supply behaviors between both types of households in the aftermath of the reforms. Importantly, detailed demographic data is used to simulate the entire process of population aging and the accompanying macroeconomic effects on factor prices, which might change over generations.

Two model versions are simulated: one is inhabited only by time-consistent households and resembles the majority of literature when evaluating pension reforms. The second is inhabited by 50% time-consistent and 50% time-inconsistent households. Interestingly, when studying the baseline scenarios, it becomes clear that time-inconsistent households are hit more severely by an aging population than their time-consistent counterparts, this effect being due to the systematic under-saving of present-biased households such that assets cannot serve as a buffer against aging.

Representing pension reforms targeting the retirement age, an increase of the retirement age from 65 to 67 and a reform that connects the retirement age to changes in life expectancy are simulated for both model versions and compared to their respective baseline scenarios. Within the 50%/50% model version, present-biased households react more strongly in terms of labor supply to these two reforms than their time-consistent counterparts. However, when taking into account endogenous adjustments of factor prices, aggregate labor changes less in this model version, which consequently affects the pension system. Therefore, positive effects for pension systems are dampened when taking into account time-inconsistency. However, these effects are relatively small compared to findings on the individual level: in terms of household welfare, the reforms are beneficial for both types of households. However, the positive effect is substantially larger for present-biased households. As a consequence, neglecting the possibility that some households might act in a time-inconsistent manner underestimates the positive effects for welfare of these kinds of pension reforms.

A third simulation evaluates a proposal that is often put forward to avoid old age poverty: stabilizing the current levels of replacement rates and therefore returning to a defined benefit pension regime. As a result, the contribution rate to the PAYG pension system has to increase more to guarantee the funding of the pension system. This, in turn, poses negative labor incentives on labor supply. It is found that aggregate labor supply is harmed more in the model that is populated with 50% present-biased households. As a consequence, the increase in contribution rates over time due to population aging is slightly more severe in this model version than in the model version that is inhabited only by time-consistent households. Therefore, a model that does not take into account time-inconsistent behavior would underestimate the negative incentive and feedback effects for pension systems arising from such a reform proposal even though differences are small. In terms of welfare losses, however, the conventional model with time-consistent households would clearly overestimate the negative impact of this reform proposal.

In the sensitivity analysis, it is shown that the above-mentioned results still hold when the share of present-biased households differs from 50%. When controlling for realistic profiles of income and mortality rates for both types of households, the relative order mostly persists. Quantitative differences, however, might change. The same holds for a regime with low interest rates.

These findings are especially important for policy makers when evaluating reforms for PAYG pension systems. According to the previous results, conclusions drawn from purely time-consistent agent models might underestimate or overestimate the effects of pension reforms depending on the type of reform. Arguments questioning the economic significance of some reform proposals might consequently not apply anymore since the actual reform effect might be larger than previously derived under purely rational agent models. However, although differences in individual behavior might be substantial at first sight, macro-variables like factor prices and contribution rates do not differ much between model versions.

Furthermore, results reveal that it is the present-biased households which profit more from the reforms which induce more labor supply. Since they also represent the population group with rather low savings and high mortality rates (see sensitivity analysis), those reforms could be more beneficent than previously thought from a social policy perspective. In sum, a careful analysis using different sets of assumptions is proposed to guarantee the quality of pension reform evaluations. Next to the labor supply behavior of present-biased households at the intensive margin, this also includes retirement behavior of hyperbolically discounting households and its consequences on reform evaluation, which is the focus of analysis of ongoing research.

7. The aging-inflation puzzle: on the interplay between aging, inflation and pension systems

This chapter was written in co-authorship with Duarte Nuno Leite.

7.1 Introduction

The demographic structure of most developed countries has changed in recent decades. As the baby-boom generation ages, we observe that the age dependency ratio has steadily been increasing. At the same time, inflation peaked in the 1970s and since then has steadily been declining. Interestingly, this pattern coincides with the entrance of the baby-boom generation into the labor market and their posterior transition to older ages, while the number of young workers has decreased. Looking at the basic relationship between cumulative inflation and age dependency ratios for different age groups in various countries, we observe that these two variables seem to be correlated depending on the structure of the population (see Figures C.7.1-C.7.3 in the Appendix C)[37]. This phenomenon is especially pronounced in Japan, which faces a rapidly aging population and persistent deflation (and stagnation) at the same time. As Juselius & Takáts (2016) put it, there is a puzzling link between inflation and population age structure. We argue that the puzzle can be extended to whether demographic change and inflation are interconnected and to what the nature of this relationship is, illustrated by Figures C.7.1-C.7.3 and the example of Japan.

In fact, a growing bulk of mostly empirical literature has focused on trying to disentangle the roots behind this puzzling relationship and has not reached a consensus[38]. Lindh & Malmberg (1998; 2000) look at age structure and inflation and find a robust correlation indicating that an increase in the share of net savers (workers) dampens inflation while an increase in the share of dis-savers (young retirees) fosters inflation. Accordingly, this increase in the savings rate dampens inflation by reducing aggregate demand and, consequently, exerts a deflationary pressure on the price level in the economy. Juselius & Takáts (2016) obtain similar results by observing a stable and significant negative correlation between the share of workers and inflation.

[37] Note that these figures do not aim to provide an answer to the relationship between demographic change and inflation due to the limitations inherent to the method used. They only provide a motivation for the correlation of various population groups with inflation.

[38] See Figures C.7.4 and C.7.5 for contradicting, empirical findings in the literature. For instance, while Yoon et al. (2014) find that the over 65 age group leads to deflationary pressures Juselius & Takáts (2016) find the opposite for the same age group.

Anderson et al. (2014) contradict this view by demonstrating that population aging exhibits deflationary tendencies, such as in the case of Japan. These deflationary tendencies stem from a decline in growth, falling land prices, and dis-savings by the elderly, which puts a downward pressure on asset prices. Katagiri (2018) investigates the impact of changes in demand structure due to aging in Japan and concludes that these shocks cause deflationary pressures. Similarly, Gajewski (2015) and Yoon et al. (2014) find a negative relationship between the share of older people and inflation for varying samples of OECD countries. Nevertheless, Nishimura & Takáts (2012) find opposite outcomes and state that a larger base of working age people has a positive impact on inflation.

Another branch of literature defends the idea that the general growth or shrinkage of the population size affects prices. Yoon et al. (2014) found that population growth has a positive impact on inflation for Japan. The same positive correlation between population growth and inflation is also found for OECD countries in the 2000s by Shirakawa (2012). Contrasting these findings, McMillan & Baesel (1990) find a negative relation between total population growth and inflation, indicating that shrinkage in population due to aging would lead to inflationary tendencies.

Hence, a general perusal of empirical literature quickly ascertains that there is little concrete consensus in the literature as to the genuine impact of aging on inflation[39]. Given these mixed puzzling empirical findings, the point of departure in this chapter is to understand demographic change as a combination of two phenomena: a change in population size and structure. A significant part of the literature concentrates on only one of these phenomena and does not clearly define the differences in the effects of population growth/shrinkage and a changing age distribution. This chapter addresses these shortcomings first by clearly distinguishing between both demographic mechanisms and then by identifying the impacts they have on inflation rates using an OLG macro-simulation model. To our knowledge, we are the first to study the effects of aging on inflation, as well as the effects of a PAYG pension system on inflation, by differentiating between the two types of mechanisms in a simulation model, therefore contributing towards the understanding of the aging-inflation puzzle. In order to capture the fundamental channels through which the change in structure and size of population can apply, this chapter extends an OLG model à la Auerbach & Kotlikoff (1987) where actual population dynamics are explicitly

[39] Besides the strict relationship between aging and inflation, different strands of the literature follow a political economy approach. For instance, Doepke & Schneider (2006) and Bullard et al. (2012) show how different structures of a population can influence decisions of policy makers through voting behavior. Katagiri et al. (2014) argue that governments will act differently and plan different targets for inflation depending on how population aging evolves.

modelled using real data. We combine this OLG framework with a money-in-the-utility (MIU) model for households[40].

The first thought when thinking about addressing inflation and monetary issues is to apply the typical New Keynesian framework. However, to address demographic change, during which population size and structure is constantly varying through time, a New Keynesian model framework is less suited to incorporate all the demographic features we introduce in the model and to obtain the type of predictions at which we are aiming[41]. New Keynesian models have a stronger focus on analyzing short-run shocks on inflation and on observing the departure of the main macroeconomic variables from equilibrium until they return to it again. Instead, we are interested in studying the long-term effects of demographic change on price development via life-cycle decisions of individuals when facing these demographic changes. Consequently, changes in consumption demand and money holdings as well as savings and investment patterns, and ultimately economic growth will impact aggregate money demand and therefore prices. This OLG-MIU setting allows for a variety of channels through which both demographic mechanisms, i.e. the size and structure effect, might work. Additionally, we discuss channels that may amplify the magnitude of these mechanisms, such as labor decisions and the presence of a pension system. Special considerations of monetary policy are not taken into account in this chapter, although they are important regarding the strength of demographic change on its effectiveness and impact on the main macroeconomic variables[42]. Nevertheless, in the model economy the government controls money supply and we examine different degrees of government reactions to money demand in our sensitivity analysis. Throughout the chapter, we conduct several experiments under partial and general equilibrium settings which allow us to identify the strength of each demographic mechanism. We calibrate the model carefully through the inclusion of actual and forecasted population data for a sample of selected countries. This successful replication of various

[40] Introducing a MIU framework into an OLG model is one of the most used approaches to introduce a monetary economy into a neoclassical framework (Walsh, 2010). Since individuals derive utility from money and consumption, it is possible to have, under MIU, demand for money as a positive function of consumption. This allows mimicking the empirically observed positive correlation between consumption demand and money demand under a neoclassical model where individuals have perfect foresight and can save for future consumption. Subsequently, under these conditions, our model opens the channel between aggregate demand and inflation through money demand.

[41] Some exceptions that include demographic variables are Galí (2017) and Fujiwara & Teranishi (2006). Nevertheless, their demographic analyses are restrained to changes in the dependency ratio, which hide several life-cycle mechanisms and a more general long term effect of demographic change (e.g. demographic structure).

[42] On the impact of demographic change on monetary policy effectiveness see, for example, the works of Miles (2002), Fujiwara & Teranishi (2006), Imam (2013), Wong (2014), Juselius & Takáts (2016) and Chen (2016).

fundamental empirical moments gives confidence about the model validity concerning the impact of demographic change on inflation.

Our first main conclusion indicates that the part of the inflation rate that is attributed to demographic change is mainly driven by changes in population size. We find that in a shrinking society, deflationary pressures will prevail, while in a society with an expanding population, inflationary pressures will emerge. This stems from the consumption and money demand decisions in the economy. A decrease in aggregate consumption following a decrease in population leads to lower demand for money holdings, which the government accommodates for by adjusting money supply accordingly. This causes a dampening of inflationary pressures, the opposite occurring for positive population growth, which is in accordance with empirical results by Shirakawa (2012) and Yoon et al. (2014). The latter study finds a positive correlation between population growth and inflation although no channel is identified in the regression analysis.

Our second finding shows that, depending on the life-cycle consumption profile, an aging population structure can have inflationary or deflationary tendencies. The crucial point here is the interaction between the consumption and money holding mechanisms and the age when the consumption profile reaches its peak. If the peak is reached at working ages, an aging population structure will lead to a decline in consumption and money demand. However, if the peak is reached after retirement, an aging population structure produces a rise in consumption along with money holdings. This is in line with Lindh and Malmberg (1998; 2000), and Juselius & Takáts (2016), if the consumption peak occurs around retirement age. Both studies by Lindh and Malmberg advocate for the same channel as in this chapter: high consumption and low savings induces higher aggregate demand, fostering inflation. It also holds for empirical findings by Yoon et al. (2014) and Gajewski (2015) who state that a larger number of very old people pose a downward pressure on prices.

A third result shows how the existence of a PAYG pension system is an important vehicle through which aging affects inflation. Although it is well-known that in some economies financing additional social expenditures in pension systems by printing money is one of the main channels that produce inflation, the goal of this chapter is not to focus on this specific channel. Instead, we concentrate on alternative channels, where the share of working age or dependent groups in the economy and, subsequently, the share of net savers and net consumers has an impact on inflation. According to our findings, the presence of a pension system reduces savings of individuals at working age and has an influence on consumption of both workers and retirees, and, consequently, on money demand. The introduction of a pension system then reinforces the effects of changes in population size and structure on inflation by producing deflationary pressures.

Furthermore, when facing changes in interest rates and wages, it is within the ability of individuals to adjust the amount of labor supply that mitigates pension systems' deflationary tendencies, accordingly. To our knowledge, this is the first time that such a relationship between pension systems and inflation is examined.

Finally, we perform an illustrative simulation of inflation trends driven by demographic changes in a selected sample of countries. The countries selected represent societies at different stages of demographic change, and, in addition, have differing generosities of pension systems. This delivers interesting examples of the interaction of demographic change and pension systems. Aging countries like Germany, Italy, and Japan are already facing deflationary pressures, while countries like China will experience these same trends during the next decades. The structure effect is found to be especially prominent in Japan starting in the early 1990s, and is explained by early increases of the age dependency ratio. Young countries with fertility rates that are still high such as the US and India, will further go through inflationary pressures stemming from the size effect, while the structure effect will not play a major role.

The chapter is structured as follows. Section 7.2 introduces the model and all its modules. The methodological approach including calibration is described in Section 7.3. Section 7.4 identifies possible channels through which aging affects inflation in a partial equilibrium setting. Section 7.5 contains a general equilibrium model and simulates this model to illustrate the effects of different demographic stages and channels on inflation in a sample of countries. Section 7.6 discusses the results and concludes this chapter. A detailed sensitivity analysis is carried out in Appendix C.

7.2 OLG-Inflation model

The applied OLG model consists of a household sector, a PAYG pension system and a representative firm in the general equilibrium framework developed by Auerbach & Kotlikoff (1987). We extend the household's decision problem by adding real money holdings (MIU framework, see Sidrauski (1967)) and a simple government sector that provides money supply. We follow Hamann (1992), Shimasawa & Sadahiro (2009) and Walsh (2010) when describing the money market and the government's money supply rule. The MIU framework allows for introducing a monetary economy into a neoclassical framework and incorporates individuals whose utility depends directly on their consumption of goods and money holdings in the basic neoclassical model.

7.2.1 Household problem

Households choose between consumption, leisure, and real money holdings. Holding money directly delivers utility to the households (MIU framework). This can be interpreted as stemming from lower transaction costs when consuming goods (Walsh, 2010). Households of age *j* at time *t* receive utility from consumption, $c_{t,j}$, money, $m_{t,j}$ and leisure, $1 - h_{t,j}$ according to the instantaneous utility function given by

$$u(c_{t,j}, m_{t,j}, 1 - h_{t,j}) = \frac{1}{1-\theta}\left[\eta c_{t,j}^{\frac{\sigma-1}{\sigma}} + (1-\eta) m_{t,j}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma(1-\theta)}{\sigma-1}} + \Psi \frac{(1-h_{t,j})^{1-\varrho}}{1-\varrho}, \tag{7.1}$$

where η denotes the utility weight of consumption. Parameters θ and ϱ are measures for risk aversion. σ is a measure for the elasticity of substitution between money and consumption. Under a CES utility function, demand for money is a positive function of consumption which allows for mimicking the empirically observed positive correlation between consumption and money demand. Therefore, even though we are under a neoclassical model where individuals have perfect foresight and can save for future consumption, individuals still want to hold money in proportion to consumption in order to increase their utility creating the channel between aggregate demand and inflation. Finally, the parameter Ψ describes the relative weight of leisure in the utility. Utility is additively separable in leisure, as observed in the literature on business cycles (Walsh, 2010).

Households are neoclassical life-cyclers with perfect foresight. They solve an expected utility maximization problem over the entire life-cycle which lasts for a maximum of J years. The life-time maximization problem of a cohort is therefore given by

$$max \ \sum_{j=1}^{J} \beta^{j-1} \varphi_{t,j} \, u(c_{t,j}, m_{t,j}, l_{t,j}), \tag{7.2}$$

where β is the pure time discount factor. In addition to pure discounting, households discount future utility with their unconditional survival probability, $\varphi_{t,j}$, expressing the uncertainty about the time of death. We do not include intended bequests in our model and assume that accidental bequests resulting from premature death are taxed away by the government at a confiscatory rate and used for otherwise neutral government consumption.

The household's disposable non-asset income $y_{t,j}$ is

$$y_{t,j} = h_{t,j} w_t (1 - \tau_t) + p_t + \sigma_{t,j}, \tag{7.3}$$

which has three components. The first term of the right-hand side reflects labor income (hours worked, $h_{t,j} = 1 - l_{t,j}$, multiplied by the net wage, $w_t(1 - \tau_t)$, while the second term is pension income. Thirdly, $\sigma_{t,j}$ denotes government transfers to the households which originate in the redistribution of seigniorage in proportion to real money holdings (see also equation (7.17) below).

Denoting total assets by $a_{t,j}$, maximization of the household's intertemporal utility is subject to a dynamic budget constraint given by

$$a_{t,j} = (1 + r_{t-1})a_{t-1,j-1} + \frac{m_{t-1,j-1}}{1+\pi_t} - m_{t,j} + y_{t-1,j-1} - c_{t-1,j-1}, \qquad (7.4)$$

where π_t is the inflation rate and r_t the real interest rate. Retirement is assumed to be exogenously determined by a mandatory retirement age, R, at which individuals must stop working and will begin receiving pension benefits. This implies that $p_t = 0$ for $j \leq R$ and $h_{t,j} = 0$ for $j > R$.

Over a household's lifetime, the following intertemporal budget constraint in real terms is given by

$$\sum_{j=1}^{J} PDV_j c_j + \sum_{j=2}^{J} PDV_{j-1} \xi_j m_j = \sum_{j=1}^{R} PDV_j h_j w_j (1 - \tau_j) + \sum_{j=R+1}^{J} PDV_j p_j + \sum_{j=2}^{J} PDV_j \sigma_j. \qquad (7.5)$$

PDV_j is the factor of the present discounted value, ξ_t is the marginal cost of holding real money and is defined as $\xi_t = i_t/(1 + i_t)$. Accordingly, the sum of life-time income from labor, pension benefits, and government transfers (right hand side) has to equal the sum of life-time consumption and real costs from holding money.

7.2.2 Pension system

The pension system is a defined benefit PAYG system which promises a defined replacement rate, ρ_t. Contributions are due until age R-1; pension benefits are paid from the claiming age, R, onwards.

The contribution rate to the system, τ_t, is computed to balance the PAYG system in every period t. Revenues are the product of the contribution rate, τ_t, and the wage bill, $\sum_{j=1}^{R-1} w_t h_{t,j} NW_{t,j}$, where the number of workers of age j at time t is denoted by $NW_{t,j}$. Expenditures are the sum of the products of pension benefits p_t and number of pensioners, $NP_{t,j}$. The budget-balancing contribution rate is thus given by

$$\tau_t = \sum_{j=R+1}^{J} p_t NP_{t,j} \,/\, \sum_{j=1}^{R} w_t h_{t,j} NW_{t,j}, \quad (7.6)$$

with individual pension benefits, p_t, given by

$$p_t = \rho_t \, w_t(1 - \tau_t). \quad (7.7)$$

7.2.3 Production

The production sector consists of a representative firm. Production is given by a Cobb-Douglas production function using capital stock, K_t, and aggregate effective labor, L_t as inputs

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}. \quad (7.8)$$

A_t is technology (growing at rate g_t). α is the capital share in the economy. Since factors earn their marginal product, real wages and real interest rates are given by

$$w_t = A_t(1-\alpha)k_t^{\alpha}, \quad (7.9)$$

$$r_t = \alpha k_t^{\alpha-1} - \delta\,, \quad (7.10)$$

where k_t denotes the capital stock per efficient unit of labor ($K_t/(A_t L_t)$) and δ is the depreciation rate of capital.

7.2.4 Money market

Real aggregate money demand in the economy, M_t^D, at time *t* is the sum of all real money holdings by households alive at time *t*

$$M_t^D = \sum_{g=j-J-1}^{j} m_{g,j+1}. \quad (7.11)$$

Thus, aggregate money demand in the economy will be positively correlated with aggregate output/income since consumption and real money holdings are complements for households (see discussion of the household parameter σ in Appendix C, Table C.7.5). Since we model the interest rate to be given by the marginal product of capital (see equation (7.10)) and thereby do not model a rate of return for the bond market, aggregate money demand depends only on aggregate output/income and not additionally on the bond market interest rate, as is often the case in classical LM theory (Hicks, 1937).

In the money market, real money supply and money demand have to be equal. In the absence of a bond interest rate which would equate aggregate money demand and supply, the price level has to adjust to reach the equality of money demand and supply in the economy

$$M_t^D = \sum_{g=j-J-1}^{j} m_{g,j+1} = \frac{M_{t+1}^S}{P_{t+1}}. \tag{7.12}$$

As a consequence, growing output with an accompanying increase in money demand by households would lead to a falling price level. Since empirical literature finds no such negative relationship (usually no or a slightly positive correlation for OECD countries is found, see McCandless & Weber (1995)), money supply creation is modelled following Hamann (1992) and Walsh (2010). Thus, the government creates nominal money supply at an exogenous rate (μ_t) following the equation:

$$M_{t+1}^S = (1 + \mu_t) M_t^S. \tag{7.13}$$

The money growth rate, μ_t, is a function which is governed according to the following rule

$$\mu_t = \mu_{SS,t} + \rho_\mu\left(\mu_{t-1} - \mu_{SS,t-1}\right) + \phi_\mu\left(\frac{Y_t}{Y_{t-1}} - 1\right). \tag{7.14}$$

We assume that the government's decision, μ_t, is a function of its exogenously pre-defined steady state value and its realized past deviations from the steady state average ($\mu_{t-1} - \mu_{SS,t-1}$). The growth rate of money shows persistence regarding previous decisions on money supply as we define $\rho_\mu > 0$. $\left(\frac{Y_t}{Y_{t-1}} - 1\right)$ represents growth in output[43]. We assume that there is an elastic money supply by the government that accommodates money demand that arises when households consume. As Walsh (2010) summarizes, for positive parameters ($\phi_\mu > 0$), output (and aggregate demand) growth and inflation will be positively correlated. This pattern is found by McCandless and Weber (1995) for the case of OECD countries, and Gerlach & Svensson (2003) also show that both output gap and money gap are positively correlated with inflation for the years 1980-2001 for Euro area countries[44]. For moderate inflation, however, this effect is not verifiable. Since inflation rates in our model are caused by demographic change, the resulting moderate inflation

[43] Note that output, among other variables, is de-trended in our model. As a result, in the initial and final steady states (see Section 7.2.5 on the computational algorithm) no change in (de-trended) output takes place due to a constant population. Therefore, the growth rate of money creation will be equal to $\mu_{SS,t}$ in the long run.

[44] There is also empirical literature (see, e.g. Barro (2013) and Fischer (1993)) that suggests that the relationship between inflation and economic growth might be negative. However, Gosh & Phillips (1998) and Mallik & Chowdhury (2001) argue that this takes place only for periods of high inflation

rates justify the assumption of a positive correlation of output and inflation and, consequently, of a positive parameter value of ϕ_μ. Following this, we choose a parameter value of $\phi_\mu > 0$, such that output and inflation will be positively correlated.

Furthermore, we assume that money holdings must be positive. To ensure this, the nominal interest rate has to be positive

$$i_t = (1 + r_t)(1 + \pi_t) - 1 > 0. \tag{7.15}$$

For positive values of money growth, seigniorage will be collected by the government and paid as a transfer to households constituting a part of their income.

$$S_t = \frac{M_{t+1}^S - M_t^S}{P_t} = \sum_{t=j-J}^{j-1} \sigma_{t,j}. \tag{7.16}$$

Furthermore, it is further assumed that the seigniorage is distributed in proportion to real money holdings at the beginning of the period in order to prevent an intergenerational redistribution of resources[45]

$$\sigma_{g,t} = \mu_t m_{g,t}. \tag{7.17}$$

7.2.5 Computational algorithm

This OLG model has to be solved numerically. The algorithm searches for equilibrium paths of consumption, hours worked, money holdings, and capital to output ratios and, in the case that there are social security systems, pension contribution rates. We determine the equilibrium path of the OLG model by using the modified Gauss-Seidel iteration as described in Ludwig (2007). The solution of the life-cycle optimization is solved recursively by taking initial guesses for consumption at last age. Then, the model is solved backwards using recursive methods by applying first order conditions and appropriately handling the constraints. This procedure delivers first guesses for the vectors of consumption, hours worked and money holdings. We then calculate savings and assets, applying the budget constraint. The consumption profile, including consumption at last age, is then updated. This procedure is repeated until consumption, the hours profile and money holdings converge. After the convergence of these inner loops, all cohorts' asset holdings and hours worked at a given year t are aggregated to receive the capital stock, K_t, and labor supply, L_t. By using equations (7.9) and (7.10), the wage and interest rate can be

[45] The proceeds from seignoriage are transferred back to households in the same proportional way as they were paid before, avoiding any intergenerational transfer.

updated. Then, real money holdings by households are aggregated for every period *t* to receive aggregate money demand. Using the money market clearing condition (Hamann, 1992; Shimasawa & Sadahiro, 2009), we compute the aggregate price levels, which will be used for the next iteration until convergence is reached.

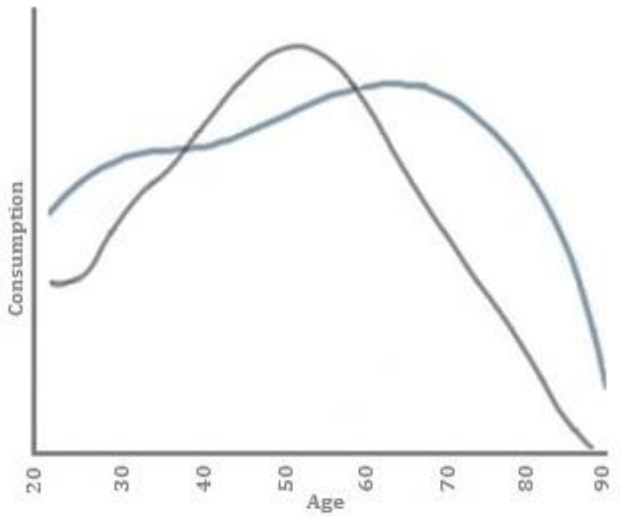
Our time line has four periods: a phase-in period, a calibration period, a projection period, and a phase-out period. First, we start calculations with the assumption of an “artificial” initial steady state in 1850. The time period around 2015-2017 is then used as the calibration period to determine the structural parameters of the model. Our projections run from 2015 until 2050. For technical reasons, the model then continues to run during a transition to a steady-state population in 2150 and an additional 100-year period until the model reaches its final steady state in 2250.

7.3 Calibration

The life-span of the household is assumed to be 100 years. The household enters the labor market at age 15 and retires at age 65 (mandatory retirement). The structural parameters of the household model are calibrated to target several macro- and microeconomic moments observed in the data. The simulated moments of our model which are matched with their empirical counterparts in the data are a capital-output ratio of 2.6 (based on estimates of the stock of fixed assets to output), a consumption-output ratio of 0.75 (based on Forrester (2017)), average hours worked during working time of individuals, and a consumption profile that matches estimates obtained from Yang (2009), Fernández-Villaverde & Krueger (2007) and Park & Feigenbaum (2018).

The latter empirical moment is important since the shape of the consumption profile will have a strong influence on the structure effect: depending on the age at which the consumption profile peaks, the change in population structure will have a different impact on inflation (structure effect) through time. Therefore, we calibrate the model such that the consumption profile of individuals approximately resembles the ones observed empirically. Note that due to the presence of survival rates (φ_j, see equation (7.2)) in the utility maximization problem, the shape of the life-cycle consumption profile of our model is defined by cohort-specific survival rates in addition to the time preference and interest rate. In the data, we observe that consumption expenditures reach its peak when individuals reach ages between 55 and 60 years. We calibrate the model such that this pattern is approximately matched. In this way, we capture a more realistic relationship when analyzing the impact of changes in the population structure on total consumption and consequently inflation. The structure effect will especially depend on the pattern of the profile since different cohort sizes at a point in time with corresponding divergent levels in consumption expenditures affect aggregate consumption and inflation. Figure 7.1 depicts the empirical (black) and calibrated (blue) consumption profile for a representative cohort in this model entering the labor market in 2017[46]. To obtain these profiles and to match the other empirical moments, we calibrate the parameters in accordance with the literature. Table 7.1 gives an overview.

Figure 7.1: Empirical and calibrated consumption profiles



Source: own calculations and Fernández-Villaverde & Krueger (2007). Note that this is the adult equivalent form. Empirical estimates are in black, calibrated model output is in blue. The life-cycle consumption profile for the model outcome is for a representative cohort entering the labor market in 2017.

To achieve these targets, the discount rate, ρ, is set to 0.025 (see overview by Frederick et al. (2002)). The risk preference parameter, θ, is assumed to be 2, which makes the household slightly risk averse and lies in the middle of estimates in the literature (see overview by Bansal & Yaron (2004) and Browning et al. (1999)). The same value is assumed for ϱ. The capital share, α, in the economy is assumed to be 0.35 and annual productivity growth is 1.5%. The depreciation rate of capital is calibrated to 6% per year, given our calibration target of a capital output ratio of 2.85. As already referred to in Subsection 7.2.4, the steady state growth rate of money creation is set to 2%, while the lag persistence parameter (ρ_{μ}) and the output growth coefficient (ϕ_{μ}) are set to 0.85 and 0.7, respectively. In Appendix C (Tables C.7.4-C.7.7), we present a sensitivity analysis of the results with respect to the parameters η, σ, ϕ_{μ}, and Ψ.

[46] Note that the peak in the consumption profile happens at slightly too high ages despite a careful calibration. This is a general problem that Park & Feigenbaum (2018) discuss in their paper proposing a time-inconsistent modelling of the household problem to receive an even more realistic consumption life-cycle profile. This, however, is beyond the scope of this paper and will be a point of future research.

Table 7.1: Parameter calibration

Parameter	Values	Sources
Discount rate (ρ)	0.025	Frederick et al. (2002)
Risk preference (θ)	2	Bansal & Yaron (2004) and Browning et al. (1999)
Labor weight in utility function (Ψ)	0.3	Assumption
Labor parameter (ϱ)	2	Bansal & Yaron (2004) and Browning et al. (1999)
CES substitutability parameter (σ)	0.4	Walsh (2010)
Consumption weight in utility function (η)	0.97	Walsh (2010)
Capital share in production (α)	0.35	Cooley & Prescott (1995)
Growth rate of labor productivity (g)	0.015	Assumption
Depreciation rate of capital (δ)	0.06	Assumption
Steady state growth rate of money creation (μ_{SS})	0.02	Inflation target of most Central Banks
Lag persistence coefficient of money creation (ρ_{μ})	0.75	Walsh (2010)
Output growth coefficient in money creation (ϕ_{μ})	0.7	Assumption
Retirement age (R)	65	Legal age in most developed countries

Demography is described by the size of each cohort, the survival of that cohort, and additions through net migration. We treat all three demographic forces as exogenous. The size of the population aged *j* in period *t* is given recursively by

$$N_{t+1,j+1} = N_{t,j}\varphi_{t,j}, \tag{7.18}$$

where $\varphi_{t,j}$ denotes the age-specific conditional survival rate. The original cohort size for cohort *c* depends on the fertility of women aged *k* at time *c*=*t*-*j*:

$$N_{c,0} = \sum_{k=0}^{\infty} f_{c,k}N_{c,k}. \tag{7.19}$$

Population aging has three demographic components: past and future increases in longevity, expressed by $\varphi_{t,j}$; the historical transition from baby-boom to baby-bust expressed by past changes of $f_{c,k}$; and fertility below replacement in many countries expressed by current and future low levels of $f_{c,k}$. Population data, age distributions, and assumptions on projections for fertility, mortality, and migration rates are taken from the Human Mortality Database (2016). Variations in fertility and survival rates over time will lead to changes in population size and structure, known as demographic change. These ongoing, yearly shocks in population will influence labor supply and money holdings through the dynamics of the economy households' consumption, leading to inflationary and deflationary pressures over the years.

7.4 The aging-inflation puzzle: partial model

This section gives an overview of the effects that are essential to understand the interplay between aging, inflation, and pension systems. For this purpose, we simulate a partial equilibrium model by taking the real interest rate and real wages as exogenously given and constant over time. Since our main concern here is to first disentangle the main channels that connect aging and inflation, we choose the simplest model possible. A general equilibrium model calibrated to account for the main macroeconomic indicators will be presented in Section 7.5.

In this chapter we follow the strand of literature which identifies savings and consumption patterns as the main channels for age effects on inflation (e.g. Lindh & Malmberg (2000); Juselius & Takáts (2016)). While studying the impact of demographic change, this channel highlights how aging influences total consumption and savings which will ultimately affect total demand for money and, hence, determine (de-)inflationary pressures. In detail, the increase in consumption and demand of goods intensifies the demand for money as a means to pay for transactions. As the demand for money increases, the government accommodates this need by issuing more money which also increases money supply resulting in inflationary pressures in the economy.

Since aggregate demand in an economy depends on demographics[47], it is essential to differentiate between changes in population size and shifts in population structure. In times of demographic change, the former reflects the shrinkage of population since mortality rates are higher for older age groups and fertility rates are often low for the younger age groups, while the latter stems from the decrease in the share of young age groups in population and the increase of the share of old age groups in total population. In the case of population shrinkage, aggregate demand decreases leading to a fall in money demand causing deflationary pressures. We label this mechanism "Size Effect". Taking into account that the peak of consumption is reached around ages 55/60 (see

[47] See Figure C.7.6 in Appendix C for the claim that population growth affects aggregate demand in our model framework. Since our simplified production sector is perfectly competitive (equation (7.8) to (7.10)), goods markets clear in all *t*, i.e. produced output always equals aggregate demand (abstracting from capital depreciation and government consumption).

Figure 7.1), a change in the structure of population that increases the share of population at older ages and decreases the number of population at the ages close to the peak age of consumption will negatively affect aggregate consumption in the economy. This will affect money demand negatively creating deflationary pressures. We will call this mechanism "Structure Effect". Understanding how these effects work and quantifying them is of utmost importance to detect how future demographic developments of different countries will lead to different patterns of inflation.

In contrast to other models in the literature we allow for endogenous savings decisions. Furthermore, we integrate labor supply decisions and preferences for money which, on the one hand, prevent superneutrality of money[48], and, on the other hand, make the model more sensitive to changes in demographics. Additionally, we study the impact of pension systems on individuals' reactions and, as a consequence, on inflation developments.

In the following section, we first analyze both structure and size effects individually. After the analysis of this basic model, we introduce a PAYG pension system that can affect prices through adjustments in savings behavior since PAYG pensions force households to contribute to the pension system out of their labor income. Due to small individual effects of labor supply in partial equilibrium, the combination of labor supply behavior with the dynamics of a PAYG pension system is shown[49] and the macroeconomic effects of both demographic effects in a full model are described.

7.4.1 Structure and size effects

The size effect is calculated by assuming a moment in time from which we hold the population structure constant (year 1990 in the baseline scenario) but still take into account changes in the size of population. This allows us to exclude the effect that stems from changes in population structure and isolates the pure size effect. The robustness of results regarding the year when population structure becomes constant is presented in Appendix C (Table C.7.8). Second, we then account only for the pure structure effect. This is the share of inflation that results from changes in the share of population groups in the total population which is not explained by the size effect. It

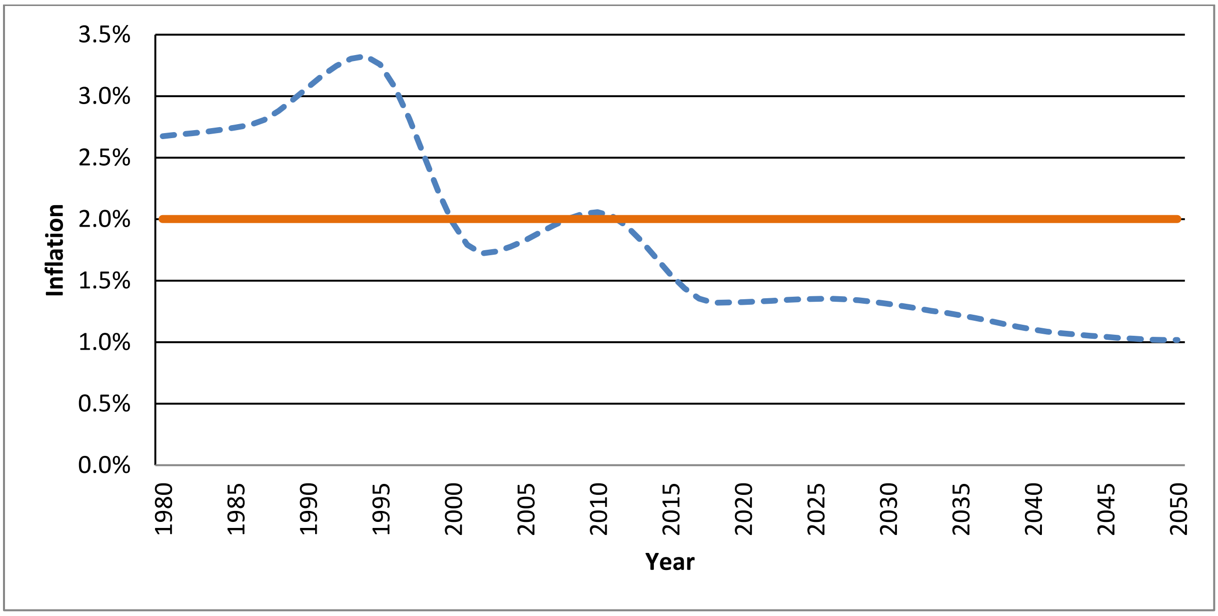
[48] See, for example, Drazen (1981), Barro (1995), Gahvari (2007) or Walsh (2010) on (non-) superneutrality of money.

[49] Formally, it is important to note that this connection might also work in the opposite direction: inflation rates can affect labor supply behavior and therefore pension systems. However, we found that this effect is negligibly small in this model framework.

is given by the residual difference between our benchmark model scenario (containing both size and structure effects) and the scenario that assumes population structure constant (containing only the size effect).

In this subsection we assume a simple partial equilibrium model which does not contain decisions on labor supply but only a consumption/savings decision. Additionally, it does not assume a public PAYG pension system but instead all old-age assets are accumulated through private savings. It further assumes a pro-cyclical government[50]. The model is calibrated such that consumption profiles fit the empirical moments (see Section 7.3) so that we can assure that the structural effects are representative of the actual behavior of individuals. This will be our benchmark model for Section 7.4. The driving force influencing inflation rates will be aging, i.e. enduring shocks in population size and structure in every period.

Figure 7.2: Inflation



Source: own calculations.

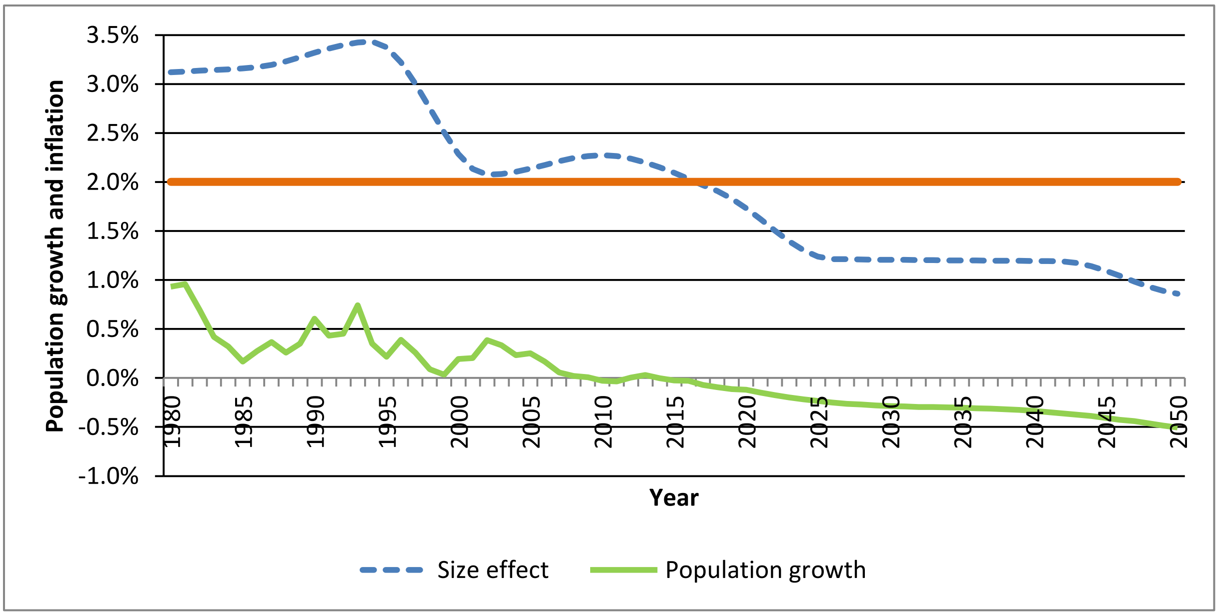
Figure 7.2 shows the resulting inflation rates for the time period from 1980 to 2050 in our benchmark model. Steady-state inflation rates are determined by money supply under the absence of any demographic shock. This means that from equations (7.13) and (7.14), money supply growth under no population change and no other shock in the economy is given by $\mu_t = \mu_{SS,t} =$ 2%. When demographic change takes place, both size and structure effects will affect inflation via changes in both consumption aggregate demand and accommodating money supply such that

[50] Table C.7.6 in Appendix C gives an overview and discussion on different types of government actions (different parameterization of ϕ_μ) and its impact on the economy and inflation in particular.

$\mu_t \lesseqgtr 2\%$. Under this framework, values of inflation above 2% represent inflationary pressures as a consequence from demographic change, while inflation rates below this 2% threshold mean a deflationary pressure. As seen in Figure 7.2, inflation rates are above the 2% steady-state threshold (orange line) until the year 2000, which means the presence of inflationary pressures - inflation rates have a value up to 3.3%. As demographic change takes place, inflation levels tend to decrease over time and deflationary pressures gain power when inflation rates become lower than the 2% steady state level.

In other words, demographic developments would initially lead to inflationary pressures until the year 2000 and would from then on turn deflationary. To understand the source of this pattern, it is essential to differentiate between the size and the structure effect. Figure 7.3 depicts the size effect of demographic developments on inflation as it was explained in the beginning of this section, jointly with the growth rate of population. It becomes clear that a major part of inflation can be explained by the size effect. The size effect and population growth rates have a parallel development. Positive population growth rates induce higher total consumption in the economy, leading to upward pressures on prices, whereas a shrinking population leads to the opposite effect. Indeed, exactly at the point in time (2017) when population growth turns negative, the size effect on inflation rates is below the 2% threshold. These results are in accordance with the empirical findings by Shirakawa (2012) and Yoon et al. (2014) explained in the literature review.

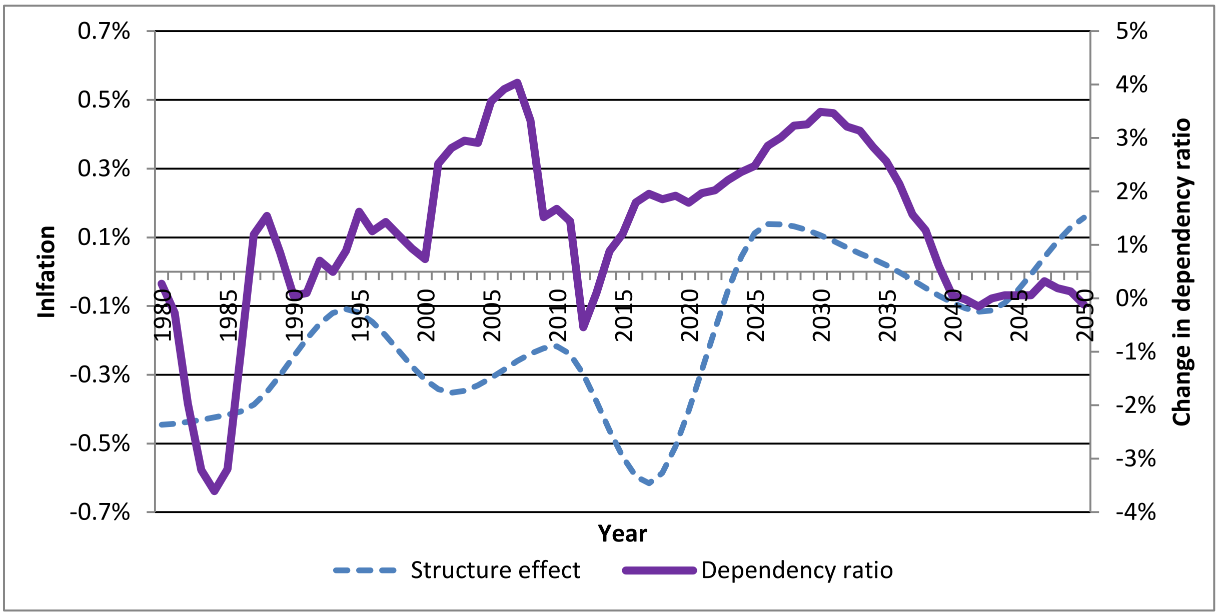
Figure 7.3: Size effect



Source: own calculations.

For a better understanding of the structure effect, Figure 7.4 also depicts the growth rate of the dependency ratio since it gives a good measure for a changing population structure during times of aging. As the vertical axis on the left indicates, the structure effect is smaller than the size effect. It is negative until the year 2023 and slightly positive afterwards. Values reach up to -0.6 p.p. of inflation around 2018 and 0.15 p.p. in 2050. When comparing the structure effect and growth rates of the dependency ratio, we detect a slight positive correlation between the two measures over time.

Figure 7.4: Structure effect



Source: own calculations.

This positive correlation between dependency ratio growth and the structure effect has its origins in the shape of life-cycle consumption profiles (see Figure 7.1). These consumption profiles usually peak around the retirement age. As a consequence, when the share of people aged around 65 increases due to an aging population (i.e. a rising age dependency ratio), aggregate consumption in the economy rises as well and the consumption life-cycle profile induces inflationary pressures. Accordingly, the correlation between the structure effect and the growth of the dependency ratio is positive, although slightly lagged, through time. In contrast to the size effect, demographic change represented by the structure effect is first deflationary and afterwards, when baby boomers reach their retirement age, slightly inflationary.

When applying the same channel as in this model, Lindh and Malmberg (1998; 2000) show that a larger share of young retirees is inflationary which agrees with our results if the consumption peak occurs around retirement age. Along the same line of thought, Juselius & Takáts (2016) find that a larger share of workers is deflationary, which is also predicted by our model for young workers. Last, Yoon et al. (2014) and Gajewski (2015) state that an increasing number of old people has a downward pressure on prices (without identifying an exact channel), a conclusion that is also reached by our model.

In conclusion, the size effect shows inflationary pressures in early years of the time range studied while it shows deflationary pressures during later years. The structure effect has, in contrast, a deflationary impact in early years and a slight inflationary effect later, although its magnitude is smaller than the size effect.

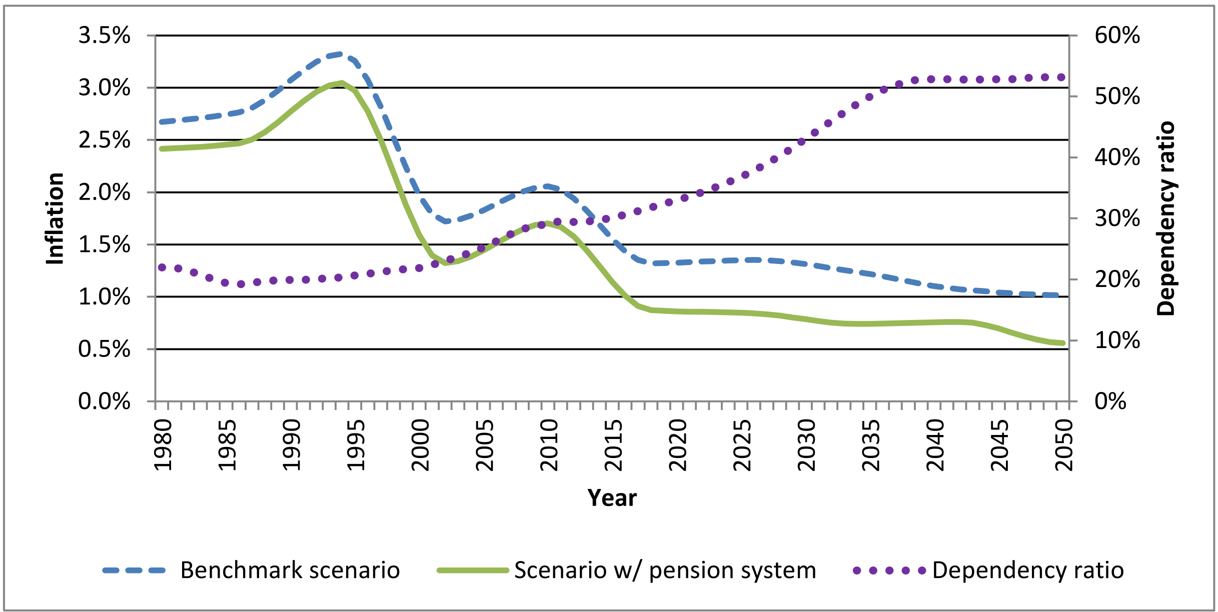
7.4.2 Pension system's effects

In addition to the previous discussion, it is also important to look at the effects of the implementation of a pension system on inflation. In this section we introduce a PAYG pension system with defined benefits as explained in Subsection 7.2.2. A pension system of this type implies that individuals will have forced contributions during their working life which tend to reduce total consumption of individuals over the life-cycle as long as the internal rate of return of the pension system is lower than the market interest rate – which is the case for our calibration and is due to population aging under the typical PAYG pension systems. The key variable to understand this section's outcome is consumption over the life-cycle. The PAYG system forces households to contribute to the system from their labor income. This potentially decreases consumption because of two reasons. Firstly, available income during working age is diminished and private savings necessarily have to decrease or become negative (in the case of borrowing) if the household wants to keep the same consumption level as in the case without a PAYG system. This implies less income received through the capital market. Secondly, since pension benefits are paid at old age there is less need to privately provide for one's old age during the working phase of life. Since the market interest rate tends to be higher than the internal rate of return of the pension system, which has been true in recent decades due to demographic change, then individuals have a present value of income which is lower than in the case without a pension system. This will reduce consumption over the life-cycle, money demand and, therefore, prices. The result that a decrease in aggregate consumption and, therefore, demand dampens inflation is in line with theoretical and empirical findings (see Lindh & Malmberg (1998) and Juselius & Takáts (2016)).

In Figure 7.5, we can observe that introducing a pension system reduces inflation in comparison to the benchmark scenario. The difference between inflation rates adds up to roughly 0.3

percentage points in early years. In later years, the difference is half a percentage point. For instance, in year 2017 the difference in inflation rate amounts to 0.4 p.p.. This effect would be even stronger for more generous pension systems. Although the impact is not always similar over the years, there is a clear reduction of inflation due to the pension system. The reason for this behavior stems from the decreasing internal rate of return of the pension system that occurs due to the increasing share of old age individuals that receive pension payments in comparison to the reduction of the working age population paying for the system.

Figure 7.5: Inflation with and without a pension system



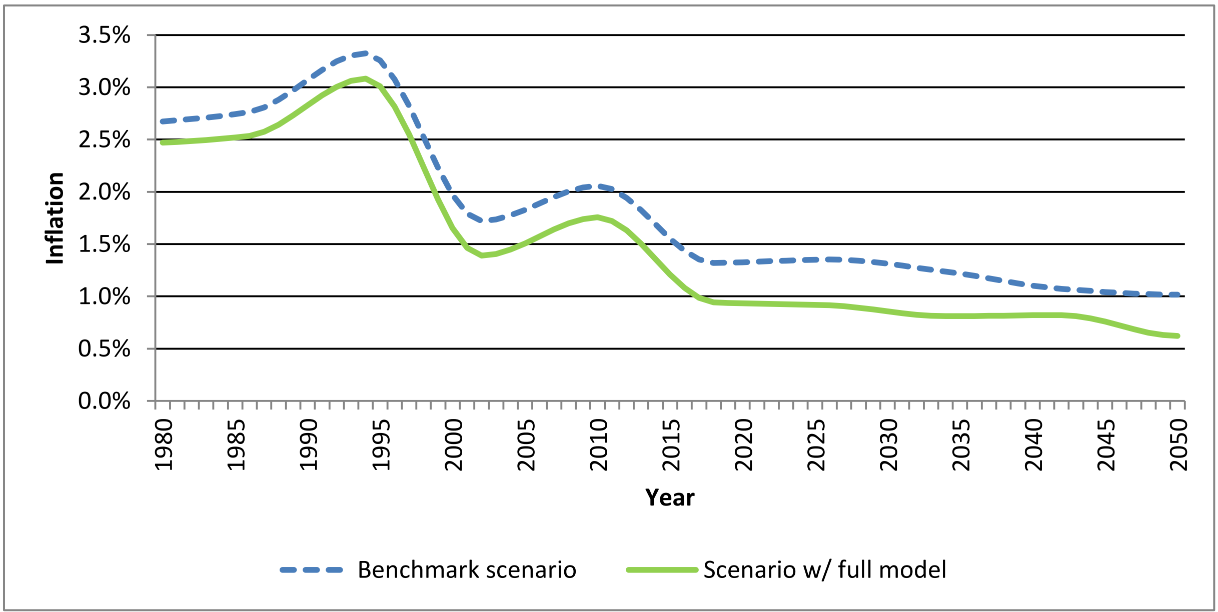
Source: own calculations.

Following the upward trend in the dependency ratio as depicted in Figure 7.5 (right scale), contribution rates also increase over time to compensate for the decreasing number of contributors to the system, pushing available income downwards. Hence, the impact on inflation described above will be reinforced and create deflationary pressures: lower savings imply lower capital income which reduces consumption possibilities and, therefore, money demand, which, in turn, implies lower inflation rates under a pro-cyclical government. The increasing dependency ratio, therefore, ultimately leads to a wider gap between the two scenarios with and without a pension system, see Figure 7.5. As will be seen in the country example in Section 7.5, the magnitude of this gap will also depend on the size of the PAYG pension system.

7.4.3 Pension system and labor supply interactions

After describing the main individual paths through which aging can affect inflation, we join all these paths and observe the overall impact of aging on inflation under a partial equilibrium setting. For this purpose, the same simulation from Section 7.4.1 is carried out but by assuming both endogenous labor decisions and a PAYG pension system. The main impact of the introduction of these elements is a reduction of the inflation rate. Comparing the levels of inflation calculated in Section 7.4.1 with the outcome levels in this section (see Figure 7.6), we can clearly observe this pattern.

Figure 7.6: Inflation rates in the benchmark and full model scenarios

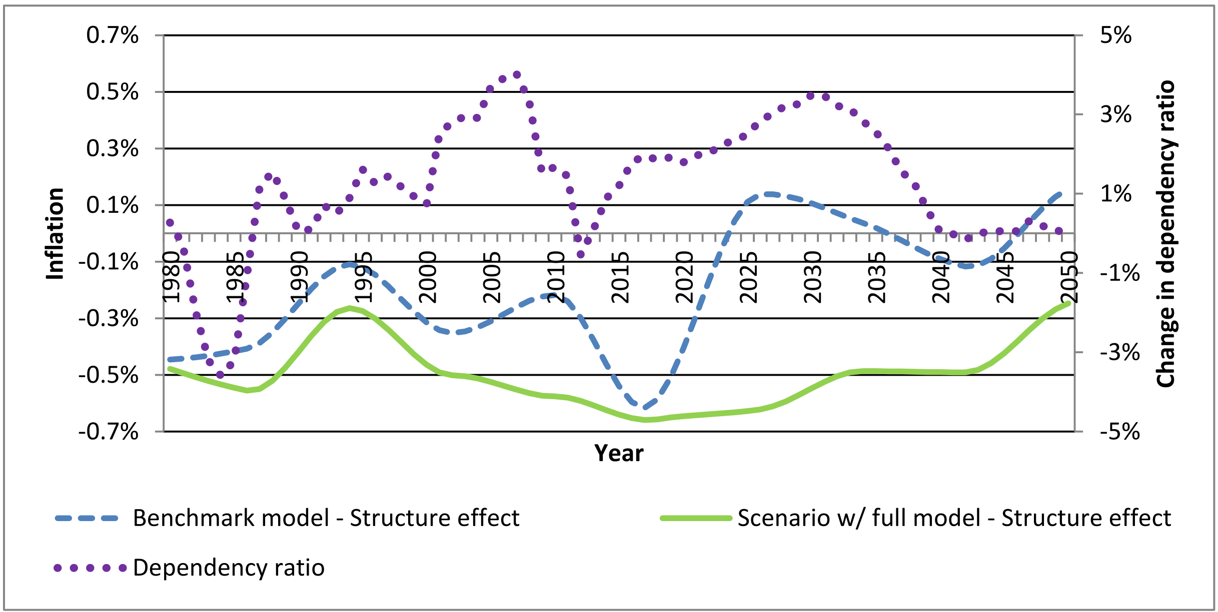


Source: own calculations.

As we highlighted in previous sections, the existence of a pension system affects inflation levels. As expected, the overall negative effect prevails over the entire period of analysis due to a weak effect of labor supply in contrast to the large effect observed when introducing a pension system without an endogenous labor decision. The pattern retains the main features observed previously in Subsection 7.4.2 in regards to the stronger effect of aging in the pension system's internal rate at later periods.

Comparing the size effect of both this scenario and the benchmark scenario, we observe that deflationary pressures are stronger under the former than under the latter. At the same time, the structure effect is negative during the entire time range, having a smaller negative value as the structure of population shows more individuals close to retirement age. The existence of a pension system for a given age structure of population leads to larger losses of disposable income and affects consumption over the life-cycle, producing deflationary pressures. As is visible in Figure 7.4.6, the structure effect is consistently and largely negative over time in the scenario with a pension system in place, while in the benchmark scenario the effects become slightly inflationary later in time. Moreover, the negative impact of the age dependency ratio on inflation is amplified due to the presence of the pension system. The interdependence between population structure and the pension system through the internal rate of return of the system leads to stronger reactions to a change in the dependency ratio as seen in Figure 7.7.

Figure 7.7: Structure effect in both scenarios and dependency ratio

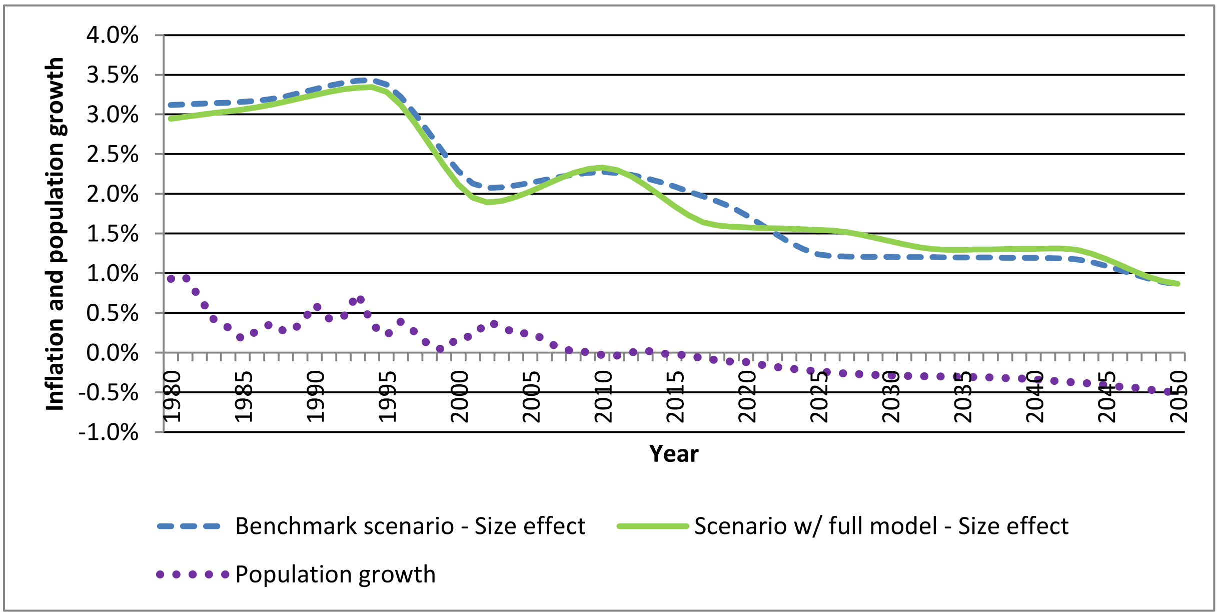


Source: own calculations.

We can infer that without a pension system a structural change in the population has small effects on inflation, and, if there is an effect, it is first negative and then positive due to working age population consumption not being hindered by large payments of contributions and the increasing share of retirees not being sufficiently large to have a negative impact on money demand and, hence, on inflation. But, if there is a pension system, the impact on inflation is stronger. The reason is twofold. The first reason is the larger amount of retirees which have a decreasing consumption profile. This is also true in an economy without a pension system. The second and distinguishing reason is the decreasing consumption of the working age population, which reaches its peak around retirement and becomes sufficiently strong to create a downward trend in money demand and, consequently, in inflation. It is the combination of a smaller working population at the age of peak consumption and a decrease in consumption due to the pension system that conducts a negative structure effect. This is mostly visible after the 1990s because of the constant increase in the dependency ratio.

In addition, Figure 7.8 shows that the size effect presents the same decreasing pattern as was observed in the benchmark scenario as a consequence of a shrinking population. The same channels regarding population levels and aggregate money demand apply here, too. Still, note that the levels are almost identical in both scenarios. This means that lower inflation levels are, in fact, driven by structure effects and not by size effects. Therefore, we should concentrate the analysis on the path of the size effect through time instead of only on a specific point. Still, the overall effect of both structure and size effects leads to a reduction of the inflation rate. This leads to the conclusion that the structure effect is highly affected by the existence of a pension system and this has a large impact on the overall behavior of inflation. This should be noted as the problems that future aging economies may face regarding inflation could be related with the expansion of their pension systems necessary to cope with a larger amount of pensioners and pension payments. We will come back to this issue in Section 7.5 when we compare and quantify these impacts on different types of aging economies.

Figure 7.8: Size effect in both scenarios and population growth



Source: own calculations.

So far, our results emphasized the major impact that a pension system has on the consumption and saving behaviors of individuals. Nevertheless, another feature is implemented in our model, namely, labor decisions. Not surprisingly, in a partial model set-up with exogenously set wages, endogenous labor decisions do not play an important role as a vehicle to affect inflation.

However, when integrated in a model with a pension system, interaction effects between these two channels take place, amplifying the impact of labor decisions. These effects work through the fact that labor decisions affect total contributions to the pension system. If endogenous labor decisions lead to a reduction of total hours worked, the pension system will require a higher contribution rate for each individual, which will dampen savings and consumption. This decrease in consumption will then foster deflationary pressures via lower money demand. Still, this effect remains small in comparison to the pension system effect. Figure C.7.7 in Appendix C shows that differences represent at maximum around 0.1 p.p.. Despite this small value, it is still significant in relative terms as inflation levels are low[51].

The results so far confirm that the combination of several elements – pension systems and endogenous labor decisions – has a significant impact on inflation. Nevertheless, we must take into account that we are still in a partial equilibrium setting, which assumes constant interest rates and wages. As we will see in the next section, this will produce different outcomes as a result of the impact on savings, which will not only highly depend on interest rates' movements, but also on consumption, which depends on savings and wage profiles.

In order to have an overall perspective on the impact of aging, pension systems, and labor supply behavior on inflation, Table 7.2 summarizes the main effects of each element depicted in percentage of benchmark inflation.

Table 7.2: Comparison between scenarios (time span: 2015-2025)

	Inflation level	**Size Effect**	**Structural Effect**	**Ratio (scenario/benchmark)**
Benchmark scenario	1.37%	1.69%	-0.33%	100%
Scenario w/ endogenous labor	1.36%	1.46%	-0.10%	99.6%
Scenario w/ pension system	0.90%	1.54%	-0.63%	66.1%
Scenario w/ full model	0.97%	1.62%	-0.64%	71.4%

Source: own calculations.

As described in Table 7.2, the size effect exerts a negative effect on inflation – it is lower than steady state inflation level - which increases over time due to population shrinkage (positive

[51] Since utility is additively separable in leisure, it is not expected that the effects of introducing labor in the model should be large. Most of the effects are mainly indirect through wages, which affect consumption and preference for money, and through savings and, hence, interest rates (in the case of the general equilibrium model in Section 7.5).

correlation). On the other side, an introduction of a pension system and structural changes in the population leads to a stronger structural effect that becomes largely negative in the full scenario. These results give strength to the arguments presented by the strand of literature which argues that population growth has an impact on inflation. As we find here, population growth through the size effect has a negative impact on inflation and a positive correlation with inflation. Interestingly, population structure changes its impact magnitude depending on the economic model we assume. The main difference between models is the presence of the pension system. Indeed, if there is no pension system that absorbs available income and consumption of the working age population, structure changes, which become stronger in the last decades, have a mostly negligible effect (see Table 7.2 and Figure 7.7). In contrast to this pattern, when a pension system is in place, the population structure effect becomes more negative, reflecting diminishing available income and consumption. This results from the decline of the working age population, as well as a decrease of population at the age when consumption reaches its peak and from the increase of population in retirement who already passed their consumption peak and has a decreasing consumption profile.

7.5 The aging – inflation puzzle: general equilibrium results

Moving from a partial equilibrium setting to a general equilibrium framework introduces a series of new elements - such as equilibrium interest rates and wages. While interest rates and wages in Section 7.4 were assumed to be constant, they now depend on demographic changes and on individual's decisions. Accordingly, interest rates and wages will tend to fluctuate over time due to enduring shocks in population size and structure, which creates positive or negative incentives regarding savings, consumption and hours worked, which are, as we have seen before, the main determinants for inflationary trends. In light of the importance of these interactions, we start by examining the main impacts that a general equilibrium framework has on inflation. Furthermore, we compare how each channel between aging and inflation, which was presented in the last section, changes or is strengthened under this general equilibrium framework.

In the second part of this section, we provide a quantified analysis of how much demographic change can explain inflation in different countries. These countries are in different stages of demographic change and present different types and coverage of public pension systems. This will allow us to observe and quantitatively explain the main arguments and channels presented in this chapter and show how aging has a potential effect on inflationary trends.

7.5.1 Demographic mechanisms in general equilibrium

In times of demographic change, interest rate variations depend on the amount of savings in an economy. Since our model depends on savings accumulation to mount capital, today's changes in population structure where groups of savers (working age population) increase first will force interest rates to decline, and at the same time, wages to increase. As a consequence, on the one hand, consumption and money demand tend to increase due to higher wages but, on the other hand, declining interest rates make savings less rewarding, which leads to lower consumption growth. The overall effect is at first sight ambiguous because of these two counteracting effects. Indeed, they work in such a way that inflation, in comparison to the partial model, is significantly lower when population ages (compare Tables 4.1 and 5.1). Therefore, the decreasing interest rate effect overcomes the wage effect in later years of demographic change.

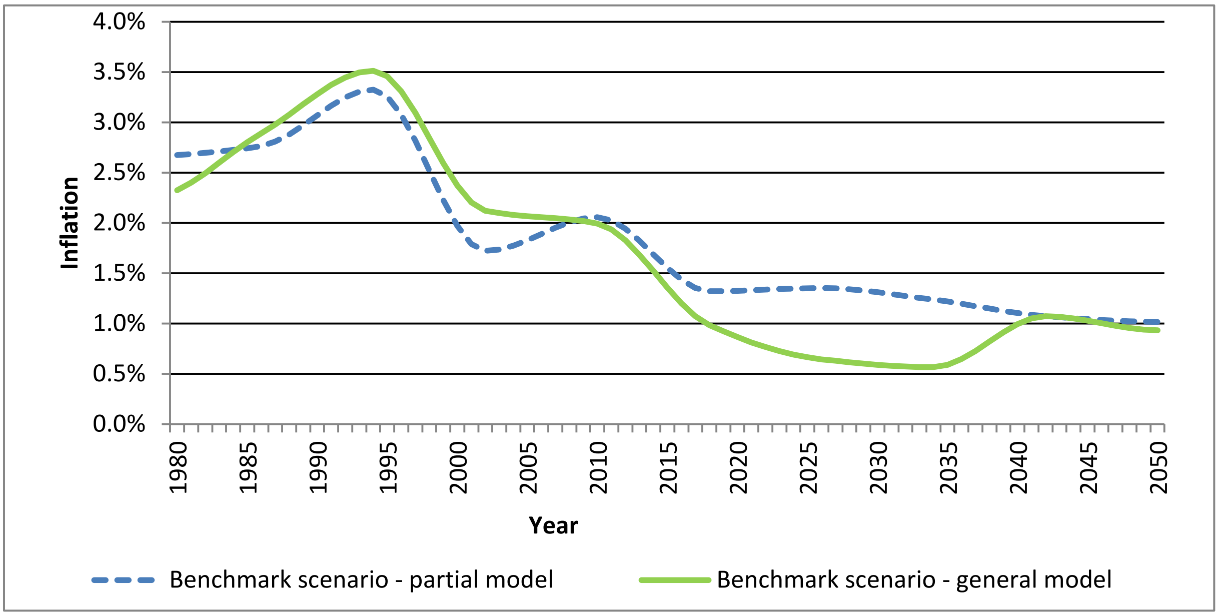
Table 7.3: Comparison between scenarios (time span: 2015-2025)

	Inflation level	Size Effect	Structural Effect	Ratio (scenario/benchmark)
Benchmark scenario	0.91%	1.79%	-0.87%	100%
Scenario w/ endogenous labor	1.05%	1.77%	-0.71%	115.1%
Scenario w/ pension system	0.88%	1.79%	-0.91%	95.9%
Scenario w/ full model	1.04%	1.77%	-0.72%	114.2%

Source: own calculations.

This can also be observed in Figure 7.9, where inflation rates are lower than those in the partial equilibrium setting from 2009 onward, mainly due to the decline in the interest rate. Before 2009, in contrast, the wage effect mostly dominates the interest rate effect. This induces additional consumption and money holdings through higher work income implying higher inflation rates than in the partial model. In total, the general equilibrium setting with its varying factor prices reinforces demographic effects on inflation because the partial model with its constant factor prices closes an additional channel through which demography can work.

Figure 7.9: Inflation under partial and general equilibrium



Source: own calculations.

Taking into account the importance of marginal productivities of capital and labor in the general framework, aging will also influence inflation through labor decisions. Due to the reaction of labor decisions on variations in wages and interest rates, consumption and savings choices are now dependent on labor decisions. While in the benchmark model any variation in both wages and interest rates will only directly affect consumption and savings decisions, reactions of hours will now dampen the strength of this direct path. By inspecting the results for labor decisions (see Appendix C, Figure C.7.8), in general equilibrium with increasing wages and decreasing interest rates during demographic change, hours reacts less to demographic change. Therefore, any variation in these variables will be dampened by hours worked decisions. This means that changes in consumption and savings will also be hampered, creating weaker reactions in money demand and, hence, smaller deviations from the 2% steady-state inflation level than in the benchmark scenario.

Table 7.3 shows the main outcomes, where one can see a less negative reaction of inflation in the endogenous labor model in comparison to the benchmark model. This is a substantial difference to the partial equilibrium setting which showed almost no difference between the benchmark scenario and the scenario with endogenous labor. The higher inflation level compared to the benchmark scenario in the general equilibrium setting is a result of the lower negative impact of the structure effect on inflation. This stems from the dampening effects of hours worked on changes in wages and interest rates operated through changes in the structure of population. This is why the structure effect is less negative in this scenario than in the benchmark scenario.

Another channel that was introduced in the previous section is the existence of a pension system. Again, the negative impact of demographics on inflation is slightly stronger than in the benchmark scenario as was already the case in the partial equilibrium setting. However, this difference is much smaller under a general equilibrium model. A share of savings is now absorbed by the pension system which makes interest rates higher. Moreover, changes in the population structure which increase the amount of retirees will create shocks on contribution rates that will reflect onto consumption and savings and, hence, on inflation. This effect will be amplified by reactions of wages and interest rates that reinforce the negative impact on inflation. This creates deflationary pressures, as we can see from the structure effect of -0.91% in Table 7.3. As the ratio scenario/benchmark depicts, under a general equilibrium framework, the reduction of inflation is smaller than under a partial equilibrium setting (95.9% instead of 66.1%) due to the feedback effects produced by wages and interest rates.

Lastly, when we incorporate all the channels together in a single full model, we observe that the small deflationary effect of a pension system is dominated by the stronger positive effect of endogenous labor. As Table 7.3 shows, the inflation level is on average similar in both the scenario with endogenous labor and the full model scenario (115.1% and 114.2% of benchmark scenario levels, respectively). This shows how endogenous labor more than compensates for the small, negative impact of pension systems through an impeded reaction to changes in wages and interest rates, which are caused by the structure effect. The structure effect, as explained above, leads to a stronger reaction of consumption and savings when a pension system exists. The possibility of labor decisions, however, more than erodes this effect. As we have shown, the channels can be hidden either by the general model features explained in this section, or by the several channels involved that may compensate for each other. The importance of these channels will become clear in the next section when we compare different countries with different specificities regarding pension systems and stages of demographic change. The just applied general model will be further used in this chapter to quantify and specify the particularities of each country and show how, in reality, aging is partially affecting inflation in each of these countries.

7.5.2 Country simulations

After evaluating the impact of endogenous interest rates and wages on inflation in Section 7.5.1 and being aware of the identified channels, we can now simulate the model by making use of real world examples. The aim of this section is to illustrate the channels and mechanisms described above and at the same time portray the main inflation dynamics of countries with different macroeconomic and demographic specificities. The model is simulated using parameters that match the empirical moments of each country and reflecting comparable macroeconomic dynamics where possible. We want to highlight the fact that with these simulations, we are not seeking to obtain exact estimates for inflation[52]. In fact, we are concerned to simulate and illustrate possible impacts of demographic change on inflation.

In accordance with Section 7.5.1, the general equilibrium model is then employed for a selection of different countries. We have chosen a set of aged countries that have a generous pension system – such as Germany, Italy and Japan. France is also included as a country with a generous pension system but it does not have yet an aged population, proving different dynamic patterns than the ones observed in the previous countries. Finally, a set of young countries composed of US and India represent the countries with a still young population and also with a less generous pension system. China is also included in this group as a country with a less generous pension system and young population, but which is going to age quickly in the near future. These countries with distinct levels of generosity of pension systems and in different stages of demographic change allow us to have a good overview of the impacts of the different channels on inflation levels.

As a first step, we assume that no public PAYG pension system is existent. Later in this chapter, the respective size of national pension systems will be added in order to identify possible interaction effects and their magnitude for our sample of countries. Note that each country scenario is simulated separately (closed economy setting) since we want to abstract from possible mutual interactions at this point.

We use different calibrations of the model to match key facts of each economy and capture their inflation trends. A series of empirical moments observed in the calibration year 2015 (see Table 7.5) are matched with their corresponding model outcomes. The respective calibrated parameter values for each country are summarized in Table 7.4.

[52] As it should be clear, the myriad of channels that drive inflation, as already explained, are too many to be implemented and considered in a sole model. Here, we are just concerned in solely detecting the specific impact that demographic change may have on inflation. Therefore, it is expected that the inflation patterns should match the empirical ones but it is not expected that we could calibrate the model such that inflation levels should exactly match the real ones over a large period of time.

Table 7.4: Parameter values

	Discount factor (β)	Consumption weight (η)	CES subst. parameter (σ)	Labor weight (Ψ)	Labor parameter (ϱ)	Depreciation rate (δ)
France	0.999	0.07	0.4	0.05	2	0.045
Germany	0.999	0.07	0.4	0.12	2	0.055
Italy	0.999	0.2	0.5	0.09	1	0.035
USA	0.965	0.91	0.4	0.22	1	0.05
Japan	0.999	0.01	0.4	0.01	2	0.05
China	0.999	0.008	0.4	0.008	2	0.04
India	0.999	0.82	0.5	0.2	1	0.07

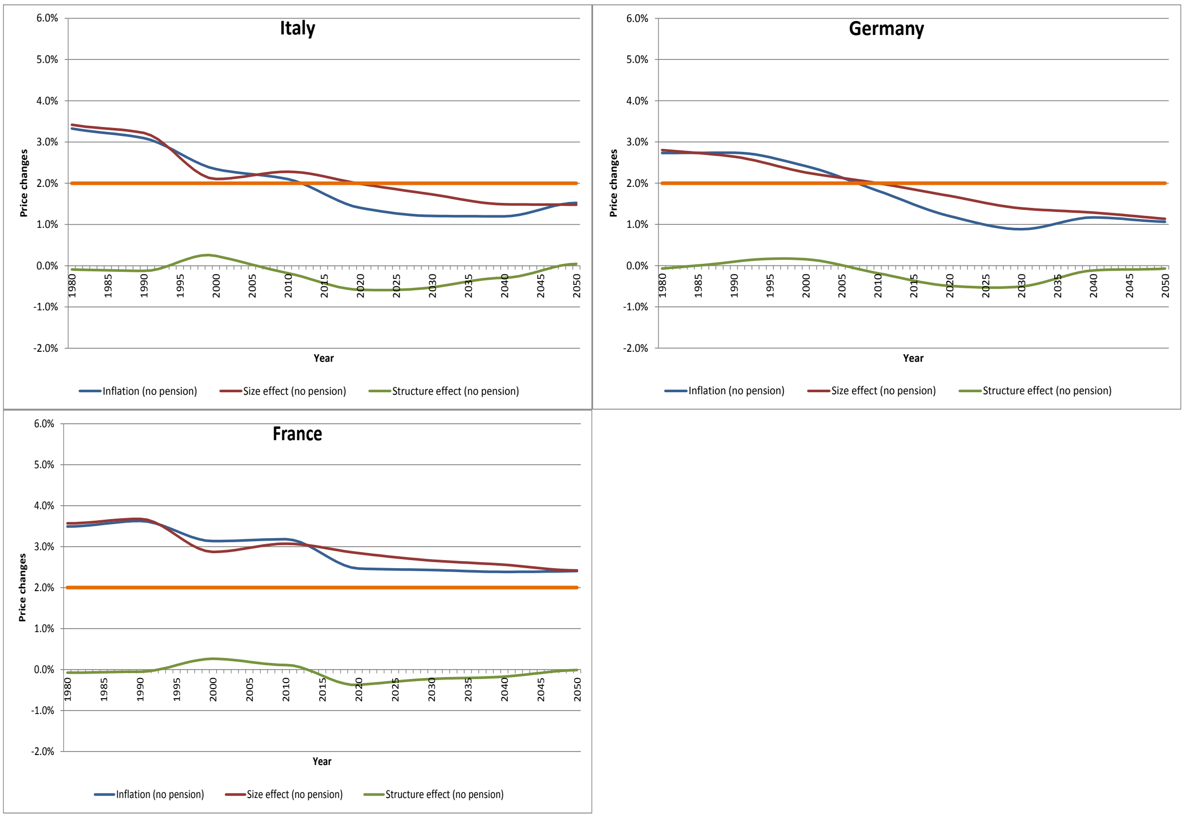
Parameter values are calibrated to match empirical moments displayed in Table 7.5. The main goal in this Section is to match each country's empirical moments with our model outcomes, even if parameter values might seem extreme for some countries. Hereby, the discount factor and the depreciation rate are used to target the empirical capital-output ratio. The consumption weight parameter is used to target the consumption-output ratio and the money-output ratio. Finally, the two labor parameters are used to mainly target average annual hours worked.

7.5.2.1 Countries' inflation dynamics

Figure 7.10 shows the resulting inflation rates and magnitudes of effect sizes for the three largest EU countries: Germany, France, and Italy. Among these countries, Germany and Italy represent a regime of aging (or already aged) populations, incorporating high survival rates and low fertility rates at the same time. France's population, in contrast, is mostly defined by higher survival rates and longevity but less by low fertility rates and population shrinkage.

Correspondingly, inflation rates show a clear downward trend for Germany and Italy, which is clearly driven by the size effect. Since fertility rates have been low for decades in these countries, populations shrink when baby boomers become old and these large cohorts reach age groups with high mortality rates. Therefore, the size effect on inflation rates exhibits a deflationary pressure from the year 2021 onward in Italy and a decade earlier in Germany. However, inflation rates drop below the 2% threshold some years earlier. This is due to the negative structure effect, which is also depicted in Figure 7.10. When large cohorts reach the stage in their life-cycle at which consumption decreases, there is deflationary pressure on inflation rates. This happens from 2006 onward in Italy and Germany. France, in contrast, is different: while we still see a small deflationary structure effect due to aging baby boomers, the size effect on inflation always shows strong inflationary tendencies. This causes inflation rates to be consistently above the 2% threshold. As mentioned above, this effect stems from relatively high fertility rates in France during the last decades that have prevented aggregate population from shrinking.

Figure 7.10: Inflation rates and effect sizes for three major EU countries

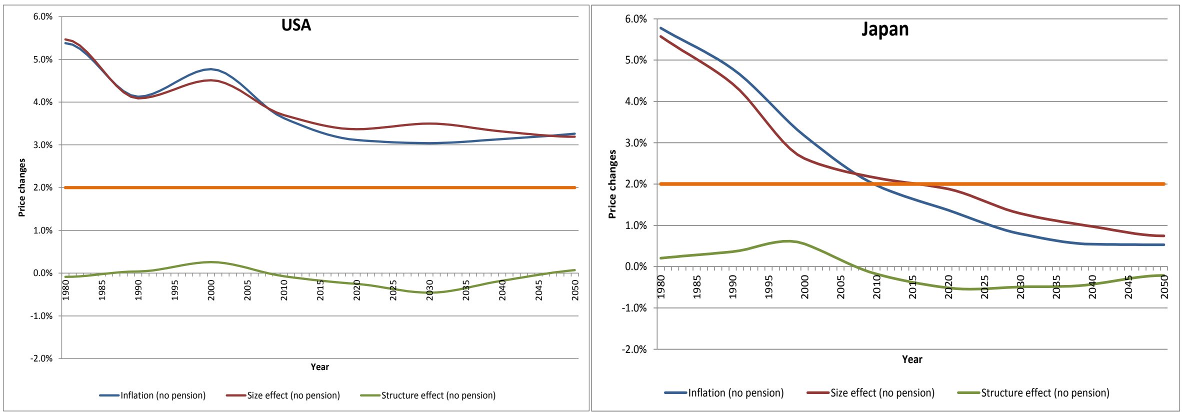


Source: own calculations.

Leaving the European context, we next compare two major economic powers: the US and Japan. Despite being both among the most developed countries, their demographic structure differs substantially: while the US still enjoys relatively high fertility rates and a growing population, Japan is closer to the aging European countries and suffers from a substantial shrinkage of population due to low fertility rates. Again, this is perfectly mirrored by inflation outcomes depicted in Figure 7.11.

In the US, the size effect on inflation causes inflationary tendencies due to permanent positive population growth. The structure effect is similar to the ones in the European countries due to aging baby-boomers and their life-cycle consumption profiles. However, since the size effect is massive, the structure effect does not play a major role. In Japan, though, the situation is very different. Comparable to European countries, an increasing population pushes inflation rates above the 2% threshold until the late 2000s. Afterwards, a shrinking population induces inflation rates to fall strongly below the 2% level because of the size effect. This effect gains substantial importance and becomes larger over time. In 2040, inflation rates stabilize at a very low 0.5% despite a policy target of 2%. However, this is not only due to the size effect but also due to the structure effect, from which Japan extraordinarily suffers, driving inflation rates even further down.

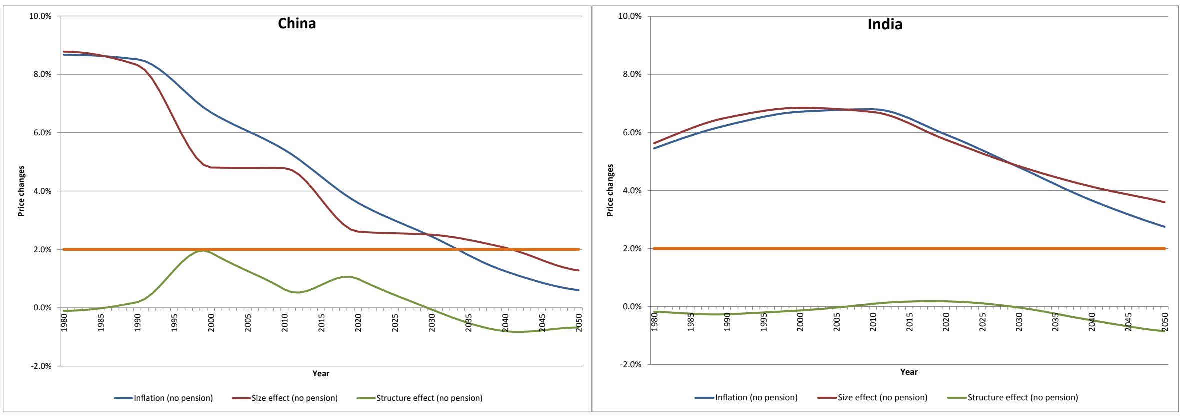
Figure 7.11: Inflation rates and effect sizes for USA and Japan



Source: own calculations.

Finally, the two largest Asian countries in terms of population, China and India, are examined in Figure 7.12. China's one child policy as a reaction to population growth pressures is well-known as a major driver of its current demographic development. Large population growth rates during the past decades induced the size effect to have an inflationary pressure on inflation rates until recently (up to 7 p.p. above the 2% threshold). However, this pattern has quickly changed and China's population will soon shrink (roughly around the year 2035). This will, in turn, lead to a size effect that causes deflationary pressures after the year 2035. In parallel to the aging European countries, where these patterns are already occurring, a strongly negative structure effect will further drive down inflation rates such that they will be close to zero in 2050.

Figure 7.12: Inflation rates and effect sizes for China and India



Source: own calculations.

In India, the picture looks completely different. India's population is still growing around 2% per year and will continue to grow during the next decades at rates around 1%. Therefore, the size effect elevates inflation rates consistently above the 2% steady state inflation. The structure effect, in contrast, is small compared to other countries and does not add much to the enormous size effect. This is due to the slow growth of the dependency ratio in India. In sum, inflation rates are up to 5 p.p. above the 2% threshold for a prolonged period of time.

The previous analysis was conducted without a PAYG pension system in place. Accordingly, this allowed for comparing countries' inflation rates while abstracting from interactions with the pension system. However, the generosity of public pension systems differs significantly between countries. In our sample of countries, France, Germany, Italy, and Japan possess fairly generous pension systems with replacement rates (as a share of the net wage) ranging from 60% to 70%. China and India, in contrast, have public pension systems with low generosity. For these countries, we simulate our model with replacement rates of 10%. For the US, which constitutes an intermediate candidate in terms of generosity, we take a replacement rate of 30%. As was already discussed in Section 7.4 and in Section 7.5.1, the inclusion of a pension system changes some basic dynamics and adds an additional channel through which aging can influence inflation rates. Therefore, we study the same sample of countries but assume realistic sizes of each country's PAYG pension system. Figure 7.13 displays the selection of countries, discussed earlier.

Generally, our findings derived in the beginning of this chapter remain valid under pension systems. Inflation rates, however, are now lower than in Figures 7.10 to 7.12 from the 2020s onward if a pension system is in place. This is especially pronounced for Germany and Japan, the countries which are aging the strongest. The explanation was already given earlier: due to population aging, the internal rates of return of PAYG pension systems in these countries are lower than the market interest rates. Therefore, life-time income and therefore consumption are lower in these aging countries, inducing a lower demand for money and, consequently, lower inflation rates. Subsequently, the structure effect is shifted towards (more) negative values since lower consumption expenditures cannot be explained by the size effect, i.e. population growth.

As described above, China and India's public pension systems are not very generous and only exhibit replacement rates of roughly 10%. This also holds in part for the US, where we assume a replacement rate of 30%. Since the generosity of these systems is small, a depiction of inflation rates in Figure 7.13 for these three countries does not deliver visible differences. In conclusion, the same qualitative results hold as for the aforementioned countries: the presence of pension systems shifts inflation rates slightly downwards. However, for countries with such small pension systems, the quantitative differences are negligible.

Figure 7.13: Inflation rates with and without a PAYG pension system

Source: own calculations.

7.5.2.2 Model validity and data comparisons

Comparing the results above to the data reported in the previous subsection, we observe that the main key macroeconomic moments for each country are matched by our model for the year 2015.

Table 7.5: Calibration targets and model outcomes

	Average annual hours worked	Capital-Output ratio	Consumption-Output ratio	Money-Output ratio
		France		
Empirical moments	0.73	3.09	0.55	4.12
Model outcomes	0.70	2.93	0.60	4.10
		Germany		
Empirical moments	0.66	2.85	0.54	4.12
Model outcomes	0.61	2.80	0.57	4.19
		Italy		
Empirical moments	0.83	3.32	0.61	4.12
Model outcomes	0.81	3.22	0.64	4.10
		USA		
Empirical moments	0.84	2.34	0.68	0.66
Model outcomes	0.84	2.34	0.74	0.65
		Japan		
Empirical moments	0.83	2.85	0.57	9.17
Model outcomes	0.78	2.88	0.51	8.16
		China		
Empirical moments	0.84*	2.85**	0.37	8.38
Model outcomes	0.75	2.45	0.52	7.63
		India		
Empirical moments	0.84*	2.34**	0.59	0.79
Model outcomes	0.85	2.37	0.64	0.79

Source: European Commission (2018), FRED (2018), The World Bank (2018). Calibration year is 2015. Average annual hours worked are displayed as the fraction of assumed maximum hours worked of 40 hours/week * 52 weeks/year = 2080 hours/year. *Data for annual hours worked for China and India is not available. However, it seems to be very high. Therefore, it is assumed to be the highest in our sample together with the USA. **Data for capital output ratios for China and India is not available. FRED (2018) data, which defines capital in a much wider sense than other sources, suggests that the Chinese capital-output ratio is comparable to the ratio in Japan. The same relationship holds between India and the USA.

Matching the empirical moments for each of the countries allows us to make conclusions about the level and inflation trends that can be attributed to the demographic change prevailing in these countries. Table 7.6 summarizes the previous findings of countries and compares them to observed data on inflation. For this purpose, we calculate the difference in the average inflation rates between the periods 1990-2000 and 2006-2016 and divide it by the average inflation rate in the period 1990-2000. This procedure is executed for both the time series of model output and real world data obtained from OECD (2018) and the World Bank (2018). Changes in average inflation rates are ranked with respect to the magnitude of the decrease between the two time periods.

Table 7.6: Change in inflation rates – Empirical data and model outcomes

	% change in average inflation (Data)	% change in average inflation (Model)
India	10.22	-2.88
France	34.97	10.98
USA	37.46	19.26
Germany	43.95	32.75
China	60.6	32.64
Italy	61.91	26.79
Japan	73.07	50.27

Source: OECD (2018), World Bank (2018), and own calculations. We calculate the difference in the average inflation rates between the periods 1990-2000 and 2006-2016 and divide it by the average inflation rate in the period 1990-2000. A sensitivity check with respect to differing time periods can be found in Appendix C, Tables C.7.1 – C.7.3.

From the table above we observe that the predicted value of average inflation is always smaller than the actual average inflation rates. Nevertheless, the negative trend of inflation rates is captured in all of the countries (with the exception of India). As can immediately be observed from Table 7.6 (left column), inflation rates have decreased in the entire sample of countries between the two time periods. Applying the same procedure to model outcomes (right column), one can observe that our model results match the ranking of real world data quite well.

In those countries where we predict the smallest (largest) decrease in inflation rates, we can actually observe the smallest (largest) decrease in real world data. For instance, in the case of India, we predict the smallest change in inflation rates between the two time periods. Model outcomes show that India's inflation has not substantially changed between the two time periods, while the actual data shows a decline of almost 10 p.p.. In the case of Japan, the country for which we predict the largest decrease in inflation due to the rapidly aging population (50.27% decline) is indeed the country with the largest decline in inflation rates observed (73.07%). The only two countries which switch their ranks are Germany and Italy. However, the general message holds: the set of countries with the strongest aging process have also exhibited the largest decline in inflation rates, which was predicted by the model.

In general, our model can capture average changes in inflation between a range of 27% (France) to 75% (Germany), where the exception is again India with a contrary development of -2%. Since the model does not account for several determinants of inflation such as aggressive monetary policies (as quantitative easing in Europe and Japan), financial disturbances, technology shocks and other events, it should be expected that predictions of inflation in this model will not explain the levels of inflation observed in the data. In fact, the effects of demography on inflation are long ranging and are an underlying force hidden by short run events that have a more immediate impact on inflation. Nevertheless, we can retain from these simulations how demographic change influence and push inflation trends in the real world through life-cycle behavior of individuals. We can conclude that demographic change in Japan has reinforced disinflationary pressures observed in this country while, on the contrary, India's demographic evolution creates positive pressures on inflation despite the actual negative trend observed. The major short run factors that have a direct effect on inflation dilute the long term effects of demography on inflation.

7.6 Conclusions

Since the 1970's inflation has decreased while age dependency ratios have increased. This pattern has posed the puzzle in the literature of whether demographic change and inflation are interconnected. Although many argue that either population structure or population growth can pose positive or negative pressures on inflation, no consensus has been reached until now. Some attribute an increase in the share of net savers towards the dampening of inflation while also believing that an increase in the share of dis-savers fosters it (e.g. Lindh & Malmberg (1998); (2000)). Others instead argue that population aging and associated changes in demand structure exhibit deflationary tendencies (e.g. Gajewski (2015)). Still another branch focuses on population size where a positive correlation between population growth and inflation is found (e.g. Shirakawa (2012) and Yoon et al. (2014)). With such a dispersion of theories and results, the aging-inflation puzzle has now received more attention as a time of population aging starts to dominate most of the developed economies in the world.

This chapter contributes to the literature by applying a theoretical OLG model that provides a partition of demographic change as a combination of a change in population size and structure. While in the literature usually only one of the mechanisms is examined, both of them are analyzed jointly in this chapter. To our knowledge, we are the first ones to study the effects of aging on inflation in this stratified manner as well as the effects of the introduction of a PAYG system on inflation, which has strong implications on the inflation process.

Our findings indicate that a part of the actual inflation rate can be attributed to demographic processes. While changes in population size seem to have the most prominent effect (size effect), the change in population structure also contributes to inflation (structure effect). Population growth is positively correlated with inflationary pressures. As seen in Sections 7.4 and 7.5, the size effect follows the trend in population growth, which stems from the decrease in aggregate consumption that reduces money demand and, hence, pressures on inflation. Since the structure effect depends on the change of shares of each age group, the decline in the (relative) size of those groups which are situated at the peak of life-cycle consumption leads to a decline in consumption and money demand, negatively affecting inflation. These impacts are strengthened by the existence of PAYG pension systems that amplify the fall in consumption due to increasing contributions necessary to balance the system. Since demographic change is intimately connected to fluctuations in the main variables of the pension system and they, in turn, affect individuals' decisions, it is unavoidable to study the impact of pension systems on inflation when talking about the aging-inflation puzzle. As exposed in Sections 7.4 and 7.5, the introduction of a pension system creates deflationary pressures and exacerbates the size of the structure effect. This is even more visible under the general equilibrium setting where changes in interest rates and wages are highly dependent on the generosity of the pension system. It is indeed under this framework that we clearly observe how the size effect is quite stable over different scenarios, reinforcing the role of the structure effect that depends on the existent economic institutions, such as the pension system. These effects show how demographic forces jointly with the mechanics of a pension system (without printing money) can conduct to deflationary pressures. These findings are countervailing effects to the literature that focus on the role of printing money to finance the additional social expenditures in pension systems as a channel that creates inflationary pressures, and are important to understanding the different channels in which pension systems affect inflation.

This leads us to think about how inflation in different countries, with different demographic processes and sizes of pension systems, evolves over time. According to our simulations, aging countries like Germany, Italy, and Japan already face deflationary pressures while China will experience a similar trend in the next decades. The structure effect is found to be especially prominent in Japan starting in the early 1990s which is explained by early increases of the age dependency ratio. Young countries with high fertility rates like the US and India, will further go through inflationary pressures stemming from the size effect, while the structure effect will not play a major role.

Our findings are as follows: demographic change has an impact on inflation. We do not claim that inflation only depends on demographic change but rather that long-term trends in inflation are dependent on demographic change. This finding has numerous implications for economic growth and monetary policy that must be coordinated with policies that tackle the aging process of economies. The size effect seems to be directly related with population growth and would have to be solved through incentives affecting demography or consumption and expenditures. The structure effect, on the other hand, is much more prone to being tackled by policies that prolong working age that will move consumption peaks to later in life, as well as policies that increase consumption possibilities for older age groups. Although our country comparisons do not intend to determine the exact level of inflation of today's economies but only the deviations and trends in comparison to steady state inflation, some of the lessons taken can be seen as recommendations. Some countries, like Japan, would benefit greatly from these policies since it is one of the countries with the most negative structure effect. Tackling this pattern would be a step forward to break with the low inflation trap that persists in the economy.

Despite the urge to always have the most complete possible model, as always, economic models abstract from many aspects of real life. Our model does not explore many of the features of monetary policies used by central banks to address many of the deviations from inflation targets under their mandates. As we referred to previously, this is addressed in many papers of the literature, but in order to concentrate on pure impacts of demographic change, we drop these interactions and address them in the sensitivity analysis.

The only force driving inflation rates in our simulations is demographic change with its accompanying effects on population size and structure. Hereby, we abstract from any policy reforms such as increasing statutory eligibility ages for retirement and other parametric pension reforms (see, e.g. Chapter 3 of this dissertation). Indeed, such reforms might potentially have interesting and unforeseen consequences on prices, which are worth studying. Since the idea of this chapter is to put light on the size and structure effect mechanisms through which aging affects inflation, this task will be left to future research.

Another issue is financial markets. Of course, in the course of life, private investment decisions change over time which will be reflected in the way central banks can influence savings decisions and transmit their monetary policy to individuals and the economy. In this chapter, financial markets are taken to be as simple as possible without any kind of choice between types of financial assets or uncertainty. This aspect will be tackled in future research but not in this chapter.

Finally, our model is mute on business cycles or any type of New Keynesian mechanisms. We apply a MIU model that is more suitable to connect the OLG setting to demographic transitions and mechanisms that we explain in this chapter in a more elegant way. This, of course, has the trade-off of not including some of the New Keynesian modelling elements but, again, regarding the goal of the chapter, does not harm the main conclusions and findings.

A. Appendix Chapter 4

This appendix shows the results for the extreme scenarios not described in Subsection 4.4.3.

Scenarios with different productivity profiles and fixed cost levels

Productivity	Time costs of working		
	Zero	Moderate	High
Flat	Table A.4.1	see Figure 4.6	Table A.4.2
Moderate	see Figure 4.7	Benchmark in Section 4.4.1	see Figure 4.7
Steep	Table A.4.3	see Figure 4.6	Table A.4.4

Scenarios with different consumption preferences and fixed cost levels

Consumption preferences	Time costs of working		
	Zero	Moderate	High
Flat	Table A.4.5	see Figure 4.8	Table A.4.6
Moderate	see Figure 4.7	Benchmark in Section 4.4.1	see Figure 4.7
Steep	Table A.4.7	see Figure 4.8	Table A.4.8

Table A.4.1: (productivity: flat; fixed costs: zero)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
ω = 0%	72	60	85	60	85	72	60	85	60	85	72	60	85	60	85
ω = 3.6%	72	60	85	63	85	72	60	85	63	85	72	60	85	63	85
ω = 6.3%	72	70	85	71	85	72	70	85	71	85	72	70	85	70	85

Table A.4.2: (productivity: flat; fixed costs: high)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
ω = 0%	60	60	64	60	61	60	60	67	60	63	60	60	69	60	67
ω = 3.6%	60	62	60	60	60	60	60	66	60	63	61	60	69	60	66
ω = 6.3%	68	68	60	68	60	67	67	63	67	63	68	68	66	68	66

Table A.4.3: (productivity: steep; fixed costs: zero)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
ω = 0%	62	60	76	60	76	63	60	77	60	76	6	60	77	60	77
ω = 3.6%	69	60	76	61	75	69	60	76	61	76	70	60	77	61	76
ω = 6.3%	71	69	77	68	76	71	69	77	68	77	71	69	77	68	77

Table A.4.4: (productivity: steep; fixed costs: high)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
ω = 0%	60	60	59	60	58	60	60	63	60	61	60	60	66	60	63
ω = 3.6%	60	60	58	60	58	60	63	61	60	61	60	60	65	60	63
ω = 6.3%	68	68	58	68	58	68	68	61	68	61	68	68	63	68	63

Table A.4.5: (fixed costs: zero; consumption weight: flat)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
$\omega = 0\%$	65	60	85	60	85	66	60	85	60	85	67	60	85	60	85
$\omega = 3.6\%$	72	60	85	62	85	72	60	85	62	85	72	60	85	62	85
$\omega = 6.3\%$	72	69	85	70	85	72	69	85	70	85	72	69	85	70	85

Table A.4.6: (fixed costs: high; consumption weight: flat)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
$\omega = 0\%$	60	60	63	60	60	60	60	65	60	63	60	60	68	60	66
$\omega = 3.6\%$	60	61	59	60	60	60	60	64	60	63	61	60	67	60	65
$\omega = 6.3\%$	68	68	59	68	60	68	68	62	68	62	68	68	65	68	65

Table A.4.7: (fixed costs: zero; consumption weight: steep)

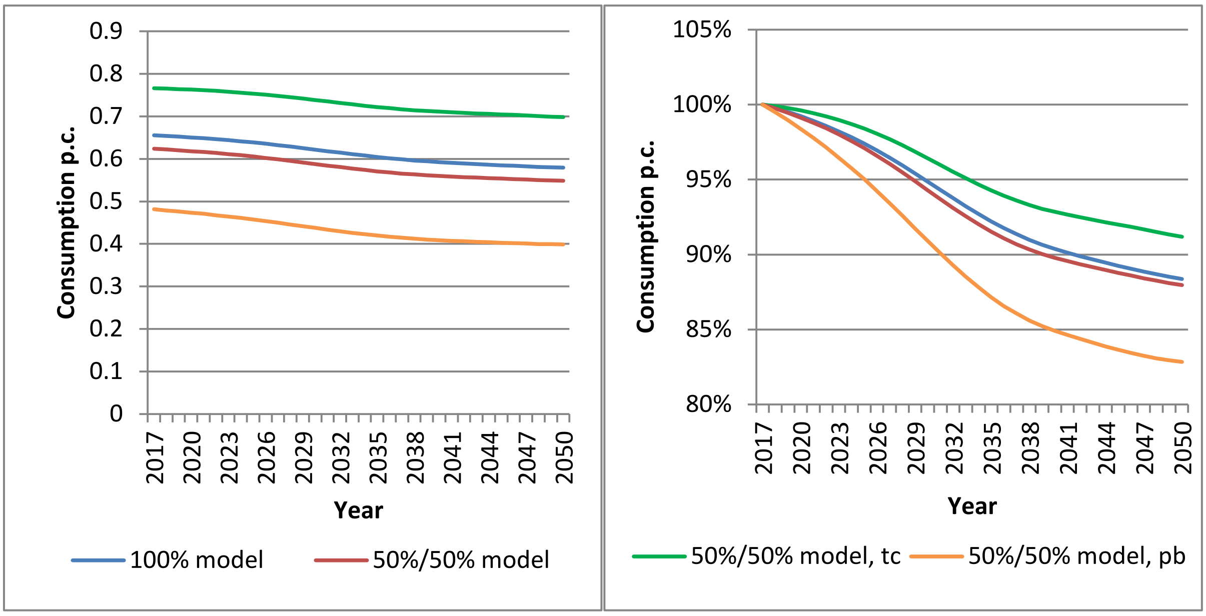
ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
$\omega = 0\%$	64	60	85	60	85	65	60	85	60	85	66	60	85	60	85
$\omega = 3.6\%$	71	60	85	62	85	72	60	85	62	85	72	60	85	62	85
$\omega = 6.3\%$	72	69	85	70	85	72	69	85	70	85	72	69	85	70	85

Table A.4.8: (fixed costs: high; consumption weight: steep)

ϕ	0.55					0.60					0.65				
Scenario	**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**		**With ET**	**No ET**		**Flexibility Reform**	
$\omega = 0\%$	60	60	58	60	58	60	60	64	60	62	60	60	66	60	64
$\omega = 3.6\%$	60	60	58	60	58	60	60	64	60	62	60	60	65	60	64
$\omega = 6.3\%$	68	68	58	68	58	68	68	61	68	61	68	68	63	67	64

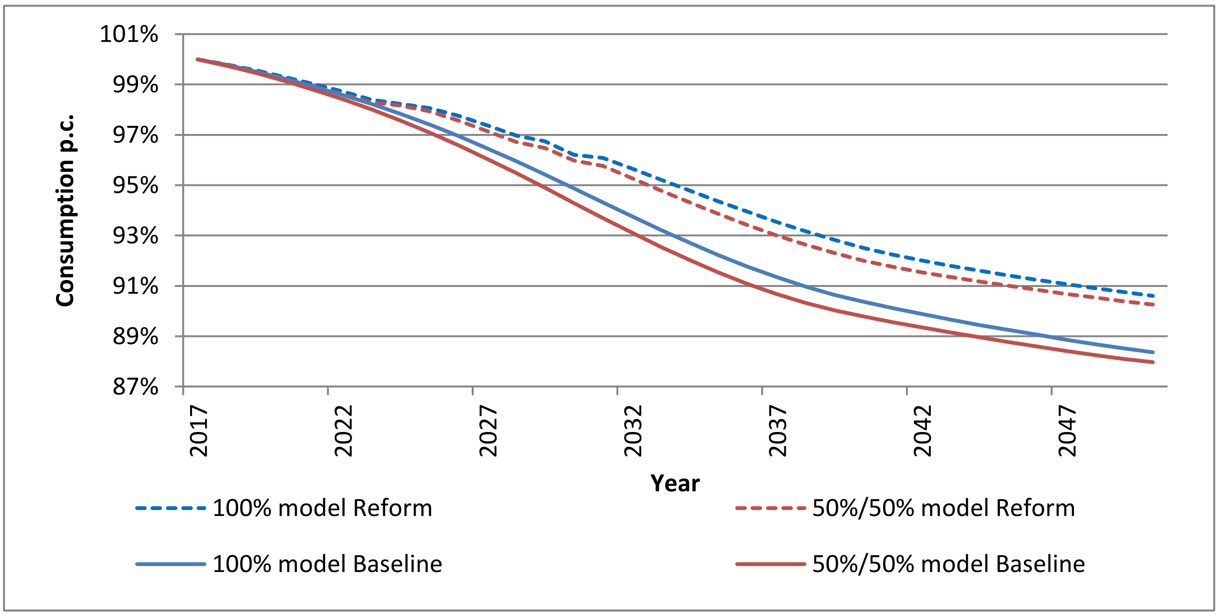
B. Appendix Chapter 6

Figure B.6.1: Consumption p.c. (Benchmark)



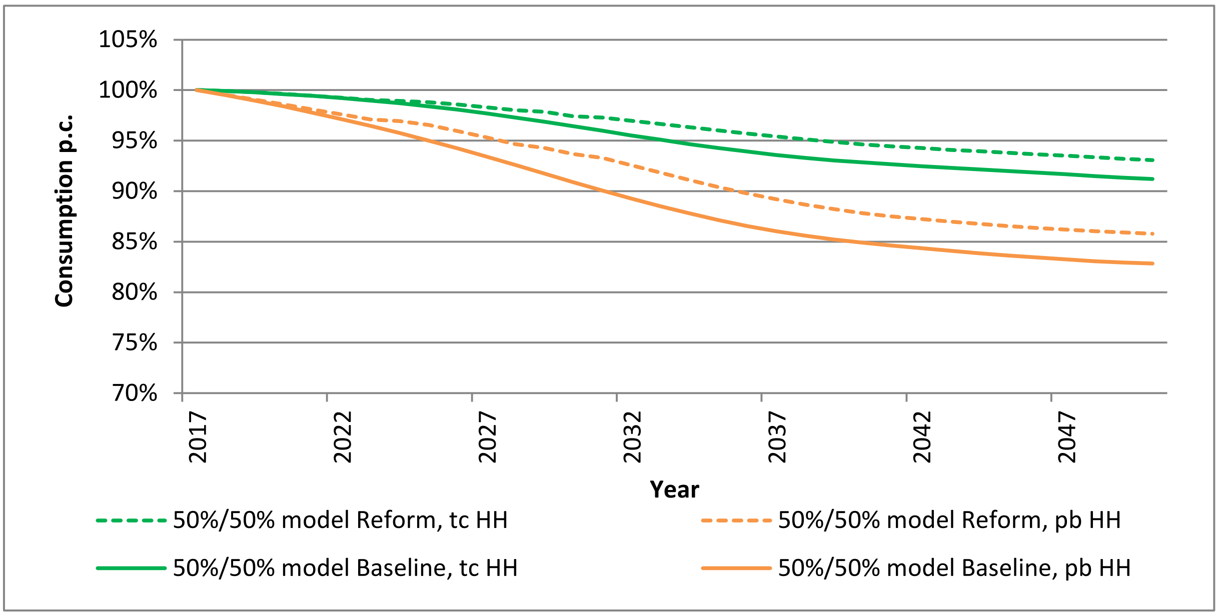
Source: own calculations.

Figure B.6.2: Consumption p.c. (67 reform)



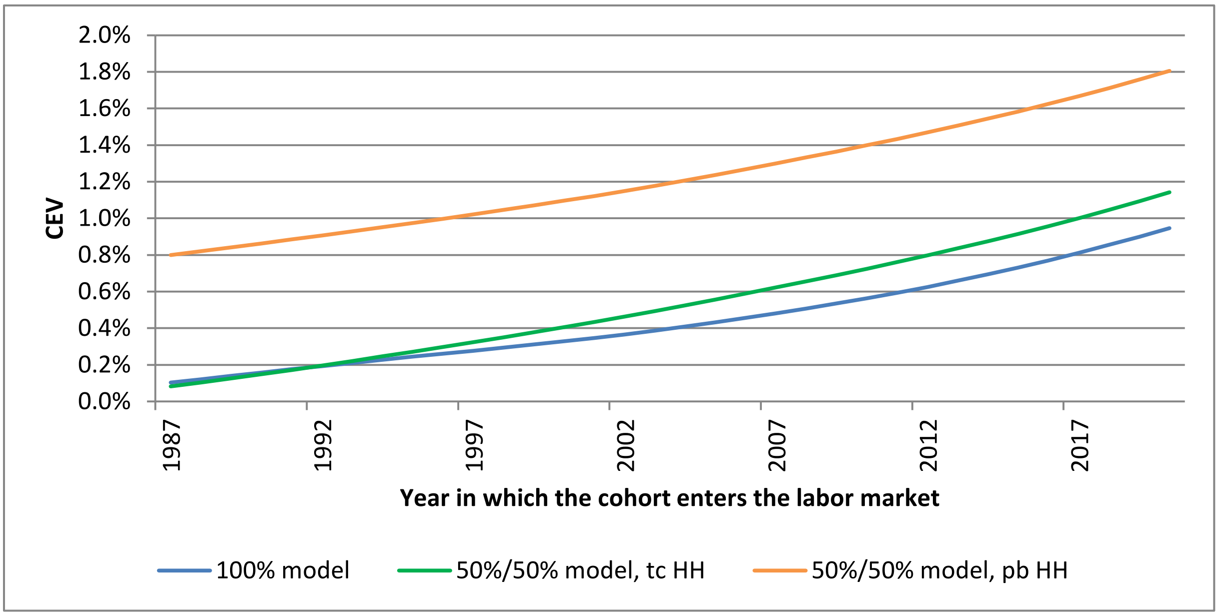
Source: own calculations.

Figure B.6.3: Consumption p.c. of different households (67 reform)



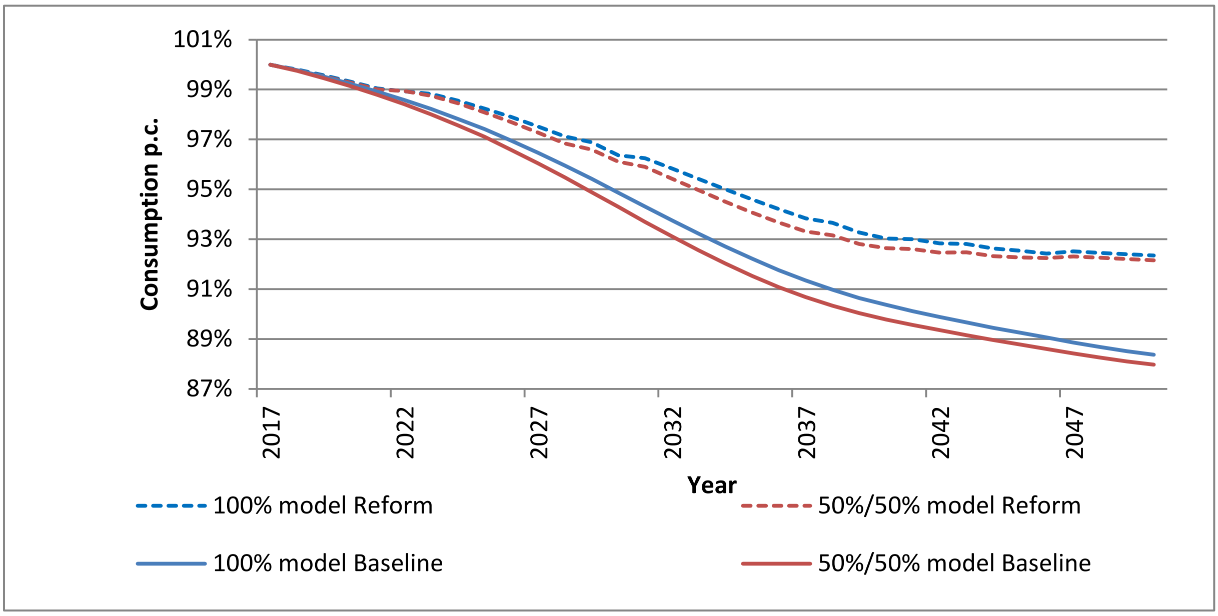
Source: own calculations.

Figure B.6.4: Consumption equivalent variation for different households (67 reform)



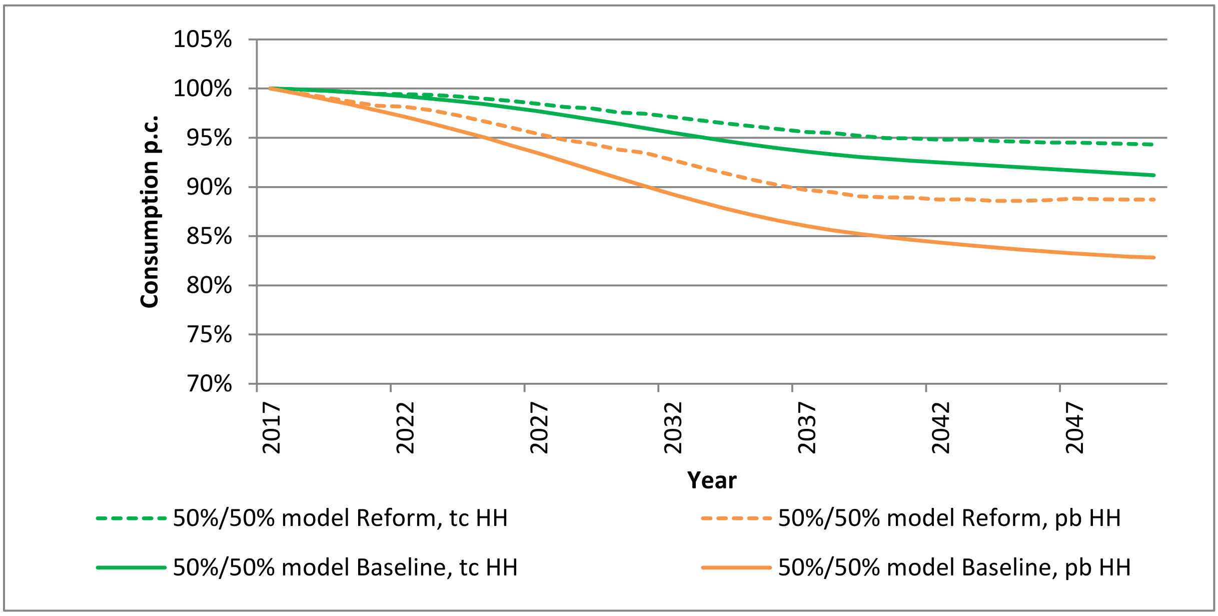
Source: own calculations.

Figure B.6.5: Average consumption (2:1 reform)



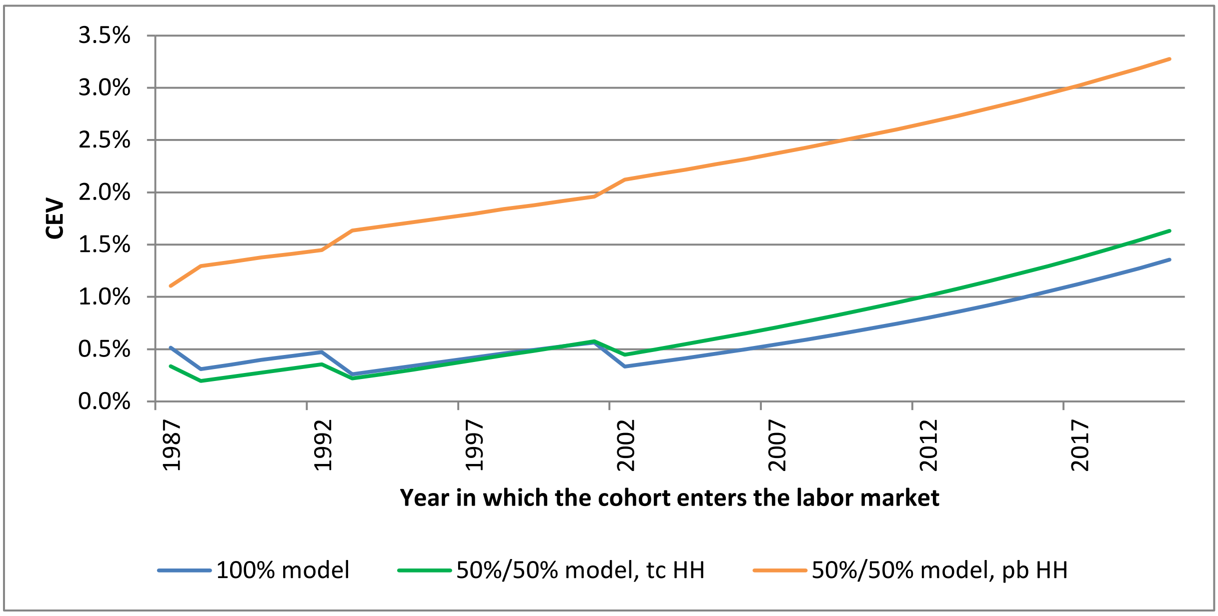
Source: own calculations.

Figure B.6.6: Consumption p.c. of different households (2:1 reform)



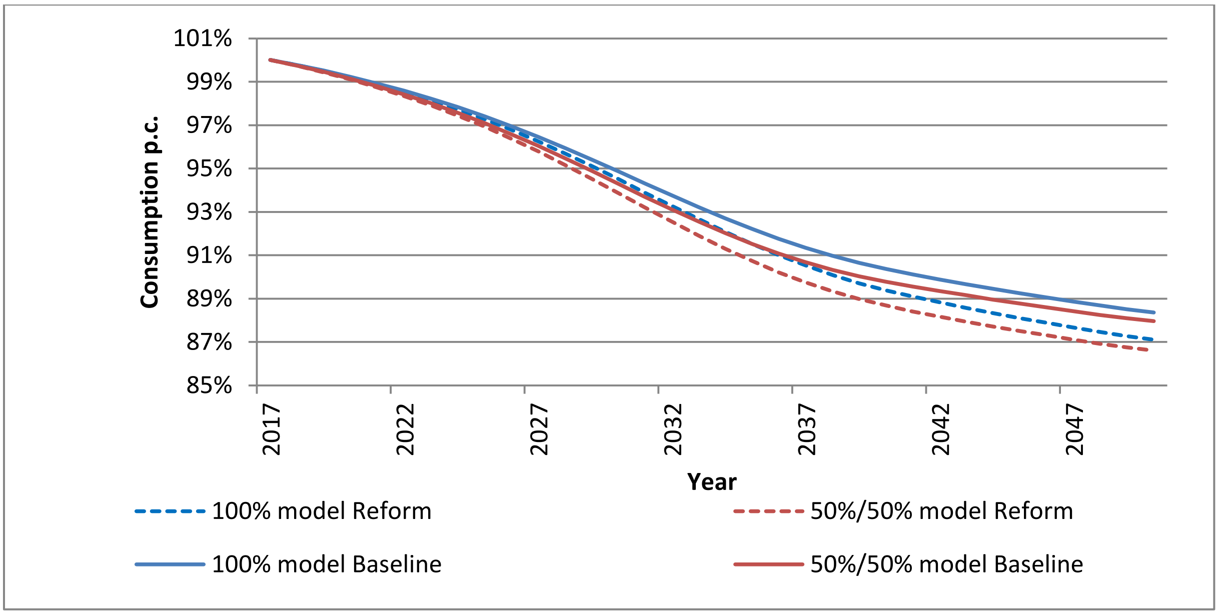
Source: own calculations.

Figure B.6.7: Consumption equivalent variation for different households (2:1 reform)



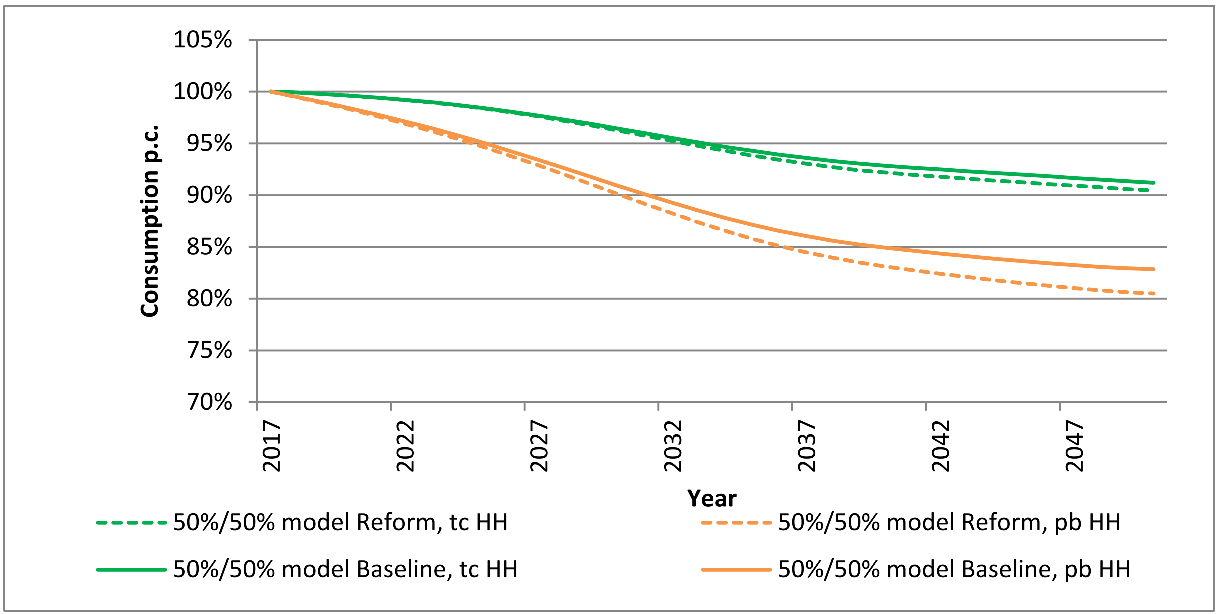
Source: own calculations.

Figure B.6.8: Average consumption p.c. (DB reform)



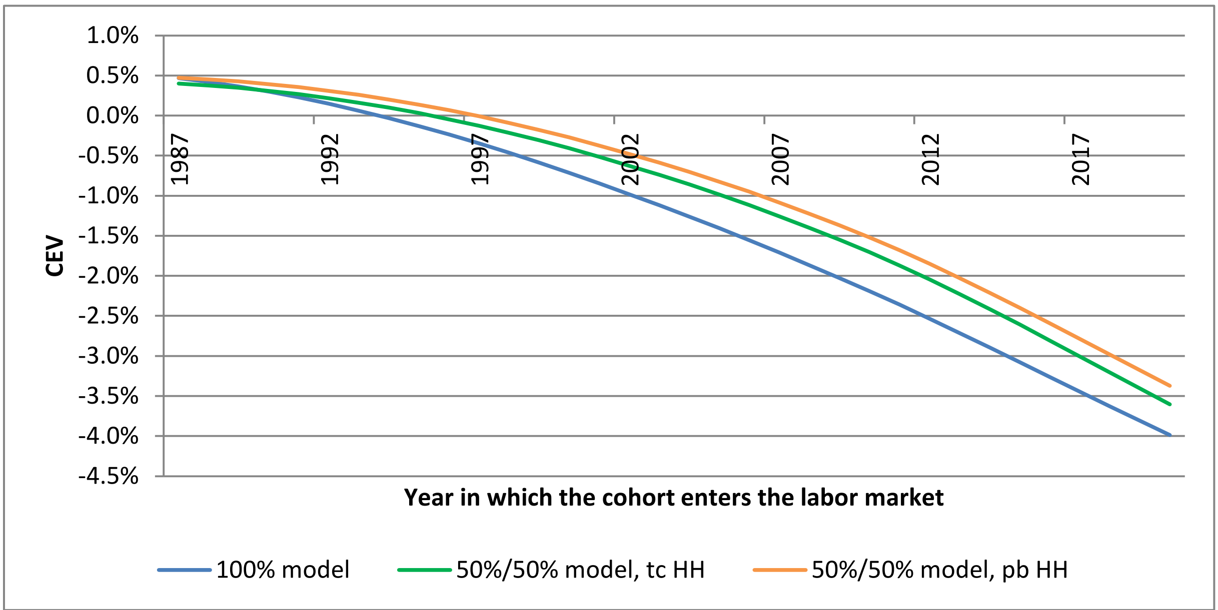
Source: own calculations.

Figure B.6.9: Consumption p.c. of different households (DB reform)



Source: own calculations.

Figure B.6.10: Consumption equivalent variation for different households (DB reform)



Source: own calculations.

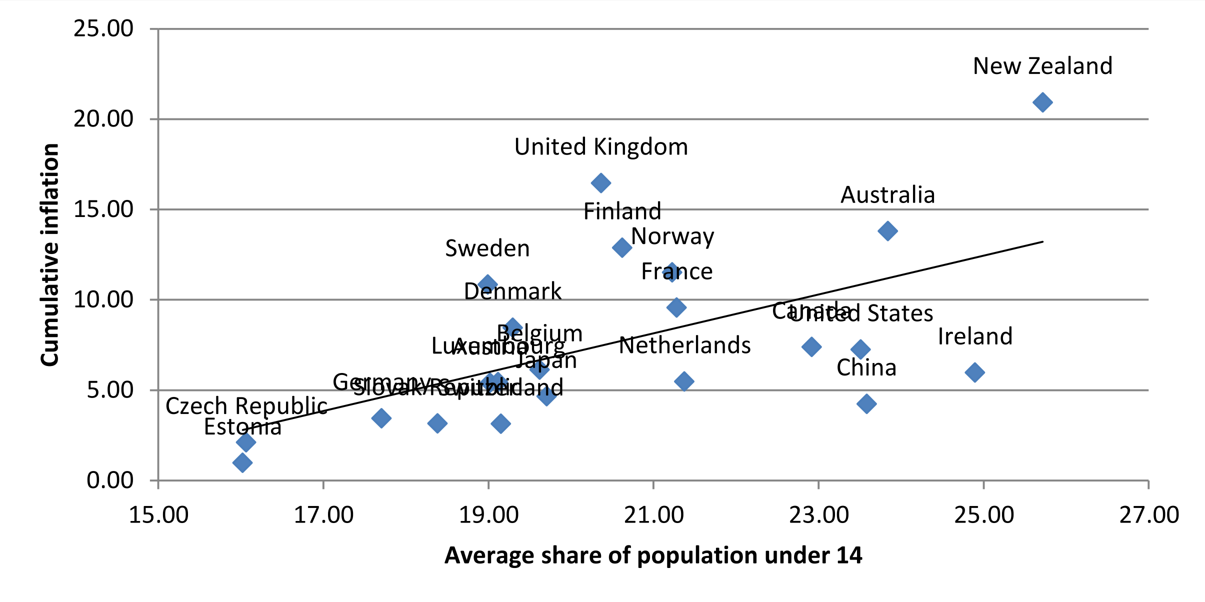
Table B.6.1: Results from benchmark model (main analysis)

	Gap in labor p.c.		Contr. rates		Welfare (CEVs)		
	100 % model	**50%/50% model**	**100 % model**	**50%/50% model**	**T.-c. in 100% model**	**T.-c. in 50%/50% model**	**P.-b. in 50%/50% model**
67 reform	2.23	2.10	-1.21	-1.19	0.95	1.81	1.14
2:1 reform	4.04	3.81	-2.55	-2.47	1.36	3.27	1.63
DB reform	-1.22	-1.34	4.49	4.57	-3.99	-3.37	-3.60

Source: own calculations. “67 reform” shows the reform which increases the retirement age from 65 to 67, while “2:1 reform” describes the reform proposal which increases the retirement age in parallel to the development in life expectancies. “DB reform” holds the “sustainability factor” constant and therefore mimics a return to a defined benefit regime. “Gap in labor p.c.” gives the percentage gap between aggregate labor supply between the respective reform scenario and the baseline scenario. “Contr. rates” indicates the change in contribution rates in p.p.. Welfare in CEVs compares the gain in life-time consumption due to the respective reform for the types of households. All numbers for the first to measures are from the year 2050. For cohort measures (right three columns on the right), the cohort entering in 2020 is taken as an example.

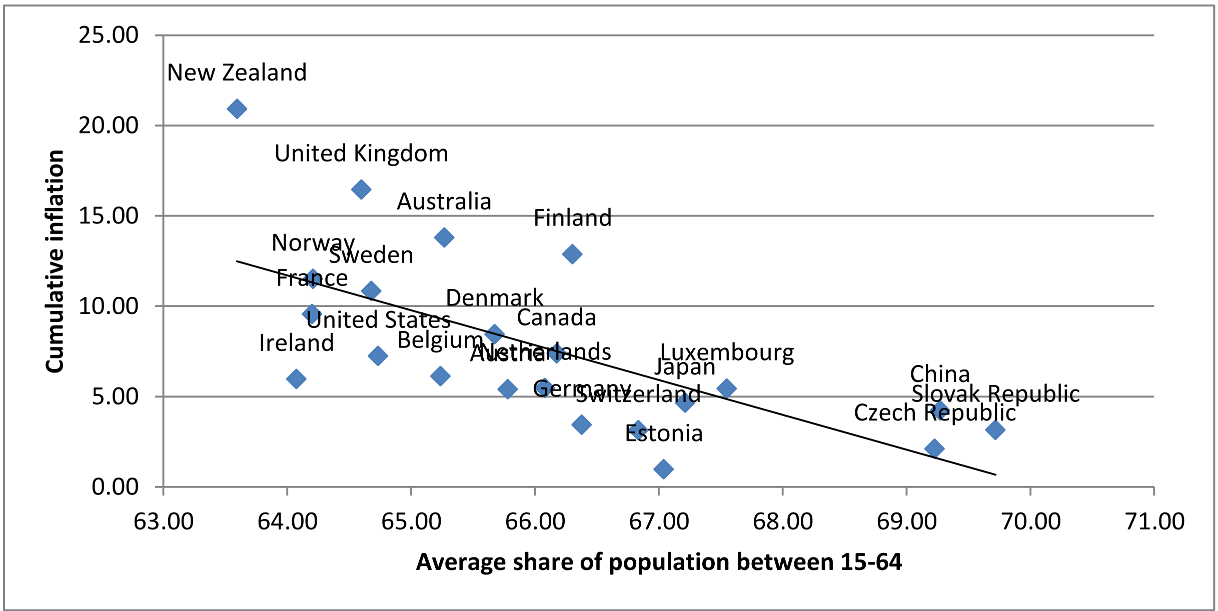
C. Appendix Chapter 7

Figure C.7.1: Cumulative inflation vs. average share of population under 14



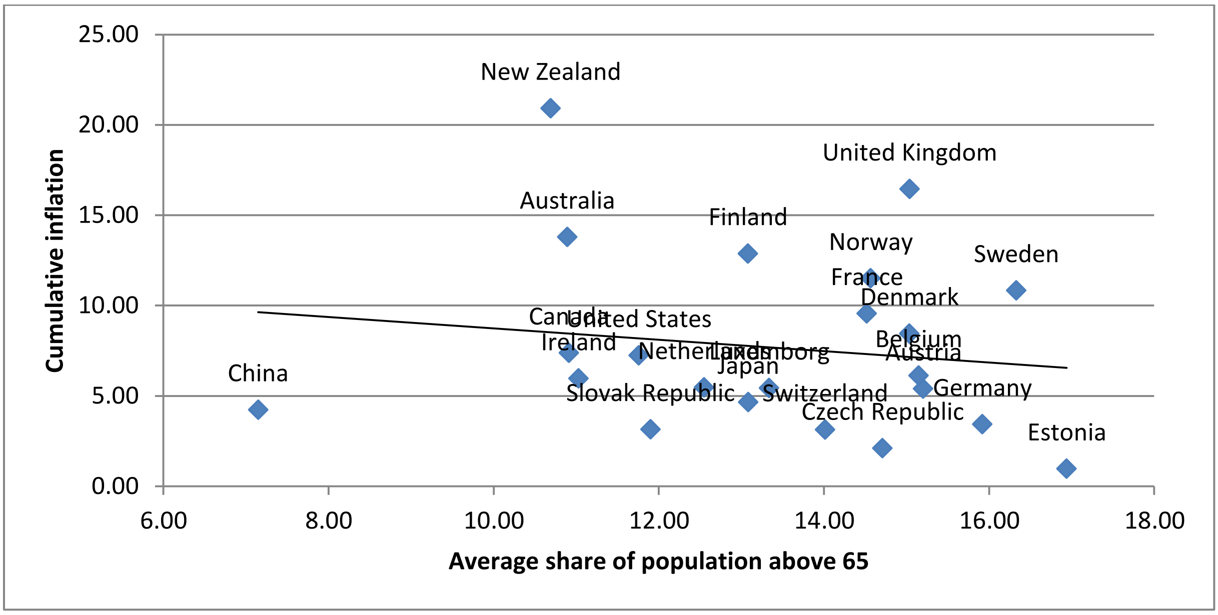
Source: OECD (2018) and World Bank (2018). The vertical axis shows the cumulative inflation rates over the time period 1960-2016, while the horizontal axis shows the average share of population which is under 14 years old during this time period. Note that we do not take any additional explanatory variables into account since this correlation is only for motivational reasons. As can be derived, there is a positive correlation between the variables for the countries examined. However, this does not imply that there is causality. See Figures C.7.4 and C.7.5 for a more in-depth empirical evaluation.

Figure C.7.2: Cumulative inflation vs. average share of population between 15-64



Source: OECD (2018) and World Bank (2018). The vertical axis shows the cumulative inflation rates over the time period 1960-2016, while the horizontal axis shows the average share of population which is between 15 and 64 years old during this time period. Note that we do not take any additional explanatory variables into account since this correlation is only for motivational reasons. As can be derived, there is a negative correlation between the variables for the countries examined. However, this does not imply that there is causality. See Figures C.7.4 and C.7.5 for a more in-depth empirical evaluation.

Figure C.7.3: Cumulative inflation vs. average share of population above 65



Source: OECD (2018) and World Bank (2018). The vertical axis shows the cumulative inflation rates over the time period 1960-2016, while the horizontal axis shows the average share of population which is more than 65 years old during this time period. Note that we do not take any additional explanatory variables into account since this correlation is only for motivational reasons. As can be derived, there is a slight negative correlation between the variables for the countries examined. However, this does not imply that there is causality. See Figures C.7.4 and C.7.5 for a more in-depth empirical evaluation.

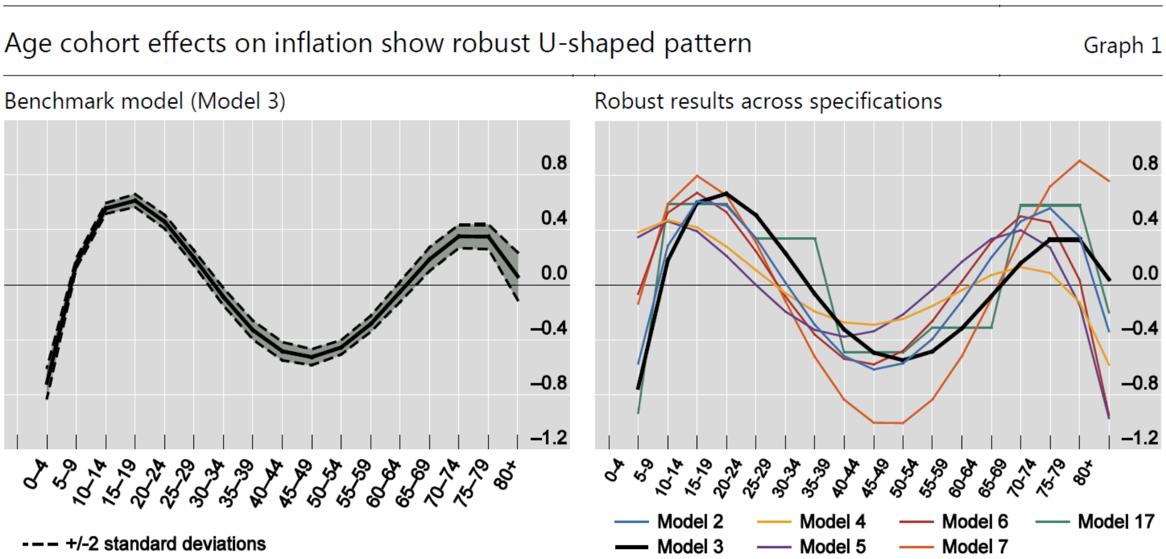
Figure C.7.4: Empirical findings I

	OECD					Japan				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Population Growth	0.339	0.524		0.549	0.317	6.689	6.363		6.708	6.725
	[0.715]	[0.577]		[0.570]	[0.764]	[0.005]***	[0.003]***		[0.001]***	[0.001]***
Share of 65 and over		-0.176	-0.125	-0.137	-0.416		-0.101	-0.321	-0.300	-0.242
		[0.009]***	[0.013]**	[0.006]***	[0.008]***		[0.394]	[0.082]*	[0.060]*	[0.227]
Share of 15-64			-0.101	-0.103	-0.330			-0.476	-0.544	-0.499
			[0.226]	[0.233]	[0.037]**			[0.030]**	[0.008]***	[0.026]**
Life Expectancy					0.304					-0.092
					[0.043]**					[0.748]
TOT change	-0.145	-0.144	-0.145	-0.144	-0.143	-0.169	-0.174	-0.178	-0.148	-0.147
	[0.005]***	[0.005]***	[0.005]***	[0.005]***	[0.005]***	[0.016]**	[0.014]**	[0.013]**	[0.016]**	[0.016]**
GDP growth	-0.750	-0.795	-0.799	-0.802	-0.784	-0.246	-0.319	-0.517	-0.431	-0.452
	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.000]***	[0.015]**	[0.033]**	[0.008]***	[0.008]***	[0.022]**
M2 growth	0.192	0.183	0.180	0.180	0.176	0.059	0.034	0.007	-0.009	-0.015
	[0.000]***	[0.000]***	[0.001]***	[0.001]***	[0.000]***	[0.118]	[0.379]	[0.869]	[0.826]	[0.751]
Budget Balance Chg.	0.129	0.153	0.153	0.158	0.150	-0.105	-0.086	0.006	0.040	0.059
	[0.051]*	[0.022]**	[0.033]**	[0.018]**	[0.022]**	[0.540]	[0.563]	[0.971]	[0.776]	[0.690]
Constant	-0.053	2.418	8.443	8.739	4.132	0.074	1.870	37.962	42.051	45.446
	[0.910]	[0.060]*	[0.149]	[0.151]	[0.255]	[0.821]	[0.399]	[0.031]**	[0.010]**	[0.038]**
Observations	1167	1167	1167	1167	1167	53	53	53	53	53
Number of ifscode	30	30	30	30	30					
R-squared	0.212	0.216	0.217	0.217	0.222	0.530	0.545	0.462	0.602	0.603
RMSE	5.235	5.227	5.223	5.223	5.209	2.077	2.066	2.246	1.954	1.973

1/ Inflation and population growth are detrended using quadratic filter.
2/ Fixed-effect estimation for OECD and OLS for individual country regressions using annual data.
3/ P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

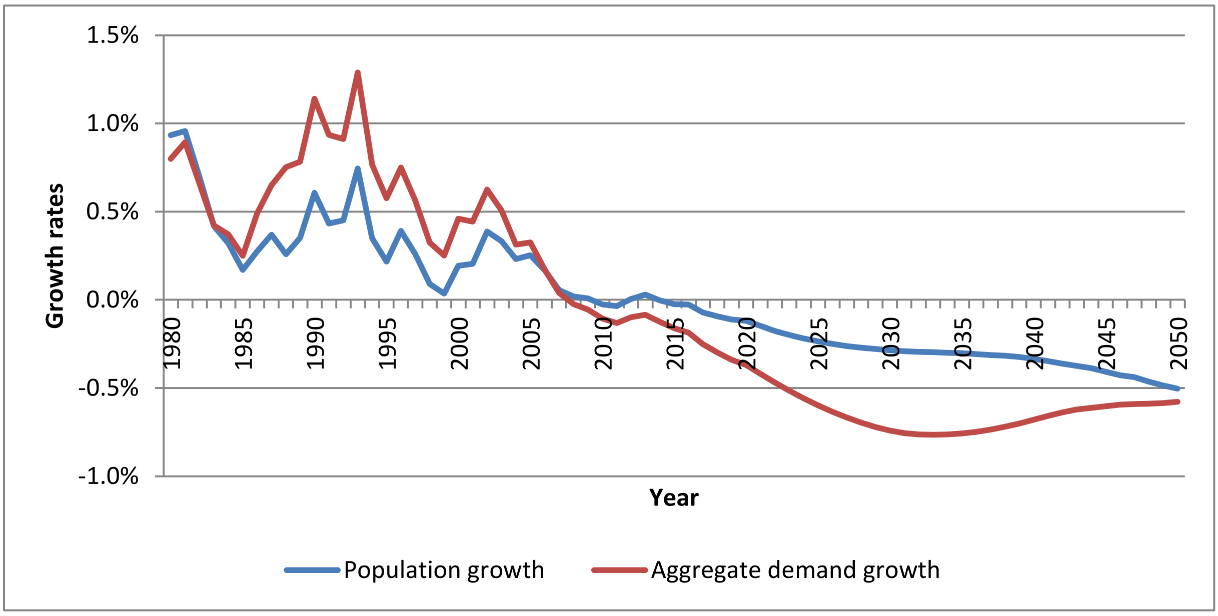
Source: Yoon, et al. (2014).

Figure C.7.5: Empirical findings II



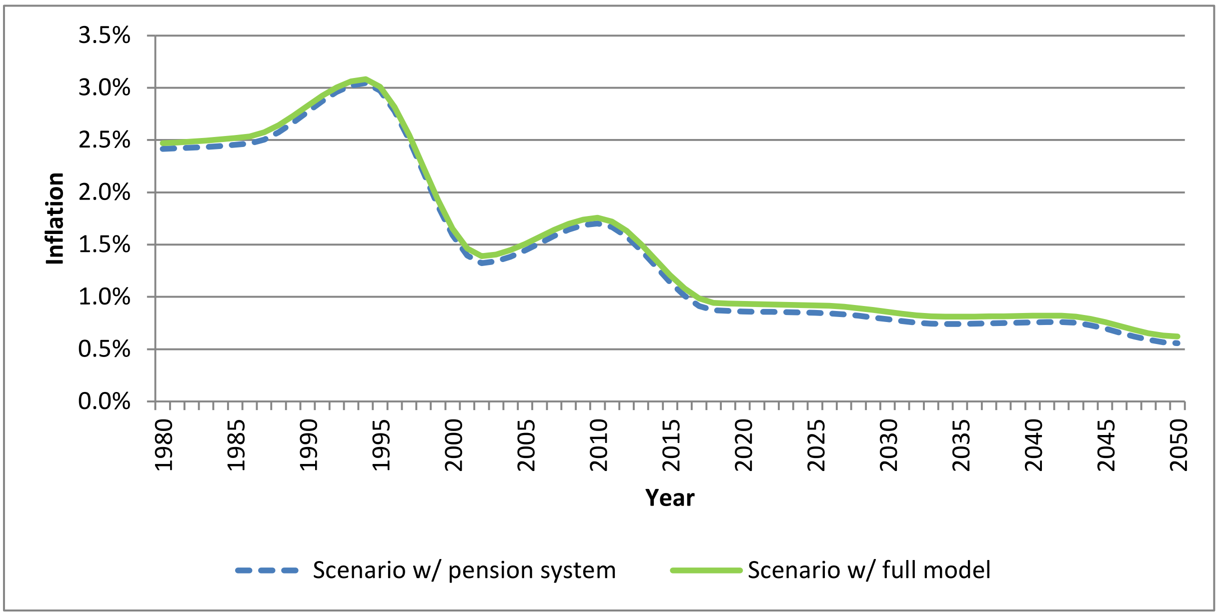
Source: Juselius & Takáts (2016).

Figure C.7.6: Comparison between population and aggregate demand growth rates



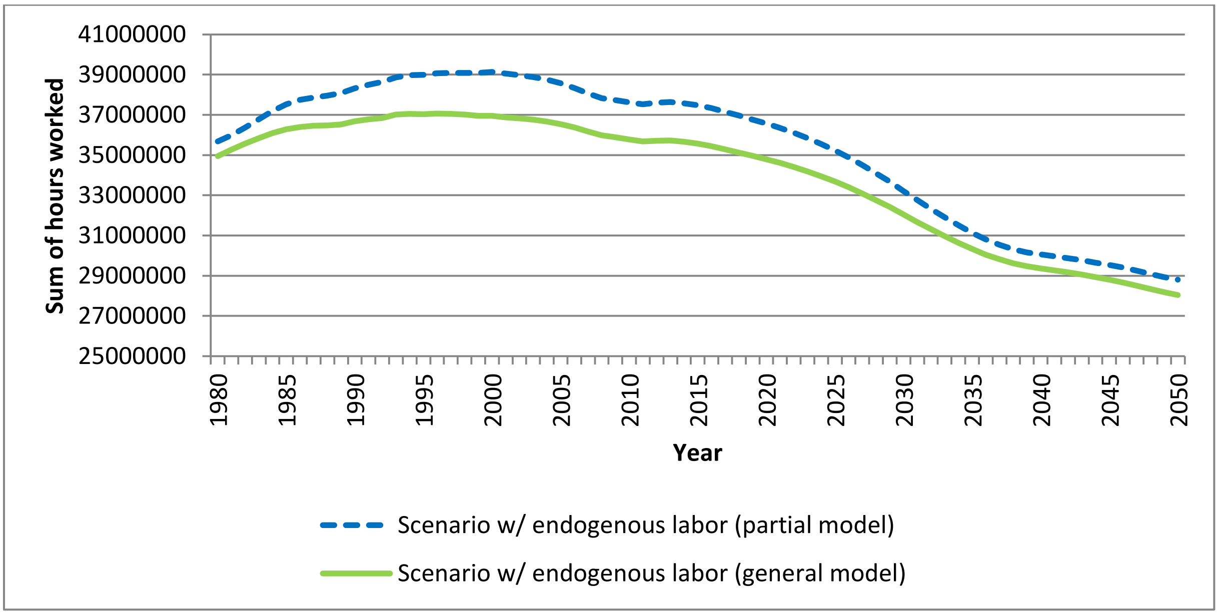
Source: own calculations.

Figure C.7.7: Comparison between models with and without labor



Source: own calculations.

Figure C.7.8: Inflation rates in partial and general model – labor comparison



Source: own calculations.

Table C.7.1: Change in inflation rates

	Periods (1986-1996 / 2006-2016)	
	% change in average inflation (Data)	% change in average inflation (Model)
India	11.20	-6.44
France	53.23	14.59
USA	45.62	16.96
Germany	42.46	35.16
China	75.88	37.39
Italy	70.93	32.26
Japan	77.55	56.65

Source: own calculations.

Table C.7.2: Change in inflation rates

	Periods (1990-1995 / 2011-2016)	
	% change in average inflation (Data)	% change in average inflation (Model)
India	25.81	-3.58
France	60.51	17.50
USA	53.09	20.84
Germany	65.11	41.51
China	76.74	41.74
Italy	77.34	36.14
Japan	65.04	59.07

Source: own calculations.

Table C.7.3: Change in inflation rates

	Periods (1995-2000 / 2011-2016)	
	% change in average inflation (Data)	% change in average inflation (Model)
India	5.59	0.24
France	27.90	10.6
USA	36.19	26.98
Germany	10.20	37.11
China	39.39	33.58
Italy	58.56	27.59
Japan	-147.16	49.81

Source: own calculations.

Sensitivity Analysis

Table C.7.4: Comparison w.r.t. different consumption weights

	Inflation level	**Size Effect**	**Structural Effect**
$\eta = 0.97$ **Baseline**	1.04%	1.77%	-0.72%
$\eta = 0.9$	1.06%	1.76%	-0.70%
$\eta = 0.8$	1.07%	1.75%	-0.68%

Source: own calculations.

An alternative set of consumption weights is displayed in Table C.7.4. Accordingly, higher inflation rates and smaller size effects are observed for lower parameter values. Consequently, the structure effect is less negative for lower values. In general, lower values mean that for utility purposes consumption is valued less and money holdings more. In steady-state this will not have an effect on inflation, but in transition the effects of demographic shocks on individuals' decisions will have an impact on inflation rates. On one side, changes in consumption due to the consumption life-cycle profile induce smaller changes in money holdings. As a consequence, the structure effect has a lower impact on the overall demographic effect on inflation. Therefore, its negative effect on inflation is hindered and since the size effect is almost stable, inflation levels are not as low as before. On the other side, a lower preference for consumption reduces the impact of macroeconomic changes on consumption which leads to lower money demand and suppress inflation. Overall, the former effect is stronger than the latter, as we may observe in Table C.7.4.

Table C.7.5: Comparison w.r.t. different CES substitutability

	Inflation level	**Size Effect**	**Structural Effect**
$\sigma = 0.5$	0.92%	1.76%	-0.84%
$\sigma = 0.4$ **Baseline**	1.04%	1.77%	-0.72%
$\sigma = 0.3$	2.38%	2.89%	-0.52%

Source: own calculations.

Table C.7.5 displays various outcomes for different CES substitutability parameters. According to this, higher inflation rates and higher size effects can be observed for lower parameter values. Consequently, the structure effect is less negative for lower parameter values. In theory, lower parameter values mean money and consumption are more complementary goods, i.e. changes in consumption go along with larger changes in money holdings and therefore inflation rates. Since consumption p.c. (C/N not C/AN) grows, households hold more money which increases inflation.

Table C.7.6: Comparison w.r.t. different output growth coefficient

	Inflation level	Size Effect	Structural Effect
$\phi_\mu = 1.0$	0.43%	1.55%	-1.12%
$\phi_\mu = 0.7$ **Baseline**	1.04%	1.77%	-0.72%
$\phi_\mu = 0.3$	1.84%	1.96%	-0.12%
$\phi_\mu = 0.0$	2.36%	2.09%	0.26%
$\phi_\mu = -0.3$	2.90%	2.22%	0.68%

Source: own calculations.

Different degrees of monetary accommodation are shown in Table C.7.6. Higher positive values imply a more pro-cyclical reaction of governmental money supply to changes in output and therefore also on money demand. Negative parameter values imply a counter-cyclical reaction. Inflation rates and the size effect are larger for lower parameter values since the government accommodates less to changes in money demand. The structure effect is consequently decreasing as parameter values increase. Accordingly, more extreme values such as $\phi_\mu = 1$, lead to a lower size effect and a more negative structure effect. We nevertheless assume $\phi_\mu = 0.7$ in order to have a large accommodative effect but still not a one to one impact of output growth on government's decisions. Our choice of a more conservative value works, in any case, in the favor of our results since it underestimates the impact of demographic change.

Table C.7.7: Comparison w.r.t. different labor weight

	Inflation level	Size Effect	Structural Effect
$\Psi = 0.5$	1.05%	1.77%	-0.72%
$\Psi = 0.3$ **Baseline**	1.04%	1.77%	-0.72%
$\Psi = 0.1$	1.02%	1.76%	-0.74%

Source: own calculations.

Table C.7.7 displays outcomes for different values of Ψ, the labor weight in the untility function. One can observe lower inflation rates for lower values of the parameter. At the same time, the size effect is slightly smaller and the structure effect more negative for lower parameter values. In general, lower values mean a lower weight on leisure, i.e. more weight on money holdings and consumption and labor. Therefore, consumption (in levels) is higher, which does not impact inflation (level effect) in general. However, changes in these (high) consumption levels due to the life-cycle consumption profile are larger. Therefore, money holdings change more strongly. This causes a larger reaction in the structure effect. With a size effect being almost constant, this reduces inflation.

Table C.7.8: Comparison w.r.t. years at which aging is held constant

	Inflation level	**Size Effect**	**Structural Effect**
1980	1.04%	1.84%	-0.8%
1990 Baseline	1.04%	1.77%	-0.72%
2000	1.04%	1.69%	-0.64%

Source: own calculations.

In Table C.7.8, we display different years at which we hold the population constant. The resulting inflation rates of these model versions are displayed as the size effect; accordingly, the difference to the baseline model is the structural effect. It is found that the earlier we hold aging constant, the higher the size effect and the more negative the structure effect. Differences however are not very large and direction of the effect stays the same. The explanation is, the earlier we hold population constant, the less demographic change has affected population yet. Therefore, inflation is closer to the 2% steady state for early years. Consequently, the negative structure effect must be more negative, since it is the difference between baseline inflation and inflation when holding population constant.

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