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ARTICLE

Can fiscal incentives to saving alleviate looming old-age poverty?

Joanna Tyrowicz[1], Krzysztof Makarski[2] and Artur Rutkowski[3]

[1]University of Regensburg, University of Warsaw, FAME|GRAPE, and IZA, Warsaw, Poland, [2]FAME|GRAPE, and SGH Warsaw School of Economics, Warsaw, Poland and [3]FAME|GRAPE, Warsaw, Poland
Corresponding author: Joanna Tyrowicz; Email: j.tyrowicz@uw.edu.pl

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Abstract

We develop a general equilibrium overlapping generations framework with incompletely rational individuals to study old-age saving incentives. Such incentives are used worldwide to help achieve the high savings rate required to sustain sufficient consumption in old age. We show that they raise the welfare of financially illiterate individuals and those with a high degree of time inconsistency. They also reduce the incidence of poverty in old age. We further quantify the fiscal cost, crowd-out, and ability to target the transfers to individuals who need the most. Given the high prevalence of these schemes, our paper has broad policy implications.

Keywords: incomplete rationality; old-age poverty; saving incentives; welfare effects

JEL Codes: H31; H55; I38

1. Introduction

Growing life expectancy accompanied by low fertility rates amplifies the concerns over old-age poverty. Around the world, governments implement changes in mandatory social security to balance trade-offs between fiscal stability on the one hand and sufficient consumption means in old age on the other hand.[1] The alternative policy response is to encourage citizens to save more for old-age consumption via tax-incentivized old-age saving programs (OAS), which are increasingly prevalent around the world (OECD, 2018). However, these government-subsidized private pension schemes raise several concerns regarding effectiveness, efficiency, and redistribution. For example, the redistributive effects may go against *de nomine* policy objectives depending on the design of the tax incentives. Furthermore, in an economy populated by entirely rational agents, crowd-out of private voluntary savings by accumulation in OAS schemes is a concern (for extensive treatment, see, e.g., Bütler, 2001; Conesa and Garriga, 2008; Kitao, 2014; Blau, 2016).

As far as effectiveness, efficiency, and redistribution are concerned, OAS plans face some of the same challenges as mandatory social security because the latter typically has a negative net present value due to indexation rates being lower than the long-run interest rates (Schmelzing, 2020). While for fully rational agents, the yields from postponed consumption due to mandatory social security contributions are negative, incompletely rational agents benefit from a variety of attributes

[1]In addition to comparative works of, for example, Gruber and Wise (2009); Feldstein (2016), see also Imrohoroğlu and Kitao (2012) for the US, Fehr *et al.* (2012) for Germany, Braun and Joines (2015) for Japan, Díaz-Giménez and Díaz-Saavedra (2009) for Spain or Li and Mérette (2005) for China.

associated with mandatory character, indexation, etc.[2] Agents with time inconsistent preferences may observe welfare gain from a mandatory pay-as-you-go social security, which comes at the cost of lower capital accumulation relative to the scenario of no social security (e.g., Imrohoroğlu *et al.*, 2003; Lindbeck and Persson, 2003; Kumru and Thanopoulos, 2008; Fehr *et al.*, 2008*a*; Cremer and Pestieau, 2011).

Savings of incompletely rational agents ought to be subsidized (e.g., Krusell *et al.*, 2010; Hosseini and Shourideh, 2019). Nevertheless, it is not necessarily neutral at which stage subsidies occur: contribution, accumulation, or collection (e.g., Kingston and Piggott, 1993; Creedy and Guest, 2008). With fully rational agents, effectively reducing the taxation of capital through the introduction of OAS plans may lead to higher capital accumulation, thus improving the tax mix in a country and raising efficiency, as shown by Fehr *et al.* (2008*b*) for the case of Germany.[3]

This paper studies the effects of tax-incentivized old-age saving programs for incompletely rational agents. To this end, we build an overlapping generations model with intra-cohort behavioral heterogeneity. Our agents may lack financial literacy and self-discipline.[4] Our economy features the following types of agents: (1) fully rational; (2) with time-inconsistent preferences (in the spirit of Imrohoroğlu *et al.*, 2003; Fehr *et al.*, 2008*a*; Andersen and Bhattacharya, 2011; Caliendo, 2011); (3) financially illiterate (they have access only to storage technology and no access to saving technology (in the spirit of Hirschhorn, 1984; Lusardi, 2012; Xu and Zia, 2012; Lusardi and Mitchell, 2014; Klapper *et al.*, 2015; Fagereng *et al.*, 2016; Lusardi *et al.*, 2017)); and (4) both time inconsistent and financially illiterate. In this framework, we quantify the effects of OAS schemes on individuals and the economy.

With a broad spectrum of incomplete rationality, we can portray the impact on a comprehensive set of behaviorally heterogeneous households. We thus quantify intuitions concerning partial and general equilibrium effects of tax incentives to old-age saving schemes. We compare them to reforms in mandatory social security of equivalent magnitude. We study a broad range of OAS plans: incentives at the various stages in the life cycle, proportional, and lump-sum. We carefully set the size of the OAS programs to match the rise otherwise necessary to balance mandatory social security. We thus effectively compare larger mandatory social security with the introduction of tax-incentivized OAS plans.

We calibrate our economy to Germany for three major reasons. First, Germany expects a pronounced rise in longevity with substantial changes to the age structure of the population and an increase in the dependency ratio. With the current social security system, balancing social security requires either a reduction in pension benefits or an increase in contribution rates. The latter gives us a clear benchmark for the size of the potential OAS schemes. Second, the so-called point system makes current contributions directly related to future pension benefits. While the link is not as close as in the case of private voluntary savings, the extent of distortion in the intra-temporal decision is lower than in most advanced economies, which conveniently gives a lower bound on the comparison between OAS and an increase in the contribution rate to the mandatory social security. Third, this economy already has a plethora of OAS schemes, including a reasonably comprehensive and mandatory additional OAS scheme covering 4.2 mln salaried workers (Versorgungsanstalt des Bundes und der Laender), heavily subsidized by the government (trade-offs between efficiency gains and redistribution in this system were analyzed by Fehr *et al.*, 2008*b*).

We provide several novel results. First, introducing incomplete rationality delivers wealth profiles closer to observational data. Second, while fully rational agents demonstrate effectively complete crowding out, they are the key beneficiaries of instruments addressing savings shortages among incompletely rational agents. In fact, fully rational agents already raise their consumption profiles

[2]As Caliendo (2011) puts it, '[*b*]*eginning with Feldstein (1985), economists have modified the LCPI* [*life cycle permanent income*] *model with a variety of alternative behavioral frictions in order to understand whether a social security program with a negative net present value may be rationalized under different specifications of shortsightedness*' (p. 668).

[3]Holzmann and Piggott (2018) edited a volume on the taxation of pensions, including private voluntary pensions.

[4]Backus *et al.* (2004) provide an overview of departures from fully rational agents in macroeconomic models, see also Brzoza-Brzezina *et al.* (2013); Branch and McGough (2018).

when young, whereas the other types of agents only observe gains after retirement. This counter-intuitive redistribution raises doubts over fairness of such instruments, even if welfare accounting shows large positive effects for incompletely rational agents and small losses for fully rational agents. Finally, we document the stark contrast between the direct and general equilibrium effects across the types of agents, particularly in the economy where fully rational agents are not a majority.

Our study contributes to answering three questions of paramount policy relevance. The **first question concerns the potential to alleviate poverty among old-age individuals**. With increasing life expectancy and declining fertility rates, it may become infeasible to provide for the elderly. Many countries openly declare that OAS are intended to reduce old-age poverty without increasing the burden on the working generations. We show that insufficient asset accumulation is responsible for a large share of old-age poverty without OAS schemes. Thanks to OAS plans, one may effectively eliminate old-age poverty stemming from insufficient savings. In this respect, OAS programs are more effective than increasing the contributions to mandatory social security. We further show that OAS programs induce considerable crowd-out for agents with time inconsistency, whereas they facilitate asset accumulation of financially illiterate agents.

The **second question relates to the effects of tax-incentivized OAS programs for incompletely rational agents**.[5] We evaluate (i) the assets gap operationalized as **saving regret** (in the spirit of Boersch-Supan *et al*., 2018), (ii) **welfare**, and (iii) voluntary **participation** in OAS plans. We show that the saving regret proxy declines substantially for financially illiterate households. It is reduced by 40 percent. These declines are much less substantial for financially literate agents, particularly among agents with little time inconsistency. Welfare effects are heterogeneous across the types of agents – positive for financially illiterate agents but negative for most financially literate ones. Finally, we show that voluntary participation in OAS programs is a poor proxy for judging their success.

Our study builds on three strands of literature. In the first relevant strand of the literature, incomplete rationality has been used in the past as a case for mandatory social security (see e.g., Imrohoroğlu *et al*., 2003; Cremer *et al*., 2008; Findley and Caliendo, 2009; Bucciol, 2011; Caliendo, 2011). The overall consensus in this literature is best summarized as follows: mandatory pay-as-you-go security is inefficient, but it may be socially desirable for several policy-relevant reasons. Mandatory security is a free commitment device for agents with time-inconsistent or temptation preferences.[6] By comparing the mandatory pay-as-you-go social security to incentivized and, by construction, funded OAS plans, we relate to the earlier literature, which focused on the trade-off between efficiency (due to capital accumulation) and welfare gains from a commitment device.

We contribute to this debate in three ways. First, we study mandatory social security with negative net present value for agents with a wider variety of incomplete rationality. To the best of our knowledge, the prior modifications to the life cycle permanent income model did not include financial illiteracy. Indeed, these behavioral limitations translate to significant departures from the asset accumulation path of a fully rational agent. Second, we compare the welfare of incompletely rational agents when they can save in a negative net present value instrument (mandatory social security) as opposed to a positive net present value instrument (tax-incentivized OAS programs, which come with higher taxation to finance the incentives). Third, we expand on the dimensions of the trade-offs by allowing fully endogenous enrollment at any age.

The second relevant strand of the literature relates to evaluating OAS incentives. Following the introduction of 401 k in the United States in 1978 and a subsequent large overhaul of this program in 1986, ex-post evaluations for the size of the crowd-out, macroeconomic as well as redistributive

[5]There is a growing number of empirical studies on the incomplete rationality and its causes (e.g., Lusardi *et al*., 2017; Parker, 2017). Linking empirical evidence and theoretical framework, there are papers modeling different types of consumers' preferences and savings (e.g., Attanasio and Wakefield, 2008; Attanasio and Weber, 2010; Kaplan and Violante, 2014).

[6]High share of agents with time inconsistent preferences leads to non-trivial spillovers for the rest of the economy: the aggregate effects depend on the interplay between partial equilibrium adjustments for fully rational and time inconsistent agents and the general equilibrium adjustments.

and welfare consequences of this program remain ambiguous (including but not limited to a special issue of the Journal of Economic Perspectives, with contributions from Engen *et al.*, 1996; Poterba *et al.*, 1996; Gelber, 2011, provides recent evidence). After the introduction of 401 k in the US, OAS schemes with preferential tax treatment have spread to all OECD countries[7] and have been subject to numerous policy and academic debates.

The most frequent concern is that such programs allocate fiscal relief/subsidy to those individuals who otherwise would have no difficulty accumulating wealth for old-age consumption, and at the same time, they do not provide sufficiently meaningful incentives or support for the rest of society (Madrian and Shea, 2001; Boersch-Supan *et al.*, 2015; Chu *et al.*, 2017). Studies on observational data demonstrate that behavioral departures from full rationality strongly differentiate pension wealth (Clark *et al.*, 2017; Lusardi *et al.*, 2017; Kacperczyk *et al.*, 2019). By exploiting a broad array of behavioral heterogeneity, we provide insights into the winners and the losers of tax-incentivized OAS programs.

Finally, as the third strand of the literature, our paper adds to numerous studies of Germany, one of the largest world economies. We calibrate our economy to replicate the features of this economy. There is an abundance of studies analyzing the consequences of changes in the mandatory social security in Germany (e.g., Fehr and Habermann, 2006; Fehr and Jess, 2007; Dieckhoener and Peichl, 2009; Boersch-Supan *et al.*, 2015; Dolls *et al.*, 2018; Seibold, 2019, to name just a few), also in the context of incomplete rationality (Fehr *et al.*, 2008*a*).

There appears to be less scrutiny of the multiple OAS programs implemented in this country. Boersch-Supan and Quinn (2015) present the features of specific OAS programs and show that the changes in the design mandated by the constitutional tribunal ruling (*Bundesverfassungsgericht*) make these different programs more similar in terms of delivered outcomes. Corneo *et al.* (2009) evaluate the crowd-out from the so-called Riester plan (one of the voluntary OAS programs). Ihle and Siebert-Meyerhoff (2017); Bönke *et al.* (2019) study the distributions of pension wealth and net worth in observational data. Fehr *et al.* (2008*b*) provide insights on the trade-offs between insurance and efficiency with the tax subsidies on private voluntary savings in an overlapping generations model. We provide insights comparing OAS to raising the size of mandatory social security in an economy with incompletely rational agents.

The paper is structured as follows. Section 2 presents the model, specifically focusing on how incomplete rationality affects inter-temporal choices of agents. In section 3, we discuss at length the policy instruments and provide intuitions on their potential direct and indirect effects. Section 4 presents data and calibration. In addition to the standard discussion of macroeconomic aggregate parameters, our study also has intra-cohort behavioral heterogeneity, as discussed in section 5. Section 6 presents the results. The final section concludes with insights for further research and policy implications.

2. The model

Our economy is populated by $N_{j,m,t}$ agents where m denotes their type, j their age, and t the calendar year. Agents live for $j = 1, 2, 3, \ldots, J$ periods, $\pi_{j,t}$ denotes their survival probability, with $\pi_{J,t} = 0$ at the maximum age. The probability of survival is homogeneous within a birth cohort, that is, common across m types of agents. Entry at $j = 1$, which corresponds to age 21 in reality, allows us to abstract from the education choice. Denote $N_{j,t} = \sum_m N_{j,m,t}$.

In the model, we compare the initial (*ISS*) and the final steady state (*FSS*). The economy is fully annuitized, that is, both private voluntary assets and incentivized OAS yield a rate of return including unintentional bequests (see also Bruce and Turnovsky, 2013). Thus, we ignore the utility of life span uncertainty insurance, which typically differentiates private voluntary savings from public social security. Note that with this solution, there are no longer bequests to enter on the income side of the budget constraint.

[7]The OECD (2018) provides a broad overview of the instruments implemented across the member countries. Tax incentives for old-age savings have been implemented worldwide, including all OECD countries; participation rates and the scope of incentives differ.

We denote the behavioral types of agents by m. The first type is the fully rational agent typically featured in economic models. However, growing literature demonstrates that a small fraction of households behave in a manner consistent with complete rationality. For example, the consumption of retirees is substantially lower than that of the working-age population, whereas the difference is so large that it cannot be explained away by the decline in work-related consumption expenditures (Haider and Stephens, 2007; Battistin *et al.*, 2009). To account for this empirical regularity, our model also features agents whose behavior is characterized by incomplete rationality.

2.1 Preferences

Agents of all types derive utility from consumption $c_{j,m,t}$ and leisure $(1 - l_{j,m,t})$, where $l_{j,m,t}$ denotes endogenous and perfectly elastic labor supply. We assume the instantaneous utility function of

$$u(c_{j,m,t}, l_{j,m,t}) = \log [c_{j,m,t}^{\phi}(1 - l_{j,m,t})^{1-\phi}], \tag{1}$$

where ϕ denotes the weight of leisure in utility, identical across and within cohorts. Note that with log utility substitution and income effect cancel out, which is a conservative assumption from the perspective of this study.

Denote gross consumption by $\mathcal{C}_{j,m,t} = (1 + \tau_t^c)c_{j,m,t}$, where $c_{j,m,t}$ is the experienced consumption and τ_t^c is the consumption taxation. Analogously, denote labor income earned by agents with $j < \bar{J}$ by $\mathcal{I}_{j,m,t} = (1 - \tau^l - \tau)w_{j,t}l_{j,m,t}$ with $w_{j,t}$ denoting age-specific wages. Labor income tax is denoted by τ^l, and accordingly, τ denotes the contribution rate to mandatory and universal social security. Net pension benefits are denoted by $\mathcal{I}_{j,m,t} = (1 - \tau^l)b_{j,m,t}$ for $j \geq \bar{J}$. The net capital income of an agent is denoted by $\mathcal{K}_{j,m,t} = \{[1 + r_t(1 - \tau^k)](N_{j-1,t}/N_{j,t}) - 1\}a_{j-1,m,t}$, with r_t denoting the interest rate in the economy and $a_{j,m,t}$ denoting the stock of assets. The annuitization of the economy implies that agents receive the survivor premium on assets.

Given that the agents can borrow during the working period against the OAS income (in particular, the financially illiterate agents would find it optimal), we impose a no-borrowing constraint, that is, $\forall_{j,m,t}\ a_{j,m,t} \geq 0$. Absent bequest motive, the terminal condition is given by $a_{J,m,t} = 0$. For brevity, it is convenient to define a sequence of lifetime consumption starting from age j in period t that has a length $J - j$ as $\tilde{c}_{j,m,t} = \{c_{j,m,t}, c_{j+1,m,t+1}, \ldots, c_{J,m,t+J-j}\}$ and analogously for sequence of lifetime labor supply $\tilde{l}_{j,m,t}$ and assets $\tilde{a}_{j,m,t}$.

2.2 Behavioral heterogeneity

Fully rational agents find optimum consumption and leisure path by solving the following problem:

$$\begin{aligned} U_{j,m,t} = \max_{\{\tilde{c}_{j,m,t}, \tilde{l}_{j,m,t}, \tilde{a}_{j,m,t}\}} & u(c_{j,m,t}, l_{j,m,t}) \\ & + \sum_{s=1}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} u(c_{j+s,m,t+s}, l_{j+s,m,t+s}) \end{aligned} \tag{2}$$

$$\text{subject to: } a_{j,m,t} - a_{j-1,m,t-1} = \mathcal{I}_{j,m,t} + \mathcal{K}_{j,m,t} + \Upsilon - \mathcal{C}_{j,m,t} + \mathcal{T}_t. \tag{3}$$

where index $m = FR$ and δ signifies time discounting; Υ denotes a lump-sum tax in the economy. We define intra-cohort lump-sum transfers $\mathcal{T}_t$, see equation (11) below. It is useful to represent the intertemporal behavior of the agents as marginal rate of substitution (MRS), which takes the

following form for the fully rational agents.

$$\begin{aligned}\text{MRS at } age = j: \frac{u_c(c_{j,m,t}, l_{j,m,t})}{u_c(c_{j+1,m,t+1}, l_{j+1,m+1,t+1})} \cdot \frac{1}{\delta} \cdot \frac{\pi_{j,t}}{\pi_{j+1,t+1}} \\ = \mu_{j+1,t+1} + (1-\tau^k)\bar{r}_{j+1,t+1},\end{aligned} \tag{4}$$

with $\bar{r}_{j,t} = \mu_{j,t} \cdot r_t$, where r_t follows from financial markets equilibrium, and $\mu_{j,t} = N_{j-1,t-1}/N_{j,t}$ is the survivor premium. The Euler condition generally holds only when the non-negative constraint on assets is non-binding. Otherwise, the LHS of the Euler equation for subsequent ages is greater than the RHS.

Time-inconsistent agents solve the following problem:

$$\begin{aligned}U_{j,m,t} = \max_{\{\tilde{c}_{j,m,t}, \tilde{l}_{j,m,t}, \tilde{a}_{j,m,t}\}} u(c_{j,m,t}, l_{j,m,t}) \\ + \beta \sum_{s=1}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} u(c_{j+s,m,t+s}, l_{j+s,m,t+s})\end{aligned} \tag{5}$$

$$\text{subject to: } a_{j,m,t} - a_{j-1,m,t-1} = \mathcal{I}_{j,m,t} + \mathcal{K}_{j,m,t} + \Upsilon - \mathcal{C}_{j,m,t} + \mathcal{T}_t. \tag{6}$$

where index $m = TI$. We denote additional discounting applied to all future periods by β. It is the so-called quasi-hyperbolic or *naive* time inconsistency. The MRS implied for the time-inconsistent agents is given by

$$\begin{aligned}\text{MRS at } age = j: \frac{u_c(c_{j,m,t}, l_{j,m,t})}{u_c(c_{j+1,m,t+1}, l_{j+1,m+1,t+1})} \cdot \frac{1}{\beta\delta} \cdot \frac{\pi_{j,t}}{\pi_{j+1,t+1}} \\ = \mu_{j+1,t+1} + (1-\tau^k)\bar{r}_{j+1,t+1}.\end{aligned} \tag{7}$$

For fully rational agents, MRS evaluated at $j+s$ horizons is consistent with equation (4). It is not the case for time-inconsistent agents, for whom equation (7) holds between j and $j+1$ at age j. The optimum s periods ahead, that is between j and $j+s$ when evaluated at j is given by:

$$\frac{u_c(c_{j,m,t}, l_{j,m,t})}{u_c(c_{j+s,m,t+s}, l_{j+1,m+1,t+1})} \cdot \frac{1}{\beta\delta^s} \frac{\pi_{j,t}}{\pi_{j+s,t}} = \prod_{i=1}^{s} (\mu_{j+s,t} + (1-\tau^k)\bar{r}_{j+s,t}).$$

Time inconsistent-agents progressing in age systemically under-save. Note that in a limit, time-inconsistent agents behave like hand-to-mouth agents: with the infinite preference for the present period ($\beta \to 0$), these agents will consume entire income instantaneously. Time-inconsistency implies that an agent sets an optimal plan but cannot implement it.

Financially illiterate agents solve the following problem:

$$\begin{aligned}U_{j,m,t} = \max_{\{\tilde{c}_{j,m,t}, \tilde{l}_{j,m,t}, \tilde{a}_{j,m,t}\}} u(c_{j,m,t}, l_{j,m,t}) \\ + \sum_{s=1}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} u(c_{j+s,m,t+s}, l_{j+s,m,t+s})\end{aligned} \tag{8}$$

$$\text{subject to: } a_{j,m,t} - a_{j-1,m,t-1} = \mathcal{I}_{j,m,t} + \mathcal{K}_{j,m,t} + \Upsilon - \mathcal{C}_{j,m,t}. \tag{9}$$

where index $m = FI$. Hence, they are able to put funds aside but cannot receive capital income gains.

The implied MRS of the financially illiterate agents is given by

$$\text{MRS at } age = j: \frac{u_c(c_{j,m,t}, l_{j,m,t})}{u_c(c_{j+1,m,t+1}, l_{j+1,m+1,t+1})} \cdot \frac{1}{\delta} \cdot \frac{\pi_{j,t}}{\pi_{j+1,t+1}} = 1 \tag{10}$$

Given that the financially illiterate agents obtain no interest, they have no return on income withheld, that is, postponing consumption.

Asset market clearing. The interest rate on assets accumulated by financially illiterate agents is transferred to financially literate agents. It is implemented through lump-sum instantaneous transfers. Interest accrued by assets stored by financially illiterate agents is transferred to financially literate agents as

$$\mathcal{T}_t = \frac{\sum_{m=FI} \sum_{j=1}^{J} N_{j,m,t} \mathcal{K}_{j,m,t}}{\sum_{m \neq FI} \sum_{j=1}^{J} N_{j,m,t}}. \tag{11}$$

Since $\mathcal{T}_t$ enters the budget constraint of financially literate agents as a lump-sum transfer, it does not affect their inter-temporal choices. Section 2.5 defines the market clearing interest rate.

When discussing the results, we systematically report the results for fully rational agents, that is, agents who display no time-inconsistency and are financially literate. We then report agents with varying degrees of time-inconsistency among both financially literate and financially illiterate households. We describe in section 5 the assumed population structure.

2.3 Social security

There is a universal pay-as-you-go defined benefit social security with an exogenous contribution rate τ and exogenous replacement ρ at retirement ($j = \bar{J}$). The contemporaneous benefits are financed from contemporaneous contributions. The value of the old age pension benefit for a cohort retiring in period t is given by:

$$\forall_m: b_{\bar{J},m,t} = \rho \cdot \sum_{j=1}^{\bar{J}-1} w_{j,t} l_{j,m,t} \quad \text{and} \quad \forall_{j>\bar{J}}: b_{j,m,t} = (1 + g_t) b_{j-1,m,t} \tag{12}$$

where g_t denotes the economy payroll growth rate (in the steady state with constant population growth, it is equal to the exogenous technological progress), and $w_{j,t} = \omega_j \times w_t$ denotes the age-specific productivity profile. Note that the agents, when solving their problem, include the future pension benefit in their labor derivative (Bütler, 2002). The German pension system is of a defined benefit character, but citizens record points in the pension system, which reflect the multiplicative of their productivity relative to the contemporaneous average in the economy, thus yielding strong labor supply incentives. Adopting the implicit taxation approach in the intra-temporal choice allows to reflect this feature.[8]

[8]The point system in Germany incorporates a cut-off at 2.1 national average. Agents in our model are not sufficiently heterogeneous in productivity to reflect the full intra-cohort heterogeneity of earnings, so this cut-off would not be binding.

In the PAYG DB system, as characterizes Germany, social security budget constraint is given by

$$B_t = \sum_m \sum_J^{j=\bar{J}} N_{j,m,t} b_{j,m,t} = \tau_t w_t L_t + \mathcal{S}_t, \tag{13}$$

where we denote the social security deficit by $\mathcal{S}_t$ (it is negative if social security runs a surplus). The government clears the balance of the pension system. The universal, mandatory pension system does not change between our scenarios, although we study the change in the pension system parameters.

2.4 Government

There are four types of taxes: labor income, capital income, consumption, and lump sum tax. *Per capita* public spending G_t is stationary in both the initial and the final steady states, that is, it grows at γ_t. The government spends G_t, services public debt $r_t D_t$ and balances social security following equation (13), financed through tax revenues and issuance of new public debt.

$$\mathcal{R}_t = \tau^l w_t L_t + \tau^l B_t + \tau^k r_t A_t + \tau_t^c C_t + \Upsilon_t \sum_{j=1}^{J} \sum_m N_{j,m,t} \tag{14}$$

$$\mathcal{R}_t = G_t + \mathcal{S}_t + r_t D_t, \tag{15}$$

where C_t, B_t, and A_t denote aggregate consumption, pensions benefits, and assets, respectively, whereas $w_t L_t$ denotes labor revenue in the economy; we denote by $\mathcal{R}_t$ total tax revenue of the government. We set the debt in the initial steady state at par with the data. The final steady state debt to GDP ratio is the same; otherwise, it would generate welfare effects on its own.

In the initial steady state, we calibrate the tax rates to match the tax revenue shares in GDP, following Mendoza *et al.* (1994). In the initial steady state, we close the government budget constraint portrayed in equations (14) and (15) with a lump-sum tax (Υ). When the economy changes between the initial steady state and one of the studied final steady states, the consumption taxes adjust accordingly. Note that G_t and $\Upsilon_t \sum_j \sum_m N_{j,m,t}$ adjust due to population change. Note also that in our simulations, the contribution rate τ or replacement rate ρ adjusts to maintain $\mathcal{S}_t = 0$ in the final steady state despite longevity. As Section 4 describes, in the initial steady state, the social security is also balanced, in line with the data.

2.5 Production

The economy produces a composite consumption good. A representative firm employs labor and capital. Without loss of generality, we assume a Cobb-Douglas production function: $Y_t = K_t^{\alpha}(z_t L_t)^{1-\alpha}$, with K_t denoting capital and L_t denoting labor aggregates. Capital depreciates at the rate of d. In line with empirical evidence, the economy features labor augmenting exogenous technological progress, $\gamma_t = z_{t+1}/z_t$. Given this parametrization, a representative firm optimizes labor and capital demand, thus yielding the price of capital and wage:

$$r_t = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d \quad \text{and} \quad w_t = (1-\alpha) K_t^{\alpha} z_t^{1-\alpha} L_t^{-\alpha}. \tag{16}$$

2.6 Equilibrium and model solving

Definition 1 *A competitive equilibrium is an allocation* $\{(c_{j,m,t}, a_{j,m,t}, l_{j,m,t})_{j\in(1,\ldots,J),m\in M}\}_{t=0}^{\infty}$, *prices* $\{r_t, w_t\}_{t=0}^{\infty}$, *aggregate quantities* $\{L_t, A_t, K_t, C_t, Y_t\}_{t=0}^{\infty}$, *and government policies* $\{\tau_t^c, \tau^l, \tau^k, \Upsilon_t, D_t, \mathcal{S}_t\}_{t=0}^{\infty}$, *such that:*

- ***consumer objective:*** *for each* $(j, m, t) \in \{1, \ldots, J\} \times M \times \mathbb{N}$, *the values of:* $(\tilde{c}_{j,m,t}, \tilde{a}_{j,m,t}, \tilde{l}_{j,m,t})$ *solve the consumer problem described in* equations (2), (5), (8), *given prices, and pension system characteristics* (τ, ρ)*;*
- ***firm's maximization problem:*** *for each* t, *given prices* (r_t, w_t), *the aggregates* (K_t, L_t, Y_t) *satisfy* equation (16)*;*
- *the* ***government*** *balances budget as well as the PAYG pension, that is,* equations (13)–(15) *hold;*
- ***markets clear:***

$$\textit{labor market}: L_t = \sum_{j=1}^{J} \sum_{m} \omega_j l_{j,m,t} \tag{17}$$

$$\textit{capital market}: A_t = \sum_{j=1}^{J} \sum_{m} a_{j,m,t} \quad \textit{and} \quad K_t = A_t - D_t \tag{18}$$

$$\textit{goods market}: C_t = \sum_{j=1}^{J} \sum_{m} c_{j,m,t} \quad \textit{and} \quad Y_t = C_t - dK_t + G_t. \tag{19}$$

The consumer problem is solved with value function iterations due to the non-negativity constraint on assets. A consumer chooses optimal labor supply and consumption given prices and taxes. The Gauss-Seidel algorithm aggregates consumer decisions on savings to yield capital for the next iteration. Updating aggregate capital allows us to obtain internally consistent prices and taxes, which allows the consumer to re-optimize. Convergence and hence equilibrium is obtained once l_1-norm of the vector of capital changes is below 10^{-12} in the subsequent iteration.

3. Policy reforms

Our model features the common initial steady state across all policy experiments. In all scenarios, longevity is higher in the final steady state than in the initial one, in line with the demographic projections. In the baseline scenario, no new instruments are introduced in the final steady state. In the reform scenarios, we offer several variants of the OAS schemes.

In the baseline scenario, we obtain changes in macroeconomic aggregates purely due to changes in life expectancy. Notably, longevity implies that the pension system stops being fiscally neutral: either the contribution rate has to increase or the replacement rate has to decline. The size of either of these adjustments is obtained in the model.

(a) We raise contributions to keep social security in balance. The required adjustment in the contribution rate informs on the size of a potential corresponding capital-based OAS scheme with fiscal incentives. In other words, we use the magnitude of this rise to set the size of OAS schemes.
(b) We reduce the replacement rate (pension benefits) to keep social security in balance. The comparison of the scenarios of increased contribution rates versus reduced replacement rates informs on the preferences of agents towards *laissez faire*, that is, the size of the pension system. We also keep the scenario of pension decline as our baseline for studying the effects of OAS programs.

Thus, our baseline is consistent with the following policy choice: reduce pensions to maintain fiscal stability in light of longevity and let *laissez-faire* private voluntary savings compensate for longer life at

retirement with lower pensions. Given that we adjust the size of the OAS instruments to be fiscally equivalent, in practice, the exempt may signify full or partial tax exemption or even negative taxation (i.e., generally preferential tax treatment or a subsidy). In other words, the size of the exempt adjusts endogenously.

The key reforms in this study concern the introduction of incentivized OAS schemes. Recall that unincentivized, private voluntary savings for old-age consumption are subject to full taxation at contribution and accumulation phases but are exempt from any dedicated taxation at the disbursement stage. The government-subsidized old-age voluntary pension schemes are essentially tax incentives, that is, partial or full tax exemption. Following the OECD taxonomy, we introduce incentives to voluntary pension savings at the contribution, accumulation, and disbursement stages. Government-incentivized OAS instruments are typically capped in size (OECD, 2018, i.e., the tax-exempt eligibility is limited to a certain level of contributions or a certain level of assets). We use the implied rise in contribution rates from the baseline policy experiments to set this cap. Using OECD taxonomy, our OAS policy experiments are:

1. typical OAS schemes, denoted as E-E-T (contributions and accumulation are exempt, pension benefits are taxed);
2. T-T-E (taxed-taxed-exempt: contribution and accumulation stages are taxed, but disbursement is exempt from taxation) with proportional subsidy;
3. T-T-E with a lump-sum subsidy.

Since we introduce various schemes, keeping them comparable in terms of fiscal size is imperative. For the OAS schemes to be comparable with the changes in the pension system parameters, we evaluate the indispensable rise in the contribution rate in the public pension system to keep the pension system balanced in light of longevity. We obtain the (cap of) contribution rate to the OAS by comparing the contribution rate with and without longevity. We thus set the rate of contribution to the E-E-T scheme (a cap), and to maintain internal consistency, we fully exempt these funds from labor taxation, social security contributions (in the contribution stage), and capital income taxation (in the accumulation stage). To keep the T-T-E scheme comparable in size, we measure fiscal expenditure on the tax exempts in the E-E-T scheme as the share of GDP and then assign a subsidy to retirees at disbursement to maintain the same level of fiscal expenditure as with the E-E-T scheme.

Thus, the tax incentives are equivalent, that is, we obtain the size of exempt such that in each scenario, the same amount of government funds (in % of GDP) is allocated to the households. The participation decision is voluntary: the households use up the entire cap but are free to choose the age at which they contribute to OAS. The specific formulae for each instrument are relegated to Appendix A. Note that OAS schemes are not a part of social security. OAS schemes induce adjustments in labor supply and wages, which affect the balance of the pension system, but OAS instruments do not enter directly into the pension system balance depicted in equation (13).

Introducing OAS schemes does affect the government budget constraint described by equation (14). First, not entire earned income (labor income in E-E-T and pension income in T-T-E schemes) is subject to labor taxation due to the OAS incentives. For the same reason, not entire capital income is subject to taxation (in the E-E-T scheme). It is reflected in the following fiscal closure. Let $\Xi_t = G_t - \Upsilon_t \sum_j \sum_m N_{j,m,t}$, then:

$$t = FSS{:}\tau_t^c = \frac{\Xi_t + r_t D_t - \tau^k r_t \tilde{A}_t - \tau^l w_t \tilde{L}_t - \tau^l B_t - \mathbb{I}\tau^l \sum_{j=\bar{j}}^{J} \sum_m \text{taxable OAS benefits}}{C_t}. \tag{20}$$

In this notation, I captures the fact that in some final steady states, the OAS schemes are implemented. Consequently, $r_t\tilde{A}_t$ denotes taxable capital income, which need not be the same as r_tA_t in the presence of OAS schemes, because with E-E-T scheme capital proceeds *in* the OAS scheme are exempt from

Table 1. Policy reforms – summary

Reform	Taxing stages		Collecting	Proportional Subsidy
	Contributing	Accumulation		
E-E-T	No	No	Yes	Proportional
T-T-E	Yes	Yes	No	Proportional
T-T-E flat	Yes	Yes	No	Lump-sum

Notes: all instruments are fiscally equivalent in that the amount of tax redemptions or subsidies is the same as a share of GDP. The instruments also have the same contribution (see section 6). Participation is endogenous (voluntary) in all instruments.

taxation. Likewise, participants in either of the three OAS schemes do not pay labor income tax on contributions to the OAS, hence $w_t\tilde{L}_t < w_t L_t$ if at least one agent endogenously chooses to participate in E-E-T for at least one period. Finally, the rules for taxation of OAS benefits differ between the three studied schemes and are described in more detail in section 3.

Introducing OAS schemes changes the equilibrium definition, as per Section 2.2. Namely, the consumer choice variables include participation in OAS: the maximization problem is subject to altered budget constraints, given the relevant definition of $\mathcal{I}^r$ instead of $\mathcal{I}$ in case of participation.

The reforms are summarized in Table 1. First, we study an E-E-T scheme. For fully rational households, an E-E-T scheme implies that the interest rate in the OAS is higher than on voluntary saving (assets accumulated in the scheme are exempt from capital income taxation) and labor tax is lower (contributions to the E-E-T scheme are savings with a high return rather than taxes). Consequently, households may save less in voluntary assets (the OAS brings a higher rate of return) and effectively work less (the same number of hours worked brings a higher return over a lifetime). The implications are the same for households with access to financial markets (financially literate) but with time-inconsistent preferences. Finally, for financially illiterate households, OAS creates access to financial markets, thus dramatically raising their rate of return on savings. This group of households will most likely increase savings, but they also obtain a source of additional income, which reduces their incentives to work.

In both T-T-E instruments, at the disbursement stage, households not merely receive their savings exempt from taxes but also an additional subsidy. We study two different kinds of subsidies. In the proportional T-T-E scheme, retirees receive a subsidy proportional to their pension benefit. In this setup, the individuals internalize the size of the future subsidy in their intra-temporal choices through the implicit link between labor supply and future pensions. In the T-T-E flat scheme, retirees receive a lump sum transfer every period during their retirement. This scheme is equivalent in fiscal terms, but since the transfer is a lump sum (the same for all participants), it does not enter the labor supply decisions during the agents' working periods.

For a fully rational agent, the proportional T-T-E instrument implies the same adjustments as the E-E-T instrument, so long as the two types of instruments are of similar magnitudes. However, a T-T-E flat scheme breaks the direct proportionality between labor supply and lifetime asset smoothing because the subsidy amount does not depend on the hours worked.

For financially literate agents with time-inconsistent preferences, T-T-E instruments provide lower incentives to save early in life than the E-E-T instrument. Moreover, since gains are only observed in the future, time-inconsistent agents *assert* that the incentives in T-T-E instruments as smaller than in the E-E-T instrument.

For financially illiterate agents, T-T-E instruments, in parallel to E-E-T, provide access to the market interest rate, thus fostering incentives to save at all. Since proceeds from capital accumulated in OAS are taxed, these incentives are lower than in the E-E-T scheme. Lump sum transfer in T-T-E flat instrument reinforces this effect of dampening the incentives.

3.1 Measuring the effects of policy reforms

Introducing OAS instruments has been motivated in many ways: to combat old-age poverty, to raise the accumulation of capital in the economy, to overcome inter-generational inter-generational

'conflict', etc. Given this multiplicity of potential policy objectives, the measurement of policy outcomes needs to be particularly comprehensive. We study macroeconomic changes and propose three ways to synthesize the changes in well-being: poverty, welfare, and saving regret.

First, we look at (relative) poverty. We study the changes in the distribution of consumption across agents. This metric is applied because it helps to understand if the incentivized OAS instruments help reduce, in particular, old-age poverty. Since fiscal incentives for OAS instruments are costly, they will result in redistribution between the behaviorally heterogeneous agents, but they will also generate inefficiency due to increased taxation in the economy. Studying poverty allows for capturing post-tax consumption levels, thus helping to study the effects in terms of the ultimate policy objectives. Note, however, that old-age poverty in our setup stems from behavioral limitations (insufficient saving during the working period). Thus, we take into account heterogeneity in the degree of rationality, but we abstract from other sources of poverty, for example, health or earning abilities.[9]

Second, inspired by recent work on saving regret (Boersch-Supan *et al.*, 2018), we study the role of the asset gap at retirement in welfare. Namely, in partial equilibrium, we obtain the *post-retirement* choices of the incompletely rational agents as if they obtained (in the form of a windfall gain) assets of the fully rational agents. Having observed these choices, we may obtain an entirely counterfactual measure of felicity 'loss' related to not having this windfall gain. We then convert the difference between actual post-retirement utility and this counterfactual utility into consumption equivalents, which essentially inform about the utility value of regret for not having accumulated the same amount of assets as a fully rational agent. Since this measure is also utility based, it faces the same problems as pure welfare metric. We use all three approaches to measuring saving regret: multiple selves, backward-looking, and forward-looking.

Finally, we provide normative inference. Standard welfare analysis is based on consumers' choices among the available bundles (e.g., how much to consume and work at a given age). Using the observed choices to infer preferences (Gruber and Koszegi, 2001) is standard. We can then use those preferences to infer if another bundle raises the felicity of agents. Consider the welfare of agents. To measure welfare, one typically compares the optimized lifetime utility U in the *status quo* scenario with the analog in a given reform scenario U^r. We express the welfare effect of reform in terms of consumption equivalent.

Unfortunately, with time inconsistency, there is no unique utility function, which makes it impossible to map choices uniquely into a welfare function. Lifetime utility measured at $age = j$ differs from lifetime utility measured at $age = j + s$.[10] The literature proposes to rely on compensating variations between multiple selves (Laibson *et al.*, 1998; Bhattacharya and Lakdawalla, 2004; Caplin and Leahy, 2004), and in the context of pension analysis, this approach has been operationalized by Imrohoroğlu *et al.* (2003). This approach effectively weights welfare gains from the best available choice at different ages with the quasi-hyperbolic time preference with the discount δ. In the main body of the paper, we report inference based on Imrohoroğlu *et al.* (2003).[11]

[9]Individuals without or with low earning abilities would not benefit from OAS anyway; hence other instruments are due.

[10]The expected ex-ante and actually experienced utility differ, and aggregating over a lifetime is thus not straightforward. For example, agents may expect to supply a certain amount of labor when being in age j for the period when they are aged $j + s$, but those s periods later, their actual labor supply may differ from their original plan. It is why time inconsistency is sometimes considered to be an issue of commitment or self-control (Strotz, 1955; Gul and Pesendorfer, 2001, 2004).

[11]There are two alternatives to this approach. The first measures utility from realized choices rather than the actual utility at the time of decisions (e.g., Carroll *et al.*, 2009; Heutel, 2015). Note that agents do not rely on this utility when making their choices. This approach is effectively backward-looking because it can only be obtained once the agent has made choices about all her ages. The second approach uses the welfare of an agent as computed in the first period (e.g., Krusell *et al.*, 2002). This approach is forward-looking in the sense that all periods but the first are additionally discounted with the factor β. The advantage of this approach is that we do not omit the additional impatience given by the factor β, which is an essential characteristic of time-inconsistent households. The disadvantage is that the reference point, the first period of life, is chosen completely arbitrarily. Since all three welfare measures aggregate experienced utility, the only difference between the obtained

4. Calibration

The economy is calibrated to replicate the features of the contemporaneous German economy. Demographics and technological progress are entirely exogenous in our model. We use the demographic forecast from Eurostat for 2080 to obtain survival rates for the final steady state. We assume the contemporaneous survival rates to reflect the initial steady state.

Following European Commission (2018), we set the rate of exogenous technological progress at 1% per annum in the initial steady state. We assume the capital income share in the economy to be $\alpha =$ 33%. Hours worked are calibrated using OECD Employment Outlook data. Our calibration features age-specific productivity profile ω_j. We follow Fehr *et al.* (2015) in setting the age profiles.

We use national accounts data from Eurostat to obtain the target aggregates for the investment rate, government spending, and public debt as a share of GDP. We use averages for 1995–2017 as targets. We assume the interest rate of 6%, which is a conventional assumption for Germany.[12] This interest rate, together with the investment rate, defines the depreciation rate in this economy.

We use OECD Tax Database data to obtain tax revenues as a share of GDP for consumption, labor, and capital taxes in the initial steady state. We follow Mendoza *et al.* (1994) to obtain effective tax rates from these aggregates. We use averages for 1995–2017 as targets.

We use the share of pension expenditure in GDP to obtain the replacement rate. The Aging Working Group report for Germany (European Commission, 2018) provides data on the share of pension benefits in GDP.[13] We assume the social security to be balanced in the initial steady state, thus directly implying a contribution rate.[14] Relying on OECD (2018), we set the retirement eligibility age at $\bar{J} = 65$.

Table 2 reports the calibration of the macroeconomic aggregates in the model economy in the initial steady state. Note that our model economy is fully annuitized, whereas the aggregate German economy is not.

5. Behavioral (intra-cohort) heterogeneity

Observational data, especially if only cross-sectional, give limited opportunities to identify the scope of behavioral biases of incompletely rational agents. It is due to two major reasons. First, having no instantaneous savings is consistent with a wide variety of behavioral biases and life situations: hand-to-mouth behavior, a high degree of time inconsistency, and financial illiteracy – they all yield virtually no asset accumulation in the early years of the career.

Similarly, lack of instantaneous savings is also consistent with repaying credit, for example, mortgage, if individuals pursue investment in real estate as an old-age saving strategy. Second, observing instantaneous savings may be consistent with precautionary motives and savings for indivisible consumption goods and services (e.g., relatively more expensive durable goods or more expensive services

welfare measures stems from the method of aggregation. These three conventions for aggregation yield qualitatively similar conclusions but quantitatively different outcomes. This reinforces two points we raise in our paper. First, aggregation of welfare is problematic conceptually already at the individual level, let alone across agents of different behavioral types. Hence, the selected welfare measure can largely influence the *ex-ante* evaluation of the reform. Second, in the case of agents of incomplete rationality, the welfare change heavily depends on the assumption of the origin of incomplete rationality. Financial literacy enters through the budget constraint in our setup, whereas time inconsistency features the utility function. One could think about other types of incomplete rationality and equivalence between utility function and budget constraint. For example, hand-to-mouth agents could be modeled either through the budget constraint (no ability to save at all) or through the utility function (extremely high discounting of the future).

[12]See Fehr and Habermann (2006); Fehr and Jess (2007); Fehr *et al.* (2008*a*); Corneo *et al.* (2009); Dieckhoener and Peichl (2009); Dolls *et al.* (2018); Seibold (2019).

[13]The implied average replacement rate in this economy, computed as average benefit divided by average salary, amounts to 34.8%. The current reports for Germany reveal a similar replacement rate, that is, 38% (OECD, 2018).

[14]Germany currently observes a minor surplus in the social security of roughly 0.3% of GDP (European Commission, 2018). Given that the system is roughly balanced, one could use the approach of Mendoza *et al.* (1994) to obtain effective contribution rates. The two calibration approaches yield contribution rate parameters of similar magnitudes.

Table 2. Calibration of the macroeconomic parameters

Parameter		Value	Data source		Data Target	Model (annuitization) No	Model (annuitization) Yes
Macroeconomy							
Depreciation	d	0.0664	National accounts	Investment rate	20.00%	20.00%	21.39%
Leisure preference	ϕ	0.3193	OECD	Hours worked	35.00%	35.00%	36.03%
Time preference	δ	1.0037	–	Interest rate	6.00%	6.00%	5.18%
Taxes & government							
Consumption	τ^c	0.1500	OECD	$\tau^c \cdot \left(\sum_{j,m} C_{j,m}\right)/Y$	9.18%	9.18%	8.97%
Labor income	τ^l	0.0881	OECD	$\tau^l \cdot wL/Y$	6.75%	6.75%	6.75%
Capital income	τ^k	0.2253	OECD	$\tau^k\left(\sum_{j,m} K_{j,m}\right)/Y$	4.47%	4.47%	4.07%
Contribution rate	τ	0.1432	–	*subsidy*/Y	0%	0%	0.01%
Replacement rate	ρ	0.0079	AWG 2018	B/Y	9.60%	9.60%	9.61%
Gov't expenditure	G	0.1882	National accounts	G/Y	18.82%	18.82%	18.82%

Note: We denote subcohort by m. AWG: Aging Working Group. National accounts data from Eurostat. Employment data from OECD Employment Outlook. Tax data from OECD Tax Database. We obtain the values of the parameters by calibrating the economy, which is not fully annuitized. This calibration refers to a capital share in the economy $\alpha = 33\%$. We report the alternative calibration of the initial steady-state with a capital share in the economy $\alpha = 45\%$ in Table F.1 in the Appendix. The interest rate reported in Table 2 is r_t as per equation (16). In the model with full annuitization on top of the interest rate, r_t, financially literate agents get annuity premium, $\mu_{j,t}$. This renders the net interest rate faced by financially literate agents age-specific.

such as children's education or vacation travel). It is particularly troublesome in cross-sectional data, where individual asset and consumption decisions are observed over time.

Given these constraints, empirical evidence on the behavioral structure of populations worldwide is scarce. We thus model our economy with the interest of insights into the varying degree of time inconsistency and its potential interaction with financial literacy. Accordingly, equinumerous subgroups of agents exhibit a different degree of time inconsistency. These subgroups are again split into financially literate and financially illiterate groups.

More specifically, our population consists of agents with varying degrees of time inconsistency as follows: equinumerous eleven subcohorts with $\beta \in \{0.5, 0.55, \ldots, 1\}$. Within each such subcohort, 50% of agents are characterized by a lack of financial literacy, and 50% of agents are financially literate. Overall, that implies twenty-two subcohorts, each of the same share in a cohort of a given age, reflecting various behavioral patterns. This behavioral structure does not intend to reflect the prevalence of incomplete rationality in the population. Instead, it helps us to study in detail specific types of individuals.

In Figure 1, we portray the heterogeneity of asset accumulation lifetime profiles across the types of agents. Notably, agents lacking financial literacy are characterized by meager savings even if they do not suffer from time inconsistency. Agents with no financial literacy also postpone the period in life in which they begin to accumulate assets. A higher degree of time inconsistency further delays the moment of accumulating assets. Financially illiterate agents also de-accumulate assets faster than fully rational or financially literate agents with comparable levels of time inconsistency. Two mechanisms are at play, both working in the same direction. First, since these agents earn no interest on private voluntary savings even after retirement, their assets do not increase in value for lack of accrual. Second, postponing consumption comes at a high price: their MRS remains bound by 1, as revealed in equation (10). Agents with time inconsistency also de-accumulate assets faster than fully rational agents.

In Figure 2, we portray the proxy for saving regret across the diverse group of incompletely rational agents. The fully rational agents are represented in this figure as financially literate with no time inconsistency (the bottom right corner of the graph). Intuitively, fully rational agents display no saving regret. Overall, the greater the departure from the profile of a fully rational agent, the greater the share of permanent consumption that an agent would give up to obtain the assets of a fully rational agent at retirement. This share reaches approximately 30–40% (depending on the metric) for the financially illiterate agents and as much as 45–60% for the financially literate agents with a high degree of time inconsistency ($\beta \approx 0.5$).

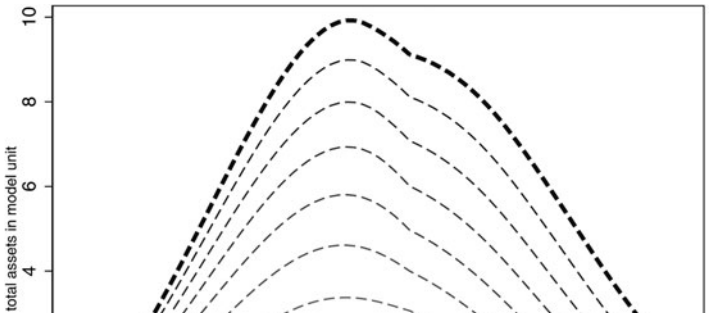

Figure 1. Assets: private voluntary savings in initial steady state – calibration for $\alpha = 33\%$.
Note: figure portrays baseline profiles of asset accumulation across various types of agents. Dashed lines are used for financially literate agents. Solid lines are used for financially illiterate agents. Darker shades of gray signify β parameter closer to 1 (i.e., lower extent of time inconsistency). Thick black lines denote agents with $\beta = 1$ for reference. Fully rational agents are financially literate with no time inconsistency ($\beta = 1$, thick dashed lines).

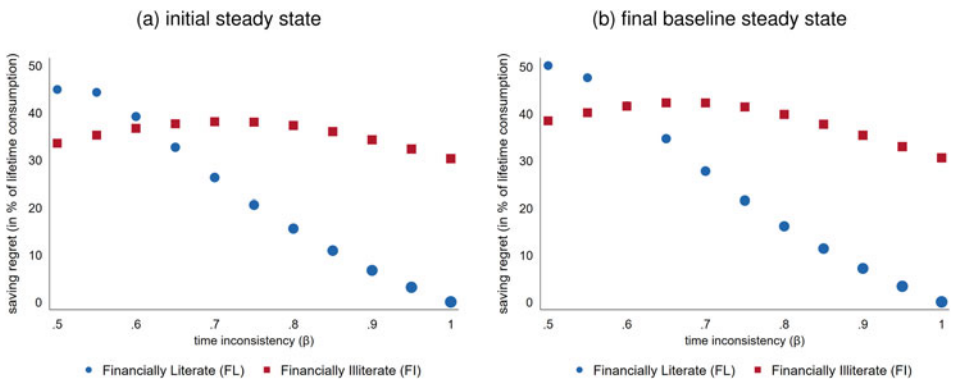

Figure 2. Saving regret, welfare in the spirit of Imrohoroğlu *et al.* (2003).
Note: saving regret computed following the procedure described in Appendix B.4. Saving regret is expressed in terms of consumption equivalent (% of lifetime consumption). The baseline scenario assumes pension decline to maintain pension system balance. Welfare in the spirit of Imrohoroğlu *et al.* (2003), see Appendix B.

Among financially literate agents, the 'saving regret' proxy is the highest for the highest degree of time inconsistency, which stems from the fact that these households deviate from the fully rational optimization the most. For financially illiterate agents, regardless of the degree of time inconsistency, the regret remains high, reflecting a high share of lifetime income lost due to the inability to accrue interest. The fact that welfare loss from not behaving 'rationally' about asset accumulation is greater for financially literate agents with extreme time inconsistency than for financially illiterate ones reflects the fact that financial literacy is modeled through the budget constraint, and those agents receive no interest on their assets past retirement (welfare gain from having their asset gap bridged is lower). The differentiated level and patterns of saving regret corroborate the case for studying financial literacy and time inconsistency as separate phenomena.

6. Results

This paper aims to answer two key questions: (i) can fiscal incentives to old-age savings alleviate looming old-age poverty; (ii) what are the effects of government-subsidized OAS for incompletely rational agents. Answering the first question, we quantify the changes in poverty rates among old age and the

total population. While answering the second question, we report saving regret, welfare, and participation.

In the baseline scenario of no new policy instruments, longevity necessitates a rise in contributions or a decline in pensions. In our calibrations, either the pensions have to decline to 74% of the current (initial steady-state) level, consistent with earlier literature for Germany (Fehr *et al.*, 2012), or the public system has to raise the contributions by 5.07 percentage points from the current (calibrated) 14.32%. We use these results as benchmarks for the OAS schemes.[15]

In the reform scenarios, when introducing the OAS schemes, we keep the public pension contribution rate unchanged from the initial steady, and the *additional* contribution of 5.07 percentage points is raised towards funding the OAS schemes. Note that public system pensions have to decline to maintain the stability of social security. All inference concerning the saving regret and welfare is done relative to pure pension benefits decline to adjust for this fact.

6.1 Poverty

Poverty incidence substantially declines with the introduction of OAS schemes, as we portray in Figure 3. Recall that old-age poverty in our setup stems from the degree of incomplete rationality rather than adverse life events or low earning potential, as these require other policy tools. A change from hollow to filled marker portrays the change in the age-adjusted incidence of poverty, separately for financially literate (red) and financially illiterate (blue) agents. We define poverty as consumption below 60% of median consumption in the initial steady state. Using data from our simulation outcomes, each agent at each age is classified as poor if her consumption falls short of this threshold. We then estimate a probit model of poverty incidence across types of agents, adjusting for age.

Poverty incidence is high in the baseline of declining pensions (i.e., a baseline scenario where the government reduces pension benefits to balance the social security budget despite longevity), particularly for agents with high levels of time inconsistency. This incidence is very much reduced, almost to zero, for both financially literate and illiterate agents, regardless of time inconsistency. This large reduction in poverty is related to OAS incentives being a large transfer program.

Indeed, OAS instruments have a large redistributive element, and we ask to what extent the implied fiscal transfers are targeted to those types of agents who are most at risk of old-age poverty. We study (relative) poverty in Figure 4. The figure is based on consumption observations for each agent in each year of her life (that is, both working and retirement periods). The vertical line indicates the relative poverty line defined as 60% of median consumption in the initial steady state. The results demonstrate that reducing pension levels to address longevity would increase poverty relative to the alternative of increasing pension contributions. It is to be expected in an economy populated by households with bounded rationality because such households do not accumulate sufficient private savings, as our analysis of the saving regret proxy has demonstrated. Our results show that all three OAS schemes alleviate extreme poverty by shifting households with very low old-age consumption above the (relative) poverty line.

In Figure 5, we document redistribution through the OAS for all three types of instruments, with fully rational households portrayed furthest to the right. On the horizontal axis, we depict the asset gap at retirement relative to a fully rational household. We think of this indicator as a proxy for the pension wealth gap. On the vertical axis, we depict how much a given type of household receives through government subsidies of OAS. An efficient transfer scheme would allocate most funds to those with the highest pension wealth gap. A non-distortive transfer scheme allocates the same amount to all types of households. T-T-E flat is an example of a non-distortive transfer. In the case of E-E-T and proportional T-T-E, the transfers depend on the amount of funds accumulated in OAS; hence, they correlate with accumulated pension wealth levels.

[15]Macroeconomic implications are reported in Appendix C.

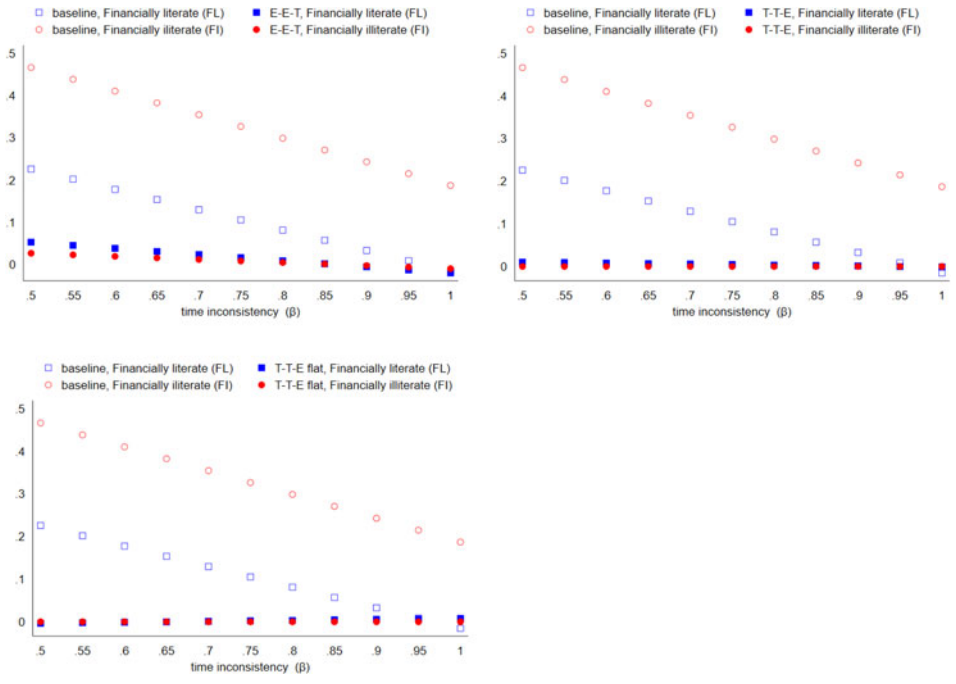

Figure 3. Age-adjusted incidence of relative poverty.
Note: The vertical axis signifies age-adjusted incidence of poverty in %. Figures portray predicted probabilities from a regression where the poverty dummy is the explained variable, and the explanatory variables include OAS/baseline, age, and financial literacy dummy. The baseline is defined as declining pensions.

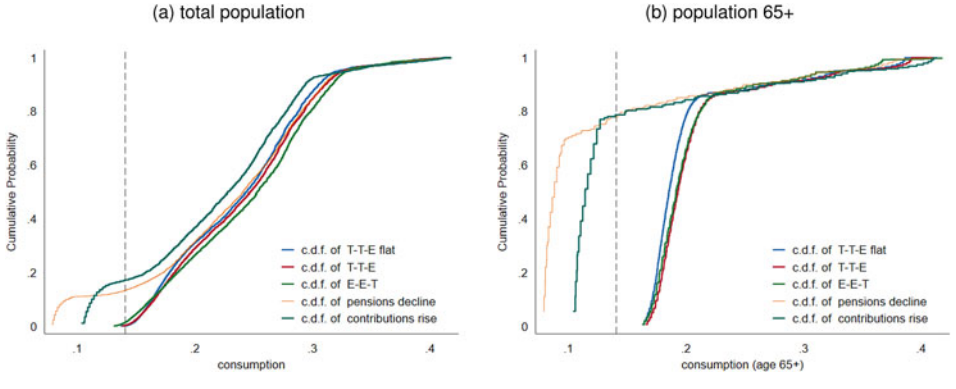

Figure 4. Relative poverty and old-age poverty.
Note: The vertical line denotes 60% of median consumption in the initial steady state. Figures report cumulative distribution plots for consumption in the final steady-state across the five studied scenarios: (i) status quo pensions with increased contribution rates; (ii) reduced pensions to maintain balanced social security; (iii) E-E-T; (iv) T-T-E and (v) T-T-E with a flat subsidy. The left panel reports the full population. The right panel reports consumers aged 65 and older. In the figures, we leave out the top 5% for clarity. Note that the consumers in our model are distinguished by age and behavioral patterns (time inconsistency and financial literacy).

Figure 5 effectively portrays how well the OAS incentives target the pension wealth gap of the incompletely rational households, suggesting that prevalent OAS schemes are not fully efficient. On the one hand, in E-E-T and proportional T-T-E, incentives reaching financially illiterate agents are generally high (the hollow data points in our figure, households generally characterized by low

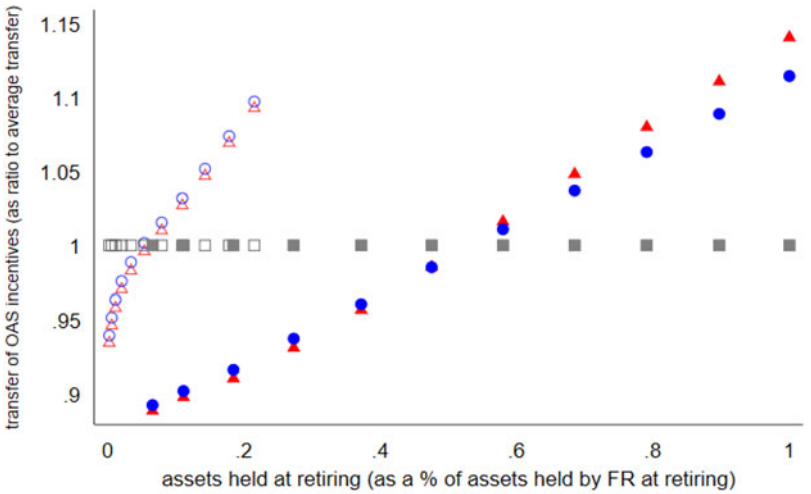

Figure 5. Transfers for OAS incentives.
Note: FR, fully rational household; FI, financially illiterate household; FL, financially literate household. Total transfer in OAS is computed in model units and expressed as a ratio to average per capita transfer. The transfer measure adds up the incentives received by a given type of agent through the OAS scheme (tax exemptions or subsidies). On the horizontal axis, we order households by the assets accumulated for retirement as a fraction of assets accumulated by fully rational households. Hollow circles denote financially illiterate households. Full circles denote financially literate households.

assets relative to a fully rational household). On the other hand, transfers received by fully rational households are larger than for any other group of households (the top right corner data points). Moreover, households with a high degree of time inconsistency *and* financial literacy receive substantially fewer transfers than financially illiterate households with a similar level of time inconsistency for virtually the same level of the pension wealth gap. To summarize, fiscal transfers do not generally go to households most in need during retirement.

6.2 Saving regret

We study how OAS schemes affect our proxy for saving regret. In general, incompletely rational agents save less than fully rational agents. When we provide them with a windfall of assets, matching their retirement assets to the levels of fully rational agents, they obviously have higher utility. This is why the saving regret proxy is strictly zero for a financially literate agent with $\beta = 1$ (the right bottom corner). This measure is purely counterfactual, that is, no actual transfer is made, but agents re-optimize their old-age consumption as if they received such windfall gain, and we obtain utility differential between the business-as-usual and the windfall gain cases. We then study if those differentials are affected by an ability to join incentivized OAS schemes, and we expect this saving regret proxy to decline with OAS because participation in these instruments should, in principle, raise one's assets at retirement. The results are reported in Figure 6.

The saving regret proxy declines for financially illiterate households. These declines are substantial: saving regret proxy is reduced by 20 percent of lifetime income (or 40 percent of the original saving regret), that is, financially illiterate agents would require 20 percent less to give up the windfall in the world with OAS than in the world without it. The declines are much less substantial for financially literate agents, particularly with relatively lower levels of time inconsistency.

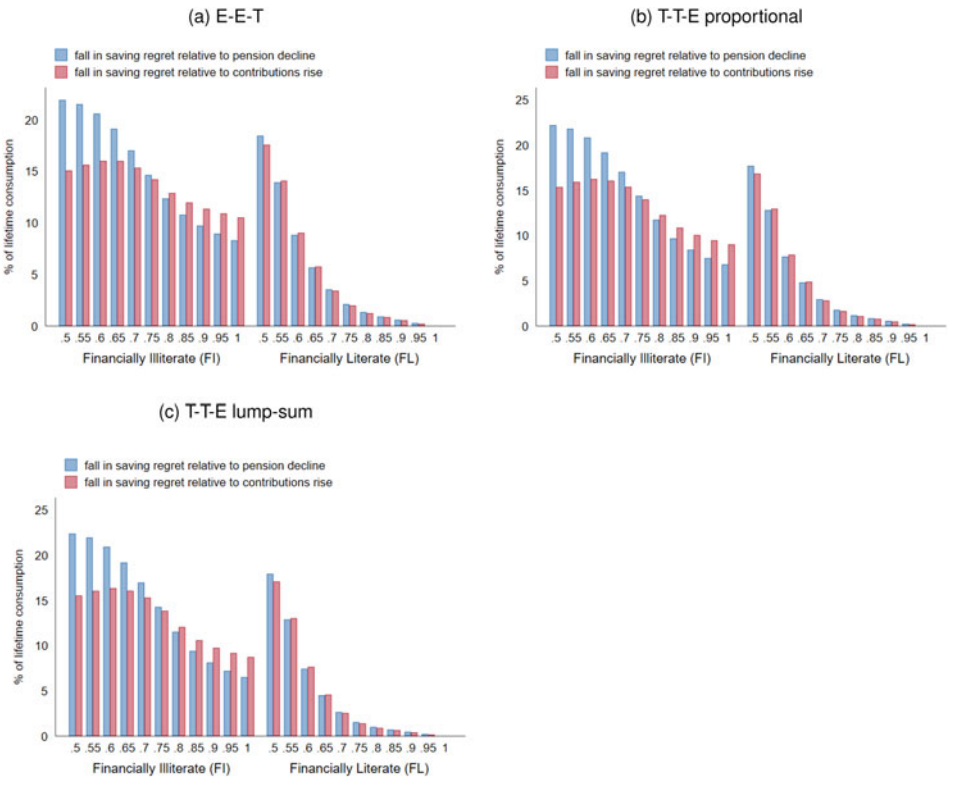

Figure 6. Saving regret decline.
Note: The bars portray a change in saving regret in welfare terms, aggregation according to Imrohoroğlu *et al*. (2003). Levels of saving regret in the initial steady state and the final steady state are reported in Figure 2.

6.3 Welfare effects

Introducing OAS raises the welfare of agents whose participation in financial markets is otherwise constrained. Figure 7 reports the change of utility-based measures across agent types. Generally, all agents join incentivized OAS schemes, and they do so as early as possible.[16] Large gains are obtained for financially illiterate households, especially relative to the scenario when these agents compare OAS to simply larger public social security. Financially literate households are unhappy about larger social security unless they are characterized by a high degree of time inconsistency.

Gains from the E-E-T instrument appear to be somewhat larger than the gains from T-T-E and T-T-E flat instruments, but these differences are minor relative to the size of the total welfare effect. In the spirit of Bütler (2000), one may gauge the potential political support for the studied instruments by studying which type of agents benefit from the change.

Two mechanisms stand behind these results. First, obtaining access to the market interest rate raises lifetime income substantially and facilitates consumption and leisure smoothing. By contrast, larger public pensions raise distortions. Note that larger public social security is a net positive present value investment for the financially illiterate agents, but since $r > g$, gains from OAS schemes are larger than gains from the larger public pension. This explains large positive welfare effects for financially illiterate agents.[17]

[16]Figure C.2 portrays endogenous participation decision.

[17]The losses from a larger mandatory social security are not monotonous in time inconsistency because households with a small degree of time inconsistency derive a high share of old-age consumption from private voluntary savings. Hence, the size

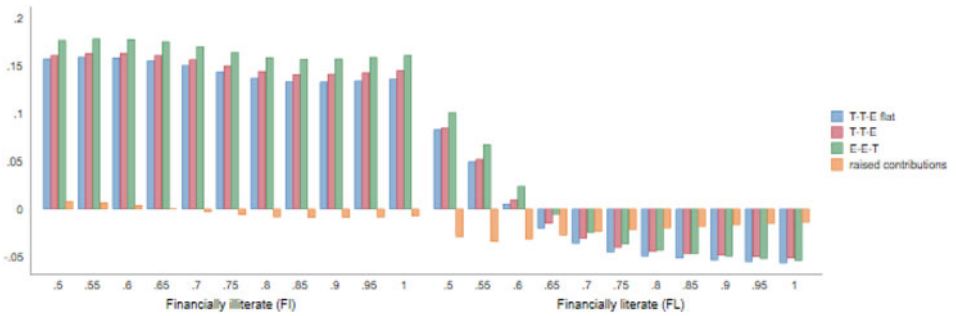

Figure 7. Welfare effects of the reform relative to *laissez-faire* of declining pensions.
Note: In this figure, we portray welfare expressed as consumption equivalent in percent of lifetime consumption across behaviorally heterogeneous groups, following Imrohoroğlu *et al.* (2003) measure. The comparison scenario for each reported result is a reduction in pension benefits such that social security is kept balanced despite the increase in longevity. The orange bars denote the scenario of raising the pension benefit contributions in order to keep pension levels constant while maintaining social security in balance. The E-E-T and two T-T-E instruments have contribution rates of the same magnitude as necessitated by the scenario of raised pension contributions. The size of fiscal incentives to the incentivized OAS instruments is such that the total fiscal expenditure on tax incentives is equivalent across scenarios in terms of share of GDP.

Second, the fiscal cost of the incentives is large. For example, a fully rational household, which would accumulate the same stock of assets under E-E-T as in the scenario of pensions decline, bears the costs of subsidies in the former. Naturally, fully rational households also receive the transfers, but these transfers are paid for saving that would occur regardless of whether the E-E-T program is implemented. In a T-T-E flat scheme, this reshuffling is neutral to consumer choice; in E-E-T and T-T-E schemes, it raises distortion for the fully rational household. For the incompletely rational household, the transfers received may be higher than the tax cost of the incentives, but only at the expense of other households. This explains the negative result for financially literate households with a relatively low degree of time inconsistency.

6.4 Sensitivity of the results

The results above take the Imrohoroğlu *et al.* (2003) as the basis of normative inference. Alternative welfare measures, taking backward-looking and forward-looking perspectives, are reported in Appendix D and E, respectively. Our inference is robust to the welfare metric.

Our main calibration assumes the capital income share in the economy to be $\alpha = 33\%$. This high labor income share in the economy means that even small changes to social security strongly affect fiscal balance. Since the capital share has been increasing over the past decades, we also present an alternative specification with the capital share in the economy of $\alpha = 45\%$ and the labor share in the economy of 55%. These results are reported in Appendix F, replicating all the main findings of the main specification.

The participation remains complete, but now for all the households' capital income is a higher share of total lifetime income. Hence, gains from implementing OAS are larger than under the main calibration, and the welfare loss of raising the contribution rate to the mandatory system increases. The system is more effective in targeting funds to financially illiterate agents, but still, most OAS incentives are received by agents with a relatively higher degree of rationality. Under this calibration, OAS schemes are less effective in eradicating the age-adjusted incidence of poverty among financially literate households, but old-age poverty disappears completely.

of the public system (and a negative net present value on the contributions to this system) is a smaller share of their welfare than for financially literate households with a high degree of time inconsistency.

In the main simulations, following European Commission (2018), we assume the total factor productivity growth will continue with the current 1% per annum. A higher rate of technological progress is more favorable towards pay-as-you-go systems because it raises the indexation rate of the pensions in the public system. Meanwhile, a lower rate of technological progress favors capital-based systems because capital is relatively more scarce and thus offers higher rewards. Since the current projections for Germany suggest an increase in technological progress to 1.54% per annum, we provide sensitivity analysis. These results are reported in Appendix G, virtually replicating all the main findings of the main specification.

Finally, many countries are considering raising the retirement eligibility age. Such a policy change has three effects. First, it reduces the scope of social security imbalance in the aftermath of longevity rise. Hence, the contributions rise may be lower (or the pensions decline may be less pronounced). Second, it may reduce old-age poverty. Directly in the pension decline scenario, simply because pensions will decline by less. Nevertheless, the indirect effect is also expected in other scenarios because the adverse fiscal impact of longevity is lower. Hence tax adjustment necessary to cover the social security deficit is also lower. Third, it also can raise labor supply and – depending on capital accumulation – even the labor tax base. Overall, OAS will be smaller, and the baseline of pension decline less painful for retirees in a world with a higher retirement eligibility age.

We quantify these effects in Appendix H, where we present all the analogous simulations for the case with a retirement age of 67 rather than 64 (as in the main simulations) in the final steady state. Despite a substantially smaller OAS (2.13% of payroll, when compared to 5.07% in the main simulations and to the overall mandatory pension contribution rate of 14.32% of payroll), all our results hold. Despite being smaller, OAS schemes reduce old-age poverty more effectively than the larger universal social security and the *laissez-faire* scenarios. They also continue to direct the majority of incentives to the agents who need them the least.

6.5 Discussion

Our results suggest that all types of households – fully rational ones and those characterized by incomplete rationality – choose to join OAS schemes as early as they can, and thus they participate throughout the entire working period even though many types of households suffer welfare loss from the introduction of OAS programs. It has two important implications. First, there are substantial differences between partial and general equilibrium effects for the OAS schemes due to the tax incentives. While some types of incompletely rational households do not experience welfare improvement, once the OAS schemes are implemented, they prefer to participate (i.e., receive fiscal transfers) than to opt-out (i.e., do not receive the transfers but nonetheless experience a rise in taxation due to other households receiving those transfers). We interpret this as an indication that participation *per se* is not a viable measure of whether OAS has political support or benefits the society.

Second, part of the behavioral economics literature argues for opt-out rather than opt-in clauses in OAS schemes design. It is believed that people procrastinate over decisions that bring benefits in the far future (Thaler and Benartzi, 2004; Benartzi and Thaler, 2007), and opt-out clauses guarantee that nobody is left behind. Instruments requiring incompletely rational households to enroll for the sake of not forcing the fully rational households to opt-out – reinforce the original mechanisms, which make incompletely rational households save too little for their old-age consumption. While one cannot accommodate the explicit choice of opt-in vs. opt-out for the OAS design in a structural approach as ours, we infer the following: once OAS schemes are in place, fully rational households prefer participation to opting out because otherwise, they bear the fiscal costs of the OAS incentives, without benefiting from them. Hence, opt-out seems desirable.

In studying the implicit redistribution through OAS schemes, we focus on old-age poverty stemming from insufficient savings during the working period, driven by incomplete rationality. Poverty may occur for various reasons, including adverse health shocks, low human capital, adverse labor market shocks, etc. These phenomena are addressed by policy instruments other than OAS schemes. In

fact, the normative inference would be unaffected by including these elements in our model (Werning, 2007). The same applies to the saving behavior driven by motives other than smoothing consumption into old age (e.g., precautionary savings, buffer stock savings, bequest motive).

7. Conclusions

Increasing life expectancy exacerbates the challenge for the economic policy of providing for consumption in old age. Recognizing these challenges, many governments worldwide offer tax-incentivized old-age savings schemes (OAS). However, studies on these instruments are rare in the literature. We contribute to the literature by studying how OAS schemes can address the challenge of old-age poverty.

Our approach innovates relative to vast pensions literature by focusing on incomplete rationality. In a standard setup with fully rational agents, roughly 55 percent of consumption at the age of 70 is financed through private voluntary savings, even in the presence of a relatively large public social security. It is clearly at odds with the empirical facts. In particular, standard models cannot explain a stark consumption decline at retirement, which is well-documented empirical regularity. While a part of this stark consumption decline can be explained away by refining measures of consumption (e.g., identifying private consumption related to professional activities from purely private consumption), it is undeniable that a large fraction of individuals holds much fewer assets than the fully rational agent would hold. Whereas studies with fully rational agents are not well suited for analyzing policies aiming at improving the economic situation in old age, our paper can fill this gap and thus inform policy. We study the consequences of government-subsidized old-age savings (OAS) schemes in an economy populated by incompletely rational agents with a realistic and dynamic demographic population structure.

Our study is calibrated to the case of the German economy, where longevity is expected to rise. We compare the effects of the OAS schemes to two alternatives. The first alternative is a smaller public social security with a *laissez-faire* approach to old-age pension benefits: households must accommodate increasing longevity and declining pensions through voluntary savings. The second alternative is increased public social security contributions to maintain pension benefits intact and social security balanced despite longevity. We show that for some incompletely rational agents, the OAS schemes improve welfare against both alternatives. In the case of financially illiterate agents, welfare gain is substantial, and they gain the most. Financially literate agents with a high degree of time inconsistency gain less but also considerably. These policy instruments also decrease relative poverty and lower saving regret.

With fiscal incentives, both incompletely rational and fully rational agents participate in these schemes. Notwithstanding, the beneficial effects for the economy as a whole are limited. First, the total capital stock increases very moderately due to substantial crowd-out. The scope of adverse effects is the largest for the E-E-T scheme, which is the most common of the OAS schemes around the world. The stock of capital increases primarily due to financially illiterate agents who hold positive assets in the OAS scheme and would otherwise save almost nothing. In the case of fully rational households, crowd-out is practically complete. OAS schemes also require a substantial rise in taxation.

Government-subsidized OAS schemes bridge the pension wealth gap between incompletely rational agents and *homo oeconomicus* to a limited extent. The effect is larger in the case of financial illiteracy than in the case of time inconsistency but only very moderately. Furthermore, fiscal incentives embedded in OAS schemes are such that agents whose pension wealth gap is relatively small get relatively more transfers. It means that fiscal support is directed to a large extent toward households that do not need it. T-T-E schemes with lump-sum subsidies successfully reduce poverty while maintaining equity of fiscal transfers. Such schemes are the least common policy instrument at this point, however.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1474747223000185.

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