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Social security and public insurance

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Social security and public insurance

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Zusammenfassung:

Bei der Diskussion über die Herausforderungen einer alternden Bevölkerung ist die unsichere Zukunft der Rentensysteme ein Thema von hoher Priorität und großen Meinungsverschiedenheiten. Das Ziel dieses Kapitels ist nicht, einen Konsensüberblick über soziale Sicherung und Sozialversicherungen bei alternder Bevölkerung zu bieten, sondern diese Debatten zu strukturieren. Wir stellen eine große Bandbreite an Modellen auf, die wir für Simulationsrechnungen verwenden, um die Herausforderungen und Kontroversen transparenter zu machen.

Das Kapitel beginnt mit einem institutionellen Blick auf Rentensysteme und Bevölkerungsalterung, der die grundlegenden rechnerischen Einschränkungen definiert, die eine alternde Bevölkerung auf individuelles Verhalten und Politikmaßnahmen darstellt. Wir fügen auch eine kurze Übersicht über real existierende Rentensysteme hinzu. Mit einem verhaltenstheoretischen Blick untersuchen wir dann Spar- und Arbeitsangebotsentscheidungen bei einer alternden Bevölkerung. Die dritte Sichtweise ist eine makroökonomische und konzentriert sich auf Rückkopplungseffekte, die im allgemeinen Gleichgewicht entstehen. Wir zeigen, dass Marktreaktionen auf Bevölkerungsalterung die Belastung einer parametrischen oder systemischen Rentenreform signifikant reduzieren. Das Kapitel endet mit einer kurzen Zusammenfassung der Hauptergebnisse und einem Ausblick in welchen Bereichen zukünftige Forschung am dringendsten benötigt wird.

Abstract:

When the challenges of population aging are being debated, the uncertain future of pension systems is a topic of high priority and large controversy. The aim of this chapter is not to provide a “consensus view” on social security and public insurance in aging populations but to put structure on these debates. We formulate a large set of models which we use for simulation exercises to make the challenges and controversies more transparent. The chapter begins with an institutional view of pension systems and population aging which defines the fundamental accounting restrictions which population aging imposes on individual behavior and policy actions. We also provide a brief survey of pension systems in the real world. We then take a behavioral view and study saving and labor supply decisions in an aging population. The third viewpoint is from macroeconomics and focuses on the feedback effects that occur in general equilibrium. We demonstrate that market reactions to population aging significantly reduce the burden of parametric or systemic pension reform. The chapter ends with a short summary of the main lessons and an outlook where further research is most urgently needed.

Keywords:
Population aging, social security, public insurance, pension reform, life-cycle saving, labor supply, retirement age, welfare, intergenerational risk sharing

JEL Classification:
C68, D64, D91, E17, E21, F21, H55, J11, J22, J26

Social security and public insurance

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1. Introduction

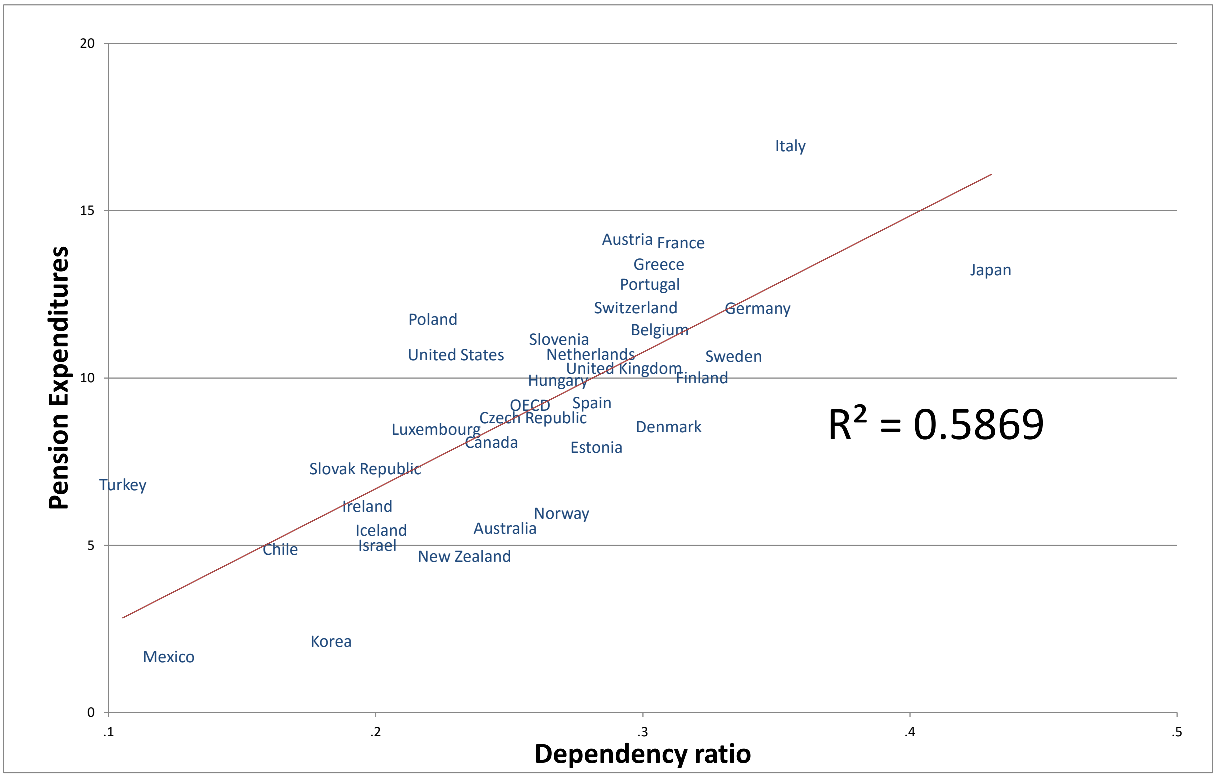
When the challenges of population aging are being debated, the uncertain future of pension systems[1] is a topic of high priority and large controversy. Opinions among citizens range from complete ignorance how serious the challenges are to the equally faulty belief that pension systems are doomed to a complete failure (Boeri et al., 2001; 2002; Walker et al., 2014). Politicians often consider reforms which are designed to make pension systems more sustainable and resilient against population aging 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 and Myrskyl, 2009). These reactions reflect the complexities of the subject and the controversies even among specialist economists. The aim of this chapter is not to provide a "consensus view" on social security[2] and public insurance in aging populations but to put structure on these debates by formulating a large set of economic models which we use for simulation exercises in order to make the challenges and controversies more transparent.

Figure 1.1 shows the key topic of this chapter: A high number of older individuals per working age population in a country exerts pressure on the economy of this country since pension expenditures demand a high share of GDP. The alignment, however, is far from perfect. Some countries have pension expenditures significantly above the regression line (Italy, Austria, Poland), while others have much smaller pension systems relative to their demographic status (Japan, Denmark, Australia). This is mainly due to the many design differences between national pension systems. These design differences have strong implications for the impact of population aging on pension expenditures which is reflected in Figure 1.2. It shows that almost all OECD countries face increasing pension expenditures as percent of GDP but that there are very large differences across countries. On average across the European Union, the cost share increases by 16% until 2030 and by 37% until 2050. In Greece and Luxembourg, however, pension expenditures will more than double until 2050, while they are projected to decline in Estonia, Poland and Sweden.

[1] As much as pension systems differ across countries, so do their names. We will avoid country-specific terms such as „Social Security" (in the US) or „Statutory Retirement Insurance" (in Germany) and follow Barr and Diamond (2008) in simply using the term "pension system". This article focuses on public pensions. Occupational pensions are the subject of the chapter by Mitchell and Piggott and private pensions the chapter by Fang in this handbook.

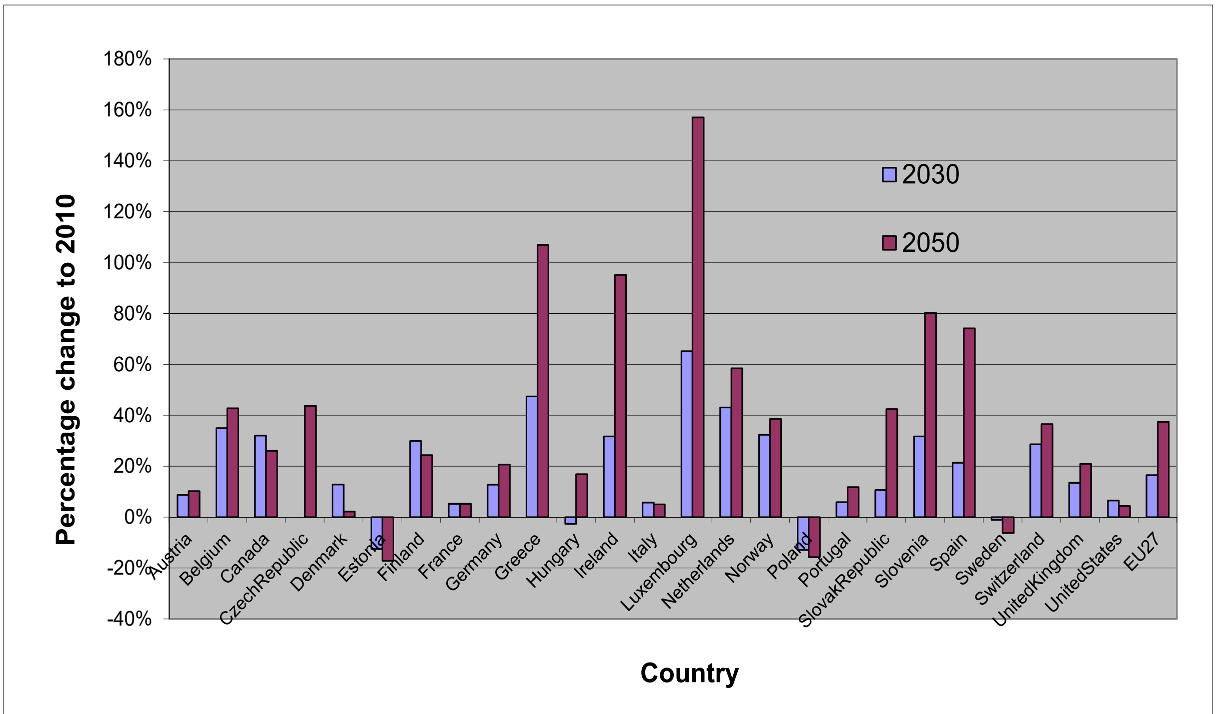
[2] The term "social security" with small letters refers to the general provision of financial security by social insurance and not to the US pension system. See also previous footnote.

Figure 1.1: Pension Expenditures (Percent of GDP) by Old-Age Dependency Ratio



Source: OECD Pensions at a glance (2015a). Old-age dependency ratio is population age 65+ divided by population age 20-64 (2013 data). Public and private pension expenditures are share of GDP (2012 data).

Figure 1.2: Projected Change in Pension Expenditures (Percent, 2030 and 2050 versus 2010)



Source: OECD Social Expenditure database (2015b)

Some of the pension systems in these countries are designed to be self-stabilizing and thus prevent high expenditure increases. The Swedish "notional defined contribution" system is a good example which is described in Section 2. Other designs create strong negative incentive effects on saving for old age (Section 3) and on labor supply, especially at older ages (Section 4). Some designs exacerbate the decline of economic capacity when populations are aging and thereby threaten fiscal capacity and economic growth at large (Sections 5 to 7).

The large deviations from the regression line in Figure 1.1 and the variation of expenditure increases in Figure 1.2 are a symptom of the complexity of the issues in this chapter. They show that population aging is not the only driver of pension expenditures. This chapter therefore centers on the interactions among social policy (pension system design), demographics (population aging) and economics (labor and capital which generate welfare and living standards). The literature on these topics is vast and we will not be able to do justice to all of its facets. We will rather pick three vantage points from which these interactions can be analyzed.

We begin with an *institutional view* of pension systems and population aging in Section 2. It defines the fundamental accounting restrictions which population aging imposes on individual behavior and policy actions and provides a survey of pension systems in the real world. The accounting equations are the backbone of economic models which describe the effect of population aging on pension systems. They are powerful devices because they make the challenges of population aging transparent. It is important, however, to realize that demographics cannot be simply translated one-to-one via accounting equations into economics. There are many countervailing forces which depend on individual behavior, policy actions and macroeconomic feedbacks. They are the subject of the remainder of this chapter and the object of the modern literature on pension systems and population aging.

In Sections 3 and 4, we will take a *behavioral view* of pension systems in an aging society. Section 3 is devoted to saving behavior, while Section 4 studies labor supply behavior, especially the role of retirement decisions which are crucial for the financial stability of most pension systems. The aim is to explore the differences in individual saving, labor supply and retirement decisions generated by the different pension systems. We will employ various specifications of partial equilibrium models in which life-time wages and the returns from capital investments are exogenously given. We will show that specification differences are not at all innocuous. They imply rather different roles of social insurance in an aging population and are the source of many controversies in public pension design.

The third viewpoint is from *macroeconomics*. It focuses on the feedback effects that occur in general equilibrium. Our analyses will be based on several versions of an overlapping generations model, the work horse of dynamic macroeconomics. We will integrate the various household decision models of Sections 3 and 4 into this macroeconomic framework. Section 5 presents baseline results under current pension systems and labor market policies. Since Europe with its diversity of social insurance schemes and a far advanced aging process is a particularly well-suited showcase, the macroeconomic analyses will focus on a setting in which a stylized European economy is embedded in a global world which ages at a slower pace than Europe. The results of Section 5 demonstrate endogenous adaptations of behavior to population aging that are precipitated solely by aging-induced changes of wages and the return to productive capital. The main point is to show that market reactions to population aging significantly reduce the burden which parametric or systemic pension reform has to shoulder in order to stabilize public pension systems in times of population aging.

Section 6 analyses parametric pension reform. Main focus are the effects of changes in key labor market parameters, especially retirement age, on the sustainability of pension systems, economic growth and redistribution between generations. While it is clear that parametric reforms are powerful devices to adapt pension systems to population aging, their quantitative effects strongly depend on the extent of behavioral reactions.

Section 7 discusses systemic reform, framed as the transition from a typical US and European public pension system which is financed pay-as-you-go and provides defined benefits to a fully funded pension system of the defined contribution type. This section provides a rather long list of arguments and counterarguments whose relevance and weight depend on assumptions about household and firm characteristics.

Section 8 finishes with a short summary of the main lessons and an outlook where further research is needed most urgently. While economic science has succeeded in nailing down some mechanisms with sufficient precision, many predictions are not robust even to reasonable variations of model specification. Hence the analysis of social security and public insurance in times of population aging remains a subject of controversies and future research is still needed.

2. Pension systems: institutions and basic accounting relations

We begin with the basic book-keeping relations between population aging and four elementary types of pension systems: Pay-as-you-go (PAYG) and fully funded (FF) pension systems, each with defined benefit (DB) or defined contribution (DC) rules. We will first describe these system types in an abstract fashion. This will also allow us to introduce the notation and the conventions used in the entire chapter. Later, we will add real-world examples and show how mixed and hybrid pension systems have developed in response to country-specific preferences and historical circumstances.

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, abstracting from migration, the survivors of the original birth cohort $N_{c,0}$:

(2.1) $N_{t,j} = \sigma_{t,j} \cdot N_{c,0}$.

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 $c = t\text{-}j$:

(2.2) $N_{c,0} = \sum_{k=0}^{\infty} f_{c,k} \cdot N_{c,k}$.[3]

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

Throughout this chapter, we will assume that demographic forces are exogenous. This is justified for the analyses in this chapter but may be questioned if one takes a historical perspective. As Cigno and Rosati (1996) have argued, pension systems may have influenced fertility directly by providing financial support in old-age which had been provided by children in earlier historical times.

2.1 Pay-as-you-go pension systems

PAYG pension systems are defined by the linkage between generations. The young generation pays the revenues of the system ("workers") and the older generation receives the

[3] We use the convenience of an infinite summation to avoid the assumption of a fixed time of death. The notation does not imply agents with infinite lifespans. Since $\sigma_{t,j}$ and $f_{c,k}$ become very small for j>100 and k>50, resp., $N_{t,j}$ is zero for large j and all sums in this chapter are finite.

expenditures ("pensioners"). Revenues in year t are in a first order approximation[4] the product of the contribution rate τ_t, the average labor income w_t and the number of workers NW_t defined as:

$$(2.3) \quad NW_t = \sum_{j=0}^{R-1} N_{t,j} ,$$

where R denotes the retirement age.[5] Expenditures are approximately described by the product of the average pension benefit p_t and the number of pensioners NP_t defined as:

$$(2.4) \quad NP_t = \sum_{j=R}^{\infty} N_{t,j} .$$

This results in the PAYG budget equation if the budget is balanced in every year:[6]

$$(2.5) \quad \tau_t \cdot w_t \cdot \sum_{j=0}^{R-1} N_{t,j} = p_t \cdot \sum_{j=R}^{\infty} N_{t,j} .$$

Population aging strains the financial sustainability of a PAYG system because fewer young contributors to the system (2.3) will have to finance a larger number of old beneficiaries (2.4). We will refer to the number of beneficiaries divided by the number of contributors as the pension system's dependency ratio:[7]

$$(2.6) \quad DR_t = \sum_{j=R}^{\infty} N_{t,j} / \sum_{j=0}^{R-1} N_{t,j} ,$$

which is closely related to the support ratio which we define by the number of workers as share of the total adult population[8]:

$$(2.7) \quad SR_t = \sum_{j=0}^{R-1} N_{t,j} / \sum_{j=0}^{\infty} N_{t,j} = 1/(1+DR_t).$$

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[4] This formulation of the budget constraint holds only approximately because it averages over the distribution of wages and benefits rather than representing their full distribution.

[5] At this point, we assume common unique retirement age R and do not distinguish between the exit from the labor force and the entry into the pension system. Section 4 introduces a richer setting which decouples these decisions and introduces a "window of retirement".

[6] Many PAYG systems have a reserve and/or other multi-year balancing mechanisms (e.g. Settergreen (2001) for Sweden). Other PAYG systems have budgets which are effectively part of the general government's budget and may increase or decrease the general government's debt (e.g. Kotlikoff (2002) for the US).

[7] This relates workers to beneficiaries. It is therefore different from the old-age dependency ratio in Figure 1.1 which is a purely demographic concept.

[8] Throughout this chapter, we will subsume the consumption of children as part of the consumption of their parents.

DR and *SR* are key statistics to understand the micro- and macroeconomic implications of population aging and its effect on public pension systems. The doubling of the dependency ratio and the decline of the support ratio in so many countries around the globe signifies the magnitude of the challenge (see the references in the chapter by Bloom in this handbook). The indexes *DR* and *SR* are, however, not purely demographic determinants since they depend on labor force participation and thus micro- and macroeconomic parameters, among them the incentives build into public pension systems, especially the eligibility age for pension benefits *R*. The term "parametric pension reform" refers to changing these parameters which can have very forceful effects (Section 6) while the term "fundamental" or "systemic" reform refers to the transition from a PAYG to a FF system (Section 7).

If the PAYG system is of the *defined benefit* type, a cohort of retirees is promised a pension benefit p_t which is typically defined by a replacement rate q_0 which is independent from the demographic and macroeconomic environment, $p_t = q_0 \cdot w_t$.[9] The contribution rate to the system must then be adjusted up or down to keep the PAYG system balanced, such that current workers cover the demographic risk for the benefit of the retirees:

(2.8) $\quad \tau_t = q_0 \cdot NP_t / NW_t$.

If the PAYG system is of the *defined contribution* type, the pension system fixes the contribution rate τ_0 for a cohort of workers. Their replacement rate then follows the path

(2.9) $\quad q_t = \tau_0 \cdot NW_t / NP_t$

and reacts passively on 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 dependency ratio.

The demographic history (2.1) and (2.2), the benefit adjustment rule (2.8) or (2.9) and the individual wage history determine the internal rate of return of the PAYG pension system, denoted by irr_c for a cohort of workers born in year *c*. It is defined by setting the expected present discounted value of the life-time contributions paid equal to the expected present discounted value of the life-time pension benefits received:

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[9] Alternatively, the replacement rate relates to the net wage $w_t \cdot (1-\tau_t)$. Defining benefits as a percentage of earnings is typical for Bismarckian pension systems such as those in Germany and the US. DB may also provide a fixed pension benefit, real or nominal, independent of earnings, which is typical for Beveridgian pension systems such as in the UK or the Netherlands (Subsection 2.5).

$$(2.10)\quad \sum_{j=0}^{R-1} \tau_{c+j} \cdot w_{c+j} \cdot \sigma_{c+j,j} \cdot (1/(1+irr_c))^j = \sum_{j=R}^{\infty} p_{c+j} \cdot \sigma_{c+j,j} \cdot (1/(1+irr_c))^j .$$

If wages grow at a constant rate *g*, if the relative number of workers grows at a constant rate *n* and if the replacement rate is defined by the DB rule (2.8), then the internal rate of return of the PAYG-DB system is equal to the growth rate of the labor force *n* plus the growth rate of wages *g* experienced during the lifespan of this cohort:

(2.11) $irr = g + n.$

Population aging has a direct and negative effect on the internal rate of return through the decline of *n.* In addition, there are many possible indirect effects of population aging affecting *n* and *g*. First, general equilibrium effects may increase wage growth *g* which in turn may increase labor force participation, thereby reducing the decline of *n.* Aging may also affect productivity (thus again *g*). While there is a widespread prejudice that older workers are less productive than younger workers, there is no robust evidence for this belief (Göbel and Zwick, 2009; Börsch-Supan and Weiss, 2016). Second, population aging may precipitate structural reforms. Parametric pension reform is designed to change the system dependency ratio, e.g. by raising the retirement age *R.* This increases NW_t and at the same time decreases NP_t which fosters the sustainability of the PAYG scheme but lowers the internal rate of return.

2.2 Fully funded pension systems

In a funded pension system, a generation pays into a fund during its working life, receives interest on the accumulated capital which is then used to finance the consumption of the same generation during retirement. In its most abstract two-period form, workers receive wage income *w* in period 1 from which they pay a percentage τ into the pension fund. Pension income *p* is then

(2.12) $p = (1+r) \cdot \tau \cdot w,$

where *r* is defined in units that are commensurable with the period length. At this level of abstraction, a funded system is equivalent to voluntary private saving and the internal rate of return is the interest rate on the capital market, *r*. Generations in a funded system are only linked through the general macroeconomic equilibrium which determines the market interest rate. This makes funded systems financially more sustainable than PAYG pension systems (cf. Sections 5 to 7).

In practice, however, there are several important differences between voluntary private saving and a funded pension system which may generate different saving behaviors vis-à-vis the textbook saving model. These differences will create different macroeconomic outcomes.

First, it matters whether the contributions to a funded pension system are invested in productive capital (e.g., via the stock market) or in debt (e.g., via government bonds). If contributions are invested in government bonds, they do not constitute funding in a macroeconomic sense since the government debt will have to be repaid by future taxes, thus using the same mechanism as a PAYG system in which pension promises have to be paid by future contributions (Diamond, 1965; Pestieau and Possen, 2000).[10] For a pension system to be fully funded, the stock of productive capital has to increase by the present value of future pension benefits. In this sense, the Social Security Trust Fund in the US is not contributing to a funded system (Kotlikoff, 2002). Similarly, the Generation's Fund in Sweden is macroeconomically funded only to the extent to which the assets are invested in productive capital. The same argument holds if such a fund invests its assets in productive capital but finances the purchase of these stocks by government debt. This is particularly relevant for a transition from a PAYG to a FF pension system in which the government subsidizes the transition burden (Section 7).

Second, the actual return to the household, r^{HH}, is often substantially lower than the market interest rate, r^{MKT}, because the management of funds can be very costly, e.g., due to distribution and marketing costs (Iglesias and Palacios, 2000; Palacios and Pallares-Miralles, 2000; Pallares-Miralles et al., 2012; Gasche et al., 2013; OECD, 2015a). On the other hand, government subsidies to old-age saving schemes can be substantial (Hinz et al., 2013), thereby increasing the internal rate of return to the household above the market rate of interest.

Hence, we need to distinguish between r^{HH} and r^{MKT}

(2.13) $r^{HH} = r^{MKT} + \Xi$

where Ξ denotes government subsidies net of fund management costs expressed in rate of return units.

[10] It does, however, change the governance of the system and therefore has indirect effects on the micro- and macroeconomic levels (Valdes-Prieto, 2005).

Third, almost all real-world public FF pension systems impose mandatory participation. If the mandatory contribution rate exceeds the saving rate which households would choose, the difference acts like a tax with associated incentive effects to the extent that households do not value the benefits associated with the increased contributions (Summers, 1989).

Fourth, the provision of a guaranteed minimum pension in a funded system such as in Australia or Chile provides an incentive to save less for lower income households. This can be interpreted as a form of moral hazard which will be analyzed in Subsection 3.3.

Fifth and finally, many FF systems provide the option (or even force households) to annuitize their accumulated savings at retirement. The option to annuitize covers longevity risks which private markets may not be able to cover. It therefore changes saving behavior relative to the textbook saving model as will be described in Subsection 3.4.

With these qualifications in mind, the rate of return in equation (2.12) is a key parameter in assessing funded pension systems. Population aging tends to reduce the underlying rate of return (Section 5). Who bears this risk depends on whether the FF system is of the DB or the DC type. If it is DB, the pension benefit p in (2.12) is fixed in advance and the sponsor (government, employer) needs to cover the capital market risk generated by the uncertain return r.[11] FF-DB systems can accommodate intergenerational risk sharing in a similar way as PAYG-DB systems. In the Netherlands and Switzerland, such FF-DB systems are the main earnings-related pension pillar (cf. Subsection 2.5). In the DC case, the FF system collects contributions at a rate which is fixed ex ante. Retirement benefits then depend on the internal rate of return of the system and the income risk is shifted from the sponsors to the retirees. In Australia and Chile, FF-DC systems are mandated by the government and carry the main responsibility for old-age provision for all but low-income households. In most other countries, funded pension plans are employer-sponsored or private individual accounts. Among employer-sponsored funded pension plans, population aging has precipitated a large shift from DB to DC, especially in the US and the UK (Mitchell, 2000; chapter by Mitchell and Piggott in this handbook).

2.3 Notional defined contribution systems

The secular shift from DB to DC in employer-sponsored pension plans has been mirrored by the development of notional defined contribution (NDC) systems for public PAYG pension

[11] The beneficiary may still carry the risk that the sponsor will go bankrupt or reneges on his promises.

schemes (Holzmann and Palmer, 2005; Holzmann et al., 2012; 2013). NDC systems mimic the accounting scheme of FF-DC plans but are financed PAYG. Contributions are defined ex ante and are credited on an individual account which is denominated in the local currency unit. The account earns a notional rate of interest. Ideally, this rate should correspond to the internal rate of return of PAYG pension systems. Following equation (2.11), this is the growth rate of the wage bill, $n+g$. Accumulated contributions plus interest yield the notional pension wealth. At retirement, the notional pension wealth is converted to an annuity, e.g. according to equation (3.9). The conversion factor is a function of the notional rate of interest and the current survival rate. In many NDC systems, this annuity is a real annuity offsetting inflation (Whitehouse, 2010).

NDC systems transparently link contributions with the notional pension wealth (and the related annuity) and thus reduce negative labor supply effects (Subsection 4.4). They offer the advantage of annuitization like other PAYG systems (Subsection 3.4). Unlike many PAYG systems, however, NDC systems adapt benefits automatically to population aging through two mechanisms (Valdés-Prieto, 2000). First, if the notional interest rate is $n+g$, then the NDC system adjusts its internal rate of return to the growth rate of the labor force, n, which may be negative in quickly aging populations. Second, the conversion of pension wealth into annuities depends on the survival rate, σ, such that increases in longevity reduce annual benefits but spread them over a longer time. If the parameters n, g, and σ are correctly set, the NDC system is financially self-stabilizing.

This has motivated the introduction of NDC systems in countries which face rapid population aging, e.g. in Sweden, Latvia, Poland, and Italy (Fox and Palmer, 1999; Disney, 1999; Palmer, 2000; 2002; Franco and Sartor, 2003; Chłoń-Domińczak et al., 2012). Benefits are automatically adapted to developments in demography and employment (equation 2.9). The self-stabilization property does not hold, however, if the notional interest rate is only g, the growth rate of wages or productivity, as it is the case e.g. in Poland (Chłoń-Domińczak et al., 1999; Rutkowski, 1998), and if the system maintains some DB characteristics (equation 2.8). In Sweden, the indexation to demographic changes is obtained through a complex equilibrium mechanism (Settergreen, 2001). Deviations of the notional interest rate from $n+g$ reflect the trade-off between the self-stabilization properties of a DC system and the opportunities for intergenerational/intercohort risk sharing in a DB system (Börsch-Supan, 2005).

2.4 Hybrid DB/DC systems and intergenerational risk sharing

DB and DC define two extremes of the intergenerational risk distribution. There are, however, hybrid pension systems which are intermediate systems providing a continuum of intergenerational risk sharing. One example in the framework of earnings-related public PAYG pensions is the introduction of a "sustainability factor" in Germany (Börsch-Supan and Wilke, 2005). It introduces DC elements into a pension system which remains framed as a DB system in order to appeal to voters' preferences.[12]

On an abstract level, such intergenerational risk sharing and the implications of population aging can be described as follows. A DB system with a stable replacement q_0 (equation 2.8) changes the average pension $p_t = q_0 \cdot w_t$ in proportion to the average wages:

(2.14) $p_t/p_{t-1} = w_t/w_{t-1}$,

while a DC system with a stable contribution rate τ_0 (equation 2.9) sets pension benefits $p_t = q_t \cdot w_t$ over time according to the rule

(2.15) $p_t/p_{t-1} = w_t/w_{t-1} \cdot DR_{t-1}/DR_t$.

These two pension benefit determination rules can be combined as

(2.16) $p_t/p_{t-1} = w_t/w_{t-1} \cdot (DR_{t-1}/DR_t)^{\mu}$,

where the weight $0 \leq \mu \leq 1$ represents all compromises between a pure DB and a pure DC system. The internal rate of return of such a hybrid DB/DC-PAYG system corresponding to (2.11) is:

(2.17) $irr = g + \mu \cdot n$.

The paramter μ can be set as a political compromise between current voters' preferences and financial sustainability. It determines the intergenerational distribution of the demographic risk generated by population aging. Setting μ=0 stabilizes the replacement rate of pension benefits to the older generation while μ=1 stabilizes the contribution rate of the younger generation. This shows quite clearly why political economy considerations are central for pension system design when populations age (Boeri et al., 2001; 2002; Persson and Tabellini, 2002; Galasso, 2007; chapter by Casamatta in this handbook).

Risk sharing between generations and, in a higher frequency setting, between cohorts is also

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[12] Depending on μ, the German hybrid system can mimic the Swedish NDC system (Börsch-Supan and Wilke, 2005; Rausch, 2014).

relevant for income risk. If income is stochastic, e.g. because productivity, wages or capital returns are stochastic, pension systems may permit sharing of these risks both intra- and intergenerationally. This can be done in PAYG as well as FF systems but requires that benefits are pre-defined to some extent (Thogersen, 1998; Chetty and Looney, 2006; Beetsma and Bovenberg, 2009; Beetsma and Bucciol, 2015). Since this chapter focuses on population aging rather than income shocks, we refer to the chapter by Beetsma and Romp in this handbook.

2.5 Mixed pension systems in the real world

The real world has developed complex pension systems which consist of several "tiers" (in the parlance of the OECD[13]) or "pillars" (in the parlance of the World Bank[14]). These systems mix PAYG and FF as well as DB and DC. Such mixes are the response to the uncertainty about future demographic and economic developments and the political mechanisms of a complex society with different preferences, different appetites for risks and different approaches to intra- and intergenerational risk sharing. Mixed systems are also attractive from a portfolio perspective. PAYG and FF systems have different kinds of risks. Capital market and expropriation risks are more prominent in FF systems, while demographic risks are particularly relevant for PAYG systems. The political risks also differ between PAYG and FF. Depending on the correlation between these risks, the combination of both systems will reduce the overall risk (Broer et al., 2010; Dutta et al., 2000; Krueger and Kuebler, 2006; Nataraj and Shoven, 2003). Table 2.1 provides a summary of pension systems in selected OECD countries.

[13] OECD (2015a).
[14] The World Bank (1994), Holzmann and Hinz (2005).

Table 2.1: Pension Systems in Selected OECD Countries

	Basic tier		Earnings-related tier		DC tier	Funds
	Max. benefit (% avg. earnings)	Coverage (% 65+)	Type	Funding	Contribution rate (%)	% of GDP
	(1)	(2)	(3)	(4)	(5)	(6)
Australia	27.1	78	None		9.5-12	102.2
Austria	28.2	11	DB	PAYG		5.7
Belgium	29.0	11	DB	PAYG		5.0
Canada	18.5	34	DB	PAYG		70.8
Chile	14.7	60	None		10.0	62.3
Czech Republic	13.1		DB	PAYG		7.3
Denmark	18.5	88	None		12.0	42.1
Estonia	14.4	6	Points	PAYG	6.0	9.5
Finland	20.8	47	DB	PAYG		48.7
France	25.6	37	DB/points	PAYG		0.4
Germany	19.0	2	Points	PAYG		6.1
Greece	29.0	19	DB	PAYG		0.1
Hungary	11.4	1	DB	PAYG		4.0
Ireland	34.7	17	None			52.3
Israel	24.1	25	None		15.0	50.5
Italy	21.4	32	NDC	PAYG		6.0
Japan	20.1	2	DB	PAYG		29.2
Netherlands	27.1	100	DB	FF		148.7
New Zealand	40.1		None			18.8
Norway	31.0	22	NDC	PAYG	2.0	8.1
Poland	23.9	12	NDC	PAYG	2.92	18.2
Portugal	30.4	59	DB	PAYG		8.9
Slovak Republic	24.4	3	Points	PAYG	6.0	9.8
Slovenia	17.8	17	DB	PAYG		3.9
Spain	33.9	28	DB	PAYG		8.8
Sweden	23.2	42	NDC	PAYG	2.5	9.1
Switzerland	21.2	12	DB	FF		113.4
United Kingdom	16.5	27	DB	PAYG	8	99.6
United States	17.3	7	DB	PAYG		83.2

Source: Authors' adaptation from OECD (2015a).

Almost all developed countries have a basic tier ("Pillar 0" in the parlance of the World Bank) which provides a fixed pension income independent of earnings. This can be a basic pension given to everyone, a minimum pension irrespective of contributions, or means-tested social assistance. Column 1 of Table 2.1 shows that benefits are low relative to average earnings but they may cover a large proportion of the population, e.g. in Australia, Chile, Denmark, Portugal and the Netherlands (Column 2). This tier is tax-financed. In the prototypical Beveridgian systems, it is the only state-provided pension, most prominently in Australia, Chile and Israel.

Many countries add a publicly provided earnings-related tier ("Pillar 1" in the parlance of the World Bank) to a means-tested and relatively small Pillar 0. The classical example is the Bismarckian scheme in Germany. The US Social Security system is another but less generous example. Most are mandatory, PAYG financed and framed as a DB systems (Columns 3 and 4). Some public PAYG-DB systems have recently been converted to notional defined contribution systems as it was pioneered by Sweden and copied e.g. by Italy (Subsection 2.3). Others have a point system strictly linking benefits to contributions (Column 3). The German system, while still formally a DB point system, is actually a hybrid DB/DC system as described in Subsection 2.4. Outside of the OECD, there are mandatory state-run earnings-related FF pensions, e.g. the provident funds in Asia.

Employer-provided pensions form a third pension pillar. In the parlance of the OECD, they are part of the earnings-related tier summarized in Table 2.1. In most countries, occupational pensions are voluntary. They are almost always FF. As noted before, there has been a secular shift from DB to DC. A notable exception is the system of the French PAYG-financed occupational pension plans which remain DB. Some countries, such as the Netherlands and Switzerland, rely on employers rather than the government to provide a mandatory earnings-related scheme. These countries have large fully funded DB schemes which provide an alternative to the PAYG-DB schemes in terms of intergenerational risk sharing. The Dutch pension system has been the focus of many studies how risks can be shared in FF-DB systems both within and across generations. This is reviewed in Beetsma and Bovenberg (2009) and the chapter by Beetsma and Romp in this handbook.

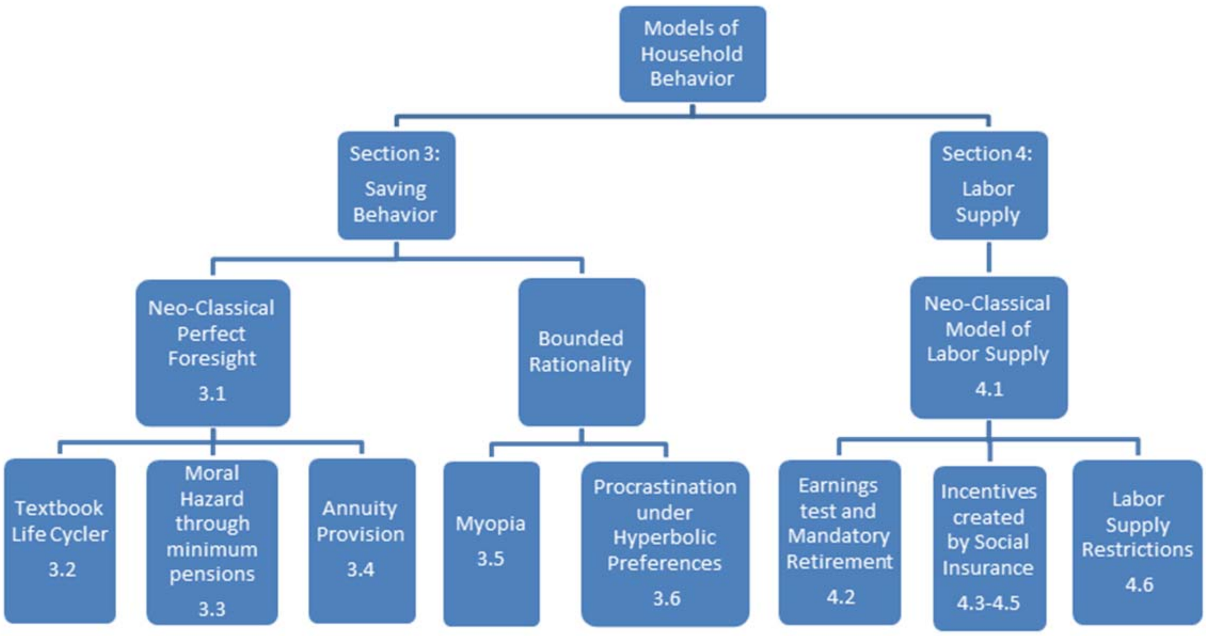
A fourth pillar consists of individual saving accounts dedicated to old-age provision which may be tax-preferred and/or state-subsidized. In many countries, these saving accounts are supplemental and voluntary. A few countries, such as Australia and Chile, have mandatory DC systems which provide most of the pension income of middle and higher income households. Their contribution rates are a substantial percentage of earnings (Column 5 of Table 2.1).

Column 6 of Table 2.1 shows the volume of funded pensions invested in productive capital and government debt. It is high relative to GDP in Australia, Canada, Chile, the Netherlands, Switzerland, the UK and the US, but very low e.g. in France and Germany.

3. Saving behavior and social insurance

The design of a pension system has strong implications for individual saving behavior. 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 saving in order to provide old-age consumption and may thus reduce the level of productive capital in an economy. Population aging tends to sharpen this trade-off. Pension systems also have strong implications for labor supply with similar trade-offs. They will be the subject of Section 4 which also looks at interactions between saving and labor supply behavior. Figure 3.1 depicts the set-up of Sections 3 and 4.

Figure 3.1: Models of Household Behavior



We will first set up the neoclassical model of the saving and consumption decisions of a household over its life course (Subsection 3.1) and begin with the assumption of perfectly foresighted life-cycle planners (Subsection 3.2). This textbook model demonstrates the trade-off between social protection and crowding out of private saving, and how this trade-off is affected by population aging. We will then augment the textbook model with additional features to motivate public insurance through pension systems (Subsections 3.3 and 3.4). Finally, we will take a radically different point of view in assuming that households fail to plan ahead (Subsections 3.5 and 3.6). This fundamentally changes the trade-off and how it is affected by population aging. Which set of assumptions best describes reality and what should therefore be the foundation for pension system design decisions is at the core of some key controversies among economists interested in saving behavior and social insurance.

The choice of different models when analyzing saving behavior and public pension systems also answers – in a by-the-way fashion – the question why mandated public pension systems have been developed in the first place (Kessler, 1989). First, most public pension systems provide insurance against old-age poverty as shown in Table 2.1. The incentive effects of such public insurance are studied in Subsection 3.3. Second, many public pension systems offer annuitization in order to cover the longevity risk associated with the uncertain time of death (Subsection 3.4). Third, public pension systems provide risk sharing between cohorts and entire generations to the extent that they maintain DB features (Boadway et al., 1991; Storesletten et al., 1999; Krüger and Kübler, 2002; Beetsma and Bovenberg, 2009; chapter by Beetsma and Romp in this handbook). Fourth, mandated public pension systems make paternalistic decisions for those households that are uninformed, myopic or procrastinate (Subsections 3.5 and 3.6).

Understanding saving behavior is also important in order to evaluate the welfare aspects of public pensions. Statements such as "households under-save" (Madrian and Shea, 2001; Poterba et al., 2012) or "households over-save" (Dutta et al., 2000; Diamond, 1977; von Weizsäcker, 2016) – often complemented by policy recommendations for social insurance – have to be based on a yardstick which determines the optimal level of old-age provision. This is a difficult question requiring a theoretical model of optimal decision making such as those presented in Figure 3.1. Since these models often do not have an explicit solution, we will set up numerical simulation models for standard parameter values in order to show the paths of consumption, saving and welfare with and without formal pension systems.

3.1 The neoclassical household model

Households gain utility from consumption $c_{t,j}$ at age j and time t. The most conventional specification is derived from an isoelasic per-period utility function given by

$$(3.1) \quad u(c_{t,j}) = \frac{1}{1-\theta}\left(c_{t,j}\right)^{1-\theta},$$

where risk aversion and intertemporal substitution are jointly described by the single parameter θ, and a von Neumann-Morgenstern (VNM) expected 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

$$(3.2) \quad \max_{c} \sum_{j=0}^{\infty} \beta^{j} \sigma_{t+j,j} u\left(c_{t+j,j}\right),$$

where β is the pure time discount factor: $\beta = 1/(1+\rho)$. In addition to pure discounting, households discount future utility with their unconditional survival probability $\sigma_{t,j}$, expressing the uncertainty about the time of death. We do not include intended bequests in our model (cf. chapter by Cigno in this handbook) 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. In situations where it is helpful to abstract from mortality risk, we assume a "sudden death" variant of (3.2) in which the life span J is known and there is no mortality risk before age J:

(3.3) $\sigma_{t,j} = 1$ for $j < J$ and $\sigma_{t,j} = 0$ for $j \geq J$.

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

(3.4) $y_{t,j} = \lambda \cdot w_{t,j}(1-\tau_t) + (1-\lambda) \cdot p_{t,j}$,

where λ=1 for $j=0,\ldots,R-1$ and λ=0 for $j \geq R$.[15]

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

(3.5) $a_{t+1,j+1} = a_{t,j}(1+r_t) + y_{t,j} - c_{t,j}$.[16]

In most specifications, we will impose a borrowing constraint

(3.6) $a_{t,j} \geq 0$,

which is typically binding at the beginning of the economic life but also prevents borrowing against pension income.

3.2 Textbook life cyclers

The key assumption of the life-cycle model is perfect foresight. In the textbook version of the model households face no mortality risk, receive a labor income which is constant over the life-cycle and are subject to borrowing constraints. If no public pension system exists, all old age provision has to be private savings. This scenario is shown in Figure 3.2 for three cases

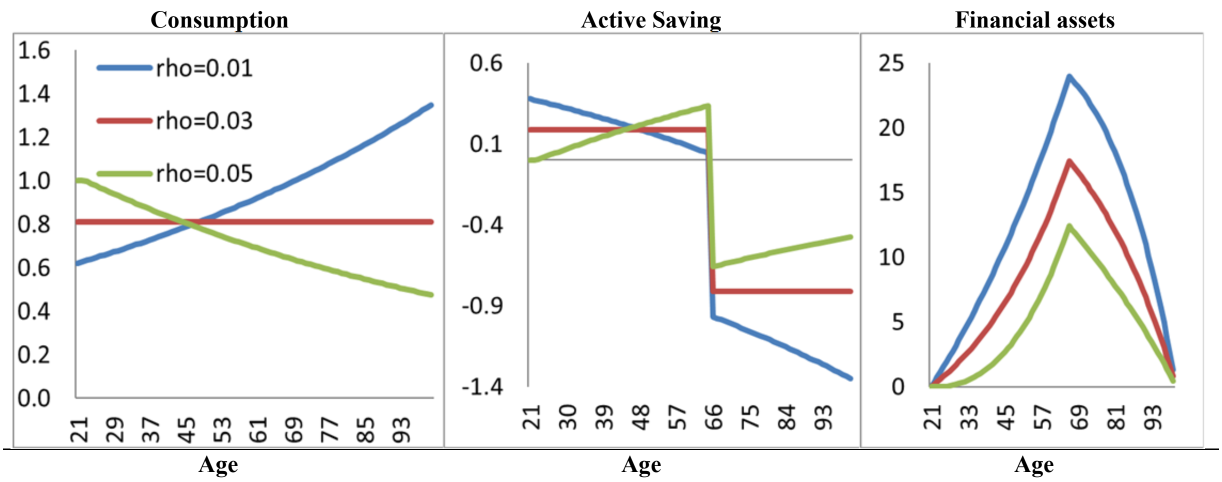
[15] Section 4 introduces a richer setting which introduces a "window of retirement" and decouples the exit from the labor force from the entry into the pension system.
[16] In this and the following section on household behavior, the interest rate r refers to r^{HH} in equation (2.13).

that are parametrized by the difference between the interest rate r and the household's discount rate ρ, reflecting the patience of households. Normal households have a discount rate equal to the market interest rate (ρ=*0.03)*; patient households have a lower (ρ=*0.01)* and impatient households have a higher discount rate (ρ=*0.05)*. Accordingly, households chose an increasing, flat or decreasing consumption profile (Figure 3.2, left). Old age provision consists of saving during the working life; consumption after retirement is financed by dissaving. Figure 3.2, middle, depicts active saving $s_{t,j}$ which is defined as saving out of current disposable non-asset income, not counting passive saving due to capital gains and accumulated interest:

$$s_{t,j} = y_{t,j} - c_{t,j} . \tag{3.7}$$

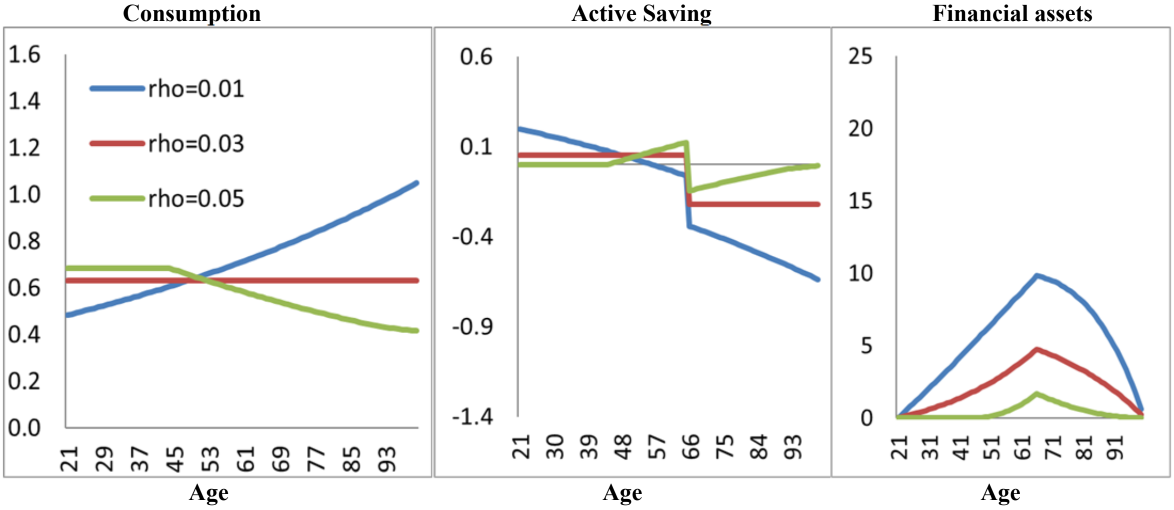
This saving pattern generates the well-known triangular asset profiles (Figure 3.2, right).

Figure 3.2: Consumption, Active Saving and Assets by Age without a Public PAYG Pension System



When introducing a mandatory pension system which provides a pension at a replacement rate of 60%, saving can be lower since part of the old-age provision is financed by pension contributions (Figure 3.3). Consequently, the stock of financial assets (the accumulated savings) is lower relative to the situation without a pension system:

Figure 3.3: Consumption, Active Saving and Assets by Age with a Public PAYG Pension System



Normal and patient households still save in addition to the public pension system because the replacement rate is only 60%. Impatient households, however, which have a very high discount rate relative to both the market interest rate and the internal rate of the pension system, would prefer to borrow initially both on their future labor income and later on their future pension income if borrowing would be allowed. Whether individuals are better off with or without the pension system depends on its internal rate of return. Welfare, defined as the lifetime utility (3.2), stays constant if $r=irr$, households are better off if $r<irr$ and worse off if $r>irr$.[17]

The textbook life-cycle model is an important benchmark and has been used in the path-breaking general equilibrium models which have analyzed the effects of population aging on PAYG and FF pension systems (Auerbach and Kotlikoff, 1987; Feldstein and Samwick, 1998) and the transition from PAYG to FF pension systems (Section 7). This textbook case of neoclassical household behavior may also be interpreted as a parable for decision making if households have subscribed to a perfect commitment device which nudges them into a perfectly time-consistent consumption and labor supply behavior (Rabin, 2013a; b). It has two strong predictions: perfect consumption smoothing over the life cycle and perfect substitution between pension benefits and private savings. The first prediction relates to a smooth continuation of the level of consumption through the transition between work and retirement. The second prediction of the textbook model is that own savings will make up for the benefit

[17] We abstract from differential risks, see the discussion at the end of Section 2, and define r and irr as their risk-free equivalents.

cuts of the pension system forced by population aging according to equation (2.9) or its variants described in Subsection 2.3. It is a matter of controversy whether these predictions hold in real life to an extent which permits the usage of the textbook life-cycle model to describe actual behavior and to make policy recommendations. These controversies reflect a lack of empirical knowledge.

Regarding perfect consumption smoothing, Banks et al. (1998), Battistin et al. (2009), Bernheim et al. (2001), and Haider and Stephens (2007) report a sharp and sudden consumption decline after retirement in many countries (the "retirement consumption puzzle"). While heterogeneity among households (Hurst, 2008; Hurd and Rohwedder, 2013) and a non-separable utility function (Subsection 4.1) may explain this "puzzle", the continuation of active saving after retirement in many countries, especially Germany, Italy and Japan, is harder to explain with conventional models (the "German saving puzzle", Börsch-Supan et al., 2001; De Nardi et al., 2010; Rohwedder et al., 2006).

There is also doubt about the other key prediction of the life-cycle hypothesis, the perfect substitution between a PAYG system and private saving. In many countries, we observe a 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 (we refer to this as "filling the pension gap": Börsch-Supan et al. (2015b), Börsch-Supan et al. (2016a) for Germany; Knoef et al. (2016) for The Netherlands, and Crawford and 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 and Shea, 2001). Recent evidence shows that the participation in private saving retirement programs has substantially declined for younger cohorts in the US although the pension gap is larger for them than for older cohorts (Stanford Center on Longevity, 2016).

Whether filling the pension gap is a valid yardstick for optimal saving is not so clear. Scholz et al. (2006) argue that most households in the US are saving at least as much as a perfect life-cycle model would predict. Börsch-Supan et al. (2003), Brugiavini and Padula (2001) and Kitamura et al. (2003) have argued that the older cohorts in Germany, Italy and Japan have actually over-saved given the generous public pension levels that these cohorts could enjoy. With this logic, the decline in saving among the younger cohorts which was recently observed by the Stanford Center on Longevity (2016) might well be the adaptation to an optimal saving level.

More direct evidence is scant. Börsch-Supan et al. (2016b) have conducted an Internet survey among individuals aged 60 and older which shows a substantial prevalence of regret over previous saving decisions. 60% of the respondents wished that they had saved more when they were younger. This contradicts the assumption of time-consistent carefully planning individuals. Moreover, we observe a demand for commitment devices even when they are costly (Ashraf et al., 2006; Beshears et al., 2011).

Germany provides a historical experiment which offers many helpful insights into the substitution between public PAYG pension systems and private saving. In 2001, the German government legislated severe benefit cuts for younger cohorts and at the same time introduced “Riester pensions” which are state-subsidized voluntary individual savings accounts (Börsch-Supan et al., 2012; 2015b; Corneo et al., 2009). Upon retirement, the pension benefit is generally paid as an annuity. The Riester pensions were explicitly advertised as a vehicle to fill the pension gap due to the benefit cuts.

On the one hand, the uptake of Riester pension contracts and of other supplemental retirement saving plans has been impressive. It shows that the substitution predicted by the life-cycle model has actually happened to some extent. This is shown in Figure 3.4.

Figure 3.4: Fraction of German Households without Supplementary Pensions

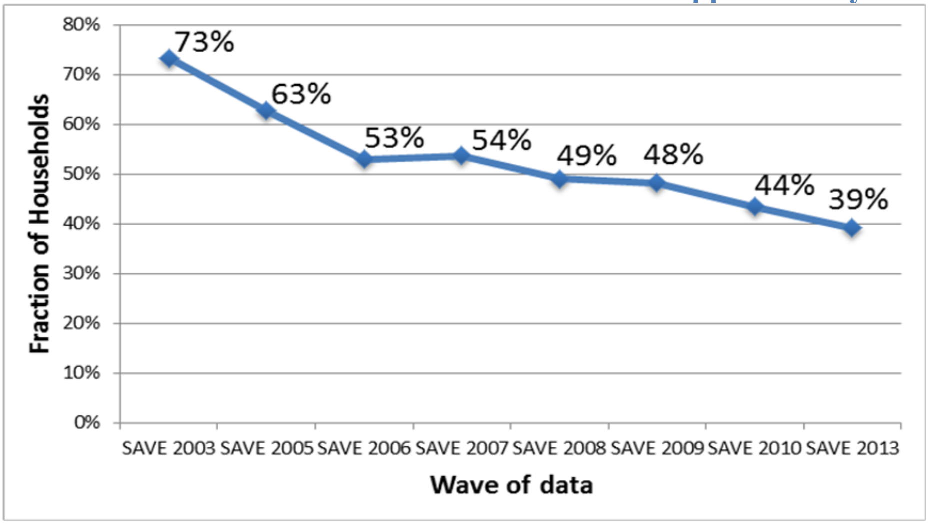


Figure 3.5: Distribution of Riester Pensions in Germany by Income Quintiles

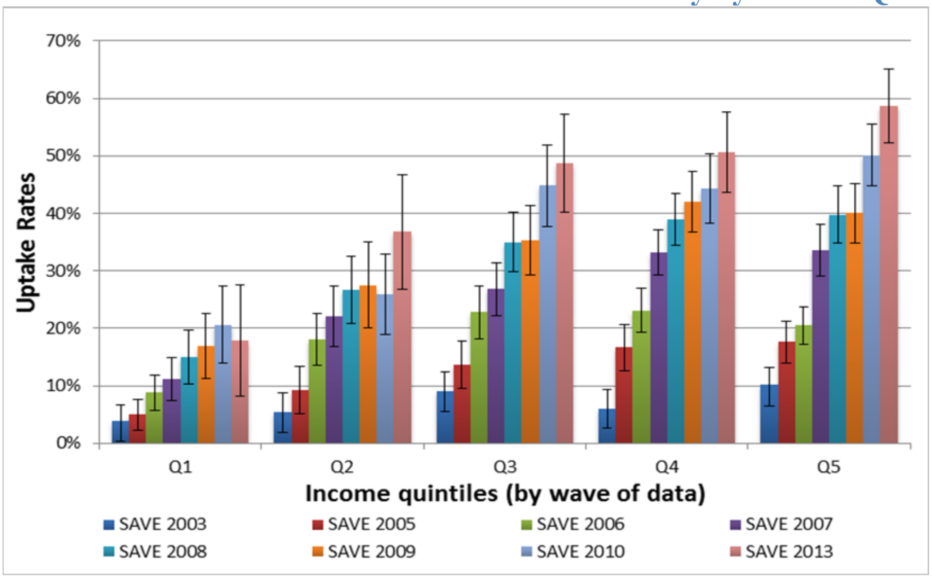
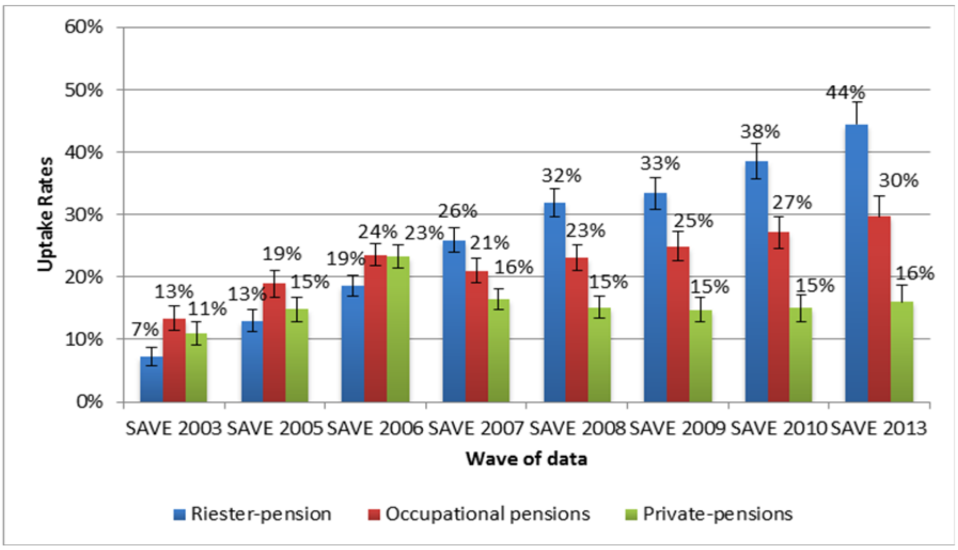


Figure 3.6: Households with Supplementary Pensions in Germany



Source for Figures 3.4-3.6: Börsch-Supan et al. (2015b).

Figures 3.4 to 3.6 are based on the SAVE panel (Börsch-Supan et al. 2015b).[18] The proportion of households without supplemental private pension plans declined from 73% to 39% in the period between 2002 and 2012. The proportion of households with Riester pensions has risen sharply, growing approximately fivefold in almost all income quantiles since 2003, see Figure 3.5, without crowding out other funded pension schemes, as shown in Figure 3.6.

On the other hand, however, the substitution of public PAYG-financed pensions by Riester-plans has not happened automatically, as the theory would predict, but was supported by heavy government intervention. The direct subsidies and the tax deductions are substantial and range from 24 percent to 90 percent of contributions depending on family income and the number of children. On average, they are about 45 percent of contributions (Deutsche Bundesbank, 2002). In spite of this, the substitution was far from perfect. The coverage has stagnated after 2012 at a level of about 45% of all eligible households and is weak among households with low income (Figure 3.5).

There is also a theoretical reason why the textbook life-cycle model is a problematic tool for the analysis of the effects of population aging on PAYG pension systems. In its simple and deterministic formulation of Subsections 3.1 and 3.2, the model fails to provide a convincing reason for installing a public PAYG-financed pension system in the first place -- except for the case in which the internal rate of return of the PAYG system exceeds the market interest rate. Whether this case can actually happen over an extended time period is questionable both for empirical and theoretical reasons which will be discussed in Section 7. In what is considered the normal case, however, the textbook model predicts that a PAYG-financed pension system would decrease welfare. Population aging with its tendency to reduce the internal rate of return of the pension system (cf. Section 5) would make the case for a public pension system even less compelling.

The literature has drawn very different consequences from this argument. A first strand takes this result as given and concludes that PAYG systems should be replaced by FF systems. We will take this up in Section 7. A second strand enriches the neoclassical textbook model of time-consistent households by elements that justify the existence of a public pension system, even when it is financed PAYG and delivers an internal rate of return that is smaller than the market interest rate. This is sometimes referred to as "the neoclassical repair shop".[19] Such

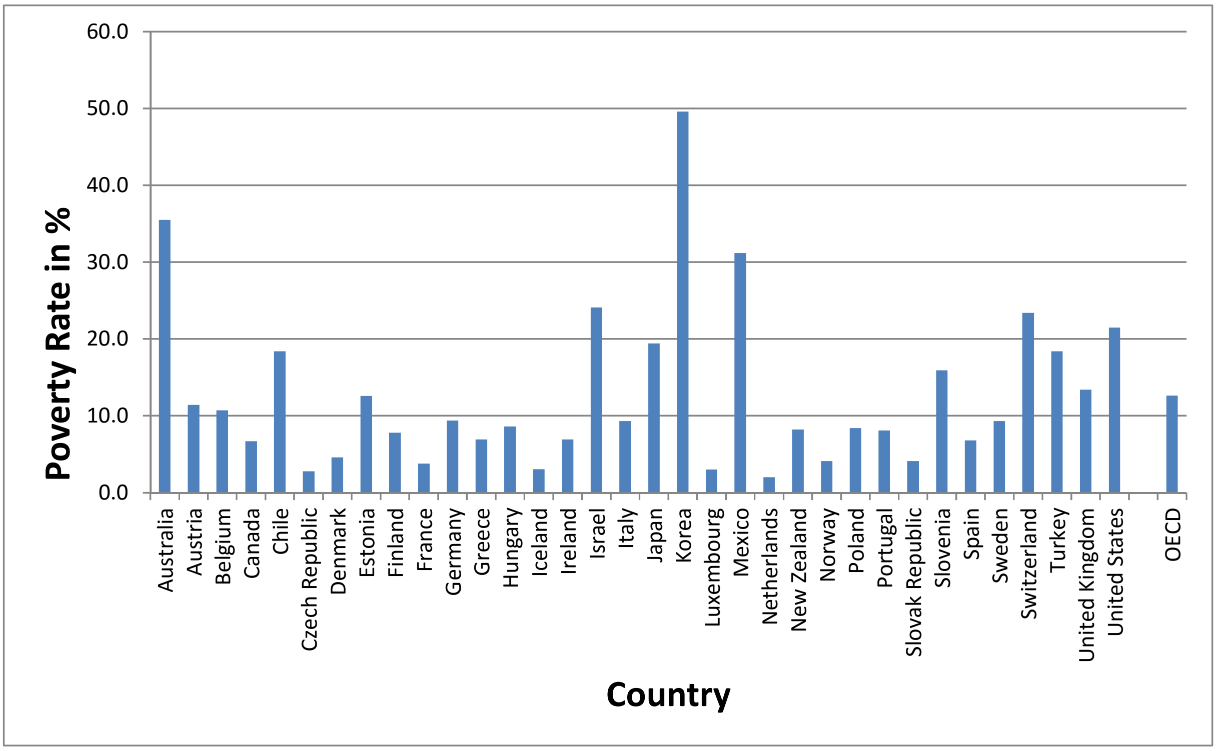
[18] For a description of the SAVE data, see Börsch-Supan et al. (2009).
[19] Interview with Werner Güth, re-printed in Andersson and Holm (2002).

extensions include poverty alleviation and longevity risks (Subsections 3.3 and 3.4), income risks, market failures and information costs (sketched in Section 2). A third strand of research more radically replaces the neoclassical paradigm with models of imperfectly foresighted behavior such as myopia, present bias and procrastination (Subsections 3.5 and 3.6).

3.3 Poverty alleviation and moral hazard

Low saving rates of households in the lower income brackets are typical for almost all countries. They are one explanation for the high old-age poverty rates in countries which rely heavily on private savings as the main form of old-age provision, see Figure 3.7:

Figure 3.7: Old-Age Poverty Rates



Source: OECD, Pensions at a Glance (2015a)[20]

In order to protect these households from poverty at older ages, governments in many countries provide a tax-financed minimum pension for households who have accumulated savings below a certain threshold. This is the key idea of Beveridgian pension systems which rely on private savings for the bulk of old-age provision. These systems may avoid some of the negative incentive effects on saving typical for PAYG-DB pension systems but are not free from them. Analyses of negative incentive effects of means-tested benefits have been

[20] Income sources include earnings, capital income, public and private transfers. Not included are lump-sum payments and imputed rents from owner-occupied housing which provide a substantial relief from poverty in countries such as Australia, Switzerland and the US.

provided by Sefton et al. (2008), Kudrna and Woodland (2011), Pashchenko (2013), Tran and Woodland (2014), Fehr and Uhde (2014), and Bütler et al. (2016). Details can be found in the chapter by Woodland in this handbook.

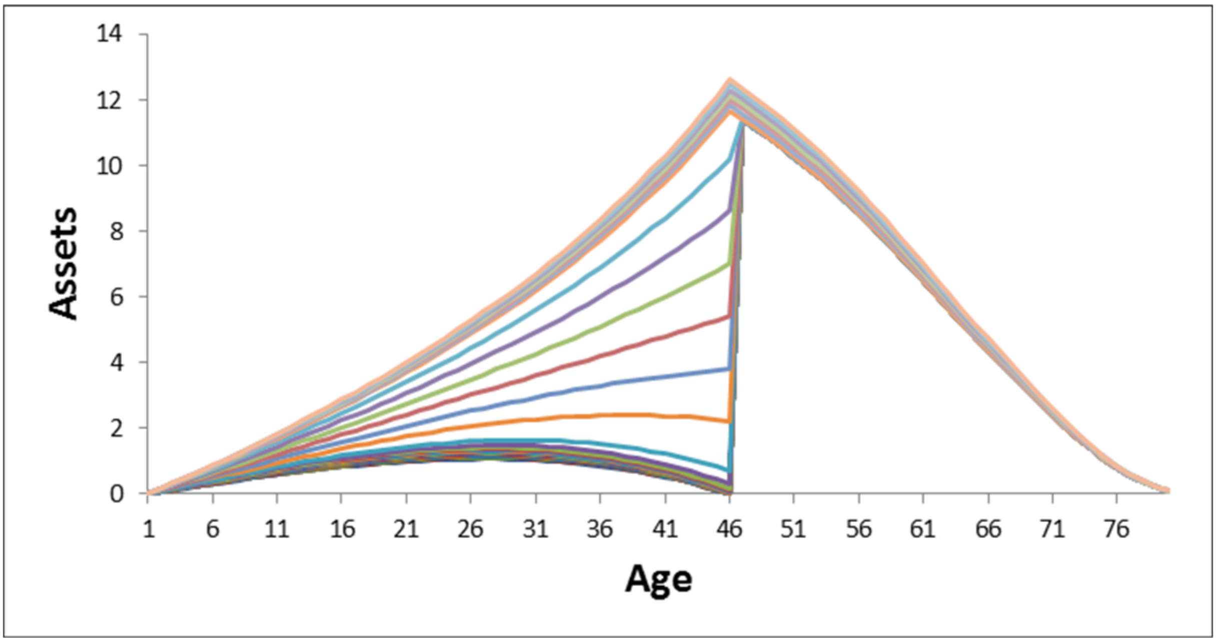
The basic argument is as follows. In many countries, governments prevent households from falling below a certain minimum income in old age, p_{min}, by applying a "gap formula" that subsidizes old-age income according to the difference between the annuity value of own accumulated assets at retirement, $p(a_R)$, defined by equation (3.9) below, and the minimum pension level p_{min}:

(3.8) $$p_{gap} = p_{min} - p(a_R) \text{ if } p(a_R) < p_{min} .$$

Households with relatively few accumulated assets will then have an incentive to consume more before retirement such that no assets are left when the amount of the subsidy is calculated. One may interpret this is a special form of moral hazard.

Figure 3.8 shows a simulation of the asset accumulation for a range of wage levels in the simple life-cycle model based on equations (3.1) through (3.6), assuming, for simplicity, a fixed life-span of J years as specified in equation (3.3). The annuity value of assets a_R is then $a_R/(J\text{-}R)$. Wages range from 0.5 to 1 and the minimum pension p_{min} is set at 0.35 which corresponds to a 70% replacement rate of the minimum wage.

Figure 3.8: Assets Profiles for Different Wages (with a Borrowing Constraint)



Depending on the level of income, households change their saving behavior as follows: low income households accumulate little savings and target consumption to have no assets at retirement. Middle income agents decrease, although not completely, their overall savings because they are only marginally entitled to receive a benefit. High income households (wage > 0.74) will not change their assets profile because they would already accumulate a higher value than the threshold required for receiving part of the minimum pension. Note that the incentive effects also affect middle-income households until a wage of more than two times the minimum pension.

Evidence for this behavior can be drawn from the German Riester experiment described in the previous subsection. Germany provides a means-tested minimum pension at a level of about 15% above the poverty line according to a version of the gap formula (3.8). Savings in Riester plans count for the means test. Currently, only about 3% of households aged 65 and older receive such a minimum pension. Households which expect to be in these low percentiles of the income distribution have no incentive to subscribe to Riester plans as their saving will be taxed away. Figure 3.5, however, shows a much larger share of households without Riester plans, reaching far into the lower middle class, exactly as the model underlying Figure 3.8 predicts.[21]

Another example for the disincentives created by means-tested pension benefits is Australia.[22] The Australian age pension is unusual among developed countries because it is means tested against both the claimant's income and assets. While means testing of pensions facilitates the aims of directing public pensions to those individuals most in need and of containing pension expenditures by governments, it also has the effect of changing the incentives of individuals to work and save. Kudrna and Woodland (2011) provide a general equilibrium analysis of saving, labor supply and retirement decisions.

They demonstrate that the existing means-tested age pension provides a strong disincentive for older middle income households to work. These disincentives arise primarily because of the reduction in the pension that a pensioner receives as a result of receiving income from extra labor effort or financial investments and are reflected in a high effective marginal rate of taxation. Numerical simulations of abolishing the means testing show that middle-income households work longer hours at older ages and delay their retirement. For low-income

[21] In addition, there is evidence on miss-information and wrong expectations. According to Lamla and Gasche (2013), 38% of German households expect to receive the minimum pension while about half of them have already accumulated pension claims that place them above the threshold of the means test. These households base their decisions today on wrong expectations about the future and might save too little.

[22] The following paragraph is quoted from Kudrna and Woodland (2011).

households the means test is not binding while a pure income effect is generated for high-income households. This reduces their labor supply.

3.4 Longevity risk

A second important reason for installing a public pension system in the framework of perfectly forward-looking households is the presence of longevity risk, i.e. the risk of outliving the accumulated savings. The risk could theoretically be covered by annuitizing the assets accumulated until retirement age (Yaari, 1965). However, there is ample evidence that annuity markets do not work sufficiently well to provide fair annuities (the "annuity puzzle", Friedman and Warshawsky, 1988; 1990; Mitchell et al., 1999; Finkelstein and Poterba 2004; Mitchell et al., 2011). Hence, the government may step in and provide an annuity based on the individual's savings. A flat annuity with an annual flow of benefits p_0 which stays constant during the retirement years is computed by the annuity formula:

$$(3.9) \quad p_0 = a_R \cdot D_R \Big/ \sum_{k=R+1}^{\infty} D_k \, ,$$

where a_R denotes the assets accumulated in the FF system until retirement age R and $D_k = \sigma_k/(1+r)^k$ where σ_k denotes the unconditional survival rate at age k and r the interest rate.[23] Alternatively, the government may provide a PAYG-financed pension which is paid as long as the beneficiary is alive, thus also covering the longevity risk.

Table 3.1 shows the results of a simulation of a simple 3-period version of the perfect foresight model (3.1) through (3.6) with and without the possibility to annuitize savings at retirement. The benchmark is the standard life-cycle model; the alternatives are government-provided annuitization and a PAYG pension system with an internal rate of return $irr \leq r = \rho$. Period 1 is work, period 2 is the part of retirement in which the household will be living with certainty, while the household will live in period 3 only with a probability $0<\sigma<1$. Results are expressed as the percent increase in life-time consumption of the benchmark case in order to make the household as well off as in the reform scenario (consumption equivalent variation). Hence, positive (negative) numbers indicate a welfare gain (loss) relative to the benchmark.

[23] This modeling approach is different from Heijdra et al. (2014) and Hansen and Imrohoroglu (2008) who define annuities which pay a benefit in proportion to the conditional mortality risk. This yields very steeply rising annuity payments at the end of life and generates consumption profiles as if there were no mortality risk.

Table 3.1: Welfare with and without Annuitization

	Survival rate = .25			Survival rate = .50		
1. No annuitization possible	Baseline			Baseline		
2. Government provides annuitization, borrowing possible	29.61%			18.63%		
3. Government provides annuitization, but borrowing not permitted	22.50%			16.63%		
	***irr*=1%**	***irr*=2%**	***irr*=3%**	***irr*=1%**	***irr*=2%**	***irr*=3%**
4. Government provides PAYG pensions	20.41%	21.11%	21.81%	13.85%	14.71%	15.56%

Parameters: rho=r=3%, theta=2, effective replacement rate=60%.

Households always do better when the government covers the longevity risk by providing an annuity in periods 2 and 3 (Table 3.1, line 2 versus line 1). For a low survival rate, households would borrow in period 1 against their certain annuity income in period 2 (line 2). If borrowing is prohibited, households are still better off with annuitization (line 3 versus line 1). This also holds if a PAYG system provides the annuity income against which the households cannot borrow, even if the internal rate of return is substantially lower than the market interest rate (line 4 versus line 1) although households would prefer an annuitization scheme based on a funded system.

The benefits of annuitization are even stronger if individuals underestimate their life expectancy. Table 3.2 shows that such underestimation is prevalent among young and mid-aged Germans.[24] The reason for this pattern is likely that the longevity increase associated with population aging induces a large difference between current life expectancy and cohort life expectancy which is most salient for young and mid-aged individuals. Similarly, the benefits from annuitization are larger for uninformed individuals (Chan and Stevens, 2008; Bucher-Koenen and Lusardi, 2011) and myopic or procrastinating individuals (Subsections 3.5 and 3.6).

[24] This pattern has been shown for many other countries. Hamermesh (1985) reports for the US that individuals underestimate their life expectancy until age 60 but are optimistic for older ages. More recent studies for different countries and cohorts find similar results: younger individuals (until age 60) are pessimistic about their survival, while older individuals are optimistic (Smith et al. (2001), O'Donnell et al. (2008), Perozek (2008), Teppa (2011), Kutlu-Koc and Kalwij (2013), Ludwig and Zimper (2013), Bucher-Koenen and Kluth (2012) and Doerr and Schulte (2012) referring to results from UK, US, NL, Australia and Germany).

Table 3.2: Subjective and Predicted Cohort Life Expectancy

	Age 40-49	Age 50.59	Age 60+
Men: subjective	75.0	73.4	78.4
cohort life tables	82.1	81.8	80.1
Difference	7.1	8.4	1.7
Women: subjective	78.2	79.4	82.3
cohort life tables	88.0	87.6	86.0
Difference	9.8	8.2	3.7

Source: Börsch-Supan et al. (2005a)

While the individual benefits of annuitization are undisputed, the long-run societal implications are not so obvious (Fehr and Habermann, 2008). Annuitization reduces the flow of bequest to the younger generation, causing a negative intergenerational income effect for future generations. It is therefore not clear a priori whether future generations will benefit or lose from annuitization. Fehr and Habermann (2008) show that this depends on the difference between the interest rate and the population growth rate. If the former is sufficiently higher than the latter, the negative transfer effect for the younger generation may outweigh the individual advantages of annuitization in general equilibrium. Heijdra et al. (2014) call this case the "tragedy of annuitization". It is unclear, however, whether a change in the size of intended bequests would undo this effect.

3.5 Myopia

A third reason to introduce a mandatory pension system is the outright failure to plan ahead. For time-consistent households, this may be explained by the high costs of information acquisition and processing when decisions are complex (Lusardi and Mitchell 2011; 2014). Such behavior has been modelled by Lusardi et al. (2013). Time-consistent life-cycle savers will only invest in financial literacy if the expected gain in returns is high enough.

A much more radical deviation from the neoclassical household behavior assumes that households fail to plan ahead even if it were economically time-consistent to do so, violating the von Neumann-Morgenstern specification of expected utility maximization in equation (3.2). This and the following subsection present several avenues to model imperfect household decisions, each of which carries different implications for social insurance and population aging. These modeling approaches are by no means new but have only recently found widespread attention when they were applied to retirement saving in the US (Laibson, 1997; 1998; Madrian and Shea, 2001). The underlying behaviors have major implications for the design of pension systems and their interaction with population aging.

Deviating from the neoclassical household model has serious consequences for welfare evaluation which are often not discussed in the literature. Most of the literature assumes that welfare evaluations are made under a different utility function than the one which is implied by the actual decision behavior of the households. One interpretation is that welfare is evaluated by the same individual ex post ("on the death bed") while decisions are made by the ill planning individual on the spot. In this case, the key assumption permitting welfare comparisons is that individuals regret their bad planning behavior and do not deny it. Evidence on such behavior is scant (Loomes and Sugden, 1982; Valenti et al., 2011; Börsch-Supan et al., 2016b). A second interpretation is that the welfare evaluation rests on social norms to which a society converges in a slow learning process while individuals lag behind in learning and fail to obey such norms (Manski, 2000). The third interpretation is time-honored in economics: a paternalistic planner who knows what is best acts according to a well-defined social welfare function while the ill planning individuals ignore such welfare considerations (Laibson, 1997; 1998).

A first and very simple way to model the failure to plan ahead is to assume that welfare evaluation still follows the time-consistent perfect-foresight program (3.2), while the actual decision function adds a parameter $0 \leq \delta \leq 1$ into (3.2) which expresses the extent of shortsightedness or present bias:

$$(3.10) \quad \max_{c} \ \{ \ u(c_{t,0}) + \sum_{j=1}^{J} \delta \, \beta^{j} \, \sigma_{t+j,j} u(c_{t+j,j}) \ \} \, .$$

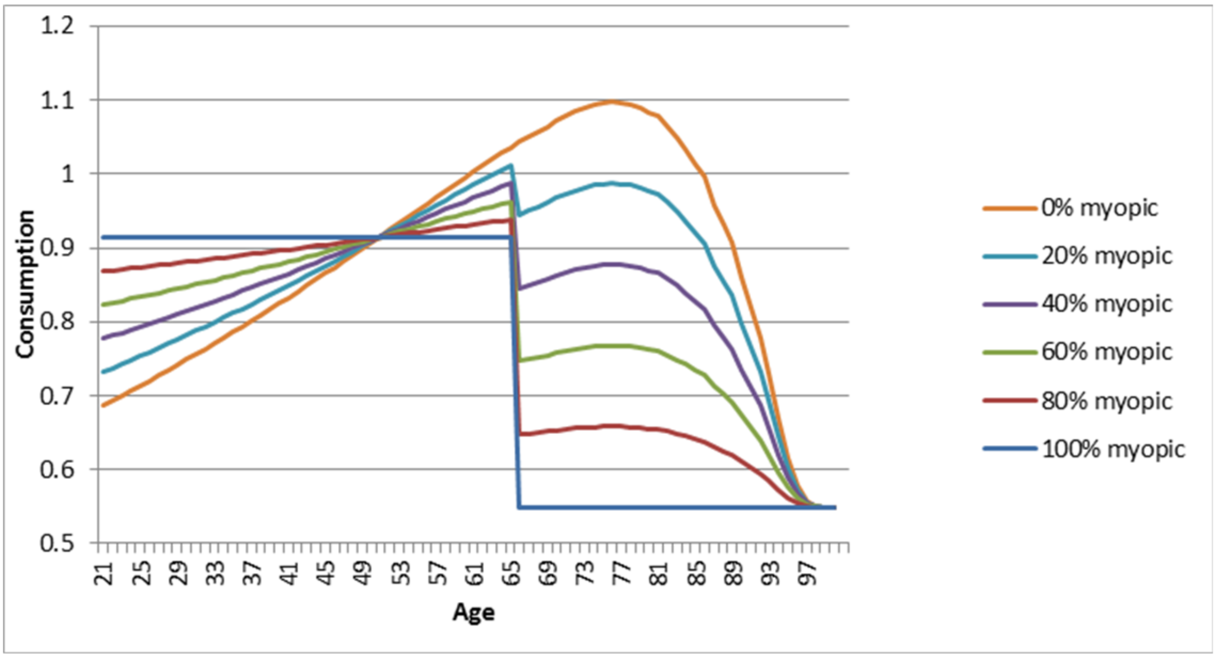
Complete myopia corresponds to $\delta=0$. In this extreme case, households focus on current utility only and ignore future utility. They do not anticipate retirement and do not save. Without a pension system, they would suffer from starvation once deteriorating health forces them to retire. A mandatory 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.

A milder form of myopia sets the factor δ in (3.10) to a value larger than 0 but smaller than 1. Feldstein (1985) calibrates a two-period version of such a model to compare the life-time welfare of households with and without a mandatory PAYG-financed pension system. This is a good example to see the sensitivity of welfare conclusions from the choice of key parameters. Feldstein uses the following key calibration parameters: labor force growth n=1.4%, wages growth g=2.2% and real interest r=11.4%. He then computes that a mandatory PAYG-financed pension system is welfare improving only if households "give a weight of less than 5% to future utility" (p. 313). His parameter choices imply an implicit rate of return of the PAYG pension system of 3.6% (cf. equation 2.11) which is substantially lower than the real interest rate assumed by Feldstein. Welfare implications are extremely sensitive to this return difference. If the real interest rate is assumed to be 3%, Feldstein's conclusion reverses and abolishing a PAYG-financed pension system would only be welfare improving if households give a weight of more than 91% to future utility. For a quickly aging population such as Germany, Italy or Japan, set n = -0.5%, g = 1.5% and r = 3%. Then the critical weight to future utility is about 42%.

Different households may exhibit different degrees of myopia. Models with heterogeneous households are instructive because they show the trade-off between social protection and economic efficiency. Again following Feldstein (1985), assume a population which has two types of households. A fraction η of households are myopic (M) and behave like described by equation (3.10) with $\delta=0$. The other households have perfect foresight (denoted by PF). While a PAYG-DB pension system is clearly beneficial for the M-households, this is different for the PF-households because they have to co-finance the M-households' pensions which reduces their utility. Moreover, the PAYG-DB system will crowd out private saving which may earn a higher rate of return.

Figure 3.9 shows the aggregate consumption paths for different fractions η of myopic households. The higher the percentage of PF-households, the lower the consumption at the beginning of life and the higher the consumption at middle age until late stages of life since PF-households prefer to postpone consumption and enjoy higher utility later in life. The crowding-out effects are clearly visible. If $r > irr$, this reduces economic efficiency.

Figure 3.9: Consumption Profiles in an Economy of Myopic and Perfectly Foresighted



The beneficial effect of a PAYG-DB pension system depends on η and the difference between r and irr. This is displayed in Table 3.3 which measures welfare as consumption equivalent variation relative to a PAYG-DB system with an internal rate of return of 3%. A negative percentage means that one has to reduce x percent of the baseline household's lifetime consumption in order to make households in a given scenario indifferent between this scenario and the baseline case. As baseline case, we take a PAYG-DB system with an internal rate of return of 3%. If the share of myopic households is relatively large, a mandatory PAYG-DB system is always beneficial, even for low internal rates of return. In the extreme case in which all households are myopic (first line of Table 3.3), the lack of a pension system implies starvation at old age. Hence, all old-age consumption has to be provided to make these households as well off as in the benchmark case. The opposite extreme, when all households have perfect foresight, reflects the results of Table 3.1 where the advantages of annuitization provide an advantage of a PAYG-DB system relative to the pure saving case when the internal rates of return equals the market interest rate. This is not the case for a PAYG-DB system with lower internal rates of return (highlighted numbers).

Table 3.3: Welfare by Share of Myopic Households

Fraction of myopic households	No PAYG	PAYG-DB pension system with IRR= 1%	2%	3%
100%	**-100.00%**	**-8.27%**	**-3.61%**	**Baseline**
80%	-34.67%	-8.26%	-3.58%	Baseline
60%	-14.94%	-8.28%	-3.61%	Baseline
40%	-7.14%	-8.26%	-3.59%	Baseline
20%	-4.14%	-8.28%	-3.60%	Baseline
0%	-3.49%	-8.28%	-3.63%	Baseline

Parameters: rho=r=3%, theta=2, effective replacement rate=60%.

3.6 Procrastination

While myopia is a failure to plan for the long-run, another failure of the life-cycle model in describing reality may be 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. Such self-control problems constitute a more subtle form of time-inconsistent behavior which persists over time than the simple myopia models of the previous subsection (Thaler, 1994; Laibson, 1997; 1998; Angeletos et al., 2001; Choi et al., 2002; Rabin, 2013a; b; Della Vigna and Malmendier, 2006).

The framework used to model this time-inconsistent behavior was first advanced by Strotz (1956) through hyperbolic discounting and by Phelps and Pollak (1968) and Pollak (1968). They model time-inconsistent behavior as a continuing game between 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. The model has three key 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_j from beliefs about future consumption behavior $\hat{c}_{j+1}$. The approach was refined by Thaler and Shefrin (1981) and later popularized by Laibson (1997; 1998). The notion of different "selves" with changing preferences allows 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. They may occur for various reasons such as monetary and psychic costs of decision making. We therefore avoid terms such as "rational" and "irrational" behavior. In specifying future beliefs, O'Donoghue and Rabin (1999) distinguish between so called "naïve" and "sophisticated" hyperbolic households. Both types have identical preferences but differ in their own perception of future preferences. The naïve households think that their future selves will behave in a time-consistent manner despite the fact that 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. $\hat{\delta}=\delta < 1$ and so seek to overcome this misbehavior by constraining their future consumption. Present discount factors for time-consistent, naïve, and sophisticated hyperbolic households are summarized in Table 3.4.[25]

Table 3.4: Present Discount Factor for each Type of Household

	Present (δ)	Belief ($\hat{\delta}$)
Time-consistent households	1	1
Naïve hyperbolic households	< 1	1
Sophisticated hyperbolic households	< 1	< 1

The current self at age j maximizes the objective function

$$(3.11) \quad \max \left\{ u(c_j) + \delta \cdot \beta \cdot \sigma_{j+1} \cdot \hat{V}(z_{j+1}) \right\}$$

by choosing current consumption c_j, subject to the budget constraint (3.5), the borrowing constraint (3.6) and his beliefs $\hat{V}(z_{j+1})$ about the behavior of his future selves for the future state z_{j+1}. The value function $\hat{V}(z)$ for future beliefs is computed recursively by

$$(3.12) \quad \hat{V}(z_j) = u(\hat{c}_j) + \beta \cdot \sigma_{j+1} \cdot \hat{V}(z_{j+1}).$$

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

$$(3.13) \quad \max \left\{ u(\hat{c}_{j+1}) + \hat{\delta} \cdot \beta \cdot \sigma_{j+2} \cdot \hat{V}(z_{j+2}) \right\}$$

[25] If θ=1 (log utility case), then naïve and sophisticated hyperbolic households have the same consumption paths.

by choosing future consumption $\hat{c}_{j+1}$ where δ is replaced by $\hat{\delta}$ compared to (3.11). Finally, welfare is computed based on the actual behavior of households:

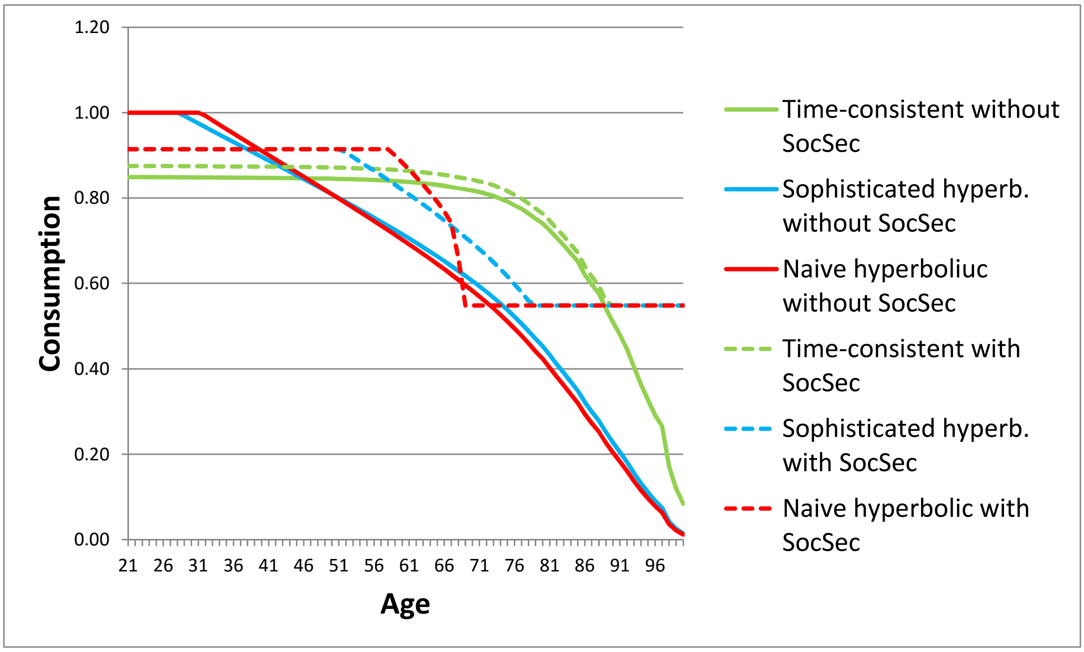
(3.14) $V(z_j) = u(c_j) + \beta \cdot \sigma_{j+1} \cdot V(z_{j+1})$.

Preferences are time inconsistent because the present-bias parameters δ and $\hat{\delta}$ appear in the decision problems (3.11) and (3.13) but not in the calculation of the value functions (3.12) and (3.14). If $\delta = \hat{\delta}$, then the beliefs $\hat{c}_{j+1}$ and $\hat{V}(z)$ will be identical to the actual behaviors c_j and values $V(z)$. Hence, 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 $\delta < 1$ and $\hat{\delta} = 1$), 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).

The model is calibrated comparably to the sections above. Interest rate r and discount rate ρ equal 3% on an annual basis. Survival rates are also taken into account. θ is set to 2. Lower values of δ exhibit more severe present bias while higher values denote moderate bias closer to a time-consistent behavior. The benchmark is $\delta = 0.6$. We show simulations with and without a PAYB-DB pension system with a replacement rate of 60% for each of the three household types (naïve hyperbolic, sophisticated hyperbolic and time-consistent).

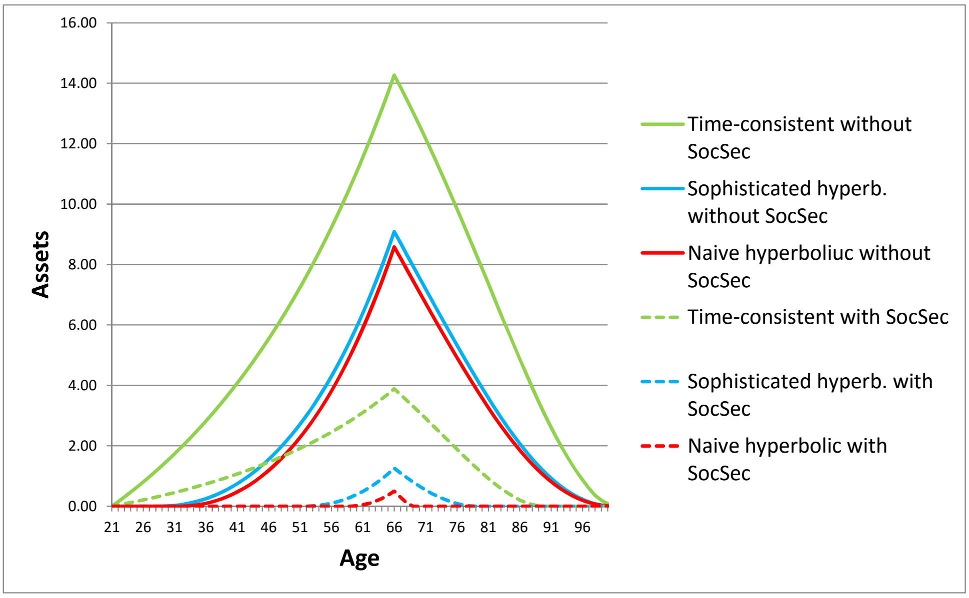
Both sophisticated and naïve hyperbolic households exhibit overconsumption in the beginning of life relative to time-consistent households (Figure 3.10). With present bias, sophisticated hyperbolic households consume more than time-consistent households in order to constrain their time-inconsistent future selves. Naïve hyperbolic households also consume more but they do not realize that this higher consumption in earlier periods will reduce substantially their consumption in the future. They therefore overconsume until later ages than the sophisticated hyperbolic households and experience a sudden decline in consumption. Moreover, the lower δ, the smaller the consumption level in future periods since impatience leads households to be eager to consume the most possible in the present (not shown in the graphs). The distinction between naïve and sophisticated hyperbolic households becomes stronger for high present bias (low δ).

Figure 3.10: Consumption Profiles for Present Bias 60% with and without a PAYG Pension System.



Asset profiles therefore show undersaving for sophisticated and naïve hyperbolic households. The more short-sighted households are, the more prevalent is undersaving. Figure 3.11 also shows the extent of crowding out of private saving by the PAYG pension system which is considerably stronger among sophisticated and naïve hyperbolic households than among time-consistent households. This crowding out effect also increases with the extent of present bias.

Figure 3.11: Asset Profiles for Present Bias of 60% with and without a PAYG Pension System.



Finally, Table 3.5 computes welfare for each type of household with and without a PAYG-financed pension system, again expressed as consumption equivalent variation. We assume an interest rate of 3%. A PAYG-DB system yields higher welfare than no pension system in most cases of Table 3.5. This holds even for low internal rates of return if the present bias is high. The highlighted numbers show the opposite case in which present bias and PAYG rates of return are low.

For a present bias of 0.6, a PAYG-DB pension system improves welfare for the sophisticated hyperbolic households if its internal rate of return is larger than 0.9%. For the time-consistent households, the internal rate of return must exceed 2.1% to improve the households' welfare vis-à-vis private saving at a 3% interest rate. For extreme short-sighted naïve and sophisticated hyperbolic households welfare is always higher for any internal rate of return compared to a private saving scenario. These results correspond to the results of Subsection 3.4 on annuitization. The welfare gain of annuitization, however, is much larger for naïve hyperbolic households than for time-consistent or sophisticated hyperbolic households, and it increases with the extent of present bias. Note that for very high levels of present bias (δ = 0.1), welfare is very low without a pension system due to very low consumption levels in old-age.

Table 3.5: Welfare for each Type of Household

	No PAYG	PAYG-DB pension system with IRR=			
		1%	2%	2.5%	3%
		Full Model – Present bias high = 0.1			
Naive hyperbolic	-97.86%	-8.29%	-3.61%	-1.70%	Baseline
Sophisticated hyp.	-52.42%	-8.28%	-3.62%	-1.68%	Baseline
Time consistent	-3.44%	-8.26%	-3.60%	-1.68%	Baseline
		Full Model – Present bias = 0.6			
Naive hyperbolic	-8.81%	-8.28%	-3.60%	-1.68%	Baseline
Sophisticated hyp.	-8.03%	-8.28%	-3.59%	-1.69%	Baseline
Time consistent	-3.44%	-8.26%	-3.60%	-1.68%	Baseline
		Full Model – Present bias low = 0.85			
Naive hyperbolic	-3.61%	-8.27%	-3.58%	-1.67%	Baseline
Sophisticated hyp.	-3.75%	-8.28%	-3.62%	-1.70%	Baseline
Time consistent	-3.44%	-8.26%	-3.60%	-1.68%	Baseline

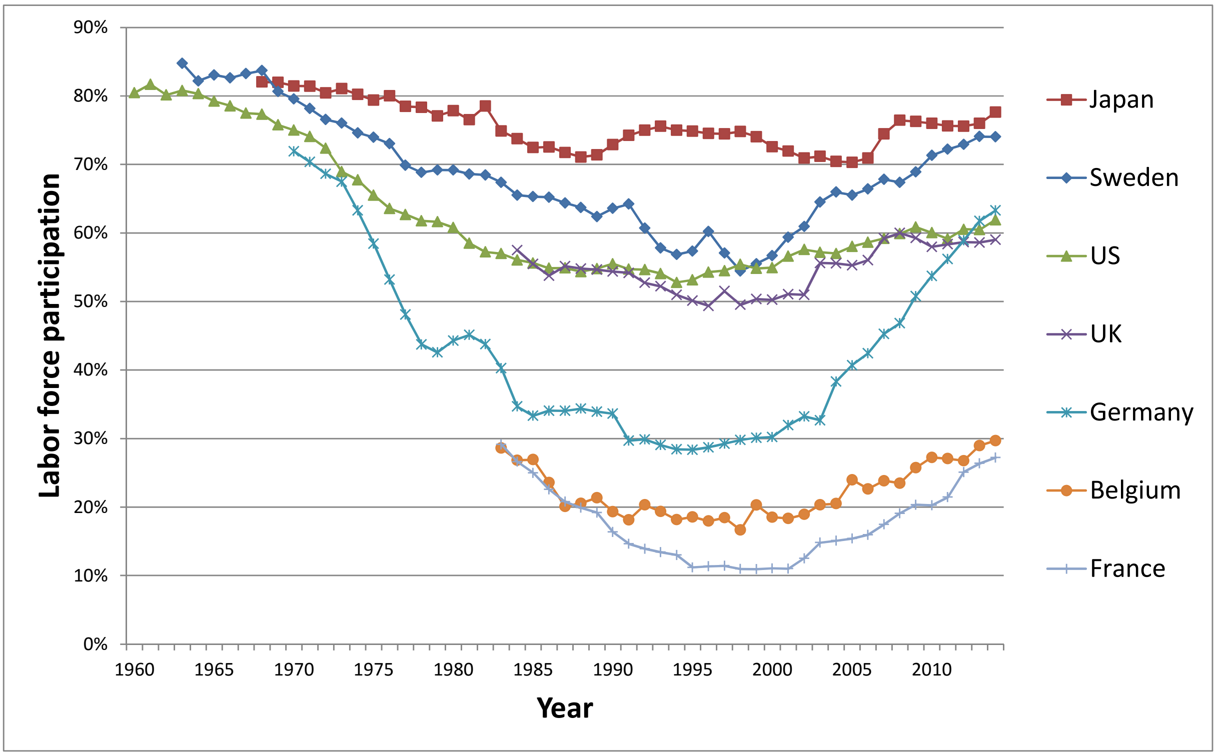
Parameters: rho=r=3%, theta=2, replacement rate=60%.

4. Labor supply and social insurance

In addition to its effects on saving behavior, the design of a pension system has strong implications on labor supply for young and older ages. Since the key economic implication of population aging is the decline of the support ratio (2.7), pension systems which exert negative incentive effects on labor supply amplify the challenges of population aging and contribute to shifting countries above the regression line in Figure 1.1.

Population aging has sparked particular attention to labor supply at older ages since working longer helps to decrease the pension systems dependency ratio both via the numerator and the denominator of (2.6). Figure 4.1 shows the stunning decline in labor supply of older individuals in many developed countries until about the mid-1990s, followed by an equally impressive increase to levels seen much earlier. It is unlikely that such a reversal is related to secular developments such as the aging of populations or rising education levels. We claim that much of the reversal can be explained by the reversal of pension policies that have encouraged early retirement. This section therefore looks at several modeling approaches which describe the interaction between pension systems and labor supply behavior.

Figure 4.1: Labor Force Participation among Men Aged 60-64, 1960-2013 (Percent of Male Population 60 to 64)



Source: OECD Employment Database (2015c)

To this end, we extend the consumption model (3.1) and (3.2) by adding households' labor supply $l_{t,j}$ at age j and time t. Households receive utility from consumption $c_{t,j}$ and leisure 1-$l_{t,j}$. The most conventional specification is a per-period utility function given by

$$(4.1) \quad u(c_{t,j}, 1-l_{t,j}) = \frac{1}{1-\theta}\left(c_{t,j}^{\phi} \cdot \left(1-l_{t,j}-\xi_j\right)^{1-\phi}\right)^{1-\theta},$$

where ϕ denotes the utility weight of consumption versus leisure and ξ_j age-dependent fixed costs of labor which mimic the effect of declining health on the disutility of work.[26] With non-separable utility between leisure and consumption, these fixed costs also model the declining utility from consumption when health deteriorates (Börsch-Supan and Stahl, 1991).

In the neoclassical textbook case, the household faces the same expected utility maximization program over the entire life-cycle as in (3.2):

$$(4.2) \quad \max \sum_{j=0}^{\infty} \beta^j \sigma_{t,j} u\left(c_{t+j,j}, 1-l_{t+j,j}-\xi_j\right),$$

subject to the asset constraints given in Section 3 and a slightly modified definition of current disposable non-asset income:

$$(4.3) \quad y_{t,j} = l_{t,j} \cdot w_{t,j}\left(1-\tau_t\right) + p_{t,j} \quad \text{with } p_{t,j} = 0 \text{ for } j < R \text{ and } l_{t,j} = 0 \text{ for } j \geq X.$$

The first term of the right hand side is labor income (labor supply times net wage). The second term is pension income. R denotes the age at which the household decides to claim its pension benefits ("benefit claiming age") while X denotes the age at which the household decides to stop working ("labor force exit age"). R and X refer to choices that are in principle independent from each other. Equation (4.3) therefore permits $R<X$, i.e., individuals keep working while they already receive pension benefits. Prominent examples for such systems are Sweden, the UK and the US (e.g. Maestas, 2010). Other pension systems, however, have an earnings test which forces workers to have a "retirement age" $R=X$ at which the worker exits the labor force and begins claiming benefits (Subsection 4.3).

Pension systems create various forms of labor supply disincentives. Regarding population aging, much attention has been given to the labor supply of older workers and the choice of the benefit claiming age R and the labor force exit age X. They will be discussed in Subsections 4.1 to 4.3. In addition, pension systems typically also exert negative incentives

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[26] We assume that fixed costs are 20% of total time available at the normal retirement age and reach 100% at age 80, forcing individuals to exit the labor force some time during this age interval.

for younger workers. First, if the contributions to the pension system $\tau_{t,j}$ are perceived as taxes, then labor supply of contributors will be discouraged (Subsection 4.4). Second, many policies also directly restrict labor supply (Subsection 4.5). These labor supply effects are important for the general equilibrium analyses of Sections 5-7.

4.1 Earnings tests and mandatory retirement

As pointed out in the context of equation (4.3), the choice of the claiming age R and the choice of the labor force exit age X are in principle independent from each other. If pension benefits correspond to contributions as in a fair insurance, there is no reason immanent in pension systems to stop working when stopping contributing and receiving a pension benefit.

Many pension systems, however, enforce an earnings test which limits or even prohibits earning wages while receiving pension benefits. In this case, R=X and the current disposable non-asset income is defined by

(4.4) $y_{t,j} = \lambda \cdot l_{t,j} \cdot w_{t,j}(1-\tau_t) + (1-\lambda) \cdot p_{t,j}$ with λ=1 for $j=0,\ldots,R-1$ and λ=0 for $j \geq R=X$.

rather than by equation (4.3). Usually, an earliest retirement age R_E restricts the choice of $R=X\geq R_E$.[27]

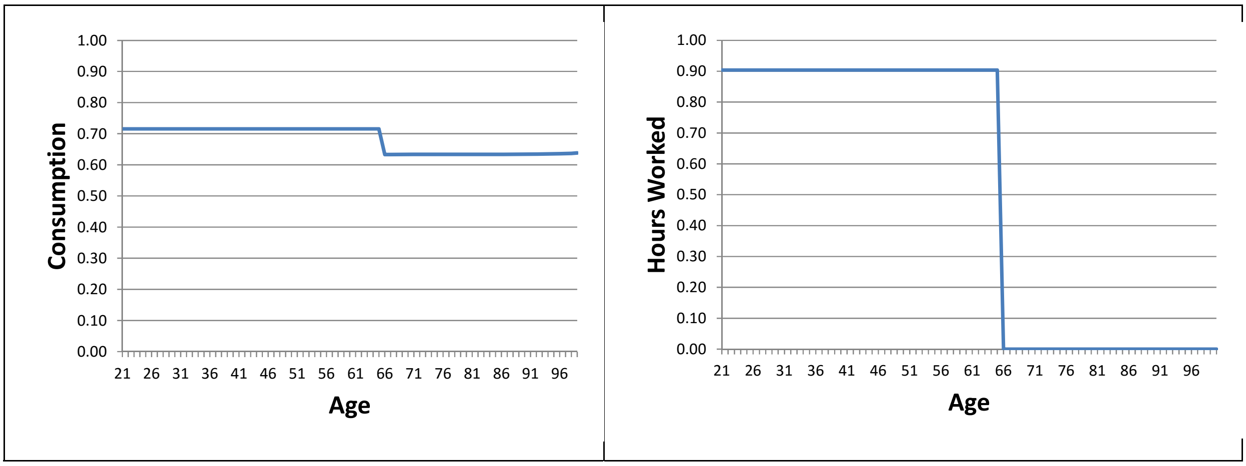
Even stronger, some countries have an exogenously given mandatory retirement age. In this case, households will choose consumption paths for $j\geq R=X$ similar to those depicted in Section 3 which are increasing, flat or decreasing according to the difference between r and ρ.

There is, however, a notable exception from the textbook result of consumption smoothing which is due to the combination of mandatory retirement and the non-separability of the utility function (4.1) between consumption and leisure. Since mandatory retirement forces a sudden increase of leisure at retirement upon the household, there will be a sharp drop in consumption after retirement depending on the wage level and the replacement rate, as shown in Figure 4.2, explaining at least part of the retirement consumption puzzle described in Subsection 3.2. Consequently, active saving and assets at retirement are lower in this augmented model which gives utility to both consumption and leisure as opposed to the simple textbook model of retirement saving of Subsection 3.2, which ignores utility from

[27] A mandatory PAYG system requires an earliest claiming age since otherwise workers can completely opt out of the PAYG system by retiring at very young ages.

leisure. In the augmented model, households keep their total marginal utility constant, not only the marginal utility from consumption.

Figure 4.2: Consumption Decline at Retirement



Parameters: rho=r=3%, theta=2%, phi=0.9, replacement rate=60%, sudden death (3.3).

4.2 Retirement decisions and the incentives created by social insurance

Most modern 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 what is colloquially termed the "normal retirement age" $\overline{R}$. Pension benefits $p_{c,t}$ for cohort c born in t-j are then adjusted to the choice of the retirement age within this window. Many governments simply multiply adjustment factors ω_R with the distance to the normal retirement age and increase the pension benefits in proportion:

$$(4.5) \qquad p_{c,j}(R;\omega_R) = p_{c,j}(\overline{R}) \cdot \left(1 + (R - \overline{R}) \cdot \omega_R\right) \text{ for } R_E \leq R \leq R_L.$$

In addition to choosing the consumption path, households of cohort c have to make two retirement-related choices: when to claim benefits (choice of R) and when to exit the labor force (choice of X at which $l_{t,j} = 0$ for $j \geq X$) unless this choice is restricted by an earnings test as described in the previous section.

The parameters ω_R create strong incentives when to claim benefits and when to exit from the labor force. They are often referred to as "actuarial adjustment factors" although the term "actuarial" only applies in a strict sense when the ω_R are computed in a way that keeps the present discounted value of participating in the pension scheme for all households of cohort c independent of their benefit claiming age R:

$$(4.6) \qquad PDV_c(R) = \sum_{j=R}^{\infty} p_{c+j}(R;\omega_R) \cdot \sigma_{c+j,j} \cdot (1/(1+r))^j - \sum_{j=0}^{R-1} \tau_{c+j} \cdot w_{c+j} \cdot \sigma_{c+j,j} \cdot (1/(1+r))^j$$

$$= \text{constant for all } R \in [R_E, R_L].$$

The resulting actuarial adjustment factors depend on the assumed interest rate r and the survival probabilities $\sigma_{c+j,j}$ of cohort c for age j. Since the survival probabilities increase with age, ω_R should increase with R.

Actuarially neutral adjustment factors at age 65 range between 5 and 7% depending on the underlying interest rate (usually 3%) and assumptions about life expectancy (Börsch-Supan, 2004; Queisser and Whitehouse, 2006; OECD, 2015a; Werding, 2007; Gasche, 2012). Pension systems which provide the same retirement benefits independent of retirement age (i.e., $\omega_R = 0$) are not actuarially neutral since they redistribute income from late retirees to those who take early retirement and thus receive the same benefit over a longer time. Thereby, the pension system creates a very strong incentive for workers to retire early, see below. The same holds to a lesser extent if the adjustment factors are lower than their actuarially neutral value. This is the case in many countries (Table 4.1).

Table 4.1: Adjustment Factors ω_R at Earliest Age of Claiming Benefits

Austria	4.2%
Germany	3.6%
France	5.0%
Italy	2.3-2.9%
Spain	6.0-7.5%
Greece	6.0%
Sweden	4.1-4.7%
Finland	4.8%
US	6.67%

The table shows the adjustment factors for statutory early retirement. Many countries have additional pathways not included here. Source: OECD (2015a)

Tables 4.2-4.4 show the results of a simulation model consisting of equations (4.1), (4.2), (4.4) and (4.5) with a constant ω for all $R \in [R_E, R_L]$.[28] The tables depict the choice of retirement age depending on the adjustment factor ω, the preference for consumption over leisure ϕ and the presence of an earnings test. Note that we refer to the "retirement age" when an earnings test forces R=X; otherwise we distinguish between the "benefit claiming age" R and the "labor force exit age" X. The model predicts that the earliest eligibility age R_E, the

[28] We therefore omit the subscript R.

adjustment factor ω and the presence of an earnings test strongly affect labor supply at older ages.

Table 4.2: Retirement Age *R* as a Function of Actuarial Adjustment – Earnings Test

	Actuarial adjustment factor ω					
Utility weight of consumption ϕ	**0**	**2%**	**3%**	**5%**	**7%**	**9%**
.45	60	61	63	65	66	66
.50	60	63	64	66	66	66
.53	60	64	65	66	67	67
.55	60	65	66	67	67	67
.60	64	68	68	68	67	67
.66	69	70	70	69	68	68

Parameters: rho=2%, r=irr=3%.

Table 4.3: Claiming Age *R* as a Function of Actuarial Adjustment – No Earnings Test

	Actuarial adjustment factor ω					
Utility weight of consumption ϕ	**0**	**2%**	**3%**	**5%**	**7%**	**9%**
.45	60	60	61	65	66	66
.50	60	60	61	65	66	66
.53	60	60	62	65	66	66
.55	60	60	62	65	65	66
.60	60	60	62	65	65	66
.66	60	60	63	65	65	65

Parameters: rho=2%, r=irr=3%.

Table 4.4: Exit Age X as a Function of Actuarial Adjustment – No Earnings Test

	Actuarial adjustment factor ω					
Utility weight of consumption ϕ	**0**	**2%**	**3%**	**5%**	**7%**	**9%**
.45	64	70	71	66	67	67
.50	70	74	75	71	68	67
.53	73	76	76	74	71	71
.55	75	78	77	75	75	73
.60	78	81	80	78	78	76
.66	82	83	83	82	82	82

Parameters: rho=2%, r=irr=3%.

In the presence of an earnings test, Table 4.2, the age at which workers start claiming their benefits and exit the labor force is identical. A less than actuarial adjustment ω creates early retirement, especially when the value of leisure is high (low values of ϕ).

Without an earnings test, workers can claim their benefits and keep on working until the utility from consumption is dominated by the utility of leisure and the fixed costs of work. For low values of the actuarial adjustment ω, workers claim as early as possible since the longer period of claiming is not penalized by a sufficiently lower benefit, see Table 4.3. If ω becomes larger, workers shift their claiming age to benefit from higher pension payments; more so, if consumption is valued highly. The optimal claiming age depends on ω relative to the discount rate including mortality risk.

Finally, Table 4.4 shows that the labor force exit age is decoupled from the benefit claiming age. How long individuals work beyond claiming age strongly depends on ϕ, the parameter which denotes the preference for consumption. Moreover, it depends on total income, wage plus pensions. For a more than actuarial adjustment ω, individuals can afford the same consumption without working very long, so the labor force exit age has a hump shape in ω which is particularly pronounced when the utility of leisure is large (low values of ϕ).

The incentives exerted by non-actuarial adjustment factors are also indirectly affecting the demand side of the labor market. Job downsizing and the restructuring of the workforce are often implemented through early retirement that is encouraged by severance payments by the employer. If the adjustment factors in the public pension system are smaller than actuarially neutral, then such severance payments can be lower and still keep the worker indifferent between staying and leaving.

Institutional features such as the size of the adjustment factors and the presence of an earnings test are also important parameters in assessing the success or failure of "flexibilization" policies which try to increase labor force participation of older workers in times of population aging (Börsch-Supan et al., 2015a). With smaller than actuarially neutral adjustment factors, the abolition of an earnings test tends to reduce labor volume, rather than to increase it. Both theoretical models (Gustman and Steinmeier, 2004; Gielen, 2009) and empirical results (Graf et al., 2011; Huber et al., 2013) show that such a policy tends to create higher labor force participation among older workers past normal retirement age, but this is offset by workers who reduce their hours before the normal retirement age. The combination of receiving pension benefits and continuing some attachment to productive work as an avenue to attenuate the negative implications of population aging is under-researched so far.

4.3 Empirical models of the retirement decision

Since raising labor force participation for older workers is an important policy option to adapt pension systems to population aging, a lot of empirical work has been focused on the actual size of the incentive effects discussed in the previous subsection and its impact on the employment of older workers (cf. chapter by Blundell et al. in this handbook).

The cleanest way to exploit the economic structure of the households decision is to set up a dynamic programming model defined by the optimization model (equations 4.1 through 4.3) and the institutional restrictions (equations 4.4 or 4.5), estimate its behavioral parameters ϕ, ρ, θ, etc., and then predict saving and labor supply behavior for different retirement policies expressed by R_E, $\overline{R}$, ω_R, etc. Examples for this approach are Gustman (1986), Rust (1990), Berkovec and Stern (1991), and Rust and Phelan (1997). Estimation by maximum likelihood or similar methods iterates in an outer loop over the behavioral parameters while an inner loop determines the optimal saving and labor supply path over the life cycle. These models produce very specific results (e.g., Gustman and Steinmeier (2005) on the joint determination of retirement and wealth; Gustman and Steinmeier (2009) on the synchronization of retirement decisions between spouses; and Gustman et al. (2010) on partial un-retirement). These results are achieved with great precision, e.g., reproducing the spikes of the retirement hazard at certain ages. However, they involve considerable computational effort and are highly sensitive to specification errors.

A more robust reduced form approach that requires less computational effort is based on the option value to postpone retirement which captures all the impacts of the various pension rules on retirement behavior in a single incentive variable (Stock and Wise, 1990). Since it has generated a string of analyses of the incentives created by US occupational pension plans and by public PAYG pension schemes in many developed countries, we describe this model in more detail. For simplicity, we assume no difference between claiming and labor force exit age, $R=X$. The option value then expresses for each retirement age the trade-off between retiring now (resulting in a stream of retirement benefits that depends on this retirement age) and keeping options open for some later retirement date (with the streams of first labor income, then retirement benefits associated with all later retirement ages).

More formally, let $V_S(R)$ denote the expected future utility discounted to current age S if the worker retires at age R, specified as follows:

$$(4.7)\quad V_S(R) = \sum_{j=S}^{R-1} v(w_j)\cdot\sigma_j\cdot\beta^{j-S} \;+\kappa \sum_{j=R}^{\infty} v(p_j(R;\omega_R))\cdot\sigma_j\cdot\beta^{j-S},$$

where w_j is labor income at age j, $p_j(R;\,\omega_R)$ pension benefits for retirement age R defined by equation (4.6), and indirect utility from income represented by an isoelastic utility function $v(y) = y^{\gamma}$. To capture utility from leisure, utility during retirement is weighted by $\kappa \geq 1$, where $1/\kappa$ is the marginal disutility of work. Utility is discounted by survival probability σ_j and the pure discount factor $\beta = 1/(1+\rho)$. Note that the parameters $(\gamma,\ \kappa,\ \beta)$ in (4.7) correspond to the parameters $(\theta,\ \phi,\ \beta)$ in (4.1) and (4.2), but the functional form of the utility function is quite different from the Cobb-Douglas-type function (4.1).

Let $R^*(S)$ denote the optimal retirement age if the worker postpones retirement past age S:

$$(4.8)\quad \text{argmax}\ [V_S(R)] \text{ for } R>S.$$

Then the option value to postpone retirement from age S to a later age is defined as

$$(4.9)\quad OPTV(S) = V_S(R^*(S)) - V_S(S).$$

The key assumption of the option value model of retirement is that a worker will retire as soon as the utility of the option to postpone retirement becomes smaller than the utility of retiring now. Hence, in a logit or probit regression of the type

$$(4.10)\quad \text{prob(retired at age } S) = f(OPTV(S), \text{ other covariates})$$

retirement probabilities should depend negatively on the option value.

The option value model is only an approximation to the true underlying maximization problem.[29] It has been successfully applied in a series of papers on US pension plans (Stock and Wise, 1990; Lumsdaine et al., 1992; Venti and Wise, 1995), public PAYG pension systems around the world (Gruber and Wise, 1998; 1999; 2004; 2010) and the sequence of German pension reforms between 1992 and 2007.[30]. The model has also been extended to the joint retirement decision of couples (Coile, 2004) and the choice among multiple retirement pathways including disability pensions (Butler et al. (2003) and Börsch-Supan (2001) with an instrumental variable interpretation).

The arguably most powerful result from these estimations is depicted in Figure 4.3 originally developed by Gruber and Wise (1999). This figure and the OECD's variant by Blondal and

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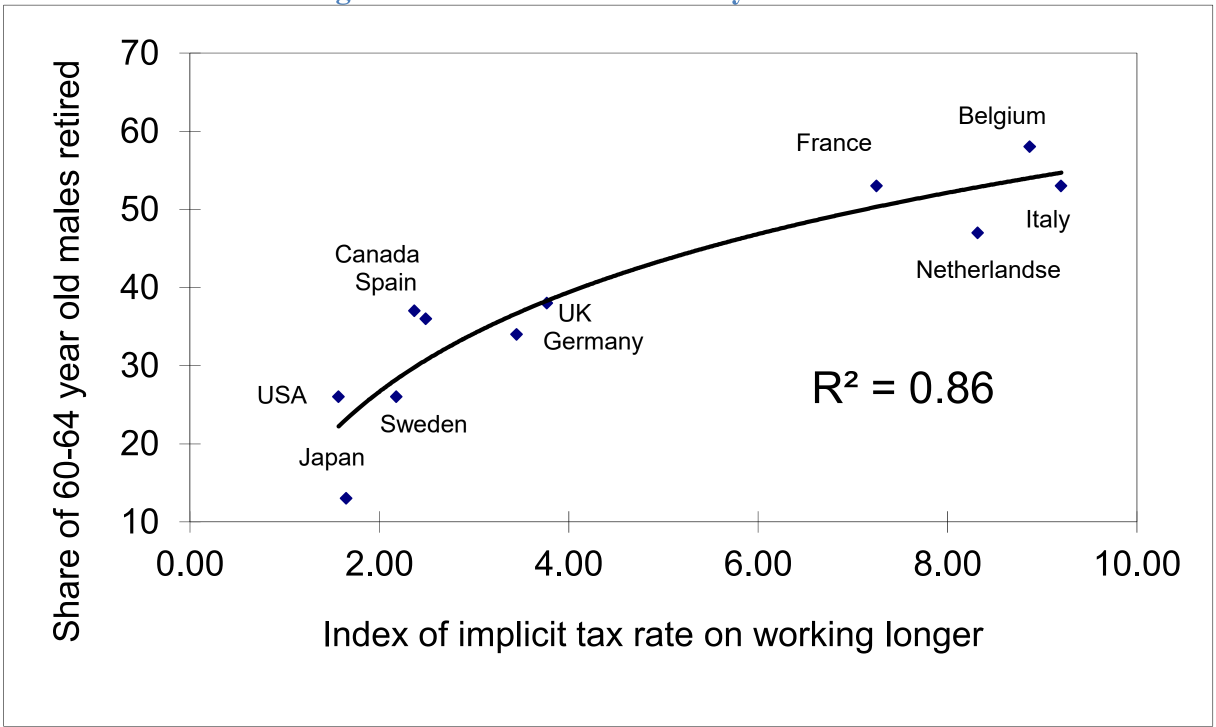
[29] Lumsdaine et al. (1992) and Butler et al. (2003) perform a comparison with the full maximization model.

[30] Börsch-Supan (1992), Börsch-Supan and Schmidt (1996), Siddiqui (1997), Börsch-Supan (2000a; b) and Börsch-Supan et al. (2004), Berkel and Börsch-Supan (2004).

Scarpetta (1999) were very influential to convince politicians to start abolishing early retirement incentives in the parametric pension reforms of the early 2000s.

Figure 4.3: Tax Force and Early Retirement



Source: Adapted from Gruber and Wise (2010)

It plots the share of early retirees against the "implicit tax of working longer" which results from the combination of an earnings test with the non-actuarial adjustment factors ω_R in equation (4.5). It is defined as

(4.11) $TAXR(R) = - [SSW(R) - SSW(R\text{-}1)] / w_{R-1}$,

where w_{R-1} is wage income just before retirement and social security wealth

(4.12) $$SSW(R) = \sum_{j=R}^{\infty} p_{c+j}(R;\omega_R) \cdot \sigma_{c+j,j} \cdot (1/(1+r))^j$$

the first term of equation (4.6).

Figure 4.3 links an index of this implicit tax to the share of those men who are already retired at age 60-64. In countries with a large implicit tax on working longer (e.g. Belgium, France, Italy and the Netherlands), the share of retirees is much larger than in countries with a low implicit tax (e.g. Sweden, the US and Japan). The corresponding microeconometric analyses (Gruber and Wise, 2004) exploiting cross-national and time-series variation in retirement policies permit a causal interpretation of Figure 4.3. A particularly striking historical example for the exogenous policy change that can be exploited for a causal interpretation is the German pension reform in 1972 and its reversal in 1992.[31]

The option value model as a device for econometric estimation of the underlying structural parameters (e.g., time preference and the disutility of labor) has two shortcomings. First, as pointed out, the description of the full utility maximization problem by the option value calculus is only an approximation (Lumsdaine et al., 1992; Rausch, 2016). When inserted in a discrete choice model (equation 4.10), it should be interpreted as a reduced form approach. Second, the specification of the value of leisure by the work disutility parameter κ in (4.7) implies that the utility from leisure is bound from above, violating the textbook conditions for utility functions (Börsch-Supan, 2014). Both shortcomings may explain the poor results observed in many European countries which have participated in the Gruber-Wise exercise where leisure (here: early retirement) is more highly valued than in the United States (Gruber and Wise, 2004).

4.4 Labor supply disincentives for workers

Contributions to a mandatory pension system are taxes to the extent that there are no benefits which are equivalent to the contributions. Such taxes have negative incentive effects. Since contributions to public pension systems are mostly based on labor income, they exert labor supply disincentives for workers (Blundell et al., 1998; chapter by Blundell et al. in this handbook).

There are several sources of non-equivalence. First, benefits may have no linkage to contributions at all. In a textbook Beveridgian system, contributions are levied on individual-specific wages but the system pays the same flat pension benefit to all retirees. Contributions are thus pure taxes since a marginal increase of labor supply does not increase pension benefits.

The textbook Bismarckian earnings-related system, on the other hand, applies an equivalence principle between contributions and benefits where benefits for individual i are given by:

(4.13) $p_{t,i} = q_t \cdot w_t \cdot \psi_{R,i}$.

[31] Cf. Börsch-Supan and Schnabel (1998), Börsch-Supan (2000), Gruber and Wise (2004).

Here q_t denotes the replacement rate which relates pensions to the aggregate wage level w_t. In addition, benefits are proportional to an individual component $\psi_{R,i}$ which depends on the contribution history of this individual up to the benefit claiming age R.

In many systems, this contribution history is captured by a point system. Workers earn one earnings point if they receive average wage income in a given period, and more or fewer points if they earn more or less than that. The points $\psi_{j,i}$ accumulate over the working life according to

$$(4.14)\quad \psi_{j+1,i} = \psi_{j,i} + \frac{\varepsilon_{j,i} l_{j,i}}{\bar{l}}.$$

The productivity of worker i at age j is denoted by $\varepsilon_{j,i}$, normalized to 1 for the average worker who supplies $\bar{l}$ units of labor. If productivity exhibits large heterogeneity across individuals, deviations from non-equivalence are large in Beveridgian systems while Bismarckian systems extend productivity-induced inequalities during working life into retirement.

In notional defined contribution systems (Subsection 2.3), the link between contributions and benefits is even more transparent since the individual notional account displays the annual accumulation of contributions and the notional interest on it in easily perceivable currency units. Relative to a flat-benefit Beveridgian pension system, labor supply distortions should therefore be smaller in the earnings-related Bismarckian, point and NDC systems.

Equation (4.13) is deterministic. However, future benefits are uncertain due to demographic, productivity and political risks. A second source of non-equivalence comes from deviations in expectations. Opinion polls regularly report a large share of especially younger workers who "do not have trust in the US Social Security system" (Walker et al., 2014) or "expect much lower benefits than currently promised" (Boeri et al., 2002). For these pessimistic workers, a pension system creates potentially large labor supply disincentives.

A third source of non-equivalence is that households may have choices which yield a higher rate of return. If the rate of return on the capital market r exceeds the implicit return of the pension system *irr*, then any mandatory PAYG system, even if it is a Bismarckian, point or NDC system without pessimism about future benefits, creates labor supply distortions due to the lost opportunity to invest in the capital market with a higher rate of return (Börsch-Supan and Reil-Held, 2001).

Finally, the optimal saving plan for a household may deviate from the contribution rate to the PAYG system. Mandating a fixed saving rate creates additional distortions even if benefits are equivalent to the mandated contribution rate because the additional benefits are worth less than those implied by the household's optimal saving plan (Summers, 1989).

Since contributions to social insurance are a large part of total labor compensation in most aging countries, modelling the resulting distortions is an important issue in predicting the macroeconomic implications of population aging (Sections 5-7).

4.5 Restrictions on labor supply

Another matter of controversy in the literature is the extent to which restrictions on labor supply should be embedded in models of retirement. In many countries employers effectively restrict the minimum hours which an employee may supply. The rationale for such restrictions is the presence of fixed costs in employing a worker. Gustman and Steinmeier (1983) cite empirical evidence that this is particularly salient for the US. They show that a minimum hours' constraint changes retirement behavior since older workers may prefer part-time but are forced to decide between full-time work and full-time retirement. The dynamic programming model by Gustman and Steinmeier (1984) predicts that the typical minimum hours' constraint in the US generates earlier retirement than in the case of unrestricted hours.

There are also restrictions on the maximum amount of labor households may supply. The most prominent example is the 35-hour week imposed by French law but there are many other more subtle institutional constraints by which labor markets and pension systems limit labor supply. Examples are the earliest labor market entry age generated by the school system which constrains the labor force participation of the young; mandatory or quasi-mandatory retirement ages which limit labor force participation of the old; inflexible working hours and unavailable day care facilities which constrain female labor force participation.

Such labor market restrictions are important in understanding the effect of structural reforms in Europe, including reforms of the pension system (Section 6). The effect of lifting labor supply restrictions through labor market and pension reforms (i.e., changing the extensive margin) depends on the number and extent of households whose labor supply (the intensive margin) has been restricted before the reform. This can be modeled by distinguishing between an exogenous and an endogenous labor supply component (Börsch-Supan et al., 2014). We split labor supply, $l_{t,j}$, in equations (4.1) through (4.3) into an exogenous component, $l_{t,j}^{EXOG}$,

[32] These are different from ξ in equation (4.1).

which denotes the maximum labor supply constraint exerted effectively by labor market and pension regulations, and a second component, $l_{t,j}^{ENDO}$, which denotes the endogenous decision by the household how much of the maximum supply the household actually desires to work:

(4.15) $0 \le l_{t,j}^{ENDO} \le 1$.

When the age-specific exogenous labor supply component is increased, e.g., due to an increase in the retirement age, the household may endogenously decrease $l_{t,j}^{ENDO}$, thereby undoing the reforms' intention. However, if the household was constrained in its labor supply before the reform ($l_{t,j}^{ENDO}$=1), it will now increase its labor supply. Hence, the exogenous variation of $l_{t,j}^{EXOG}$ affects total labor supply only for those households for whom constraint (4.15) is binding and has a smaller effect on aggregate effective labor supply than in models with exogenous labor supply.

5. The macroeconomics of pension systems in an aging population

So far, we have taken wages and the rate of return from productive capital as given in order to study individual behavior in the framework of a partial equilibrium. The effects of population aging on pension systems, however, also depend on how wages and returns change as populations age (e.g., National Research Council, 2012). Wage growth is a key parameter for the internal rate of return of PAYG pension systems while the rate of return is important in determining wealth at retirement. This and the following sections therefore take a macroeconomic point of view. We will investigate how wages and returns evolve in a general equilibrium when populations age and pension systems change. Since it is important to get the orders of magnitude right, we employ several variants of computational general equilibrium (CGE) models with an overlapping generations (OLG) structure that permits a quantitative assessment of future relative price changes (i.e., wages and returns). The main focus of our analysis will be on the dependence of such price changes on the current design and future reforms of the pension systems in countries undergoing population aging.

It is important to introduce an international dimension into these analyses because wage growth and rates of return in an open economy will react to the large cross-country differences in the timing and extent of population aging (Reisen, 2000; Rios-Rull, 2001; Brooks, 2003; Börsch-Supan et al., 2006; Attanasio et al., 2007; chapter by Attanasio et al. in this handbook). We follow Börsch-Supan and Ludwig (2013) and focus on the three largest countries of Continental Europe – France, Germany and Italy, denoted by EU3 – as one country and the US as the other country. We choose these countries as this chapter's core example for several reasons: the three European countries' populations have already substantially aged, they have large public PAYG-DB pension systems and their unsustainability has already received prominent attention. Moreover, these countries have labor markets characterized by many restrictions. The US, in turn, has a much smaller Social Security system, fewer labor market restrictions and a much less pronounced and considerably later population aging process.[33]

The following subsection introduces the model. It uses the building blocks from the earlier sections, closes the model with a simple production sector and computes the general equilibrium with three dimensions of international exchange. First, there is trade in the goods

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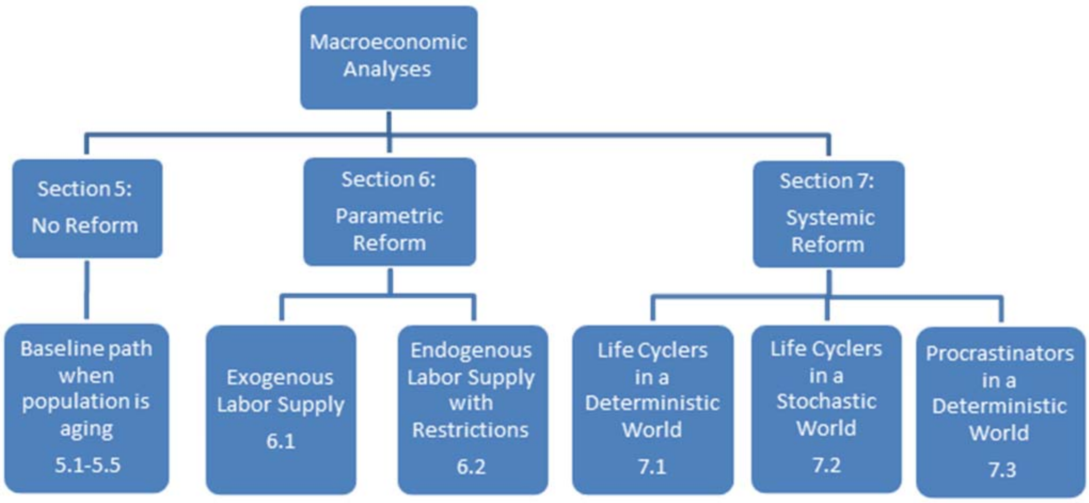
[33] Börsch-Supan and Ludwig (2009) provide variants which include aging in Asia. They show that economic growth in China and India affects the sustainability of pension systems elsewhere; effects are both positive and negative. International spillovers are also generated by structural reform Japan.

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.

We will then compute the baseline paths of output, consumption, wages and rates of return, when current policies are maintained (Subsections 5.3 through 5.5). The basic lesson here is that demography does not translate one-to-one into economics since there are price-driven adaptations to population aging which make it easier for pension policies to tackle the challenges of population aging. We will then use the model to investigate the power of parametric reform (Section 6) and finally discuss the pros and cons of systemic reform (Section 7). Figure 5.1 gives an overview of the macroeconomic analyses.

Figure 5.1: Macroeconomic Analyses



5.1 Model structure

The CGE model has four building blocks: demography, household behavior, pension system and production sector.

Demography is described by the initial size of each cohort, equation (2.2), the survival of that cohort, equation (2.1), and additions through net migration. We treat all three demographic forces as exogenous. 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 (equation 2.1). This generates the OLG structure of the CGE model which is essential for modelling many pension-specific issues such as annuitization and the intergenerational transfers within PAYG systems.

The second building block is *household behavior* which has been specified in several variants in Sections 3 and 4. For the macroeconomic analyses in this and the following section, we use three variants. The first and conventional variant is a household choosing consumption and labor supply according to the perfect-foresight utility maximization program (4.1) and (4.2), subject to the budget constraint (3.5), and an exogenous retirement age with pension income given by (4.4). As a second variant, we introduce labor market restrictions according to (4.15). The third variant deviates from the neo-classical set-up and models present-bias and procrastination according to equations (3.11) to (3.14).

In all three variants, household behavior is strongly affected by the third building block, the *pension system*. This is modelled according to the variants described in Section 2.

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

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

where $K_{t,i}$ denotes the capital stock and $L_{t,i}$ is aggregate efficient labor volume in country *i* at time *t*. α denotes the capital share and $A_{t,i}$ the technology level of country *i*. We will treat productivity as exogenous in this and the following section. This applies to both the efficiency component in $L_{t,i}$, equation (4.14), and the technology level $A_{t,i}$ which is assumed to grow at an exogenous rate *g*. For the theoretical discussion in Section 7, we will weaken this assumption and discuss the underlying mechanisms that may affect productivity.

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

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

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

where k_t is the capital stock per productivity weighted unit of labor and Δ is the depreciation rate of productive capital.[34]

[34] As opposed to the household models in Sections 3 and 4, the interest rate *r* in this section refers to r^{MKT} in equation (2.13).

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 $\{c_{t,j,i}, l_{t,j,i}, a_{t,j,i}\}$, sequences of aggregate quantities $\{L_{t,i}, K_{t,i}\}$ 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 various behavioral models in Sections 3 and 4, factor prices equal their marginal productivities according to equations (5.2) and (5.3), the PAYG-financed pension systems satisfy the balancing condition (2.5), and all markets clear in every country and every period:

(5.4) $$L_{t,i} = \sum_{j=0}^{\infty} l_{t,j,i} N_{t,j,i} \quad \text{for all } t,i\,,$$

(5.5) $$\sum_{i=1}^{I} K_{t+1,i} = \sum_{i=1}^{I} \sum_{j=0}^{\infty} a_{t+1,j+1,i} N_{t,j,i}\,,$$

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

5.2 Numerical solution and calibration

The model has to be solved numerically. 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 2005 until 2050 to encompass the historical time in which the parametric reforms analyzed in Section 6 took place and the main period of population aging following these reforms.[35]

We determine the equilibrium path of the overlapping generations model by using the modified Gauss-Seidel iteration as described in Ludwig (2006). The algorithm searches for equilibrium paths of capital to output ratios, and, in case there are social security systems, pension contribution rates in each country.

[35] 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.

Calibration is based on an *ad hoc* choice of parameters by reference to other studies. The consumption weight in the utility function (4.1) ϕ determines the relative preference for labor versus leisure. In the model variant with labor supply restrictions it thereby also determines the number of households at the constraint (equation 4.15). We set $\phi=0.66$ which corresponds with the value determined by minimum distance methods in Börsch-Supan et al. (2006). The structural model parameters are summarized in Table 5.1 below. All parameter values refer to an annual periodicity.

Table 5.1: Structural Model Parameters

α: capital share in production	0.4
g: growth rate of labor productivity	0.015
Δ: depreciation rate of capital	0.05
A_i: technology level	0.05 - 0.07
β: discount factor	0.99
θ: coefficient of relative risk aversion	2
ϕ: consumption share parameter	0.66

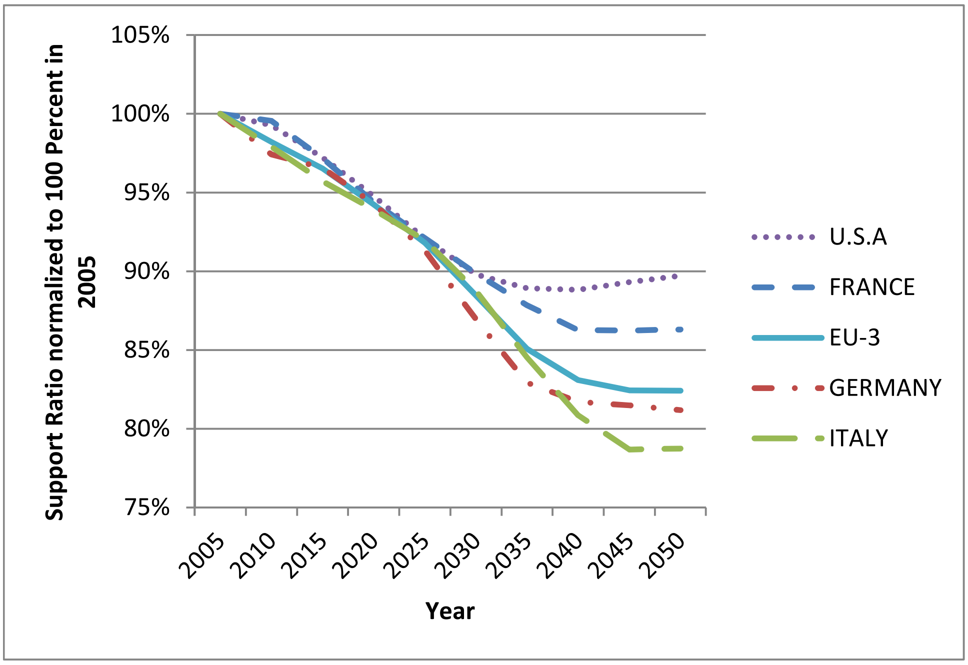
Such *ad hoc* calibration is typical for the literature but is a serious weakness reflecting the lack of a well-defined identification strategy for the underlying deep parameters. A particularly weak spot is that most macromodels which analyze pension systems and population aging have a simple production technology such as presented above. These models fail in achieving a credible marginal product of capital and a credible capital-output ratio at the same time: either the capital-output ratio is close to the value in national accounting, then these macromodels generate very high interest rates (Feldstein and Samwick, 1998; Kotlikoff, 1996; 1998; Imrohoroglu et al., 1995), or models are fitted to risk-adjusted rates of return to productive capital, then capital-output ratios become very high. The choice between these two extremes governs the difference between the market interest rate r and the internal return of PAYG-financed pension systems *irr* and has therefore large implications for assessing the welfare implications of systemic pension reform (cf. Section 7).

5.3 Conventional model variant: Baseline

The baseline path continues the historical status quo around the year 2005 before the stylized reforms of the pension systems and labor market restrictions described in Section 6 were initiated. It is therefore defined by constant age and gender-specific labor force participation rates and a constant replacement rate in the four countries' PAYG-DB systems according to equation (2.8). The exogenous force driving the general equilibrium model is then population aging modelled as an increase in the survival rates $\sigma_{t,j}$ and a decrease in the fertility rates $f_{t,j}$. Note that demographic change occurs both during the life-cycle of each household and across cohorts of different households. The following figures show the difference to a hypothetical EU-3 economy with no population aging and the same productivity growth such that the graphs isolate the effect of population aging on the macroeconomic aggregates.

As the population of the EU3 countries age, the support ratio declines by 18 percent from 2005 until 2050, with a substantial variation across the three countries (Figure 5.2). The decline is substantially smaller in the US.

Figure 5.2: Support Ratio, Indexed to 2005=100%

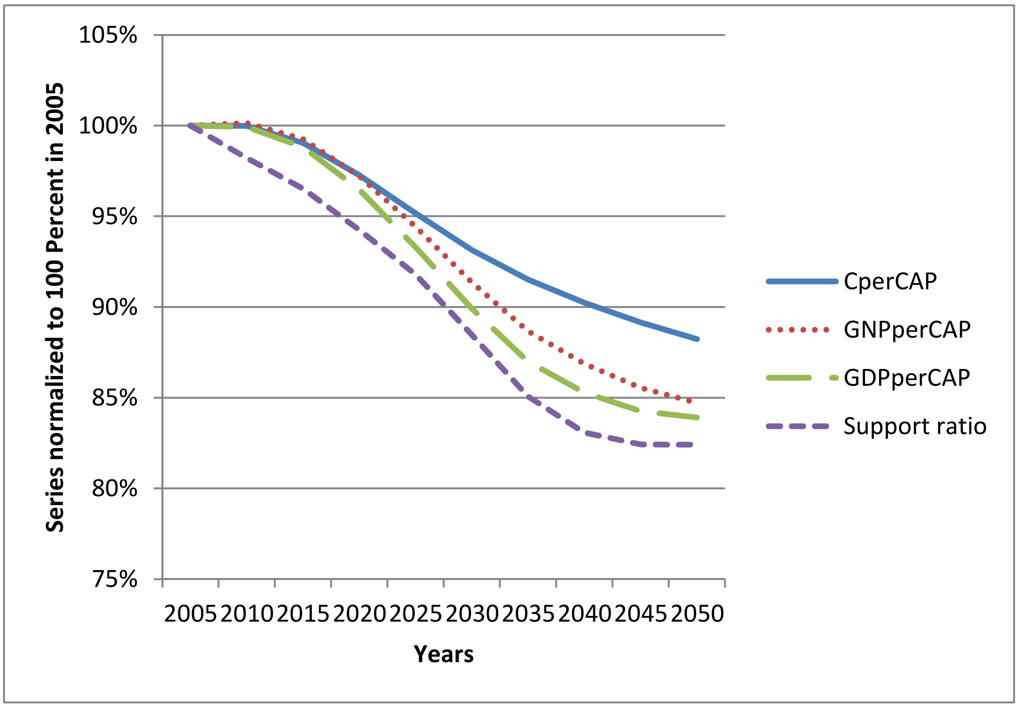


Source: Own projection. Working age is age 15 to 64.

5.4 GDP, wages, interest rates, and capital-labor substitution

The decline in the support ratio causes GDP per capita to shrink by 16 percent in the EU3 countries relative to a non-aging economy with the same total factor productivity if policies and behavior were to remain at the current status quo (Figure 5.3).

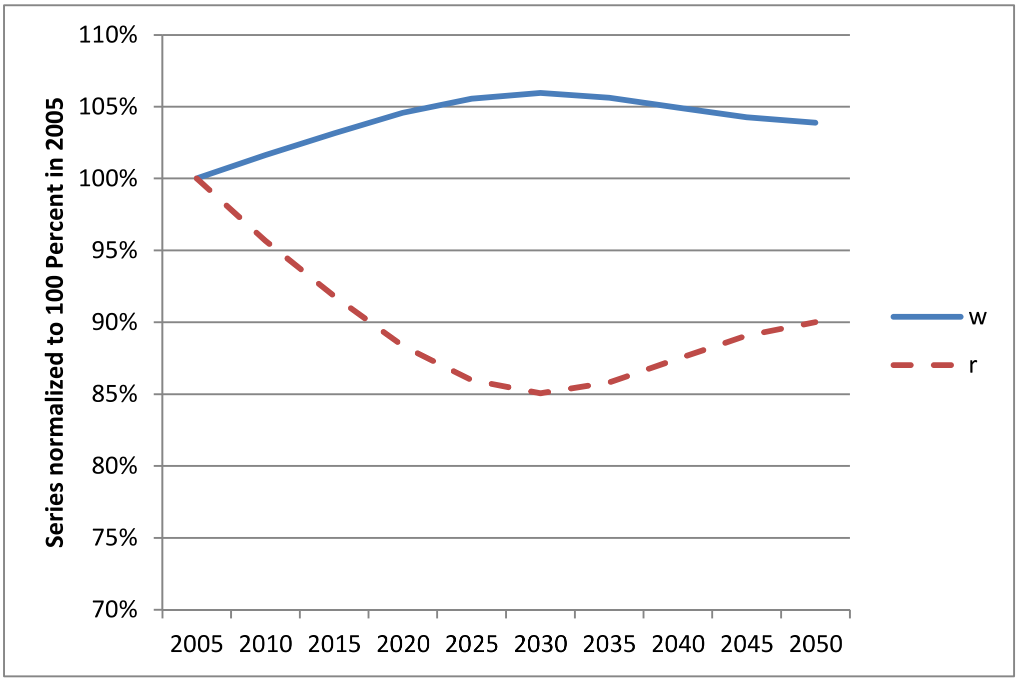
Figure 5.3: Baseline Labor Supply, GNP, GDP and Consumption per Capita, Detrended



Note: Authors' computations. Variables in the left panel are normalized to 100% in 2005 and net of TFP trend. Support ratio refers to a working age of 15-64.

The decline in GDP per capita is smaller than the reduction of the support ratio because scarce labor due to population aging is partially substituted by additional capital. This adaptation of the production sector occurs in response to rising wages and a declining interest rate which makes a more capital-intensive production profitable (Figure 5.4).

Figure 5.4: Wages and Returns to Productive Capital



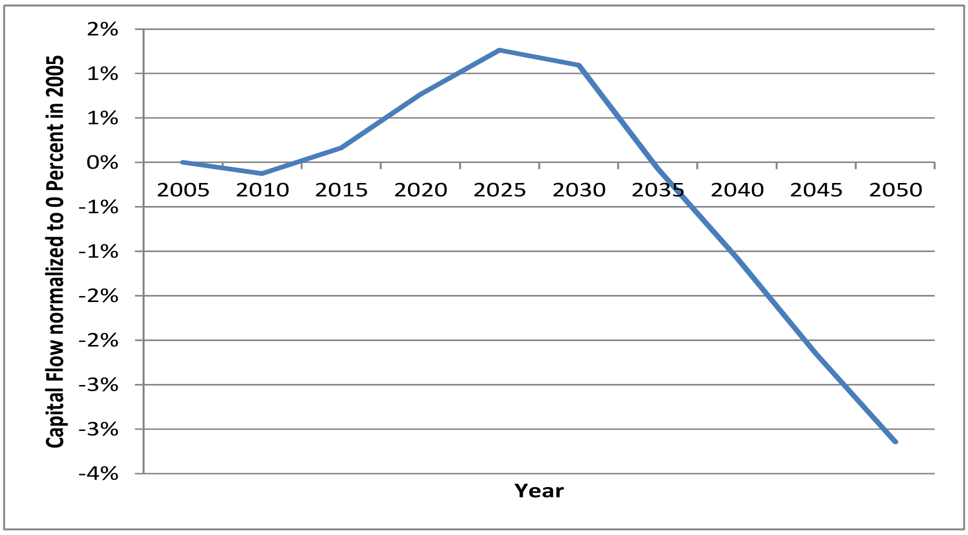
Source: Own projection.

Figure 5.4 shows that the relative decline in the rate of return from productive assets is substantial. Due to this macroeconomic feedback effect, FF pension systems are not immune against population aging in spite of having no direct intergenerational linkages which characterize PAYG systems. However, the decline does not amount to an asset meltdown (Poterba, 2004). Expressed in absolute values, an initial rate of return of 5 percent will decrease to 4.25 percent in 2030 and slightly recuperate to 4.5 percent in 2050. The demographically induced relative wage increase amounts to 6 percent.

5.5 GNP, consumption and international diversification

Figure 5.3 also depicts the path of GNP which includes, as opposed to GDP, income from assets invested abroad. De-trended GNP is larger than de-trended GDP. This difference is caused by international capital flows which are induced by population aging. Since the US is aging less than the EU3, the return to capital in the US would fall less (and wages increase less) than in the EU3 countries 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 disaggregate life-cycle point of view, such behavior differs according to age. Households will eventually repatriate their foreign savings according to the life-cycle mechanism underlying equations (4.1) and (4.2) in order to finance their retirement consumption. The aggregate effect depends on the timing and relative extent of the aging process. The large cohort sizes born in the 60s and 70s lead to first rising, then falling net capital outflows from the EU3 countries into the US until they turn negative after about the year 2035 (Figure 5.5).

Figure 5.5: International Capital Flows from EU3 to US (Percent of GDP)



Source: Own projection. Capital flows are saving minus domestic investment in Europe, relative to GDP and normalized to a balance of zero in 2005.

The predicted international capital flows reach 1.5% of GDP in 2025. They would be even larger if this model were to include the large emerging economies in Asia. Börsch-Supan and Ludwig (2009) provide several examples. They show that the international capital flows are very large in the short term while they are much smaller in the long-term because the high speed of the population aging process in Asia generates a convergence of population structures in Asia and Europe.

Capital-labor substitution and international diversification are economically substantial in the sense that consumption per capita falls much less than the support ratio (Figure 5.3). While the support ratio will shrink by 18 percent, consumption by capita will decline by only 12%. Hence, the main lesson from this section is that even without any policy changes, an aging economy will adapt endogenously in response to rising wages, falling interest rates and new opportunities in younger countries abroad. This result depends on the flexibility in the production process and the ability to invest retirement savings abroad, i.e., the ability of wages, interest rates, trade and foreign direct investment to adjust freely as assumed by our neoclassical CGE model. If this is the case, pension reform is less of a daunting task than suggested by purely demographic projections which ignore the economic feedback effects. If the aim of reform is to maintain consumption per capita, then one third of the job is done by endogenous adaptation while two thirds remain to be done by parametric (Section 6) or systemic reform (Section 7).

6. Parametric pension and labor market reform

Parametric reform changes the parameters of a given system without changing the nature of the system. In Europe, parametric pension and labor market reform has been on the agenda since the 1990s in order to relieve some of the restrictions on labor markets. This increase of labor supply is supposed to offset the decline of the demographic support ratio in the course of population aging. 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. 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.[36] Moreover, the German parliament decided in 2007 to gradually increase the statutory retirement 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. 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 this section, we demonstrate the effects of a prototypical reform package that is motivated by these historical interventions. 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 2010 and 2030 in our EU3 model economies. We distinguish two cases. First, we assume that labor supply is exogenous. Hence, the reforms increase labor supply to their full extent (Subsection 6.1). Alternatively, we assume that labor supply is endogenous but faces upper limits for labor supply which are partially lifted by the reform (Subsection 6.2).

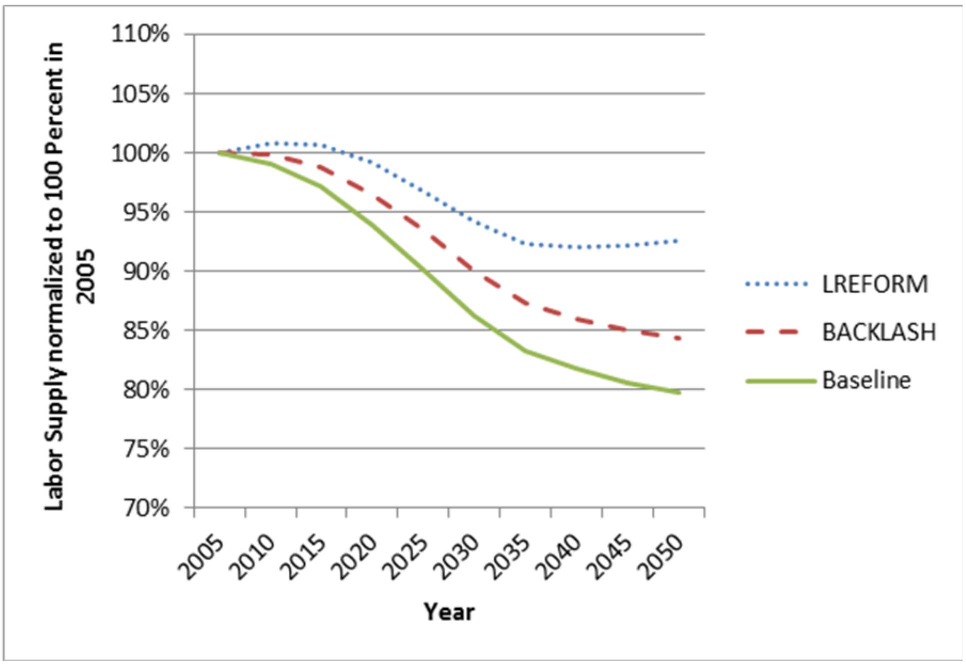
[36] Defined as the rate of unemployment that prevents inflation from accelerating (NAIRU, Ball and Mankiw, 2002).

6.1 Exogenous labor supply

Figures 6.1 to 6.4 show the potential power of such a parametric reform package. The difference between the lower solid line (baseline without reform) and the upper dotted line (LREFORM) represents the reform effects in the exogenous labor supply scenario.

Figure 6.1 depicts total hours worked. The decline in the total labor volume due to population aging in the EU3 economies is offset by more than a half through the reform. Hours worked would even increase between 2005 and 2015 and again after 2040.

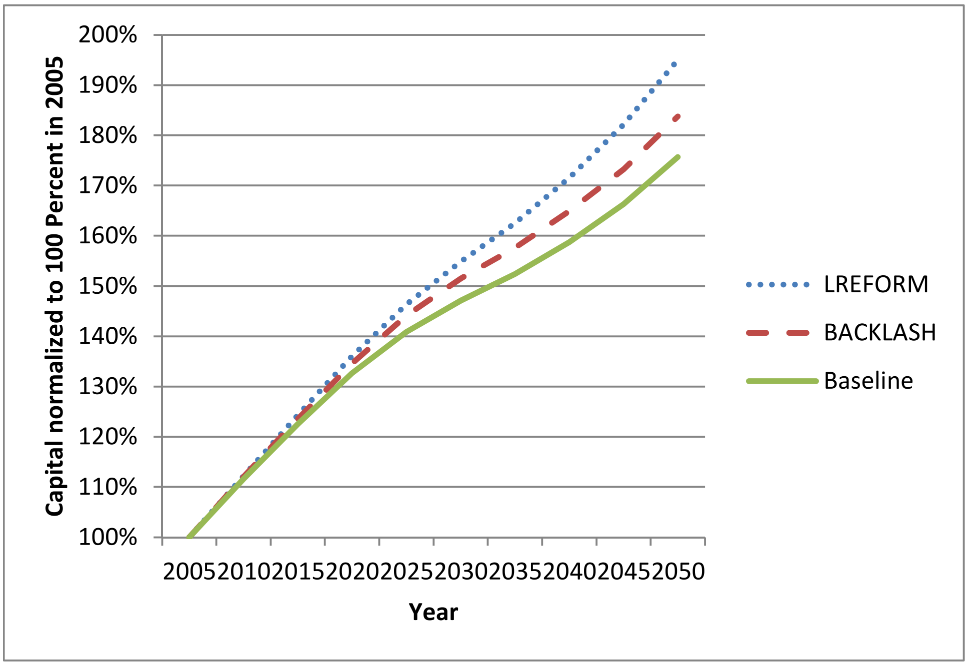
Figure 6.1: Parametric Reform: Total Hours Worked



Note: Authors' computations. Normalized to 100% in 2005.

In addition, saving and investment react to the parametric reform, leading to an increase in the domestic capital stock relative to the baseline scenario (Figure 6.2).

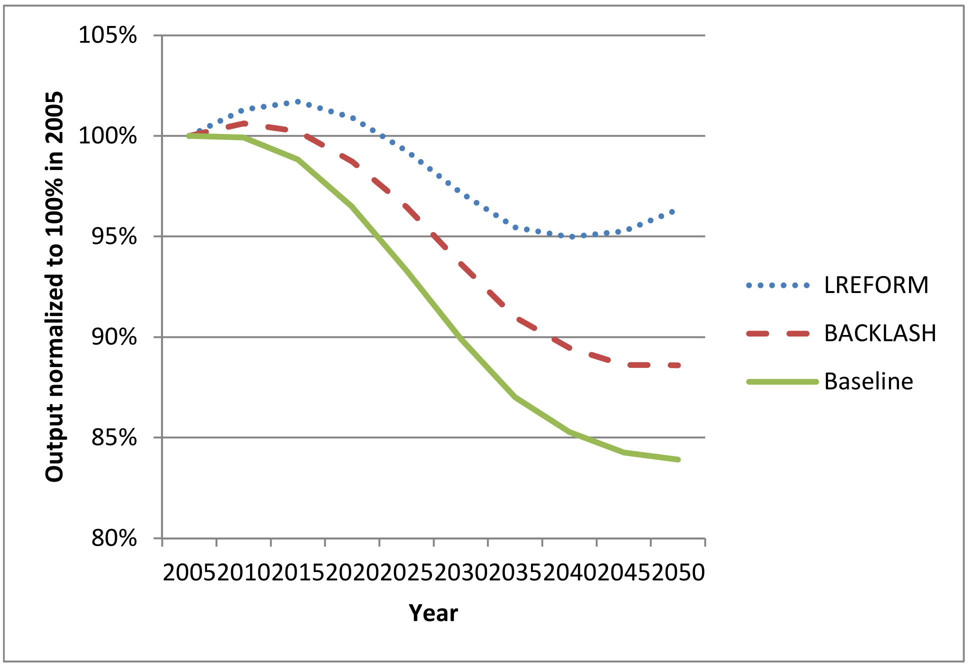
Figure 6.2: Parametric Reform: Capital Stock



Note: Authors' computations. Normalized to 100% in 2005.

Since both factors of production increase, the effect of the reform package on GDP per capita is larger than the increase in employment (Figure 6.3).

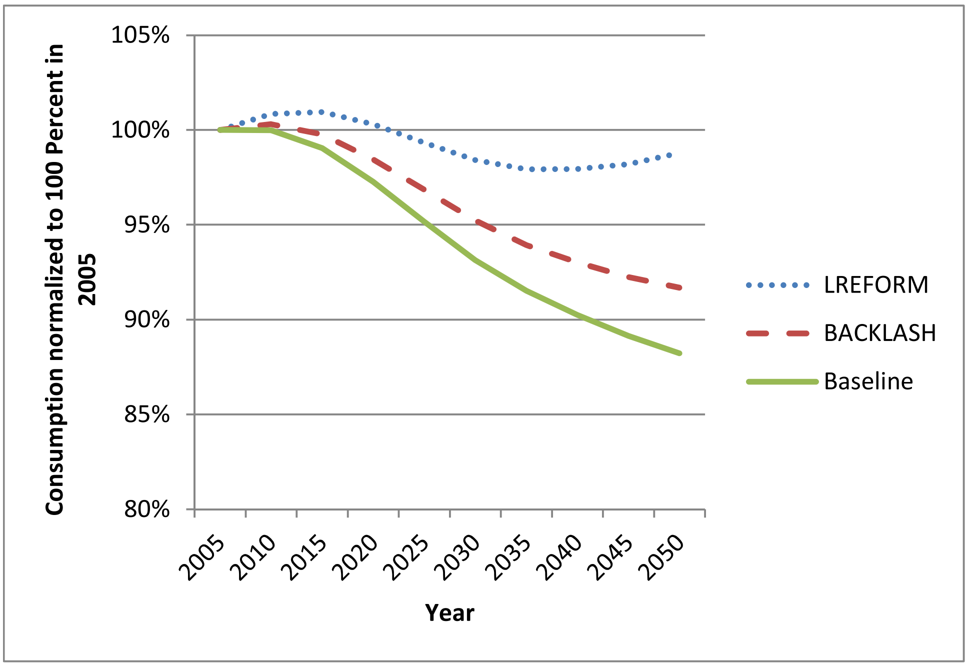
Figure 6.3: Parametric Reform: GDP per Capita



Note: Authors' computations. Normalized to 100% in 2005 and net of TFP growth.

Furthermore, some of households' savings flow from the aging EU3 countries abroad to the US which undergoes a less pronounced aging process. These savings will eventually be repatriated and will then increase consumption per capita stronger than per capita GDP (Figure 6.4).

Figure 6.4: Parametric Reform: Consumption per Capita

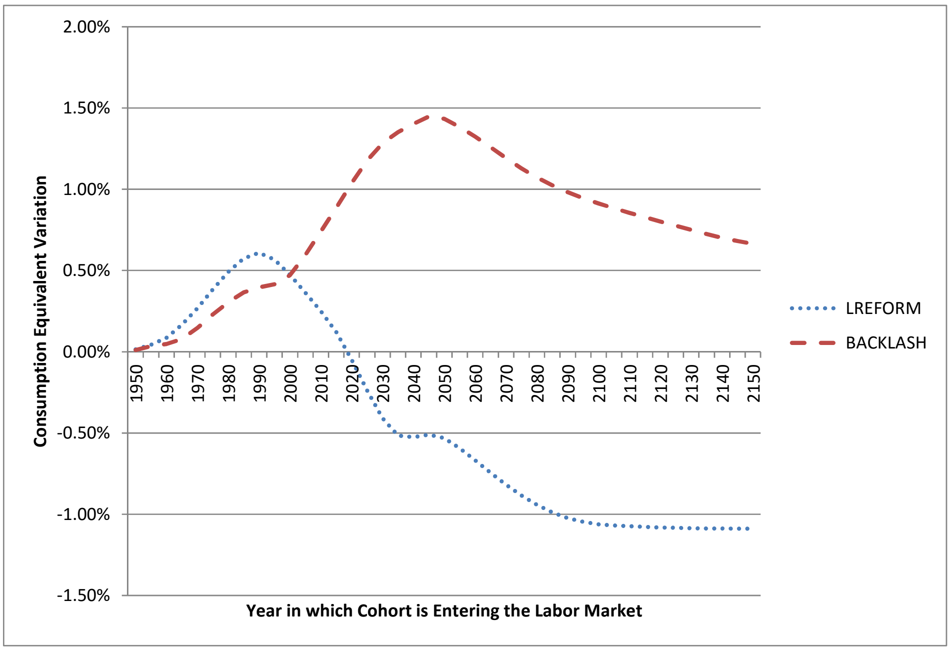


Note: Authors' computations. Normalized to 100% in 2005 and net of TFP growth

As a result, this relatively moderate parametric reform package is able to essentially stabilize economic living standards in Europe, here measured as per capita consumption, in spite of strong population aging -- if labor supply reacts to the extent which was intended by the reform package.

The welfare effects of this stylized parametric reform package depend on the birth cohort. Welfare gains created by higher consumption are offset by less leisure for the workers. Hence, pensioners gain while workers may lose. This is depicted by the dotted line in Figure 6.5. Welfare is measured as consumption equivalent variation relative to the baseline scenario in Section 5. Workers entering the labor force after 2020 are losing while the previous cohorts are gaining. However, the welfare effects are very small and never exceed 0.6% of lifetime consumption in the case of exogenous labor supply (LREFORM).

Figure 6.5: Parametric Reform: Welfare by Cohort



Note: Authors' computations. Consumption equivalent variation relative to baseline.

6.2 Lifting labor market restrictions when labor supply is endogenous

These results are sensitive to the labor supply assumptions discussed in Section 4. If labor supply is endogenous, reactions are more complex and in general less responsive than in the case of an exogenously forced increase in labor supply. We employ the second variant of our macroeconomic model in which labor supply is endogenous (equations 4.1 and 4.2) but labor market restrictions define an upper limit on labor supply (equation 4.15). Examples are a mandatory retirement age at 65 or a work week of 35 hours. The reform lifts these restrictions to the extent described at the outset of this section. However, not all households will take the added freedom up because households prefer more leisure. We call this "reform backlash". It describes, e.g., that the French government may change the 35-hour week to a 38-hour week but some households, e.g. the older ones in our model economy, decide to work less than 38 hours. Other examples of reform backlash include households who seek pathways to early retirement which circumvent the lifted new pensionable age (e.g. disability pensions) in the EU3 countries.

For households whose labor supply was unrestricted before the reform, lifting the labor supply restrictions has no effect. This is the case of an interior solution of the household's optimization problem described in Section 4.5. The reform package only affects labor supply for those households for whom the time endowment constraint (4.15) was binding, i.e. the case of a corner solution. The overall effect of the reform package is therefore substantially smaller than in the previous subsection where labor supply was exogenous. This is depicted by the broken lines of Figures 6.1 to 6.5.

Figure 6.1 shows that labor volume (total hours worked) decreases by 20% without reform, by 7.5% if the parametric reform is fully in a setting of exogenous labor supply, but only by 16% if backlash occurs in a setting of endogenous labor supply. Parametric reform helps but the quantitative effects are much reduced. The backlash setting appears to better describe the situation in France and Italy, while the exogenous setting better describes the outcomes observed in Germany between 2007 and 2015.

As a consequence, the other macroeconomic aggregates, i.e. capital stock, GDP per capita and consumption per capita, also change less than in the exogenous labor supply case (Figures 6.2 to 6.4). Since labor volume can be chosen freely by many households rather than be forced to a higher (in the exogenous labor supply case) or a lower level (when labor supply is restricted in the baseline case), welfare is unambiguously higher after the reform (Figure 6.5). The cohorts entering the labor force much earlier than the reform are better off in the exogenous rather the endogenous labor supply case. These households are pensioners who profit from the increased labor supply by the younger workers.

7. Systemic reform: The transition from PAYG-DB to FF-DC

The reforms in the Section 6 are called parametric reforms because they change parameters such as the statutory retirement age. The term systemic reform is typically associated with a complete transition from PAYG-DB to FF-DC.

It involves three steps which are often confused in the public debate and even in the academic literature. We follow the US-American nomenclature developed by Geanakoplos et al. (1998). A first step is “privatization” which occurs when a DB pension system is converted to individual accounts which accumulate defined contributions over an individual’s life-time and bear interest. A second step is “(pre)funding”. It occurs when formerly unfunded pension promises are backed up by assets in a way which reduces the implicit and the explicit debt of the pension system. A third step is “diversification” which occurs when pension funds are invested not only in domestic government bonds but also in stocks and foreign assets. Each step can be done separately from the other two; Geanakoplos et al. (1998) provide examples for every combination. We will refer to a systemic transition from PAYG-DB to FF-DC when all three steps are included.

Sweden’s transition of the basic pension to an NDC system can be called “privatization” following this US-American nomenclature. As pointed out in Subsection 2.4, Sweden’s NDC system is neither funded nor diversified. However, the introduction of the “premium pension” in Sweden is a partial transition to a privatized, prefunded and diversified system.

If a funded system invests exclusively in domestic government debt, this does not qualify as a transition to FF-DC since the underlying assets are solely a claim on future taxes of the younger generation. Such a system is therefore as unsustainable as a PAYG-DB system because the declining support ratio will force higher debt repayments per capita of the younger generation and/or lower pension benefits for the older generation if the per capita debt burden becomes unbearable for the younger generation. Moreover, if government bonds finance public transfers and government consumption, the stock of productive capital will not increase. The US Social Security trust fund therefore does not constitute prefunding (Section 2).

A systemic transition from PAYG-DB to FF-DC is often motivated by two claims: a lower sensitivity to population aging (the "sustainability issue") and a higher internal rate of return (the "dynamic efficiency issue"). Both claims are controversial.[37]

The discussion about system optimality is not new and has its origins in the seminal works by Diamond (1965), Aaron (1966) and Samuelson (1975). Whether a higher rate of return in a funded system generates higher welfare as a PAYG system or, even better, can be exploited to design a pareto-efficient transition, has dominated much of the pension literature in the 1980s and 1990s (Subsection 7.1). After reforms have introduced a higher share of funded pension provision in many countries, the discussion has been taken up again recently for two very different reasons. On the one hand, projections on the sustainability of pension systems (European Commission, 2015; US Social Security Administration, 2016) show that the recent reforms have reduced the implicit debt of many PAYG systems but that most systems are still short of being sustainable. Even worse, some recent reforms have gone backwards, e.g. the softening of parametric reforms in France and Italy (European Commission, 2015) and the introduction of a new early retirement pathway in Germany (Börsch-Supan et al., 2014b). This slow progress in, and even backlash to, implementing parametric reforms has revived discussions in favor of a systemic reform. On the other hand, however, the financial crisis in 2008, the monetary policy of quantitative easing through large purchases of assets and the ensuing low interest rates have increased the perception of capital market risks. This has undermined the belief in dynamic efficiency and revived arguments against funding.

A transition can create new macroeconomic resources under certain microeconomic conditions (Nishiyama and Smetters, 2007). The key to understand the welfare effects of a systemic transition is therefore its potentially expansionary effect on the productive capacity of the underlying economy, especially on the stock of productive capital and on labor supply, and in addition potential side effects increasing labor and capital productivity. Exploiting new resources for social security and public insurance is especially important in times of population aging since labor is becoming scarce. We will first discuss the conditions under which new resources can be created in the traditional deterministic set-up of forward-looking households (Subsection 7.1). Earlier sections have shown that PAYG-DB systems have important risk sharing properties. Subsection 7.2 therefore introduces various forms of risk.

[37] A third motivation is intergenerational redistribution. E.g., Sinn (2000) justifies an uncompensated transition from PAYG to FF with the redistribution from the old generation which failed to produce a sufficient number of children to the children's generation.

Finally, Subsection 7.3 looks at the issue of transition when households are myopic and procrastinate.

These three subsections create a long list of arguments for and against a systemic transition with many trade-offs to be considered. It is thus no surprise that most countries in the real world have developed multi-pillar mixed and hybrid pension systems as described in Subsection 2.5 and that population aging has generated in most countries only gradual moves towards more funding and more defined contributions.

7.1 Life-cycler households in a deterministic world

As pointed out in Section 3, a PAYG-DB public pension system reduces the household's need to save for retirement to the extent to which PAYG benefits cover consumption in retirement. Implicit to a public PAYG-DB pension system is that the government builds up claims against the earnings of the next generation. The PAYG-DB system therefore reduces not only the private but also the aggregate savings ratio relative to a FF-DC pension system. If these savings would rather be invested in productive capital and would earn a return r which is higher than the internal rate of return irr of the PAYG system, they would generate a higher stock of productive capital. Hence, a FF-DC economy has more resources and a higher per capita income than a PAYG-DB economy.[38] The FF-DC economy is therefore referred to as being "dynamically efficient" (Diamond, 1965; Samuelson, 1975).

Whether r is always higher than irr is a matter of controversy. If $r < irr$, the PAYG system may play a Ponzi game by permanently borrowing from the next generation, with repayment of this loan delayed in perpetuity. In this case, a PAYG pension system would create a higher aggregate welfare than a FF system.[39] This scenario of "dynamic inefficiency" occurs when the growth rate of the wage bill exceeds the interest rate, equation (2.11). Abel et al. (1989) rule it out as empirically irrelevant; Piketty (2013) and von Weizsäcker (2016) claim the opposite. While there have been substantial time periods where $n + g$ exceeded the interest rate r, e.g. in post-World War II Germany and currently in the US, there are strong theoretical reasons for ruling out a Ponzi constellation for extended periods, since the existence of a single fixed factor which is indispensable to an economy, such as land, is incompatible with dynamic inefficiency (Homburg, 1990; Imrohoroglu et al., 1999).

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[38] Breyer (1989) and Homburg (1990) provide formal proofs.
[39] This is Aaron's Social Insurance Paradox (Aaron, 1966).

In addition to this fundamental debate, there are many specific arguments in the debate whether $r>irr$ or vice versa. First, the market interest rate is sensitive to population aging (equation 2.12). While the return to productive capital does decline in reaction to a decrease in the support ratio, Section 5 has shown that this effect is not a "meltdown". In fact, the corresponding decline in *irr* is larger than the decline in *r*. Second, one may argue that administrative costs of individual accounts and mis-selling by the financial industry (Akerlof and Shiller, 2015; Gasche et al., 2013) drive a large wedge between the market interest rate r^{MKT} and the interest rate actually received by households r^{HH} (equation 2.13). This wedge may reduce r^{HH} to values below *irr* even if $r^{MKT}>irr$.

These arguments refer to comparisons between steady-states. However, a steady-state comparison of a PAYG-DB economy with a FF-DC economy does not necessarily imply that a transition is welfare or even pareto improving. This is due to the transition costs. While a PAYG-DB system can be initiated any time, a FF-DC system necessitates a build-up period covering an entire working life in order to save for the pensions of the first generation. Hence, today's working population does not have the option of exiting the current PAYG-DB system because it has to finance the pensions of the current generation of retirees. This problem of transition requires a generation to pay at the same time contributions into the PAYG-DB system for its parents and save for its own defined FF contributions. Hence, a transition from PAYG-DB to FF-DC in which the transitional generation is fully compensated by government subsidies which are debt-financed has no expansionary macroeconomic effect because no new resources are being created once the winners have fully compensated the losers.

This well-known result (Diamond, 1965; Aaron, 1966; Nishiyama and Smetters, 2007) rests on several strong assumptions. The most important ones are that labor supply is fixed, that the production technology is fixed (i.e., there are no secondary incentive effects on labor and capital productivity), that households face no constraints how much and where to invest, and that all agents are forward looking in a deterministic world. Fenge (1995) shows that this result also holds if labor supply is elastic and if contributions to the pension scheme are perceived as an actuarial premium which is perfectly linked to the retirement benefits. It is a knife-edge result in the sense that in these models the transition costs exactly offset the difference in welfare between the two steady-states. Any small deviation will shift the welfare in one or the other direction.

The extent to which these assumptions are fulfilled is therefore the subject of controversial discussions in the literature. A first line of arguments rests on labor supply distortions created by PAYG systems which become increasingly relevant if populations are aging. It is uncontroversial that labor supply is elastic with respect to payroll taxes (Blundell at al., 1998 and the chapter by Blundell et al. in this handbook). Whether pension contributions are perceived as a tax rather than an actuarial premium depends on the design of the pension system (e.g., Beveridgian vs. Bismarckian) and expectations as was discussed in Subsection 4.4. If pension contributions are perceived as distortionary taxes, efficiency gains can be obtained by reducing the effective tax rate on labor supply.

Arguments in favor of a tax character rest on the fact that all PAYG-DB systems redistribute resources across generations and many PAYG-DB systems redistribute within a generation. Across generations, retiree benefits are financed on a PAYG basis with taxes on younger workers. When the economy grows slower than the interest rate (i.e., is dynamically efficient), a worker with average earnings receives less than one dollar in present value in future benefits for each dollar they contribute. The difference is an effective tax (Börsch-Supan and Reil-Held, 2001). This tax services the implicit debt inherited from past generations who received more from the PAYG-DB system than they paid (Nishiyama and Smetters, 2007).[40] Within generations, Beveridgian pension systems such as the UK pension system or progressive pension systems such as the US Social Security system increase the effective marginal tax rates of household incomes above the economy-wide average while they reduce the effective marginal tax rates of households below that average.

Much of the Anglo-Saxon literature has therefore been based on the assumption that workers and employers perceive pension contributions as taxes which are not actuarially linked to pension benefits. In this case, a transition from PAYB-DB to FF-DC pension system has an expansionary macroeconomic effect in spite of the transition burden which is compensated by taking up public debt. The expansion occurs because labor supply responds elastically to tax cuts which can be high, especially in aging economies. The increased labor supply then creates higher saving, thus a higher capital stock, and both together higher GDP. Auerbach and Kotlikoff (1987), Kotlikoff (1998) and Feldstein and Samwick (1998) have carried out seminal simulation exercises based on CGE-OLG models for the US which design welfare-improving transition paths.

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[40] Of course, abolishing this tax imposes the transition burden on younger households. It nevertheless may distort labor supply behavior.

The literature on public pensions has considered may other distortions which may be relieved by a transition from PAYG-DB to FF-DC. E.g., a transition may be advantageous if households face liquidity constraints or cannot sufficiently diversify their investments (Pestieau and Possen, 2000). In turn, if most households hold debt and face intermediation costs such that returns on pension assets are less than households' cost of borrowing, then pension funding is costly and hence zero funding is optimal in a deterministic world (Bohn, 2011). This finding, however, is not robust when the environment is stochastic (Subsection 7.2). Another aspect of household behavior relevant for long-term issues such as old-age provision is dynastic thinking. Much of the existing literature on pension systems has taken the extreme assumption that individuals have little or no altruism. The paper by Fuster et al. (2007) takes an opposite assumption that there is full two-sided altruism. When households insure members that belong to the same family line, a transition to FF-DC can gain public support. If the transition is financed by a combination of debt and a consumption tax, the simulations by Fuster et al. (2007) result in a welfare gain for 58% of their households. These gains, however, depend critically on a flexible labor market.

Research by international organizations interested in macroeconomic development has created a body of literature which stresses the positive feedback effects of pension systems on the productivity of labor and capital. First, relating especially to developing countries, there is some evidence (World Bank, 1994; Holzmann and Hinz, 2005) that the existence of a formal pension system – either PAYG or FF – encourages participation in the formal sector of the labor market which has higher productivity than the informal sector. Second, a formal FF-DC pension system may strengthen the emerging capital market in developing countries which then increases capital productivity (Diamond, 1994; Schmidt-Hebbel, 1998; Corbo and Schmidt-Hebbel, 2003). Third, a related argument holds that FF-DC pension systems strengthen shareholder activism also in developed countries to the extent that pension contributions are invested in productive capital. This in turn increases capital productivity (Börsch-Supan et al., 2005b).

Finally, pension systems may have implications on human capital development. Kindermann (2015) argues that traditional PAYG-DB schemes subsidize human capital formation. The reason is that these systems have an implicit tax structure that features high tax rates at the beginning of working life and low tax rates toward the end. When the costs of human capital investment are mainly time costs, such a tax structure lowers the costs of human capital investments and simultaneously increases the payoff. This mechanism is enforced when higher skilled workers have steeper wage profiles over the working phase than unskilled workers.

7.2 Life-cycler households in a stochastic world

The list of arguments pro and contra a transition from PAYG-DB to FF-DC system becomes even longer when risks in a stochastic environment are considered. To the extent that the risks typical for PAYG-DB and FF-DC systems (wage risk, rate of return risk, political risks, default risks, longevity risks) are not perfectly correlated, there are gains from diversification. Hence a partial (but not a full) transition from PAYG-DB towards FF-DC increases welfare.

Matsen and Thogersen (2004) study the optimal size of a PAYG-DB system and the optimal split between FF and PAYG using a theoretical portfolio choice approach. A low-yielding PAYG system may benefit individuals if it contributes to hedge other risks to their lifetime resources, while the FF part of a pension system can be justified by potential imperfections to the individuals' free access to the stock market. Numerical calculations for Sweden, Norway, the US and the UK demonstrate that the optimal split varies considerably in response to differences in projected growth rates and the correlation between stock returns and growth. Matsen and Thogersen (2004) suggest that PAYG has an important role in the three former countries but not in UK.

In a model with political and default risks, Bohn (2011) shows that a combination of borrowing and lending may be optimal as opposed to the strict separation which holds in a deterministic environment. If pension funds serve as collateral, funding can be warranted despite the cost. Except in special cases, the optimal funding ratio is less than full funding.

Funding and diversification, however, as pointed out in the introduction of this section, is different from privatization. In general, there is a trade-off between FF and DC. Nishiyama and Smetters (2007) stress the intra- and intergenerational risk-sharing properties of DB systems (Subsection 2.4). First, progressive DB systems share wage shocks among participants that are difficult to insure in the private market. Transiting to a DC system could reduce this insurance unless it were complemented with some form of redistribution. Second, existing DB systems annuitize benefits while many DC systems do not. Nishiyama and Smetters (2007) simulate the benefits of these two insurance elements in a model calibrated to the US economy and find that privatization reduces efficiency despite improved labor supply incentives.

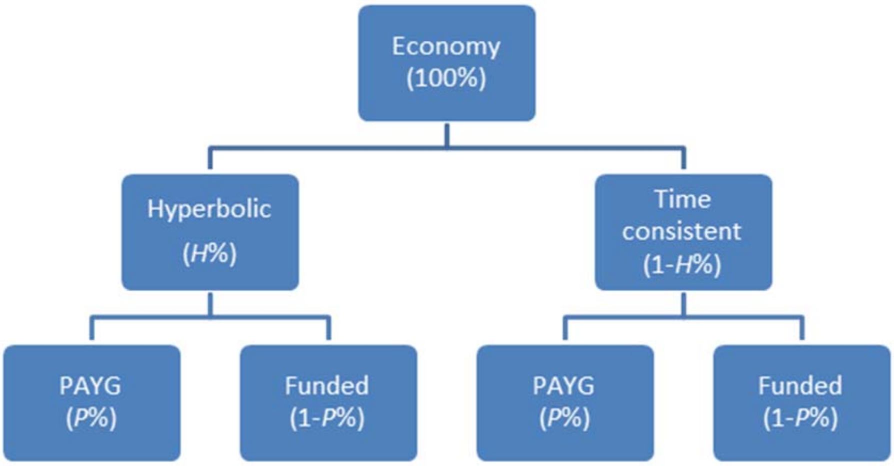
Fuster et al. (2003) study the welfare effects of unfunded social security in a general equilibrium model populated with overlapping generations of altruistic individuals that differ in lifetime expectancy and earnings ability. Contrary to previous research, their results indicate that steady-state welfare increases with a PAYB-DB system for most households, although by very different amounts. This result is mainly due to two factors. First, the presence of two-sided altruism significantly mitigates the crowding out effect of an unfunded pension system. Second, ability shocks and uncertain lifetimes generate significant heterogeneity among households to yield different induced preferences for a PAYG-DB system.

7.3 Procrastinating households in a deterministic world

Finally, we take up the results from Subsections 3.5 and 3.6 which showed that a PAYG-DB system is welfare improving for myopic and procrastinating households. Imrohoroglu et al. (2003) and Fehr et al. (2008) have inserted microeconomic models of hyperbolically discounting households into the macroeconomic environment of a CGE-OLG model. Their somewhat surprising results are that output and consumption paths differ much less than one may expect given their radically different assumptions about household saving behavior. This corresponds to earlier findings by Gustman and Steinmeier (2012) in which hyperbolic or exponential discounting made only little differences in response to alternative retirement policies. Imrohoroglu et al. (2003) show that long-run welfare effects of funding are positive. Fehr et al. (2008) reproduces this result but show that the long run gains are mainly due to losses of transitional cohorts. Their aggregate efficiency effects of funding are negative because the efficiency losses for hyperbolic households are large.

The third variant of our macro model combines the saving behavior of present-biased households as described in Subsection 3.6 with the labor supply behavior as described in Subsection 4.1. The model represents the EU3 open economy which experiences stronger population aging than the rest of the world which is represented by the US as described in Subsection 5.1. As opposed to the models by Imrohoroglu et al. (2003) and Fehr et al. (2008), we model an economy with a mix of households and pension systems. The model set-up is displayed in Figure 7.1.

Figure 7.1: Composition of the Model Economy



The economy consists of both hyperbolically discounting and time-consistent households. We set θ=1 and do not distinguish between naïve and sophisticated hyperbolic households. The extent of hyperbolic discounting is moderate with δ=0.7. A fixed share of households participates in a PAYG-DB scheme, the remainder in a FF-DC pension system. The share of hyperbolically discounting households is $0<H<1$ and the share of participants in the PAYG-DB part of the system is $0<P<1$. P is identical for hyperbolic and time-consistent households. The advantage of this set-up is to study the behavior and the welfare of all household types under the same macroeconomic conditions (wages, interest rates) for different values of H and P. This is important because the standard set-up of OLG models displays an implausibly large sensitivity of the interest rate to different model specifications.

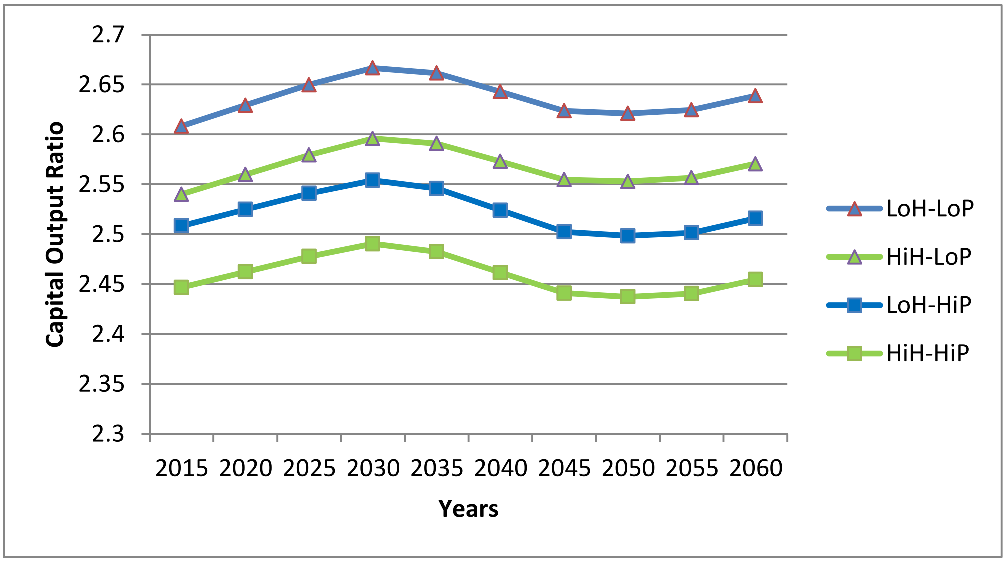
We first compare four economies which are defined by a low and a high share of hyperbolic households and by a low and a high share of funding (Table 7.1). We calibrate the model to generate a relatively low market interest rate (4%) in the reference scenario (HiH-LoP):

Table 7.1: Definition of Economies

		Share of hyperbolic households:	
		H=10%	**H=30%**
PAYG DB part of pension system:	**P=50%**	LoH-LoP	HiH-LoP (reference)
	P=80%	LoH-HiP	HiH-HiP

The four economies have different saving ratios and thus capital intensities (Figure 7.2). A higher share of funding creates a higher capital intensity. Economies with a higher share of hyperbolic households have a substantially lower capital intensity. Capital intensity increases at the peak of population aging between 2030 and 2035 and then decreases again.

Figure 7.2: Capital Intensity

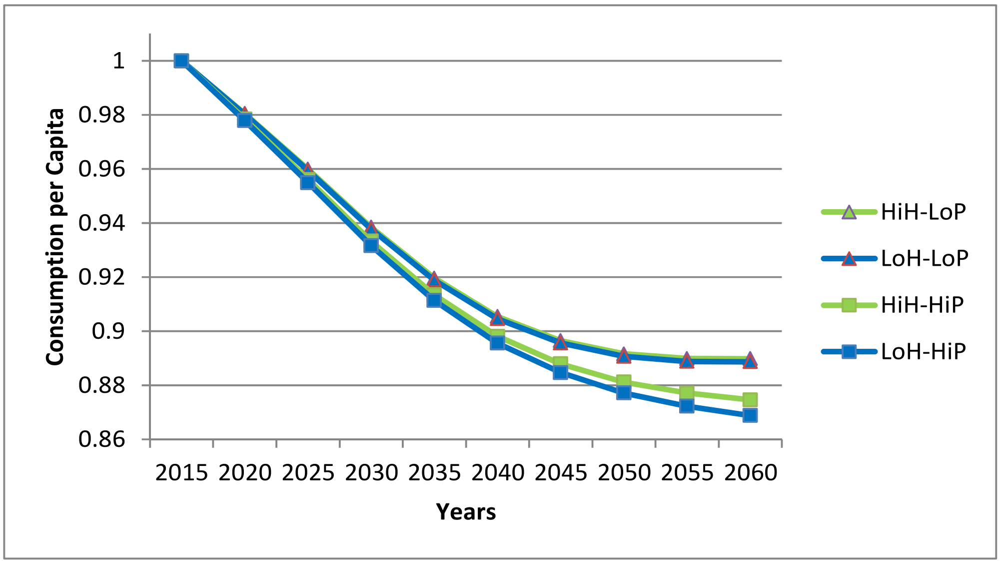


Note: Authors' computations.

While the savings behavior is very different between time-consistent and hyperbolic households, there is little difference in their labor supply: time-consistent households offer only a slightly higher supply. In contrast, labor supply is significantly lower in economies with a high share of PAYG-DB pensions, partially in response to the payroll tax to finance the PAYG-DB system (Subsection 4.4). With higher capital intensity and higher labor supply, economies with a high share of funding can create higher consumption per capita, especially when the share of hyperbolic households is low.

The relative impact of population aging on per capita consumption can be seen by normalizing initial consumption in 2015 to 100% for all four model economies (Figure 7.3). Aging affects consumption per capita the most in economies with a low share of hyperbolic households and a high share of PAYG-DB pensions, while economies with a high share of funding are more resilient against population aging. In economies with a high funding share, the impact of aging on consumption per capita is almost unaffected by the composition of hyperbolic and time-consistent households.

Figure 7.3: Consumption per Capita, Normalized to 2015=100%

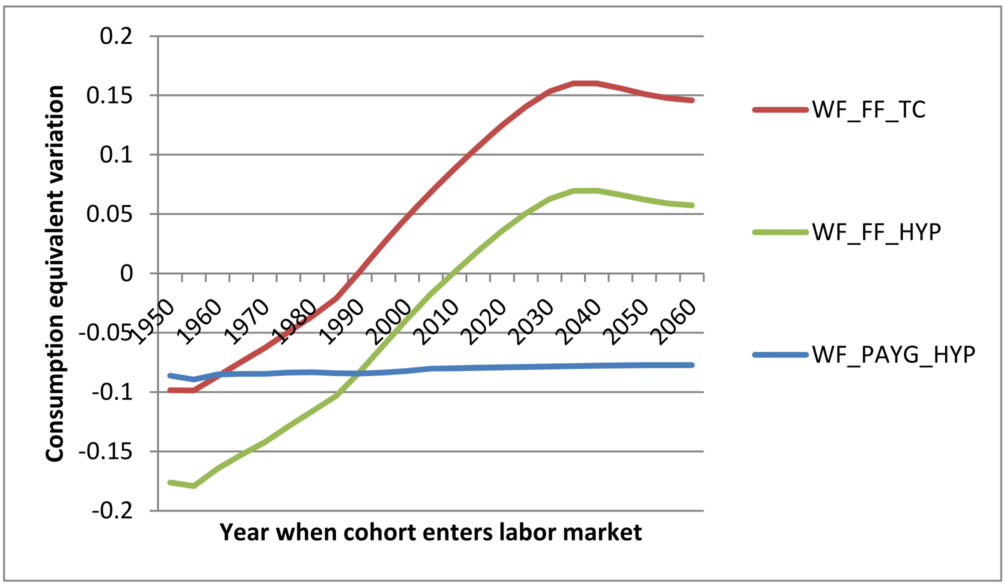


Note: Authors' computations.

Figures 7.2 and 7.3 largely reproduce the long-run findings by Imrohoroglu et al. (2003) and Fehr et al. (2008). We now use a political-economy argument that a transition from PAYG-DB to FF-DC will not find a majority. We begin with a reference economy in which 70% of households are time consistent and 30% hyperbolic. Households are equally split between PAYG-DB and FF-DC.

Figure 7.4 depicts the temporal evolution of welfare for cohorts of each household type. Welfare is measured as consumption-equivalent variation relative to a time-consistent household with a PAYG-DB plan. Units are percentage of lifetime consumption.

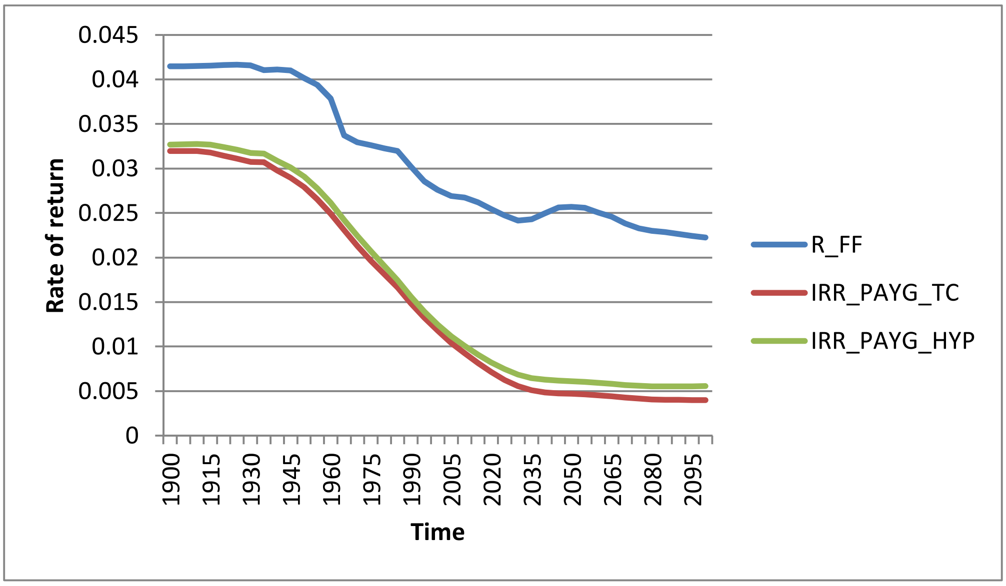
Figure 7.4: Welfare



Note: Authors' computations. Consumption equivalent variation relative to reference.

Figure 7.4 shows that both time-consistent and hyperbolic households are better off in a PAYG-DB system if they have entered the labor market before 1990. For hyperbolic households, welfare is lower than for time-consistent households. This difference is large and amounts to almost 10% of lifetime consumption. The higher welfare in the FF-DC system for the younger cohorts is a reflection of the difference between the market interest rate *r* and the internal rate of return *irr* in the PAYG-DB system (Figure 7.5). This difference increases with population aging between the initial steady state of this model economy before 1900 and the ending steady state after 2100. It makes a transition desirable for younger cohorts.

Figure 7.5: Interest Rates



Note: Authors' computations.

The main result of Figure 7.4 is the irrelevance of transition costs. Even if the transition were costless, there would be no majority for a FF-DC if there were a vote today because only cohorts entering the labor market before 2015 can vote. This result is strengthened if the share of hyperbolically discounting households or the magnitude of the present bias is higher than in the reference economy chosen.

8. Conclusions and research desiderata

How pension systems should best react to population aging is still a matter of great controversy within our profession. This chapter has shown that these controversies need not be based on political beliefs but can be traced to differences in the underlying economic models and the choice of parameters in these models.

Key differences in economic modelling result mainly from different assumptions about the extent of foresight and the time consistency of individuals. This has dominated the literature on saving behavior and public insurance (Section 3). Moreover, there are large differences in the extent to which households are assumed to understand and internalize the complex rules of pension systems. This has found much exposure in the literature on labor supply distortions created by pension systems (Section 4). It is worth noting that crowding out effects of saving and distortions of labor supply tend to increase when populations age. In addition, outcome variables on the macroeconomic level are sensitive to the choice of parameters. Particularly important is the interplay between the households' time preferences, the market interest rate and the internal rate of return from PAYG pension systems. While the literature provides a standard set of "educated guesses" for the model parameters (Section 5), they are only partially based on econometric estimates and more often on a rough calibration to macroeconomic time series.

An important lesson from the macroeconomic analyses starting with Section 5 is that endogenous adaptations (higher capital intensity and more investment in less aging countries) substantially reduce the need for labor market and pension reform in times of population aging. Section 6 shows that labor-market oriented reforms of existing PAYG systems suffice in principle to offset the remaining decline in per capita consumption. The power of parametric reforms, especially increasing the retirement age, is qualitatively robust across all considered models, although backlash effects can be large (Section 6).

Hence, the need for a full systemic transition from PAYG-DB to FF-DC due to population aging (Section 7) is less convincing. This conclusion is strengthened by the knife-edge characteristic of a systemic transition in which complex second order effects determine the welfare outcome and parameter assumptions are critical, especially those which determine the market interest rate. It is therefore important that these assumptions are made transparent. In general, welfare is higher in a PAYG-DB than in a FF-DC economy for older cohorts if the valuation of leisure is high, and if the present bias is high. Transition costs then easily wipe out the advantage of FF-DC among younger and time-consistent households with a relatively high preference for consumption.

More research is needed on mixed systems which balance the advantages and disadvantages of the two fundamentally different approaches to finance public pensions (Section 2). While genuinely funded systems have economic theory on their side, the governance and cost problems observed in real-world funded systems severely reduce this theoretical advantage, and transition costs are high relative to potential efficiency gains.

Section 3 has shown that more research is needed to better understand the heterogeneity of mortality, time preference, leisure preference, risk aversion, and similar parameters in models of procrastinating, myopic or otherwise bounded rational households. The models in this chapter were relatively simple in this respect; the optimal mix between funding and PAYG will depend on the distribution of these characteristics in the population.

Research issues related to labor market behavior, Section 4, are more specific. We have learned a lot about retirement incentives. There is ample literature on actuarial adjustments which are too low and earnings tests which are counterproductive. These examples show that it is not economic insight but social policy which has failed to strengthen pension systems in times of population aging. More research, however, is needed to fully understand which avenue should be taken to make the retirement decision more flexible without generating more early retirement. We have little evidence so far on the balance between those workers who want to reduce their labor hours before the normal retirement age and those workers who want to work part-time after the normal retirement age. This balance is crucial to assess the effect of flexible retirement on a pension system's balance when population aging is progressing. It depends on the extent of distortions embedded in the pension system and on the distribution of personal characteristics such as leisure preferences and health in the population.

The main desideratum for further macroeconomic research (Sections 5 to 7) is therefore to introduce a broader scope of heterogeneity in macro models, especially with respect to the extent of present bias, the valuation of leisure and household characteristics other than productivity. While progress has been made recently, heterogeneity has usually been confined to the single dimension of productivity. Many models so far fail to generate realistic interest rates; typically too high, leading to policy conclusions favoring funded systems and systemic transition. Our simulations have shown that when the market returns are closer to the internal rate of return in a PAYG pension, other considerations like the value of annuitization and present-bias dominate the traditional logic derived from a high-interest situation and shift the balance more in favor of traditional PAYG-DB pension systems. Our scant knowledge about the distribution of the underlying individual characteristics and preference parameters is yet another reason to study the performance of mixed pension systems and to do more empirical research on how population aging will shift the many household characteristics on which the optimal design of social security and public insurance depend.

List of symbols

i	country
j	age
J	maximum age
R	age at which pension benefits are claimed
X	labor force exit age
t	time
N	number of households
NP	number of pension recipients
NW	number of workers
DR	system dependency rate NP/NW
SR	support ratio
D	annuitization factor
n	growth rate of number of workers
f	fertility rate
w	wage
ξ	fixed costs of work
Ξ	government subsidies net of fund management costs of funded pensions
g	growth rate of wages
r / r^{MKT}	market interest rate
r^{HH}	interest rate perceived by the household
irr	internal rate of return of pension system
p	pension benefit
q	replacement rate of pension benefits
τ	contribution rate to pension system
c	consumption
s	active saving
a	assets
y	current disposable income
σ	unconditional rate to be alive at age j
ρ	household discount rate
β	household discount factor $1/(1+\rho)$
δ	present bias parameter
Δ	rate of depreciation
λ	indicator of wage vs. pension income
μ	weight of DC vs. DB in mixed pension systems
κ	inverse marginal disutility of work in Stock-Wise indirect utility function
ϕ	utility weight of consumption vs. leisure
γ	marginal utility of income in Stock-Wise indirect utility function
θ	parameter for risk aversion and intertemporal elasticity of substitution
ε	productivity
η	share of myopic households
ψ	earnings points
ω	actuarial adjustment
A	aggregate productivity
K	capital stock
k	capital stock per productivity weighted worker
α	weight of capital in production
L	labor force
l	labor supply, $1- l$ = leisure
h	hours worked

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