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FISCAL INCENTIVES TO PENSION SAVINGS – ARE THEY EFFICIENT?

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Fiscal incentives to pension savings – are they efficient?*

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Abstract

Financing consumption of the elderly in the face of the projected increase in life expectancy is a key challenge for economic policy. Moreover, standard structural models with fully rational agents suggest that about 50-60 percent of old-age consumption is financed with voluntary savings, even in the presence of a fairly generous public pension system. This is clearly inconsistent with either the data, or the alarming simulations of old-age poverty in the years to come. Old-age saving (OAS) schemes are widely used policy instruments to address this challenge, but structural evaluations of such instruments remain rare. We develop a framework with incompletely rational agents: lacking financial literacy and experiencing commitment difficulties. We study a broad selection of OAS schemes and find that they raise welfare of financially illiterate agents and to a lesser extent improve welfare of agents with a high degree of time inconsistency. They also reduce the incidence of poverty at old age. Unfortunately, these instruments are fiscally costly, induce considerable crowd-out and direct fiscal transfers mostly to those agents, who need it the least.

Key words: old-age savings, incomplete rationality, welfare effects

JEL Codes: H31, H55, I38

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1 Introduction

Growing life expectancy introduces new challenges for public policy.[1] Around the world, the governments have opted for one of the two reactions to increasing longevity. The first one is to encourage the citizens to raise private savings for the old-age consumption via tax incentivized old-age saving programs (OAS).[2] If the economies are populated by fully rational agents, this type of policy raises concerns about efficiency and redistribution. Notably, fully rational agents, respond to OAS incentives by offsetting OAS assets through reduced private voluntary savings.[3] This phenomenon is known as crowd-out and implies that overall capital is not growing. In order to build a case for government subsidies to OAS, one needs to depart from complete rationality, but the literature evaluating ex ante government-subsidized OAS with incompletely rational agents is missing.[4] We fill this gap in the literature by studying the effects of government-subsidized OAS on welfare, poverty and macroeconomic aggregates in an economy with incompletely rational agents.

The second typical reaction of governments around the world is to reform the mandatory public pension systems. In fact, incomplete rationality has been used in the past as a case for mandatory pension systems at all. Over the long run, the interest rate is higher than the payroll growth (Schmelzing 2020), which makes mandatory pension systems yield negative net present value to a fully rational agent, but may be beneficial to incompletely rational agents. Pension systems are typically of a pay-as-you-go nature and thus are typically indexed with payroll growth (see OECD 2018).[5] Meanwhile private voluntary savings and OAS alike are by definition funded and thus accrue at the market interest rate. The difference is that OAS involve tax incentives and thus are fiscally costly. To the best of our knowledge, the increasingly prevalent fiscal incentives for the OAS have not been studied so far. This is the second gap in the literature, which we fill.

Our study contributes to answering two questions of paramount policy relevance. The **first question concerns the effects of government-subsidized OAS programs for incompletely rational agents**.[6] We feature agents with time inconsistent preferences (in the spirit of Gul and Pesendorfer 2001, 2004, Imrohoroğlu et al. 2003, Fehr et al. 2008, Caliendo 2011, Ander-

[1] In addition to classical works of e.g., 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.

[2] Tax incentives for old-age savings have been implemented in all OECD countries. However, participation rates and the scope of incentives differ (see OECD 2018).

[3] For extensive treatment, see e.g. Bütler (2001), Conesa and Garriga (2008), Kitao (2014), Blau (2016).

[4] The paramount relevance of including incomplete rationality in macroeconomic modeling is emphasized in the surveys by Brzoza-Brzezina et al. (2013), Branch and McGough (2018).

[5] 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). In a classical paper, Imrohoroğlu et al. (2003) show that agents with time inconsistent preferences may observe welfare gain from a mandatory pay-as-you-go pension system, which comes at the cost of lower capital accumulation relative to the scenario of no pension system.

[6] There is a growing number of empirical studies on the incomplete rationality and its causes (e.g. Lusardi et al. 2017, Parker 2017). Linking data driven 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).

sen and Bhattacharya 2011). We also account for financial illiteracy: we include agents who have access to storage technology, but have no access to savings technology (in the spirit of Lusardi and Mitchell 2014, Lusardi et al. 2017). Finally, we allow both departures from rationality combined. For these incompletely rational agents, we evaluate the assets gap, relative to a fully rational agent, and show that, absent OAS, insufficient asset accumulation is responsible for a large share of old-age poverty. Thanks to OAS, one may effectively eliminate old-age poverty stemming from insufficient savings. In this respect, OAS programs are more effective than raising the contributions to mandatory public pension systems. We further show that OAS programs induce considerable crowd-out for agents with time inconsistency, whereas they facilitate assets accumulation of financially illiterate agents. We also build on the notion of savings regret (Boersch-Supan et al. 2018). We show that although welfare effects are mixed across the types of agents – positive for financially illiterate agents, but negative for the most types of financially literate ones – the savings regret is reduced with the OAS.

The **second question concerns the fiscal and aggregate effects of government-subsidized OAS programs in an economy with incompletely rational agents**. In the context of longevity, to avoid a deficit in the mandatory public pension system, contribution rates have to rise. We study various types of OAS programs, and we carefully set the size of the OAS programs to match the otherwise necessary rise in the size of the mandatory public pension system. We thus effectively compare a larger mandatory pension system with the introduction of government-subsidized OAS. We show that in result of government-subsidized OAS the taxes rise: to cover the shortfall in tax revenues due to the tax incentives in OAS and due to the substantial crowd-out. This makes OAS fiscally costly when compared to raising the size of a mandatory public pension system. The results are even stronger when we compare government-subsidized OAS to *laissez-faire*.

Overall, while OAS programs are beneficial for some types of incompletely rational agents, pairing them with fiscal incentives – as is frequently done – is counter-productive. Given the paramount role of income effects for financially illiterate agents and perverse role of tax incentives, we conclude that OAS should primarily focus on rates of return marked to the capital market and minimize the role of tax incentives.

We develop an overlapping generations model with increasing life expectancy. We match features of the German economy; thus our model has a public mandatory defined benefit pension system. In the German system, distortion stemming from the contributions to the pension system is limited in the sense that instantaneously higher labor supply is reflected in higher future pensions; also, rising longevity implies a rise in pension expenditure. In our model, fully rational agents accumulate assets over the working period to co-finance old-age consumption. Along with fully rational agents, each birth cohort consists of agents with incomplete rationality: agents with time inconsistent preferences, agents lacking financial literacy, and agents with these two features combined. In this economy, populated by such diverse types of agents, we study the savings behavior and old-age poverty. Next, we introduce fiscal incentives to old-age savings (OAS). The type of policy experiment we implement is stylized after instruments already at work or under policy debate in many countries and is characterized by three distinctive features. First, it is voluntary. Second, it is associated with preferential tax treatment. Third, it is capped, i.e., there is a limit on how much of the OAS may be eligible to receive preferential tax treatment. We compare this policy experiment to a compulsory program of the same magnitude (simply raising the contribution rate to the mandatory pension system) and to *laissez-faire*, where pensions are reduced, and households are expected to accommodate for longer life expectancy (and lower pensions) through adjustment in private savings.

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 pension systems (see for example 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 pension systems may be inefficient, but they are socially desirable for several policy-relevant reasons. For agents with time inconsistent preferences, a mandatory pension system is a free commitment device and thus brings gains.[7] However, to the best of our knowledge, the prior modifications to 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. By comparing the mandatory unfunded pension system to incentivized and by construction funded OAS, 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. Second, we compare the welfare of incompletely rational agents when they can save in a negative net present value instrument (mandatory public pension system) as opposed to a positive net present value instrument with higher taxation (government-subsidized OAS programs). 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 401k 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 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 401k in the US, OAS schemes with preferential tax treatment have spread to all OECD countries[8]

[7]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.

[8]The OECD (2018) provides a broad overview of the instruments implemented across the member countries.

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 the 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 show the winners and the losers of government-subsidized OAS.

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. While there is abundance of studies analyzing the consequences of changes in the mandatory pension system 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), there appears to be less scrutiny of the multiple OAS programs implemented in this country.[9] While we do not evaluate any specific OAS program in Germany (they are too proliferated in terms of individual eligibility to reasonably match eligibility and incomplete rationality), we provide insights on the consequences of specific incentives in the OAS schemes design.

The paper is structured as follows. Section 2 presents the model, specifically focusing on how incomplete rationality affects inter-temporal choices of agents. We relegate all formal derivations to Appendix A, whereas in the main text we discuss at length the policy instruments and provide intuitions on their potential direct and indirect effects. In section 4, we discuss the data used for calibration. In addition to the standard discussion of macroeconomic aggregate parameters, we also discuss various sources on the prevalence of various forms of incomplete rationality across countries. We use both the evidence from small scale experiments and commercially collected data from the financial institutions. Section 5 presents the results. The final section concludes with insights for further research and policy implications.

2 The Model

We employ an overlapping generations model: our economy is inhabited by agents of each age category, who come from subsequent birth cohorts. The model features realistic demographics, with one period referring to one year and data driven survival probability.[10] Within each birth

[9] 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 voluntary OAS programs). Ihle et al. (2017), Bönke et al. (2019) study the distributions of pension wealth and net worth in observational data.

[10] Given uncertainty about survival, annuity per se provides welfare value because it allows agents to insure against longevity risk. This line of research has been thoroughly studied (e.g. Bruce and Turnovsky 2013), we thus abstract from this literature and focus on the OAS vehicles. In order to be able to abstract from annuity value embedded

cohort, households are heterogeneous in their behavior on consumption and savings. A formal derivation of the model is presented in Appendix A, whereas this section discusses the basic intuitions of the model features.

2.1 Behavioral heterogeneity

A fully rational agent optimizes her lifetime consumption path subject to a sequence of instantaneous budget constraints. In each working-age period, a fully rational agent decides how much to work and how much to consume of instantaneous income, leaving the rest for smoothing consumption over the lifetime. A fully rational agent has the ability to perfectly plan a smooth consumption path, adjusting for all future changes in interest rates, tax rates, survival rates, etc. Once set, the fully rational agent implements her plan without further adjustments.

Fully rational agents are a useful construct for macroeconomic modeling, but one of the distinct features of models based on such behavioral patterns is that the consumption path is very smooth, and asset accumulation is quite intensive. In fact, for a plausible range of calibrations for the basic model parameters, fully rational agents finance an implausibly high share of their old-age consumption from private voluntary savings ranging between 55% and 60% of the old-age consumption levels (we illustrate this point in Figure A.1 in the Appendix).[11] Indeed, a 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. In addition to *homo eoconomicus*, each birth cohort is populated with agents characterized by incomplete rationality. First, we consider agents with time inconsistent preferences. Second, we also consider households who are able to store wealth to smooth consumption into old-age, but who earn no interest on these savings (i.e., have no access to financial markets). We name those agents financially illiterate.

Time inconsistency implies that an agent is able to set an optimal plan, but is not able to implement it. Time inconsistency has been studied widely as procrastination or myopia (Strotz 1955), as well as cognitive failure of human brains (Ainslie 1992, Wilson and Gilbert 2003, 2005), modeled as quasi-hyperbolic discounting (see Laibson 1997, 1998). This type of behavior has been established in experimental research (Sprenger 2015). Time inconsistency has been demonstrated to substantiate the case for mandatory pension systems (Gul and Pesendorfer 2001, 2004, Imrohoroğlu et al. 2003, Fehr et al. 2008, Andersen and Bhattacharya 2011).

in pension systems and OAS, we fully annuitize the economy, i.e., all assets pay rate of return adjusted for annuity premium.

[11] See for example Haider and Stephens (2007), Hurst (2008), Battistin et al. (2009) for a discussion on retirement consumption puzzle.

When thinking about distant future periods, an agent with time inconsistent preferences expects to face the same trade-offs in choices as a fully rational agent, but an additional preference for the present governs the nearest inter-temporal decision (e.g., a choice between consumption in the current and in the next year). Of course, as time progresses, each future period becomes a trade-off between this and the next year, which implies that whatever an agent has planned as her preference for age $j + s$ and period $j + s + 1$ at age j differs from the actual choices made at time $t + s$. For example, agents with an extremely high degree of time inconsistency will expect to save in every future period, but will consistently consume their entire instantaneous income. With a lower degree of time inconsistency, agents will expect to have a much higher savings rate at older than at younger ages, and the planned savings rates will also be consistently higher than the actual savings rates. In the literature, the degree of time inconsistency is captured by the so-called β parameter: when β approaches 0, the household disregards future completely.[12] and $\beta = 1$ is equivalent to a fully rational agent.

Financial (il)literacy is documented in the extant literature on mathematical skills and knowledge of basic finance among adults around the world (Lusardi 2012, Xu and Zia 2012, Lusardi and Mitchell 2014, Klapper et al. 2015). Typically, adults are unable to perform basic compound interest calculations, nor adjust nominal values to real terms.[13] One should not expect individuals with this low level of financial literacy to be able to achieve a rate of return on par with the market. Indeed, rates of return on assets are systematically heterogeneous (e.g. Fagereng et al. 2016). To capture the fact that some agents are knowledgeable about investing their assets and others are not, it is typically assumed in the literature that all agents can store wealth, but only some agents are able to earn the market interest rate on whatever income they have saved for future periods (e.g. Hirschhorn 1984). We follow this literature.

2.2 Macroeconomy

We employ a general equilibrium model, which implies that the choices by the households are reflected in the macroeconomic aggregates. For example, assets held by the household become capital used by the firms to produce the composite consumption good for the households. The equilibrium is an optimized path of consumption, leisure, and savings choices for each type of agent in each age which satisfy four conditions. First, agents make optimal decisions, given prices and taxes. Second, the government budget constraint is satisfied. Third, firms have optimized their capital and labor inputs, given wages and interest rates. Finally, the goods and inputs (labor and assets) markets clear.

[12] The literature recently employs also agents with a particular type of time inconsistency, i.e., hand-to-mouth agents (Weil 1992, Kaplan et al. 2014) There is some empirical evidence that lack of consumption smoothing may be a statistical artifact rather than empirical regularity (Havranek and Sokolova 2020).

[13] This tool follows extensive research of Olivia Mitchell and Annamaria Lusardi, in both longitudinal and cross-country applications, see Lusardi and Mitchell (2014), Lusardi (2019).

The pension system There is a universal pay-as-you-go defined benefit pension system with an exogenous contribution rate τ and exogenous replacement rate ρ at retirement (which we denote by $j = \bar{J}$). After retirement, pension benefits are indexed with the rate of payroll growth. Contributions are used to finance the contemporaneous benefits.

Germany has defined benefit mandatory public pension system. Citizens record points in the pension system. These points are given by a ratio of their total earnings relative to the contemporaneous average earnings in the economy. The points system yields strong labor supply incentives: the agents in the model observe directly that higher labor supply in a given working-age implies higher pension benefit in the future. Our model reflects this feature.

The economy continues with this system in the baseline and in the reform scenarios. With longevity, absent adjustments to the contribution or the replacement rate, the system will be in deficit.

Government The government balances the pension system. There are four types of taxes in the economy: labor income, capital income, consumption, and lump-sum tax. Spending on public goods and services is financed through tax revenues. We assume that all tax adjustments necessary for the budget to balance occurs through adjustments in consumption taxation. This assumption serves the purpose of mitigating the effects of potential fiscal adjustment on labor supply and asset accumulation decisions. We hold the debt to GDP ratio constant. This assumption serves the purpose of isolating welfare effects of OAS schemes. The stability of debt to GDP ratio allows eliminating welfare effects stemming from a permanent change in fiscal policy from the analysis.

Production Using capital and labor, the economy produces a composite consumption good, with fixed labor share and labor augmenting exogenous technological progress.

3 Policy reforms

In the baseline scenario, in the initial and the final steady states, agents can put funds aside for old-age consumption, but no tax incentives are available. Thus, 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. We compute both scenarios, providing an evaluation of the size of these two potential adjustments and the general equilibrium effects of these changes. The required adjustment in the contribution rate informs on the size of a potential corresponding capital-based OAS scheme with fiscal incentives. The comparison of the scenarios of increased contribution rates versus reduced replacement rates informs on the preferences of agents towards *laissez faire*, i.e., the size of the pension system. We keep the scenario of pension decline as our baseline for studying the effects of OAS programs as well. Thus, our baseline is consistent with the following policy choice: reduce pensions in order to maintain fiscal stability in light of longevity and let *laissez-faire* private voluntary savings compensate for longer life at retirement with lower pensions.

The key reforms in this study concern the introduction of incentivized OAS schemes. The government-subsidized old-age voluntary pension schemes are essentially tax incentives, i.e., partial or full tax exemption. Following the OECD taxonomy, we introduce incentives to voluntary pension savings at contribution, accumulation, and disbursement stages. 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. Using OECD taxonomy, then, private voluntary savings could be denoted as T-T-E (contribution and accumulation stages are taxed, but disbursement is exempt from taxation). Meanwhile, typical OAS schemes are denoted as E-E-T (contributions and accumulation are exempt, pension benefits are taxed). In practice, exempt may signify full or partial tax exemption or even negative taxation (i.e., generally preferential tax treatment, or a subsidy). In addition, 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).

Our model features endogenous enrollment in the government-subsidized old-age voluntary pension schemes, with a fixed contribution rate. We formally present each of the three instruments in Appendix B, and below we discuss the intuitions behind the instruments under policy debate. The reforms are summarized in Table 1. First, we study an E-E-T scheme. For a fully rational household, an E-E-T scheme implies that interest rate is higher in the OAS than in 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 seen as high return savings rather than taxes). As a consequence, she 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 lifetime). Naturally, a higher rate of return on those assets raises incentives to save but does not raise how much assets fully rational household wants to put aside for old-age consumption. For households with access to financial markets (financially literate) but with time inconsistent preferences, the implications are the same. Finally, for financially illiterate household, OAS creates access to financial markets, thus dramatically raising her rate of return on savings. This group of households will thus raise savings, but they also obtain a source of additional income, which reduces their incentives to work. Since E-E-T is fully proportional to the labor supply decision, all adjustments in labor supply and asset accumulation are also proportional.

In the second and the third instrument of T-T-E, at the disbursement stage household 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 retirees internalize the size of the future subsidy in their intra-temporal choices in each of their working periods through the implicit link between labor

Table 1: Policy reforms – summary

Reform	Taxing stages			Proportional
	contributing	accumulation	collecting	subsidy
E-E-T	No	No	Yes	Yes
T-T-E	Yes	Yes	No	Yes
T-T-E flat	Yes	Yes	No	No

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 have also the same contribution (see section 5). Participation is endogenous (voluntary) in all instruments.

supply and future pensions. In the T-T-E flat scheme, retirees receive a lump sum transfer at every period during their retirement. This scheme is equivalent in fiscal terms, but since the transfer is a lump sum (that is 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 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 amount of the subsidy does not depend on the number of hours worked. Since it is a lump sum, in fact it reduces distortions. 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.

Agents choose to participate in the instrument endogenously, i.e., they contribute to OAS if their lifetime utility is higher with the government-subsidized OAS than without it. Agents choose optimally the age of joining OAS, with the sole constraint that participation is irrevocable.[14] For those agents who choose to participate, the reform scenario pension benefit consists of the universal pension system plus the accrued savings in the OAS schemes. For those agents who choose not to participate, the reform scenario pension benefit consists of the universal pension system only.

Since we introduce various schemes, it is imperative to keep them comparable in terms of fiscal size. For the OAS schemes to be comparable with the changes in the pension system parameters, we evaluate what the indispensable rise in the contribution rate in the public pension system to keep the pension system balanced in the light of longevity is. By comparing the contribution rate with and without longevity, we obtain the (cap of) the contribution rate to the OAS. We thus set the rate of contribution to the E-E-T scheme (a cap), and in order to maintain internal consistency, we fully exempt these funds from the labor taxation, social security contributions (in contribution

[14]The ability to choose an age at which an agent joins the OAS is roughly equivalent to choosing the contribution rate and participating for all of the working-age periods.

stage), and from the 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 % 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.

3.1 Measuring the effects of policy reforms

Introducing OAS instruments has been motivated in many ways: as means to combat old-age poverty, as means to raise accumulation of capital in the economy, as means of overcoming the inter-generational "conflict", etc. Given this multiplicity of potential policy objectives, measurement of policy outcomes needs to be particularly comprehensive. We study macroeconomic changes and propose the following three ways to synthesize the changes in well-being: welfare, saving regret and poverty.

Standard welfare analysis is based on consumers' choices among the available bundles (e.g., how much to consume and how much to work at a given age). It is standard to use the observed choices in order to infer preferences (Gruber and Koszegi 2001). We can then use those preferences to infer if another bundle raises the felicity of agents. Consider welfare of agents. Typically, to measure welfare, one compares the optimized lifetime utility U in the *status quo* scenario with the analog in a given reform scenario U^r. Formally, the welfare effect of a reform equals the difference in utility from reform and baseline scenario and is most usefully expressed in terms of consumption equivalence units.

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 $age = j$ is different from lifetime utility measured at $age = j + s$. In short, 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. This is why time inconsistency is sometimes considered to be an issue of commitment or self-control (Strotz 1955, Gul and Pesendorfer 2001, 2004).

Prior literature proposes three approaches to overcome this difficulty. The first approach relies 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. The second approach 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 in the sense that it can only be obtained once the agent has made choices about all her ages. The third approach uses welfare of an agent as computed in the first period (e.g. Krusell et al. 2002). This approach is forward-looking in a sense that all periods but the first period 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. We obtain all three measures of welfare, and we cover them in detail in Appendix C.[15]

Third, inspired by recent work on saving regret (Boersch-Supan et al. 2018), we study the role of assets 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 felicity and this counterfactual felicity 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. Note, that since this measure is also utility based, the same problems as in pure welfare metric arise. We use all three approaches to measuring saving regret, that is: multiple selves, backward-looking, and forward-looking.

Finally, 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 in reducing, 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 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, e.g., health or earning abilities.[16]

[15]Since all three welfare measures aggregate experienced utility, the only difference between the obtained 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, change of welfare heavily depends on the assumption on the origin of the incomplete rationality. In our setup, financial literacy enters through the budget constraint, whereas time inconsistency features on 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).

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

4 Calibration

The economy is calibrated to replicate the features of the contemporaneous German economy. Demographics and technological progress are fully 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. Exogenous technological progress in the initial steady state is set at 1.01% per annum following European Commission (2018). We assume the capital income share in the economy to be $\alpha = 33\%$. This implies that the labor income share in the economy is $1 - \alpha = 67\%$.

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 assume the interest rate of 6%, which is a conventional assumption for Germany.[17] 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 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.[18] Without loss of generality, we assume the pension system to be balanced in the initial steady state, thus directly implying a contribution rate.[19] We rely on OECD (2018) setting the retirement eligibility age at $\bar{J} = 65$. For all these aggregates, we average data for the period 1995-2017. Hours worked are calibrated using OECD Employment Outlook data. 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.

Our calibration features age-specific productivity profile ω_j. We follow Fehr et al. (2015) in setting the age profiles.

4.1 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. This 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 as well as 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, e.g., mortgage, if individuals pursue

[17] See Fehr and Habermann (2006), Fehr and Jess (2007), Fehr et al. (2008), Corneo et al. (2009), Dieckhoener and Peichl (2009), Dolls et al. (2018), Seibold (2019).

[18] 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, i.e., 38% (OECD 2018).

[19] Currently, Germany observes a surplus in the pension system, with an annual surplus 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	$\tau^c \cdot (\sum_{j,m} \mathcal{C}_{j,m})/Y$	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	$\tau^k(\sum_{j,m} \mathcal{K}_{j,m})/Y$	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 **??** in the Appendix. The interest rate reported in Table 2 is r_t as per equation (A.17). 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.

investment in real estate as an old-age saving strategy. Second, observing instantaneous savings may be consistent with both precautionary motives and with savings for indivisible consumption goods and services (e.g., relatively more expensive durable goods or more expensive services such as children's education or vacation travel). This is particularly troublesome in cross-sectional data, where individual asset and consumption decisions are not observed through time.

Given these constraints, empirical evidence on the behavioral structure of populations around the world is scarce. We thus model our economy with the interest of insights into the varying degree of time inconsistency as well as its potential interaction with financial literacy. Accordingly, equinumerous subgroups of agents exhibit a different degree of time inconsistency. These subgroups are again split into a financially literate group and a financially illiterate group. More specifically, our population consists of agents with varying degrees of time inconsistency as follows: equinumerous eleven subcohorts with $\beta \in \{0.5, 0.55, ..., 1\}$. Within each such subcohort, 50% of agents are characterized by a lack of financial literacy. Overall, that implies twenty-two subcohorts, each of the same share in a cohort of a given age, reflecting a wide variety of behavioral patterns. Such an economy displays consumption behavior around retirement, which is more consistent with observational data in that it predicts less consumption smoothing than an economy modeled purely on rational agents.

For illustrative purposes, we present life-time saving profiles and saving regret in Appendix D. In Figure D.1 in Appendix, we portray the heterogeneity of assets accumulation lifetime profiles across the types of agents. Notably, agents lacking financial literacy are characterized by extremely low 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 store assets. A higher degree of time inconsistency further delays the moment of storing assets. Financially illiterate agents also de-accumulate assets faster than fully rational agents 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.[20] Agents with time inconsistency also de-accumulate assets faster than fully rational agents.

In Figures D.2-D.2 in the Appendix D we portray the proxy for saving regret across the diverse group of incompletely rational agents. 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 (β closer to 0.5). Among the financially literate agents, the "saving regret" proxy is the highest for the highest degree of time inconsistency, which stems from the fact that for these households, a departure from the fully rational optimization the strongest. For the financially illiterate agents, regardless of the degree of time inconsistency, the regret remains high, reflecting high share of lifetime income lost due to inability to accrue interest. The fact that the welfare loss from not behaving "rationally" about asset accumulation is greater for financially literate agents with extreme time inconsistency than for the 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.

5 Results

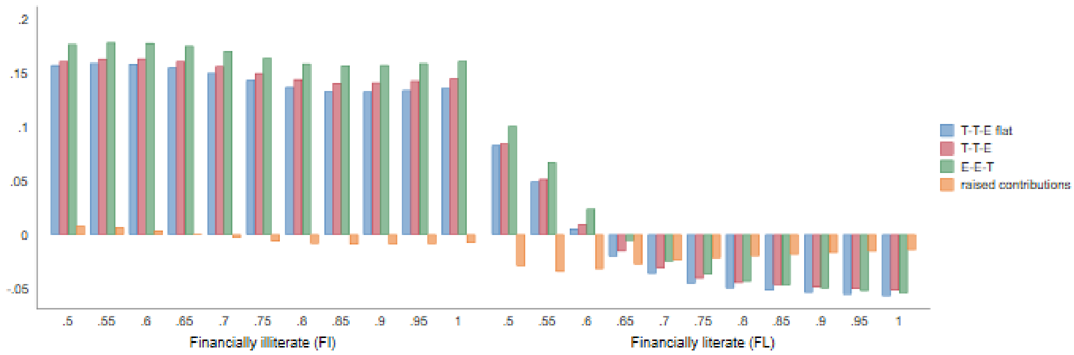
The objective of this paper is to answer two questions: what are the effects of government-subsidized OAS for incompletely rational agents and what are the fiscal and aggregate effects of having such instruments in the economy. Answering the first question, we report changes in welfare, change in the saving regret proxy, and change in the risk of poverty due to the government-subsidized OAS. Answering the second question, we discuss changes in the economy, effective crowd-out, and the origins of change in the fiscal stance.

Overall, longevity necessitates a rise in contributions or a decline in pensions by roughly 25%, which is consistent with earlier literature for Germany (Fehr et al. 2012). In our calibrations, either the pensions have to decline to 74% of the current (initial steady-state) level or the public system has to raise the contributions by 5.07 percentage points from the current (calibrated) 14.32%.

[20] In technical terms, their marginal rate of substitution (MRS) remains bound by 1, as revealed in equation (A.10).

We use these results as benchmarks for OAS scheme. When introducing the OAS scheme, 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 scheme. Note that public system pensions have to decline to maintain pension system stability. To adjust for this fact, all welfare and saving regret evaluation is done relative to the scenario of pure pension decline. We also evaluate the welfare value of the larger public pension system by studying the scenario of raising the contributions in the public pension system.

Figure 1: 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, alternative welfare measures are reported in Figure D.5. The comparison scenario for each reported result is a reduction in pension benefits such that the pension system 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 the pension system 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 pensions contributions. The size of fiscal incentives to the incentivized OAS instruments is such that the total fiscal expenditure on tax incentives are equivalent across scenarios in terms of share of GDP.

5.1 Effects of government-subsidized OAS for incompletely rational agents

Introducing OAS is beneficial for agents whose participation in financial markets is otherwise constrained. Figure 1 reports change of utility based measures across agents types, and Figure D.6 portrays endogenous participation decision. Generally, all agents join incentivized OAS schemes and they do so as early as possible. The comparison of the three welfare measures also reveals that, with incomplete rationality, aggregation of welfare across heterogeneous household is subject to some degree of discretion. On the one hand, the sign of the welfare effects appears to be the same across measures for each type of household and OAS scheme. On the other hand, the measure following Imrohoroğlu et al. (2003) yields a lower degree of heterogeneity of welfare gains across financially literate households with different degrees of time-inconsistency than the backward-looking and forward-looking measures. Large gains are observed for financially illiterate households, especially relative to the scenario when these agents compare OAS to simply larger public pension system. Financially literate households are unhappy about larger pension system, unless they are characterized by high degree of time inconsistency. Gains from 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 for the financially illiterate agents larger public pension system is a net positive present value investment, 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.[21]

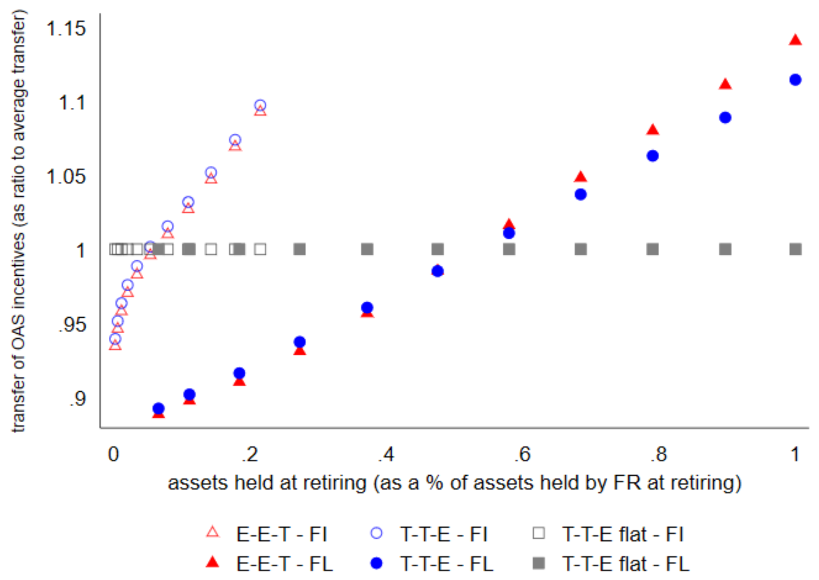
Second, the fiscal cost of the incentives is large. For example, a fully rational household, who would accumulate the same stock of assets under E-E-T as in the scenario of pensions decline, bears the costs of subsidies in the former. Naturally, fully rational household also receives the transfers, but these transfers are paid for saving that would occur regardless of whether or not 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.

In Figure 2, we document redistribution through the OAS for all three types of instruments, with fully rational household 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 of the funds to those who have 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 clearly depend on the amount of funds accumulated in OAS; hence they correlate also with levels of accumulated pension wealth. Figure 2 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

[21] The losses from a larger mandatory pension system are not monotonous in time inconsistency, because households with small degree of time inconsistency derive high share of old-age consumption from private voluntary savings, hence the size of the public system (and a negative net present value on the contributions to this system) is a smaller share of their welfare than it is for the financially literate households with high degree of time inconsistency.

assets, relative to a fully rational household). On the other hand, however, 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. Summarizing, the fiscal transfers do not go in general to those households who are most in need during retirement.

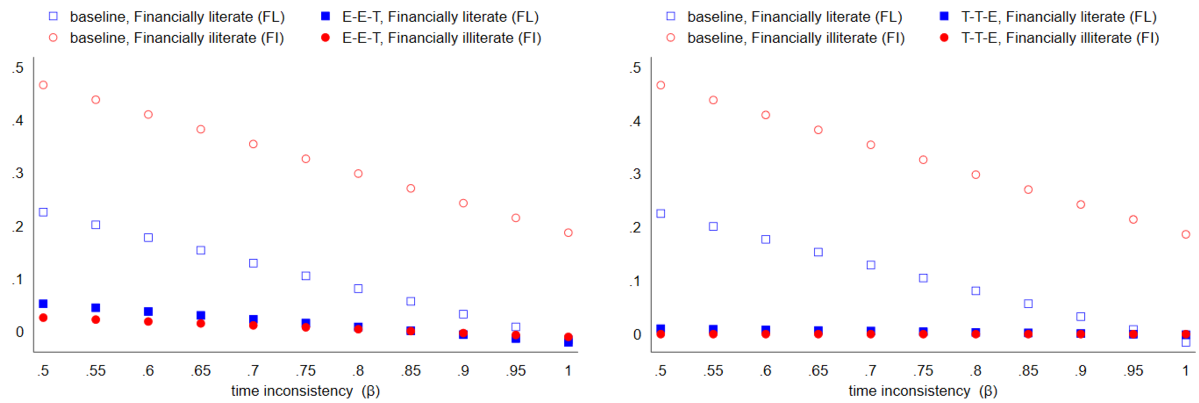
Figure 2: Transfers for OAS incentives

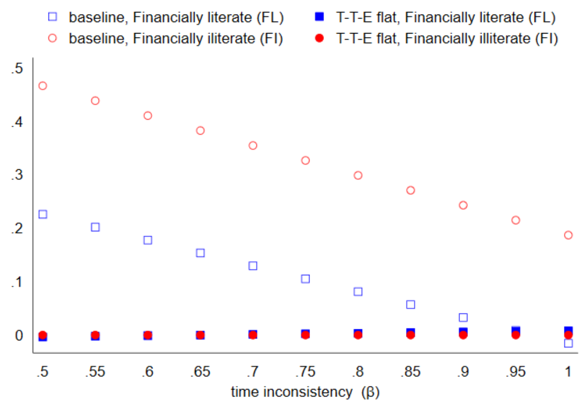


Note: FR = fully rational household. FI = financially illiterate household. FL = financially literate household. Total transfer in OAS is computed in model units and expressed as ratio to average per capita transfer. The transfer measure adds up the incentives received by a given type of agent through 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.

Despite this poor targeting, note that poverty incidence substantially declines, 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. Each agent at each age is classified as poor if her consumption falls short of this threshold, using data from our simulation outcomes. 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 social security budget despite longevity), in particular 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 the fact that OAS incentives are indeed a large transfer program, even if inefficiently targeted.

Figure 3: Age-adjusted incidence of relative poverty



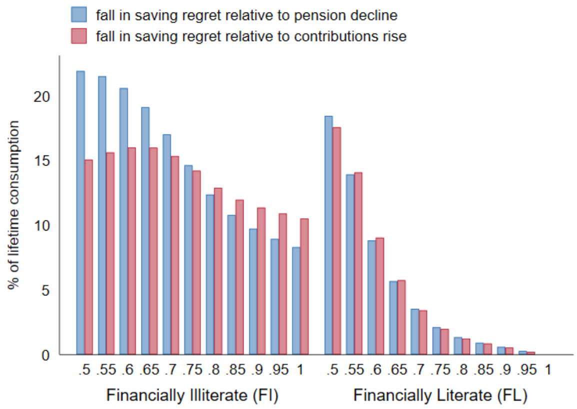


Note: The vertical axis signifies age-adjusted incidence of poverty in %. Figures portray predicted probabilities from a regression where poverty dummy is the explained variable, and the explanatory variables include OAS/baseline, age and financial literacy dummy. Baseline defined as declining pensions.

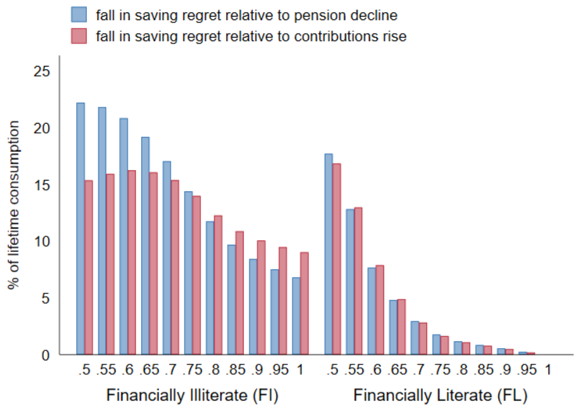
In addition to comparing the welfare effects for the different scenarios, we also study how the incentivized OAS schemes affect our proxy for saving regret. In general, incompletely rational agents save less than fully rational agents. When we provide them with a windfall of assets, matching their retirement assets to the levels of a fully rational agent, they obviously have higher utility. This is why saving regret proxy is strictly zero for a financially literate agent with $\beta = 1$ (the right bottom corner). This measure is purely counterfactual, i.e., no true transfer is made, but agents re-optimize their old-age consumption as if they actually 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 own assets at retirement. The results are reported in Figure 4.

Figure 4: Saving regret decline

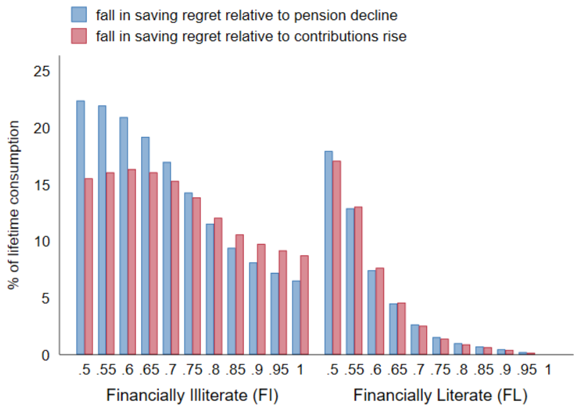
(a) E-E-T



(b) T-T-E



(c) T-T-E flat



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 in the final steady state reported in Figure D.2. These measures were also obtained for the alternative measurement of the welfare effects and are reported in Figure D.3 and D.4 for the forward-looking and backward-looking measure, respectively.

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), i.e., 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, in particular with relatively lower levels of time inconsistency.

5.2 Aggregate and fiscal effects of government-subsidized OAS

An economy, which raises contributions in the wake of longevity between the initial steady-state (ISS) and the final steady-state (FSS), experiences lower capital growth and higher distortions than an economy which reduces pension benefits – we refer to this latter scenario as *laissez-faire*. Table 3 reports the macroeconomic aggregates. An economy that reduces pensions experiences a rise in voluntary savings (by roughly 14 percent, column 3) even though it is populated by agents with bounded rationality: while the reaction of incompletely rational agents is lower than for fully rational agents, it occurs for both types of agents. The capital increase is twice as large as in the case of keeping up the pension provisions from the initial steady-state, and raising the contribution rate (column 2). The explanation lies in the overall strength of two opposing effects. On the one hand, rising longevity raises voluntary savings; a decline in pensions reinforces this effect. On the other hand, rising consumption taxes raise the value of leisure relative to consumption and thus reduce incentives to work. Lower capital accumulation reduces the growth of labor productivity, which further reduces earned income.

Table 3: Macroeconomic summary

		ISS	FSS				
			raise τ	reduce ρ	E-E-T	T-T-E	T-T-E flat
		(1)	(2)	(3)	(4)	(5)	(6)
pensions (replacement)	ρ/ρ_{ISS}	1.00	1.00	0.74	0.74	0.74	0.74
contributions rate (%)	τ	14.32	19.39	14.32	14.32	14.32	14.32
OAS contribution rate (%)	κ	-	-	-	5.07	5.07	5.07
consumption tax (%)	τ^c	15.00	14.94	13.42	16.81	17.31	17.75
OAS transfers per worker		-	-	-	0.0296	0.0293	0.0292
labor	$L = \sum_{j,m} \omega_j l_{j,m}$	100%	107.1%	108.1%	109.7%	109.6%	108.3%
aggregate product	Y	100%	109.6%	112.9%	118.7%	116.8%	115.4%
wages	w	100%	102.3%	104.4%	108.1%	106.6%	106.6%
income tax revenues	$\tau^l \cdot wL$	100%	109.6%	112.9%	102.9%	116.8%	115.4%
pension tax revenue	$\tau^l \cdot B$	100%	148.3%	112.8%	118.6%	116.7%	115.3%
aggregate capital	A	100%	114.6%	123.3%	139.2%	133%	131.5%
of which							
voluntary		100%	114.6%	123.3%	51.3%	56.9%	56.3%
in OAS scheme		-	-	-	87.9%	76.2%	75.2%
interest rate (%)	r	5.18	4.66	4.18	3.44	3.74	3.74
capital tax revenues	$\tau^k \cdot \sum_{j,m} \mathcal{K}_{j,m}$	100%	103.1%	99.5%	34.1%	96.1%	94.9%
aggregate gross consumption	C	100%	107.0%	107.5%	116.0%	115.8%	114.6%
consumption tax revenues	$\tau^c \cdot C$	100%	106.6%	96.1%	130.0%	133.5%	135.5%

Notes: ISS = initial steady state. FSS = final steady state. We denote subcohort by m. To infer about changes in *per worker* terms numbers reported in rows should be divided by the respective change in aggregate labor ($L = \sum_{j,m} \omega_j l_{j,m}$). Tax rates and contribution rates reported in nominal terms, except for the ratio of pension benefits, which is reported in relation to the initial steady state. Macroeconomic aggregates reported relative to the initial steady state, capital split between OAS and voluntary assets relative to the total stock of assets in initial steady state (when all assets where voluntary assets). Consumption tax is used as fiscal closure.

The adjustments due to inter-temporal and intra-temporal choices generate effects on wages (which rise by 4 percent in the scenario of pension decline, but only 2.3 percent in the scenario of raising contributions) and the interest rate (which declines by one percentage point in the scenario of pension decline, but only about half so in the scenario of raising contributions). Indeed, when pensions are reduced, a large rise in labor supply, combined with an increase in wages, raises overall labor tax revenue. Analogously, capital income tax revenues rise. This allows overall consumption tax to decline, and consumption to rise, despite lower pensions in this economy.

Introducing incentivized OAS schemes in an economy with reduced pensions raises the overall capital stock by further 7-12 percent (columns 4, 5, and 6), but with substantial crowd-out. The scope of adverse effects is the largest, and total capital accumulation is the smallest with the E-E-T scheme. The rise in the capital stock is predominantly generated by financially illiterate agents, who held almost no voluntary savings when their experienced rate of return was zero but record positive savings throughout their lifetime in the OAS schemes. Accordingly, they smooth consumption (and labor supply) better throughout their lifetime.

A rise in overall capital accumulation in the economy permits faster wage growth, raising further incentives to work (in particular, relative to the distortive scenario of raising the contributions). These two mechanisms increase tax revenues from earned income taxation. Meanwhile, shift of assets from voluntary (taxed) assets to OAS, combined with a further decline in the interest rate, substantially reduces tax revenues from capital income base, by more than 60 percent in the case of E-E-T (column 4).[22] This decline in capital income tax revenues is the key driver of adjustments in consumption tax. Indeed, despite the rise in the labor income tax base, the incentivized OAS schemes result in a significant rise in consumption taxation in our model (from 15 percent to between 16.8 and 18 percent, that is by 1.8 to 3 percentage points), predominantly to finance the tax incentives. Note also that labor tax revenues rise less than total payroll in the case of E-E-T.

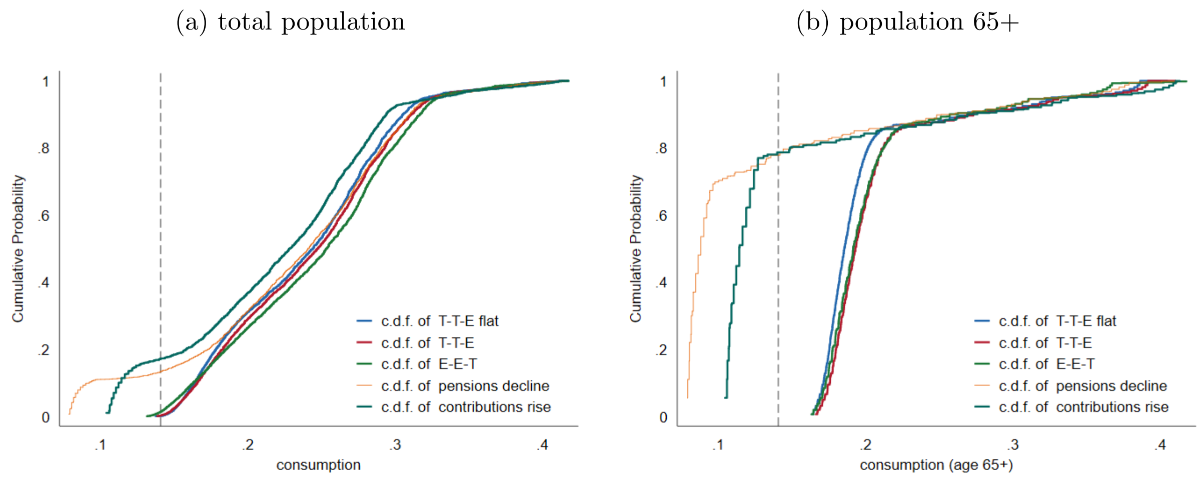
OAS instruments have a redistributive element, and we ask to what extent the implied fiscal transfers are targeted to those types of agents who are most at risk of old-age poverty. We study (relative) poverty in Figure 5. The figure is based on consumption observations, for each agent in each year of 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. This 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 manage to alleviate extreme poverty by shifting households with very low old-age consumption above the (relative) poverty line.

5.3 Sensitivity of the results

We assume 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 the pension system strongly affect fiscal balance. Since the capital share has been increasing over the past decades, we also present an alternative specification with a capital share in the economy of $\alpha = 45\%$ and labor share in the economy 55%. These results are reported in Appendix E, 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, the majority of OAS incentives are received by agents with a relatively higher degree of

[22] Decline in capital income tax revenues in the case of both T-T-E schemes is related to decline in the interest rates.

Figure 5: 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 pension system balance; (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 figures, we leave out the top 5%, for clarity. Note that the consumers in our model are distinguished by age as well as behavioral patterns (time inconsistency and financial literacy).

rationality. Under this calibration, OAS schemes are less effective in eradicating the age-adjusted incidence of poverty among the financially literate households, but old-age poverty disappears completely.

In the main simulations, we also assume, following European Commission (2018), that the total factor productivity growth will continue with the current 1.01% 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 higher rewarded. Since the current projections for Germany suggest an increase of technological progress to 1.54% per annum, we provide a sensitivity analysis of our results assuming the rate of technological progress unchanged in our preferred calibration and increasing in the alternative calibration. These results are reported in Appendix F, virtually replicating all the main findings of the main specification.

Finally, many countries consider raising the retirement eligibility age. Such a policy change has three effects. First, it reduces the scope of pension system imbalance in the aftermath of longevity rise. Hence, the contribution rise may be lower (or, alternatively, pension 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, also the indirect effect is to be expected in other scenarios because the adverse fiscal effect of longevity is lower, hence tax adjustment necessary to cover the pension system deficit is lower as well. Third, it also has the potential to 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 G, where we present all the analogous simulations for the case where the final steady state is characterized by a retirement age of 67 rather than 64 (as in the main simulations). All our results hold, 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). Despite being smaller, OAS schemes continue to be more effective in reducing old-age poverty than both the larger universal pension system and the *laissez-faire* scenarios. They also continue to direct the majority of incentives to the agents who need them the least.

5.4 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. This is despite the fact that individually many types of households would rather avoid OAS schemes being implemented in their economy. We draw two policy implications from this result. First, there are substantial differences between partial equilibrium effects 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. People are believed to 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 benefitting from them. Hence, the risk of excessive enrollment under opt-out is not relevant for policy purposes.

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. Naturally, poverty may occur for a wide variety of 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 the inclusion of these elements in our model (Werning 2007). The same applies to the saving behavior driven by motives other than smoothing consumption into the old-age (e.g., precautionary savings, buffer stock savings, bequest motive).

6 Conclusions

Increasing life expectancy exacerbates the challenge for the economic policy of providing for consumption in the old-age. Recognizing these challenges, many governments around the world 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 the extent to which OAS schemes can address the challenge of old-age poverty.

Our approach innovates relative to vast pensions literature by focusing the attention 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 pension system. This 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 economic situation at old-age, our paper can fill this gap and thus inform policy. We study the consequences of the government-subsidized old-age savings (OAS) schemes in an economy populated by incompletely rational agents with 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 that of a smaller public pension system with a *laissez-faire* approach to old-age pension benefits: the households have to accommodate increasing longevity and declining pensions through voluntary savings. The second alternative is that of increased public pension system contributions to maintain pension benefits intact and pension system balanced despite longevity. We show that for some of the incompletely rational agents, the OAS schemes improve welfare against both those alternatives. Welfare gain in the case of financially illiterate agents 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 agents 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 mostly due to financially illiterate agents who hold positive assets in the OAS scheme and would otherwise save almost nothing. In case of fully rational households, crowd-out is almost 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* only to a limited extent. The effect is larger in case of financial illiteracy than in 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. This means that fiscal support is directed to a large extent toward households who do not need it. T-T-E schemes with lump-sum subsidies are very successful in reducing poverty while maintaining equity of fiscal transfers. Such schemes are the least common policy instrument at this point, however.

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Additional material (intended for online dissemination)

A The formalized model

In each period, $N_{1,m,t}$ agents newly arrive in the economy, where m denotes their type, $j = 1$ their age, and t the calendar year. Agents at the maximum live for $j = 1, 2, 3, ..., J$ periods, where $\pi_{j,t}$ denotes their survival probability, with $\pi_{J,t} = 0$ at the maximum age. Probability of survival is homogeneous within a birth cohort, i.e. common across types of agents. As a consequence, in each period t, we have $N_{j,m,t}$ agents of type m and age j in our economy). Entry at $j = 1$, which corresponds to age 21 in reality, allows us to abstract from the choice of education. In the model, we compare the initial (ISS) and the final steady state (FSS).

The economy is fully annuitized, i.e. both private voluntary assets and incentivized OAS yield a rate of return including unintentional bequests. We thus abstract from utility of life span uncertainty insurance, which typically differentiates private voluntary savings and public pension systems. Note that with this solution, there are no longer bequests to enter on income side of the budget constraint.

A.1 Preferences

Agents of all types derive lifetime 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. Without loss of generality, we assume instantaneous utility function of

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

where ϕ denotes leisure preference, identical across and within cohorts. Note that with log utility, substitution effect and wealth effect cancel out, which is a conservative assumption from the perspective of this study. Retirement eligibility is denoted by $\bar{J}$.

Denote by $\mathcal{C}_{j,m,t} = (1 + \tau_t^c)c_{j,m,t}$ gross consumption: $c_{j,m,t}$ is the experienced consumption (i.e. enters agents' utility) and τ_t^c is the consumption taxation. Analogously, denote by $\mathcal{I}_{j,m,t} = (1 - \tau^l - \tau)w_{j,t}l_{j,m,t}$ labor income earned by agents with $j < \bar{J}$ with $w_{j,t}$ denoting age-specific wages. Labor income tax is denoted by τ^l and accordingly τ denotes contribution rate to the mandatory and universal pension system. Pension benefits are denoted by $\mathcal{I}_{j,m,t} = (1 - \tau^l)b_{j,m,t}$ for $j \geqslant \bar{J}$. In the same spirit, capital income of a household is denoted by $\mathcal{K}_{j,m,t} = \{[1 + r_t(1 - \tau^k)](N_{j-1,t}/N_{j,t}) - 1\}a_{j-1,m,t}$. The interest rate in the economy is denoted by r_t and stock of assets is denoted by $a_{j,m,t}$. Annuitization of the economy implies that agents receive the survivor premium on assets. To close the economy, we introduce lump-sum tax Υ. It is also useful to define intra-cohort lump-sum transfers $\mathcal{T}_t$, see equation (A.11) below.

Given that the agents could 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, i.e. $\forall_{j,m,t} \quad a_{j,m,t} \geqslant 0$. With the constraint on non-negative asset holding, agents cannot deplete their assets below 0. This constraint, if binding, may make the Euler solution infeasible. 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 $\tilde{c}_{j,m,t} = \{c_{j,m,t}, c_{j+1,m,t+1}, ..., c_{J,m,t+J-j}\}$ and analogously for sequence of lifetime labor supply $\tilde{l}_{j,m,t}$ and assets $\tilde{a}_{j,m,t}$.

Fully rational agents – *homo oeconomicus* – perform standard optimization of conventional lifetime utility on a budget constraint with labor income, capital income and pension benefits. As hinted above, we model two types of departure from *homo oeconomicus.* First, we consider agents with **time inconsistent** preferences, i.e. we modify the utility function. Second, we also consider agents who do store wealth to smooth consumption into the old age, but have no access to financial markets, i.e. we modify the budget constraint. We name those agents **financially illiterate**.

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

$$U_{j,m,t} = \max_{\{\tilde{c}_{j,m,t}, \tilde{l}_{j,m,t}, \tilde{a}_{j,m,t}\}} u(c_{j,m,t}, l_{j,m,t}) + \sum_{s=1}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} u(c_{j+s,m,t+s}, l_{j+s,m,t+s}) \quad \text{(A.2)}$$

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

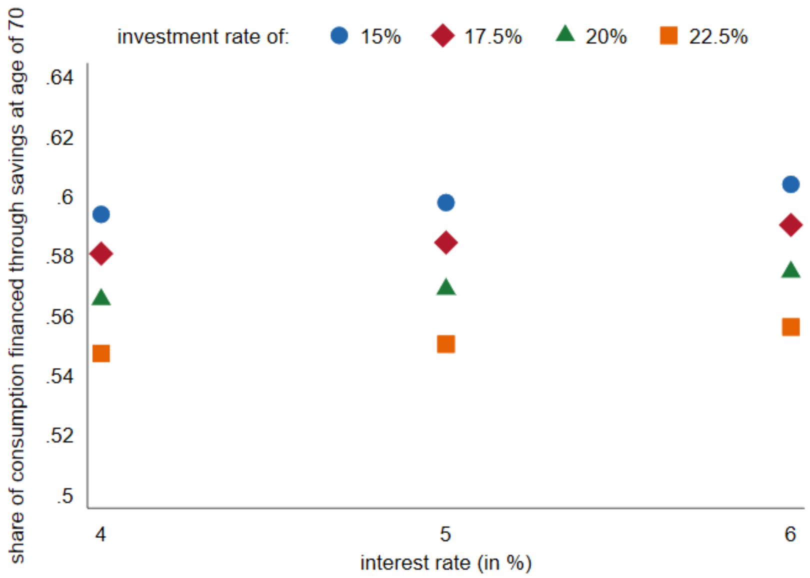
where index $m \in FR$ and δ signifies time discounting. It is useful to represent the behavior of the agents as MRS, which for the fully rational agents takes the form of:

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

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 annuity premium, i.e. the share of population of age j that did not survive to $j + 1$. The Euler conditions generally holds only when the non-negative constraint on assets is non-binding. Otherwise, LHS of the Euler equation for subsequent ages are greater than RHS.

Fully rational agents are a useful construct for macroeconomic modeling, but one of the distinct features of models based on such behavioral patterns is that the consumption path is very smooth and assets accumulation is quite intensive. In fact, for a plausible range of calibrations for the basic model parameters, fully rational agents finance an implausibly high share of their old-age consumption from private voluntary savings, typically in excess of 55 percent. We illustrate this point in Figure A.1, where we portray what share of consumption at the age of 70 years a fully rational agent is not financing through the pension benefit. We show this for various target interest rates and various investment rates in that economy to substantiate that this implausibly high share does not stem from particular calibration, rather that it is a general feature of this class of agents.

Figure A.1: Old age consumption financing by fully rational agents – comparison across calibrations



Note: Results for calibration as described in Section 4 for demographics and fiscal sector as well as labor supply and pension system. Each point represents an alternative calibration. Full set of calibration parameters reported in Table A.1 in the appendices.

Time inconsistent agents solve the following problem:

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

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

where index $m \in TI$. We denote additional discounting applied to all future periods by β. This is the so called quasi-hyperbolic and *naive* time inconsistency. Sophisticated time inconsistency would involve agents aware of their own time inconsistency and seeking a disciplining technology, thus reducing the effects of this type of departure from *homo oeconomicus* on lifetime savings patterns.

The MRS implied for the time inconsistent agents is given by

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

Naturally, this MRS holds only to describe optimal choice between j and $j+1$ at age j. The optimum for subsequent periods $j+s$ 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. They are aware that their suboptimal assets stock will require them to catch-up (i.e. work more and consume less in the future). Note that in a limit, time inconsistent agents behave like hand-to-mouth agents: with infinite preference for the present period ($\beta \to 0$), these agents will consume entire income instantaneously.

Financially illiterate agents solve the following problem:

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

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

where index $m \in FI$. 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

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

Given that the financially illiterate agents obtain no interest, they have no benefits of withholding income, i.e. postponing consumption. Hence, FI agents do not store assets until annuity premium does not start compensating their time preference.

The interest rate on assets accumulated by the financially illiterate agents is given to financially literate agents, through lump-sum instantaneous transfers. Denote by $\mathcal{N}_{\notin FI} = \sum_{m \notin FI} \sum_{j=1}^{J} N_{j,m,t}$. We then define $\mathcal{T}_t$ as transfer of interest accrued by assets stored by financially illiterate agents to financially literate agents (equal in *per capita* terms)

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

Note that this transfer is proportional from financially illiterate agents, but it is not proportional for financially literate agents, that is the amount of $\mathcal{K}_{j,m,t}$ taken from a given $m \in FI$ depends on the amount of accumulated assets, but Λ_t is equal among all $m \notin FI$ agents. In fact, since it enters their budget constraint as a lump sum, it does not affect inter-temporal choice.

A.2 The pension system

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

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

where g_t denotes the economy payroll growth rate, which in the steady state is the exogenous technological progress; and $w_{j,t} = \omega_j * w_t$ denotes age specific productivity profile. Note that that the agents, when solving their problem, include the future pension benefit in their labor derivative (through so-called implicit taxation, see Bütler 2002). 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 contemporaneous average in the economy, thus yielding strong labor supply incentives. Adopting implicit taxation in the intra-temporal choice allows to reflect this feature.[23] In PAYG DB system, as characterizes Germany, pension system budget constraint is given by

$$B_t = \sum_m \sum_{j=\bar{J}}^{J} N_{j,m,t} b_{j,m,t} = \tau_t w_t L_t + subsidy_t, \tag{A.13}$$

where we denote pension system deficit by $subsidy_t$ (it is negative if the pension system 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.

A.3 Government

There are four types of taxes: labor income, capital income, consumption and lump sum tax. *Per capita* public spending is stationary between the initial and the final steady states, i.e. it grows at γ_t (see below). Public spending on goods and services G_t as well as servicing public debt $r_t D_t$ as well as pension system balance following equation (A.13) are financed through tax revenues and issuance of new public debt.

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

$$\mathcal{R}_t = G_t + subsidy_t + r_t D_t, \tag{A.15}$$

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. The initial steady state is set at with the data. The final steady state debt to GDP ratio is the same, as otherwise they would generate welfare effects on their own.

In the initial steady state, we calibrate the tax rates to match the tax revenue shares in GDP, following Mendoza et al. (1994). We then close the government budget constraint portrayed in equations (A.15)-(A.14) with a lump-sum tax (Υ). When the economy changes between the initial steady state and the new steady states (we will study several new steady states: with new changes to macroeconomic parameters and changes to either pension system reforms or OAS schemes introduction), the consumption taxes adjust. Note that G_t and $\Upsilon_t \sum_j \sum_m N_{j,m,t}$ adjust due to

[23]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. For the sake of simplicity, it is not included in the way the implicit taxation is operationalized in our model.

population change. Note also that in our simulations contribution rate τ or replacement rate ρ adjust to maintain $subsidy_t = 0$ in the final steady state despite longevity. As we describe in Section 4, in the initial steady state the pension system is also balanced. Let $\Xi_t = G_t - \Upsilon_t \sum_j \sum_m N_{j,m,t}$, then:

$$t = FSS : \tau_t^c = \frac{\Xi_t + r_t D_t - \tau^k r_t \tilde{A}_t - \tau^l w_t \tilde{L}_t - \tau^l B_t - \mathbb{I}\tau^l \sum_{j=\bar{J}}^{J} \sum_m \text{taxable OAS benefits}}{C_t}. \quad \text{(A.16)}$$

In this notation $\mathbb{I}$ 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 $r_t A_t$ in the presence of OAS schemes, because with E-E-T scheme capital proceeds *in* the OAS scheme are exempt from 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 detail in section B.

A.4 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 rate 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 price of capital and wage:

$$r_t = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d \quad \text{and} \quad w_t = (1-\alpha) K_t^\alpha z_t^{1-\alpha} L_t^{-\alpha}. \quad \text{(A.17)}$$

A.5 Equilibrium and model solving

General equilibrium is obtained from Gauss-Seidel algorithm with the following definition of the competitive equilibrium:

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

- ***consumer objective:*** *for each* $(j, m, t) \in \{1, \dots, J\} \times M \times \mathbb{N}$*, 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* (A.2), (A.5), (A.8)*, given prices;*
- ***firm's maximization problem:*** *for each* t*, given prices* (r_t, w_t)*, the aggregates* (K_t, L_t, Y_t) *solve the representative firm problem, satisfying equation* (A.17)*;*

- *the* ***government*** *balances budget as well as the PAYG pension, i.e. equations* (A.15), (A.14), *and* (A.13) *hold;*

- ***markets clear***

$$\begin{aligned} \textit{labor market:} \quad L_t &= \sum_{j=1}^{J}\sum_{m}\omega_j l_{j,m,t} && \text{(A.18)} \\ \textit{capital market:} \quad A_t &= \sum_{j=1}^{J}\sum_{m} a_{j,m,t} \quad \textit{and} \quad K_t = A_t - D_t && \text{(A.19)} \\ \textit{goods market:} \quad C_t &= \sum_{j=1}^{J}\sum_{m} c_{j,m,t} \quad \textit{and} \quad Y_t = C_t - dK_t + G_t. && \text{(A.20)} \end{aligned}$$

The consumer problem is solved with value functions iterations due to the non-negativity constraint on assets. Consumer chooses optimal labor supply and consumption given prices and taxes. Aggregating consumer implied decisions on savings yields capital for the next iteration. Updating aggregate capital allows 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 subsequent iteration.

A.6 Re-calibration of model parameters for Figure A.1

Figure A.1 reports the share of consumption at the age of 70 years old that is financed through private voluntary savings by a fully rational agent across calibrations. Table A.1 reports calibrations alternative to Table 2 that permit to reach counter-factual investment rates and interest rates.

Table A.1: Re-calibration of Table 2 for Figure A.1

Parameter		investment rate 15% $r = 4\%$	$r = 5\%$	$r = 6\%$	investment rate 17.5% $r = 4\%$	$r = 5\%$	$r = 6\%$
Macroeconomy							
Depreciation	d	0.0146	0.0229	0.0313	0.0234	0.0347	0.046
Leisure preference	ϕ	0.3081	0.3223	0.331	0.3065	0.3191	0.327
Time preference	δ	0.9996	0.9885	0.9789	0.9985	0.988	0.9787
Taxes & government							
Consumption	τ^c	0.1387	0.1387	0.1387	0.1441	0.1441	0.1441
Labor	τ^l	0.0881	0.0881	0.0881	0.0881	0.0881	0.0881
Capital income	τ^k	0.1658	0.1713	0.1728	0.1894	0.1947	0.1956
Contribution rate	τ	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432
Replacement rate	ρ	0.008	0.0079	0.0079	0.0079	0.0079	0.0079
Gov't expenditure		18.82	18.82	18.82	18.82	18.82	18.82
		investment rate 20%			investment rate 22.5%		
Parameter		$r = 4\%$	$r = 5\%$	$r = 6\%$	$r = 4\%$	$r = 5\%$	$r = 6\%$
Macroeconomy							
Depreciation	d	0.0356	0.051	0.0664	0.0536	0.075	0.0964
Leisure preference	ϕ	0.3044	0.3156	0.3227	0.3021	0.3119	0.3183
Time preference	δ	0.9975	0.9876	0.9786	0.9968	0.9875	0.9788
Taxes & government							
Consumption	τ^c	0.15	0.15	0.15	0.1564	0.1564	0.1564
Labor	τ^l	0.0881	0.0881	0.0881	0.0881	0.0881	0.0881
Capital income	τ^k	0.2208	0.2256	0.2253	0.2647	0.2681	0.2656
Contribution rate	τ	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432
Replacement rate	ρ	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
Gov't expenditure		18.82	18.82	18.82	18.82	18.82	18.82

Note: For brevity in Table A.1 we report only values of parameters, as target values are the same as in Table 2. Data targets are the same as reported in Table 2. The time preference parameter δ is calibrated to match the interest rate, given depreciation d and investment rate. Hours worked from the OECD Employment Outlook data. Share of tax revenues in GDP from OECD Tax Database data. Investment rate government expenditure as a share of GDP taken from Eurostat national accounts. In all calibrations presented in Table A.1 we match the targets with the precision of 0.001 percentage point.

B Policy reforms

We denote by κ the contribution rate and savings above this cap are not subject to exemptions. We set the threshold κ such that the pension system budget constraint from equation (A.13) is satisfied in the final steady state with $subsidy^{ISS} = subsidy^{FSS} = 0$. Given the longevity projections for Germany, the increase in the contribution rates necessary to maintain pension system neutrality to the fiscal balance, under our preferred calibration where $\alpha = 0.33$, amounts to $\kappa = 5.07\%$.[24] We thus set $\overline{w_{j,t}l_{j,m,t}} = 5.07\% w_{j,t}l_{j,m,t}$ as the maximum exempt from labor taxation and social security contributions in the scenarios with incentivized OAS instrument.

We introduce incentives to two types of schemes: E-E-T and T-T-E. In both cases the participation decision is binary, but the timing of participation (the age at which agents chooses to start contributing to the incentivized OAS instrument) makes this decision effectively quasi-continuous.[25] Recall that

$$\forall j < \bar{J} : \mathcal{I}_{j,m,t} = (1 - \tau^l - \tau) w_{j,t} l_{j,m,t} \quad \text{and} \quad \forall j \geqslant \bar{J} : \mathcal{I}_{j,m,t} = (1 - \tau^l) b_{j,m,t}.$$

The exempt in E-E-T scheme is complete, i.e. the eligible contribution is entirely exempt from taxation, hence for participants:

$$\mathcal{I}^r_{j,m,t} = \begin{cases} (1 - \tau^l - \tau)(1 - \kappa) w_{j,t} l_{j,m,t} & \text{for} \quad j < \bar{J} \\ (1 - \tau^l) b_{j,m,t} + \tilde{b}_{j,m,t} & \text{for} \quad j > \bar{J}, \end{cases}$$

where $\tilde{b}_{j,m,t}$ denotes the pension benefit from the OAS scheme. While the universal pension system with $b_{j,m,t}$ pensions is of defined benefit nature, as portrayed in equation (A.12), the OAS scheme is of a defined contribution nature. Consequently, E-E-T pension funds accrue following $\tilde{b}_{j+1,m,t+1} = (1+\bar{r}_t)\tilde{b}_{j,m,t} + \kappa w_{j,t} l_{j,m,t}$. At retirement, these accumulated funds are transformed to pension benefit payment using life expectancy. Also, E-E-T is funded, thus $\forall j > \bar{J} : \quad \tilde{b}_{j,m,t} = (1 + \bar{r}_t)\tilde{b}_{j-1,m,t-1}$.

For the T-T-E instrument, the subsidy at disbursement stage ($j > \bar{J}$) implies

$$\mathcal{I}^r_{j,m,t} = (1 - \tau^l) b_{j,m,t} + (1 - \xi\tau^l)\tilde{b}_{j,m,t},$$

where $\tilde{b}_{j,m,t}$ denotes the benefit from OAS scheme for participating agents. Note that for $\xi = 1$ there is no subsidy, i.e. a situation equivalent to no OAS instrument, for $\xi \in (0, 1)$ the subsidy implies partial tax refund, whereas $\xi < 0$ implies a subsidy. Since this is a T-T-E scheme, pension

[24] In an alternative calibration, where $\alpha = 0.45$, the required increase in the contribution rates necessary to maintain pension system neutrality to the fiscal balance amounts to $\kappa = 6.23\%$.

[25] Typically, government incentives at the accumulation stage are combined with incentives at contribution stage, i.e. a threshold imposed on contributions κ can be expressed as mutually unambiguous threshold on assets, which makes conceptually E-T-T similar to T-E-T, and overall E-E-T instruments the most frequent type of incentives schemes (OECD 2018). Note that if individuals are permitted to choose the age at which they join the instrument, the fixed contribution rate becomes effectively a cap on lifetime earnings with quasi-continuous choices between 0 contributions and $\kappa \sum_j w_{j,t} l_{j,m,t}$ threshold.

funds accrue following $\tilde{b}_{j+1,m,t} = (1+(1-\tau^k)\bar{r}_t)\tilde{b}_{j,m,t} + \kappa w_{j,t} l_{j,m,t}$. After conversion to a defined contributions benefit at retirement, the subsequent payments are are indexed with the interest rather than payroll growth as in universal pension system, $\forall j > \bar{J}: \quad \tilde{b}_{j,m,t} = (1 + (1-\tau^k)\bar{r}_t)\tilde{b}_{j-1,m,t}$.

To make the size of the government subsidy comparable between E-E-T and T-T-E scheme, we calibrate the ξ parameter such that the government expenditure for the instrument is identical as a share of GDP in the final steady state. In addition, we also consider T-T-E instrument disbursed as a flat subsidy, that is at disbursement stage ($j > \bar{J}$)

$$\mathcal{I}^r_{j,m,t} = (1-\tau^l)b_{j,m,t} + \tilde{b}_{j,m,t} + \tilde{\xi}\tilde{\eta}_m/45,$$

where the definition of $\tilde{b}_{j,m,t}$ is the same as in the case of proportional T-T-E and $\tilde{\xi}$ denotes the lump sum transfer disbursed after retirement to all OAS participants, in proportion to their chosen number of years in participation $\tilde{\eta}_m/45$. Note that $\tilde{\xi}$ is a lump sum subsidy, meanwhile ξ is a proportional subsidy. For example, an agent who chose to participate for one year, will receive $\tilde{\xi} * 1/45$ and an agent who chose to participate during the entire career will receive $\tilde{\xi} * 1$ This lump sum is calibrated such that $\sum_m \sum_{j=\bar{J}}^{J} \tilde{\xi}\tilde{\eta}_m/45$ was equivalent to E-E-T in terms of share in GDP.

Comparing proportional T-T-E to a lump sum T-T-E is interesting, because in our setup agents optimize lifetime path conditional on the implicit taxation in the pension system. The universal PAYG defined benefit pension system brings negative net present value, because it accrues at a rate lower than the interest rate. This implies distortionary taxation on labor (implicit tax). T-T-E instruments are both positive net present value (implicit subsidy), but the lump sum is less distortionary than the proportional subsidy. Meanwhile, PAYG DB pension system is proportional. Thus, a scenario with T-T-E flat informs about the scale of this distortion, which is why replacing a proportional pension system with a lump sum transfer (reducing distortion) allows to quantify these effects in our model.

Agents choose to participate in the instrument endogenously, depending on whether the instrument increases their lifetime utility. Agents can freely chose the age $j \in [1, \bar{J}-1]$ at which they join the instrument, yet after joining they have to stick to it until retirement $\bar{J}$. There will be general equilibrium effects depending on how many agents join the instrument. By employing a fixed point method, we find the equilibrium until in subsequent iterations, agents do not wish to re-adjust their participation decisions having observed the general equilibrium outcomes (in particular the fiscal costs and size of the subsidy.

Note that OAS schemes do not enter directly the pension system balance. Namely, the contributions to OAS constitute assets in the economy (stock) rather than government revenues (flows). In addition, OAS schemes do not require subsidy, nor do they generate surplus. There are, naturally, adjustments in labor supply and wages, which affect the balance of the pension system, but OAS instruments do not enter directly on pension system balance depicted in equation (A.13).

Introducing OAS schemes does affect the government budget constraint described by equation

(A.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). This is reflected in the fiscal closure described by equation (A.16).

Introducing OAS schemes changes the equilibrium definition, as per Section A.5. Namely, the consumer choice variables include participation in OAS: maximization problem is subject to altered budget constraints, given the relevant definition of $\mathcal{I}^r$ instead of $\mathcal{I}$ in case of participation.

C Measuring policy effects

In this section we present the three welfare measures which are reported in the paper. In the case of agents with rational preferences (i.e. for agents who have $\beta = 1$), experienced and planned utility are equivalent. In the case of agents with time inconsistent preferences, experienced utility differs from planned utility. All three measures of welfare rely on experienced utility. The difference between them lies in how subsequent ages are weighed. Given that experienced and planned utility are equivalent for agents with $\beta = 1$, all three measures yield exactly the same result if agents have no time inconsistency, regardless of financial literacy.

C.1 Forward-looking welfare measure

In this approach, welfare is measured taking the perspective of age $j = 1$. On the one hand, this is appealing in a sense that welfare calculated is experienced by at least one of the many selves which time-inconsistent agents appear to be. On the other hand, this approach discounts "strongly" the future due to the additional $\beta < 1$ discounting. This approach is used by, among others, Krusell et al. (2002). Equation (C.1) states formally the forward-looking welfare measure

$$W_m^{forward} = \exp\left(\frac{U_{1,m}^r - U_{1,m}}{\phi(1 + \beta \sum_{j=2}^{J} \delta^{j-1}\pi_j)}\right) - 1, \tag{C.1}$$

where $U_{1,m}$ is the optimized lifetime utility in status quo scenario as perceived form a perspective of an agent at age $j = 1$, and $U_{1,m}^r$ is the analog in a given reform scenario. Parameters ϕ and δ are leisure preference and time preference parameters calibrated as per Table 2 and Table **??**. The functional form for $U_{1,m}$ is given in equations (A.2) and (A.5) for fully rational and time inconsistent agents, respectively. For brevity we drop time subscript t.

C.2 Backward-looking welfare measure

In this approach, welfare is measured without factoring in the time inconsistency. One interpretation of this criterion is that it represents the preferences of the consumer if she were to set a choice program before the beginning of first life period (as if period zero existed, see for example Gruber and Koszegi 2001). In order to obtain the backward-looking welfare measure, utility equation (A.5) for agents with time inconsistency is replaced with utility equation (A.2) for fully rational agents. Formally, welfare measure is obtained from:

$$W_m^{backward} = \exp\left(\frac{\sum_{j=1}^{J} \delta^{j-1}\pi_j \left[u(c_{j,m}^r, l_{j,m}^r) - u(c_{j,m}, l_{j,m})\right]}{\phi \sum_{j=1}^{J} \delta^{j-1}\pi_j}\right) - 1, \tag{C.2}$$

where superscript r denotes reform scenarios and utility without superscripts denotes baseline scenario.

C.3 Imrohoroğlu et al. (2003) welfare measure

Following Imrohoroğlu et al. (2003), lifetime utility of a time inconsistent agent evaluated at age j (i.e. this is the period at which future is discounted additionally by β) is formulated as:

$$\tilde{U}_j = \sum_{s=1}^{j-1} \delta^{s-j} \pi_s u(c_s, l_s) + \pi_j u(c_j, l_j) + \beta \sum_{s=j+1}^{J} \delta^{s-j} \pi_s u(c_s, l_s). \tag{C.3}$$

The welfare measure based on this approach is formally obtained by:

$$W^{Imrohoroglu}_{m,t} = \exp\left(\frac{\sum_{j=1}^{J} \delta^{j-1} \pi_{j,t} (\tilde{U}^r_j - \tilde{U}_j)}{\phi \sum_{j=1}^{J} \pi_j (\sum_{s=1}^{j} \delta^{s-1} \pi_s + \beta \sum_{s=j+1}^{J} \delta^{s-1} \pi_s)} \right) - 1, \tag{C.4}$$

where superscript r denotes reform scenarios and utility without superscripts denotes baseline scenario.

C.4 Saving regret measure

In the final steady state, for baseline and for each reform scenario, repeat the following steps:

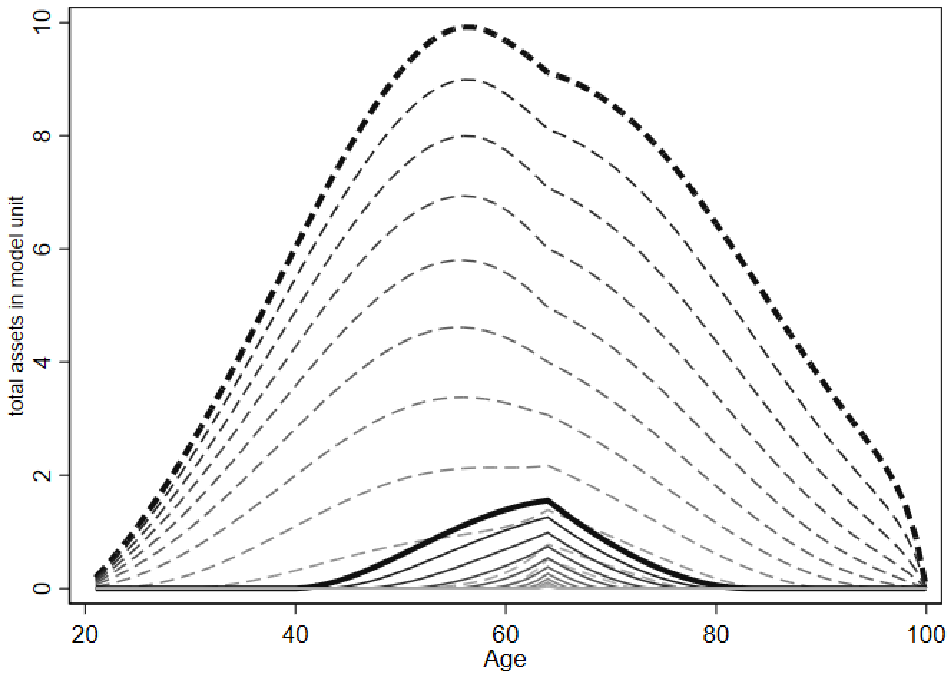
1. obtain assets for fully rational agents at $j = \bar{J}$: $a^{FR}_{\bar{J}}$;
2. instead of actually held assets $a_{j,\bar{J}} \quad \forall m \notin FR$ assign counterfactually $a^{FR}_{\bar{J}}$ to agent $m \notin FR$ at $j = \bar{J}$ [26] and reevaluate consumption choices for $j > \bar{J}$;
3. obtain welfare measure implied by step 2 in variants described in sections C.1, C.2 and C.3.

This procedure yields our proxy for saving regret, i.e. a measure of how much permanent consumption an incompletely rational agent would have given up to obtain the assets of a fully rational agent at retirement. The final step consists of comparing the measures obtained through this procedure between the baseline scenario (pensions decline in order to maintain pension system balance, there is no incentivized OAS instrument) and one of the government subsidized OAS schemes.

[26] Fully rational agents have highest assets stock $\forall_{j \in (1,..,J)}$ (see figure D.1 and E.1), hence action described in step 2 is equivalent to crediting asset stock of each agent m with the additional amount equal to $a^{FR}_{\bar{J}} - a_{m,\bar{J}}$.

D The main results

Figure D.1: Assets: private voluntary savings in initial steady state - calibration for $\alpha = 33\%$



Note: figure portrays baseline profiles of assets 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.

Figure D.2: Saving regret, welfare in the spirit of Imrohoroğlu et al. (2003), $\alpha = 33\%$

(a) initial steady state (b) final baseline steady state

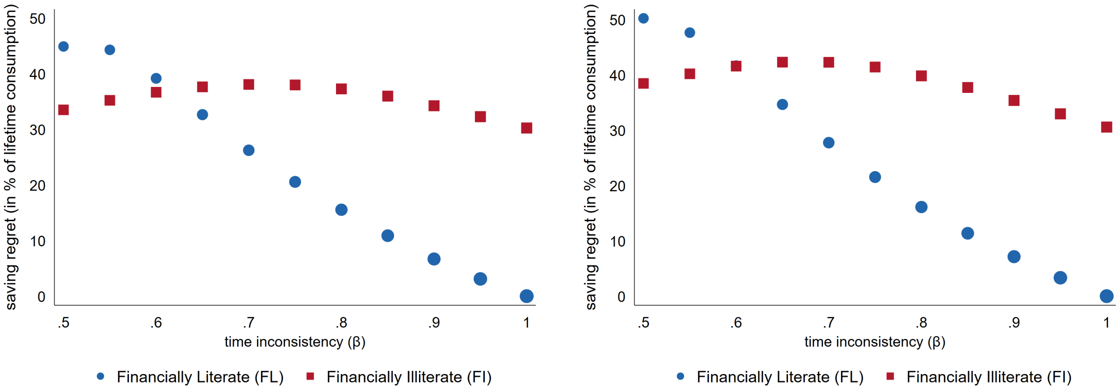


Figure D.3: Saving regret, backward-looking measure, $\alpha = 33\%$

(a) initial steady state (b) final baseline steady state

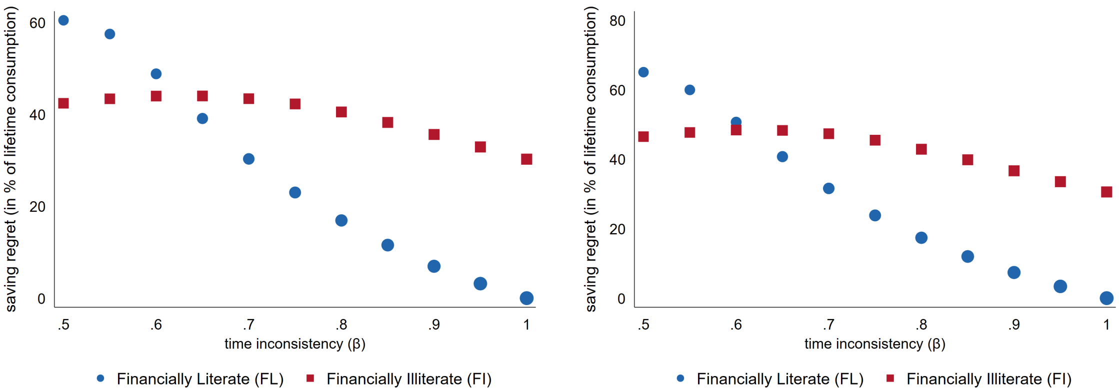
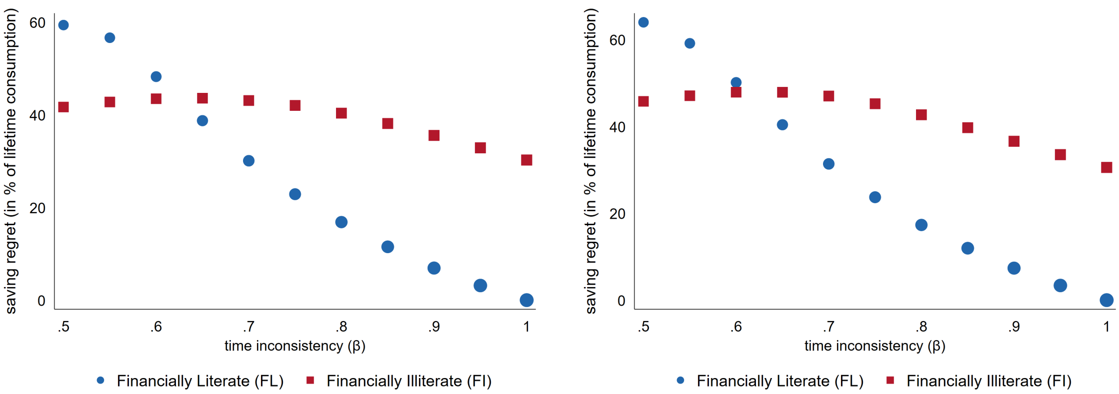


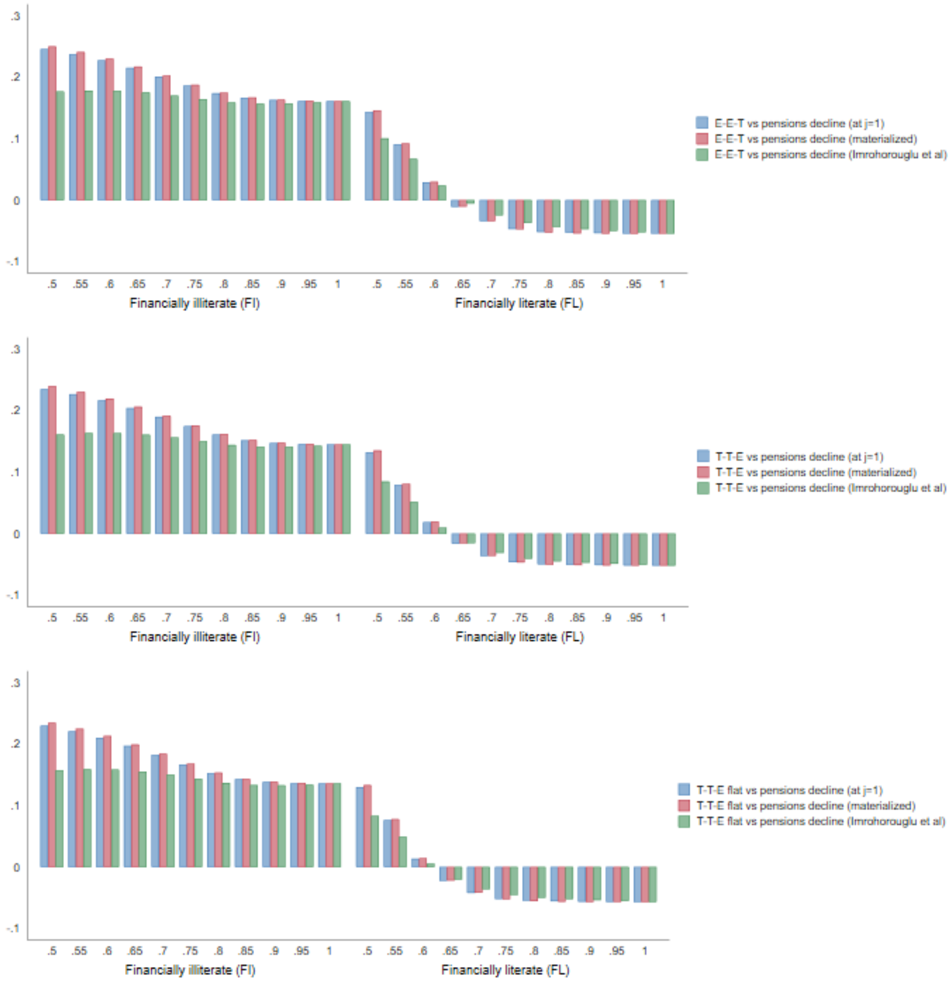
Figure D.4: Saving regret, forward-looking measure, $\alpha = 33\%$

(a) initial steady state (b) final baseline steady state



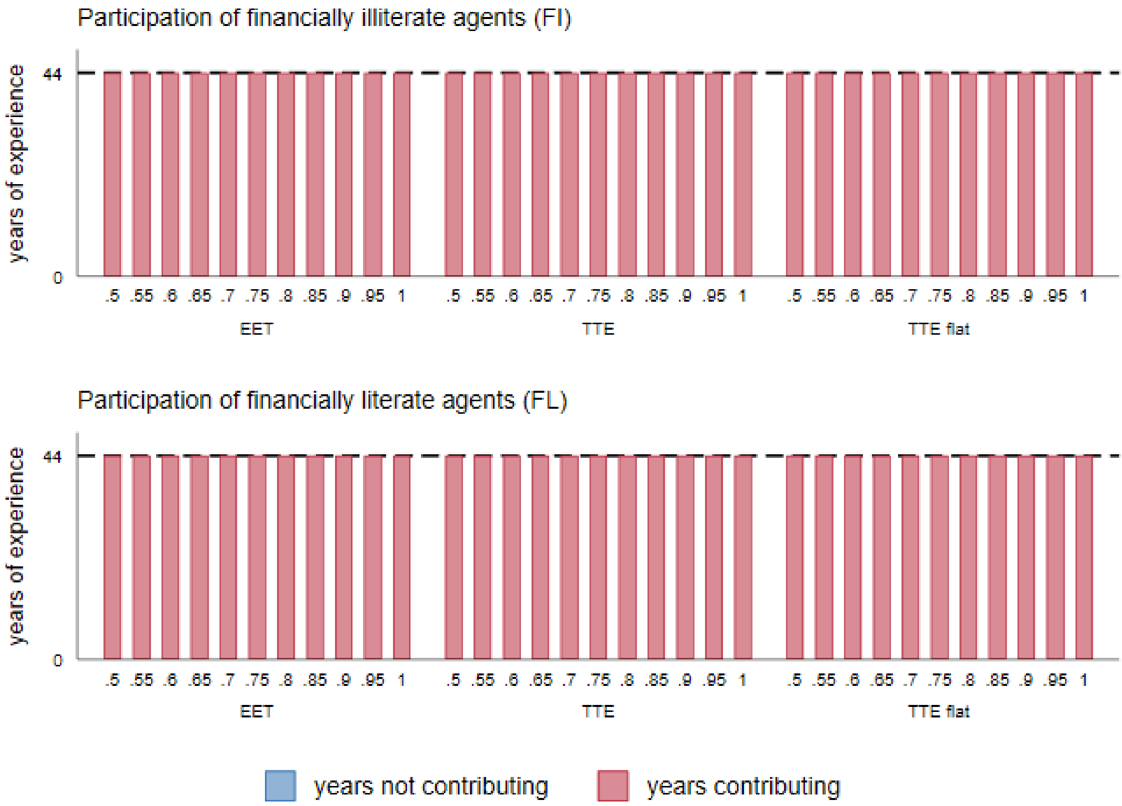
Note: saving regret computed following the procedure described in Appendix C.4. Saving regret expressed in consumption equivalent terms (% of lifetime consumption). Baseline scenario assumes pension decline to maintain pension system balance.

Figure D.5: Welfare effects of the reform – comparison of welfare measures



Note: In this figure, we portray welfare expressed as consumption equivalent in percent of lifetime consumption across behaviorally heterogeneous groups. The comparison scenario for each reported result is a reduction in pension benefits such that the pension system is kept balanced despite of 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 the pension system 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 pensions contributions. The size of fiscal incentives to the three incentivized OAS instruments is such that the total fiscal expenditure on tax incentives are equivalent across scenarios in terms of share in GDP.

Figure D.6: Participation in incentivized OAS schemes, $\alpha = 33\%$



Note: Blue part of a bar denotes working period ages in which the agent is not participating in an OAS scheme. Switch from a blue bar to a red bar signifies the age at which agents decide to enroll. When bar is only blue, given type of agent never participates in a given OAS scheme. When bar is only red, given type of agent contributes to a given OAS scheme throughout whole working period. Participation decision is endogenous in the model. At each age j agents compare subsequent lifetime utility, depending on their individual decision to participate. These decisions are aggregated, fiscal costs imposed, and in the next iteration agents reevaluate if they prefer their decision from the previous iteration or they want to change. If agent participates at age j, then agent also participates for all ages above j, until $\bar{J}$, i.e. agents are allowed to postpone participation, but are not allowed to exit the instrument (participation decision is irrevocable within an iteration). The algorithm stops when agents decision from the subsequent iteration no longer differ from the previous iteration.

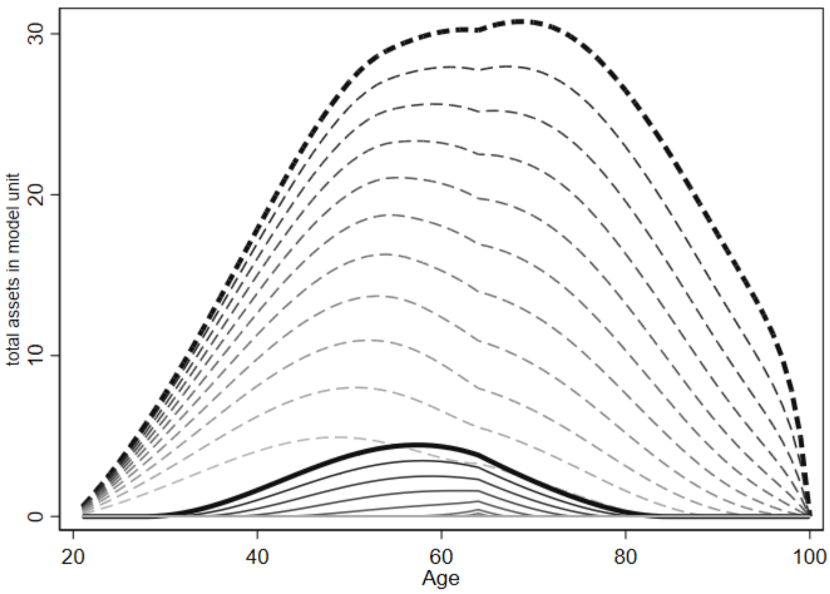
E Sensitivity: lower labor share ($\alpha = 45\%$)

Table E.1: Calibration of the macroeconomic parameters for $\alpha = 45\%$

Parameter		Value	Data source		Data target	Model (annuitization) none	full
			Macroeconomy				
Depreciation	d	0.0296	National accounts	investment rate	20.00%	20.00%	21.67%
Leisure preference	ϕ	0.3175	OECD	hours worked	35.00%	35.00%	36.46%
Time preference	δ	1.0165	-	interest rate	6.00%	6.00%	5.30%
Taxes & government							
Consumption	τ^c	0.1500	OECD	$\tau^c \cdot \mathcal{C}/Y$	9.18%	9.18%	8.93%
Labor income	τ^l	0.1045	OECD	$\tau^l \cdot wL/Y$	6.75%	6.75%	6.75%
Capital income	τ^k	0.1303	OECD	$\tau^k \cdot r\mathcal{K}/Y$	4.47%	4.47%	4.24%
Contribution rate	τ	0.1745	-	$subsidy/Y$	0%	0%	0.01%
Replacement rate	ρ	0.0097	AWG 2018	B/Y	9.60%	9.60%	9.60%
Gov't expenditure		0.1882	National accounts	G/Y	18.82%	18.82%	18.82%

Note: This table is analogous to Table 2 in the main text. The only difference is the calibration of the capital share in the economy. In an economy calibrated with $\alpha = 45\%$ the average replacement rate defined as a ratio of lifetime average gross labor income and pension benefit amounts to 56.5%. This figure differs significantly from the replacement rate reported by (OECD 2018), i.e. 38%, as well as from the replacement rate obtained in a calibration where $\alpha = 33\%$, i.e. 34.8% The interest rate reported in Table 2 is r as per equation (A.17). 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.

Figure E.1: Assets: private voluntary savings in initial steady state - calibration for $\alpha = 45\%$



Note: figure portrays baseline profiles of assets 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.

Figure E.2: Saving regret, welfare in the spirit of Imrohoroğlu et al. (2003), $\alpha = 45\%$

(a) initial steady state (b) final baseline steady state

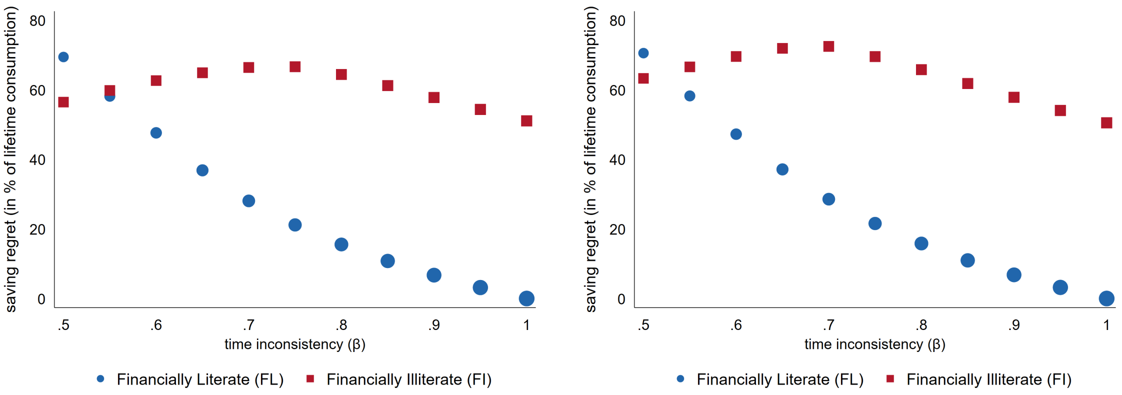


Figure E.3: Saving regret, backward-looking measure, $\alpha = 45\%$

(a) initial steady state (b) final baseline steady state

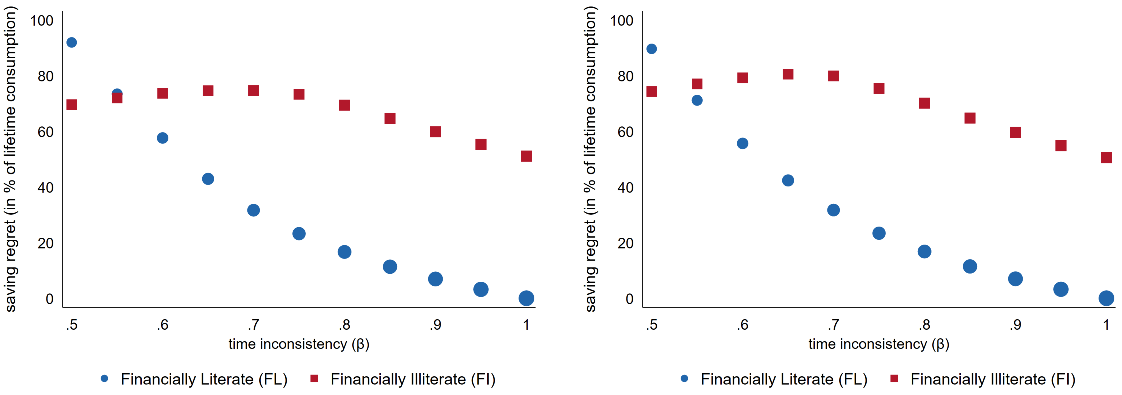
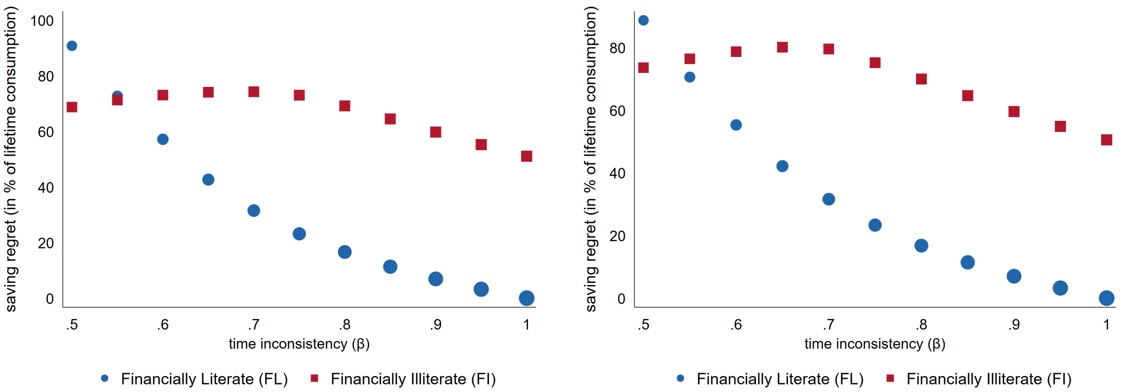


Figure E.4: Saving regret, forward-looking measure, $\alpha = 45\%$

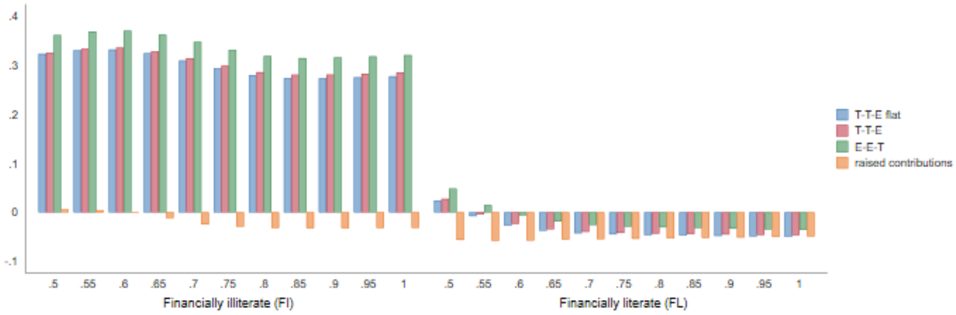
(a) initial steady state (b) final baseline steady state



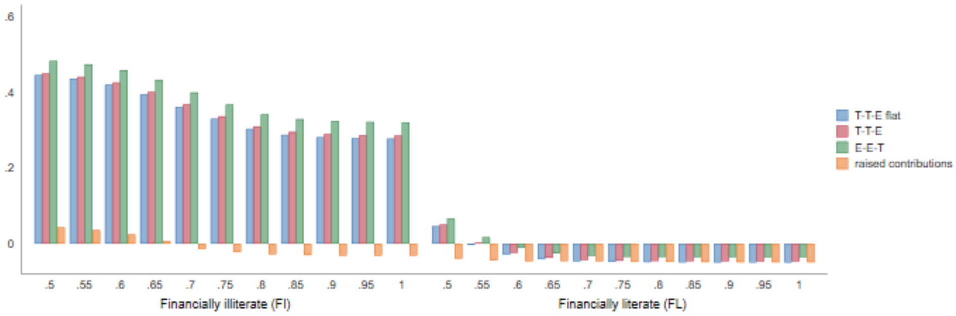
Note: saving regret computed following the procedure described in Appendix C.4. Saving regret expressed in consumption equivalent terms (% of lifetime consumption). Baseline scenario assumes pension decline to maintain pension system balance.

Figure E.5: Welfare effects of the reform – for $\alpha = 45\%$

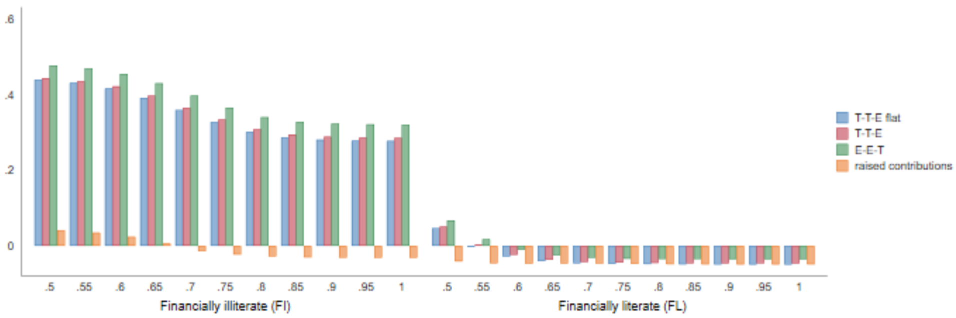
(a) Imrohoroğlu et al. (2003)



(b) backward-looking

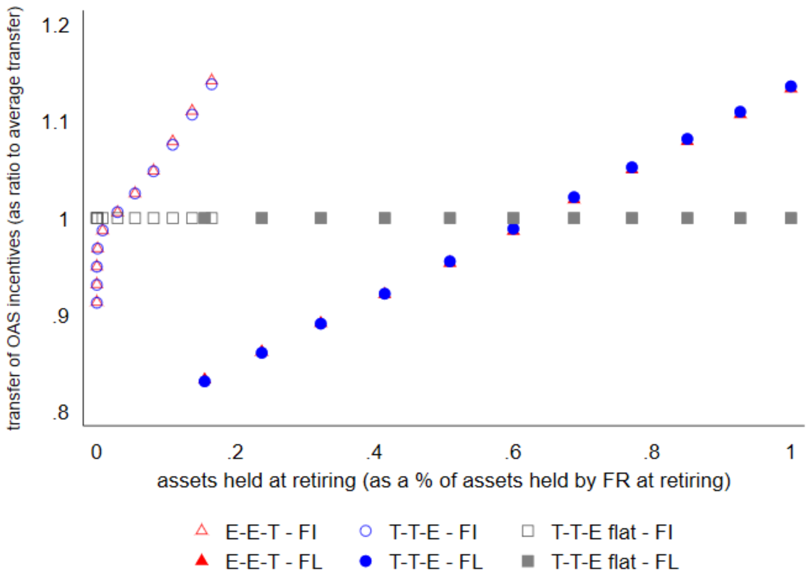


(c) forward-looking



Note: see Figure 1.

Figure E.6: Transfers for OAS incentives – re-calibration for $\alpha = 45\%$



Note: see Figure 2. The transfers are a similar ratio to the average transfer for E-E-T and T-T-E under the current calibration, but they are not identical.

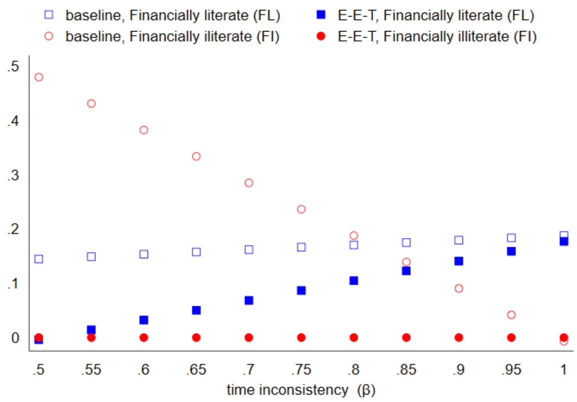
Table E.2: Macroeconomic summary – for $\alpha = 0.45$

		ISS	FSS				
			raise τ	reduce ρ	E-E-T	T-T-E	T-T-E flat
		(1)	(2)	(3)	(4)	(5)	(6)
pensions (replacement)	ρ/ρ_{ISS}	1.00	1.00	0.74	0.74	0.74	0.74
contributions rate (%)	τ	17.45	23.67	17.45	17.45	17.45	17.45
OAS contribution rate (%)	κ	-	-	-	6.22	6.22	6.22
consumption tax (%)	τ^c	15.00	12.86	9.68	12.56	13.4	13.67
OAS transfers per worker		-	-	-	0.045	0.0443	0.0443
labor	$L = \sum_{j,m} \omega_j l_{j,m}$	100%	109.7%	110.9%	114%	113.8%	112.9%
aggregate product	Y	100%	114.7%	121%	130.2%	127.4%	126.5%
wages	w	100%	104.5%	109.2%	114.2%	112%	112%
income tax revenues	$\tau^l \cdot wL$	100%	114.7%	121%	112.9%	127.4%	126.5%
pension tax revenue	$\tau^l \cdot B$	100%	155.6%	121.0%	130.1%	127.3%	126.4%
aggregate capital	A	100%	121.1%	134.7%	153.2%	146.3%	145.3%
of which							
voluntary		100%	121.1%	134.7%	88.7%	89.2%	88.7%
in OAS scheme		-	-	-	64.5%	57.1%	56.7%
interest rate (%)	r	5.31	4.87	4.47	4.07	4.24	4.24
capital tax revenues	$\tau^k \cdot \sum_{j,m} \mathcal{K}$	100%	111.1%	113.4%	68%	116.9%	116%
aggregate gross consumption	C	100%	110.5%	112%	124.2%	123.2%	122.4%
consumption tax revenues	$\tau^c \cdot C$	100%	94.7%	72.2%	104%	110%	111.5%

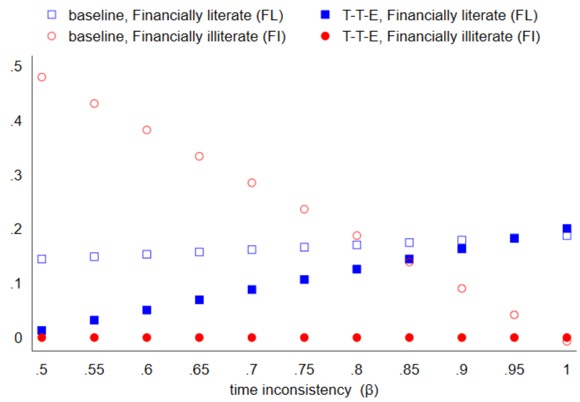
Note: ISS = Initial Steady State. FSS = Final Steady State. This table reports results analogous to Table 3, with the main difference that $\alpha = 0.45$ rather than the basic calibration of $\alpha = 0.33$.

Figure E.7: Age-adjusted incidence of poverty – for α = 45%

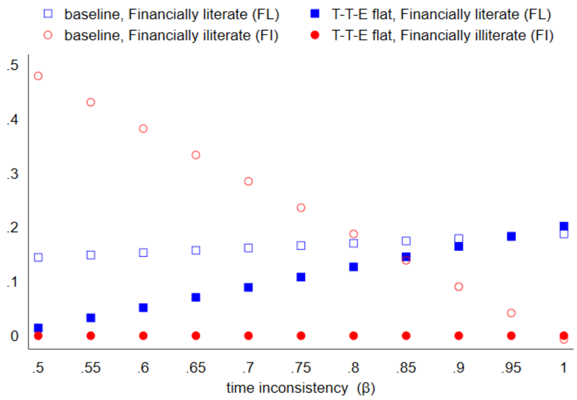
(a) E-E-T



(b) T-T-E



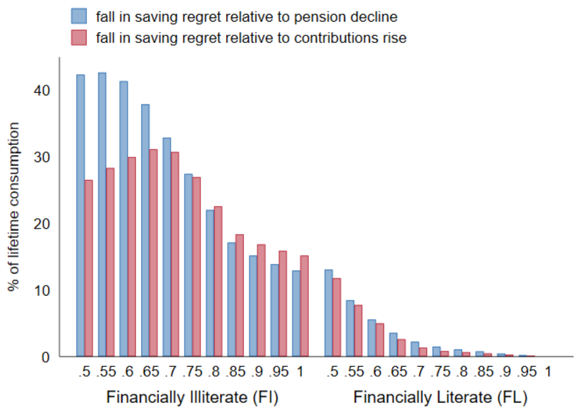
(c) T-T-E flat



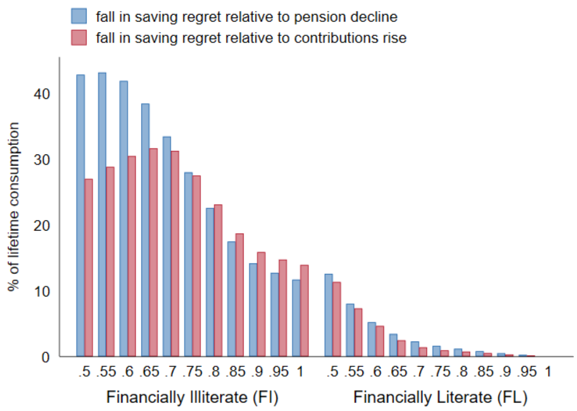
Note: see Figure 3.

Figure E.8: Decline in saving regret due to OASs – for $\alpha = 45\%$

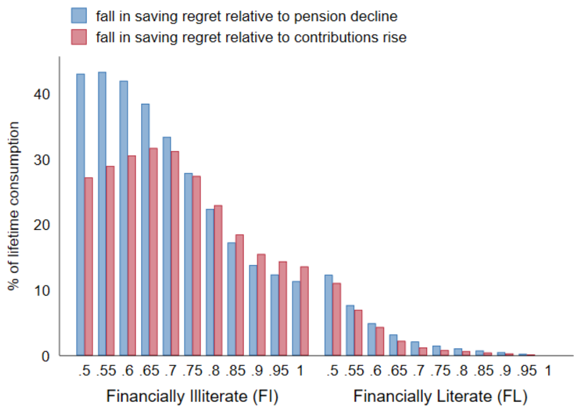
(a) E-E-T



(b) T-T-E



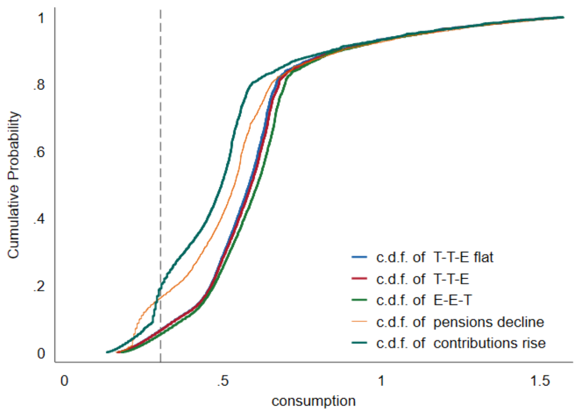
(c) T-T-E flat



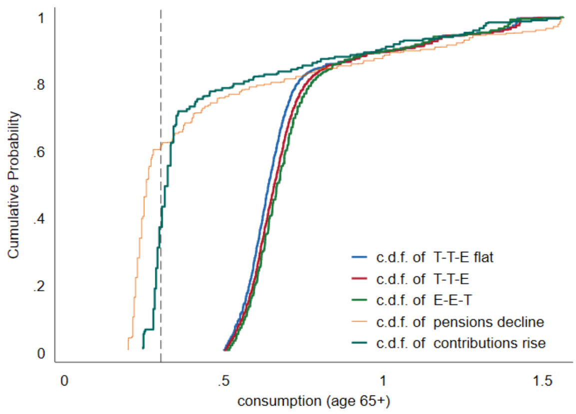
Note: see Figure 4

Figure E.9: Poverty – for $\alpha = 45\%$

(a) total population

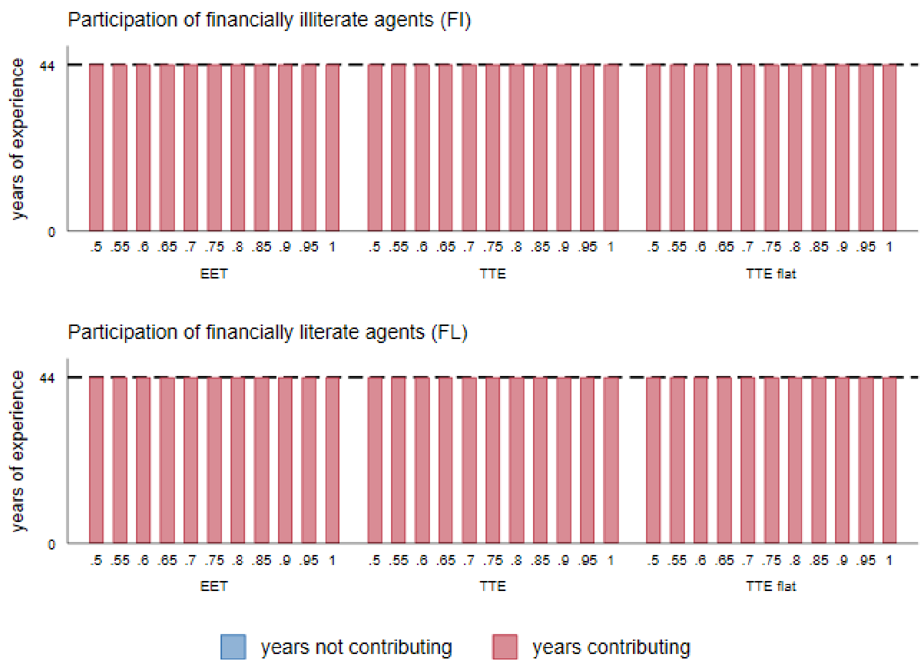


(b) population aged 65+



Note: see Figure 5.

Figure E.10: Participation in incentivized OAS schemes – for α = 45%



Note: see Figure D.6.

F Sensitivity: higher productivity growth ($\gamma_{FSS} = 1.54\%$)

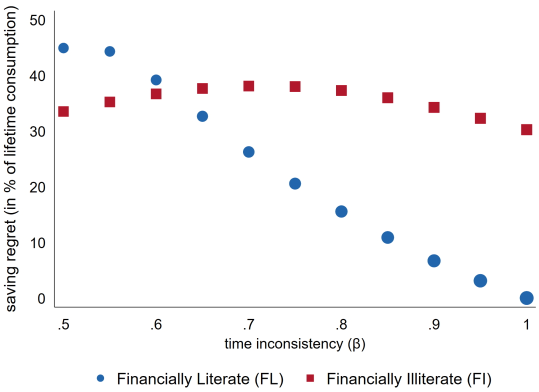
Table F.1: Macroeconomic summary – γ growing between ISS and FSS

		ISS	FSS				
			raise τ	reduce ρ	E-E-T	T-T-E	T-T-E flat
		(1)	(2)	(3)	(4)	(5)	(6)
pensions (replacement)	ρ/ρ_{ISS}	1.00	1.00	0.74	0.74	0.74	0.74
contributions rate (%)	τ	14.32	19.39	14.32	14.32	14.32	14.32
OAS contribution rate (%)	κ	-	-	-	5.07	5.07	5.07
consumption tax (%)	τ^c	15.00	16.13	14.64	17.95	18.51	19.06
OAS transfers per worker		-	-	-	0.0334	0.0329	0.0329
labor	$L = \sum_{j,m} \omega_j l_{j,m}$	100%	106.5%	107.5%	109.5%	109.4%	107.8%
aggregate product	Y	100%	106.1%	109.1%	115.3%	113.4%	111.8%
wages	w	100%	99.6%	101.5%	105.3%	103.7%	103.7%
income tax revenues	$\tau^l \cdot wL$	100%	106.1%	109.1%	100%	113.4%	111.8%
pension tax revenue	$\tau^l \cdot B$	100%	143.5%	109.0%	115.2%	113.3%	111.7%
aggregate capital	A	100%	105.1%	112.5%	128.2%	122.1%	120.4%
of which							
voluntary		100%	105.1%	112.5%	42.4%	49.4%	48.8%
in OAS scheme		-	-	-	85.7%	72.7%	71.6%
interest rate (%)	r	5.18	5.28	4.82	4	4.34	4.34
capital tax revenues	$\tau^k \cdot \sum_{j,m} \mathcal{K}$	100%	107.3%	104.7%	32.6%	102.3%	100.8%
aggregate gross consumption	C	100%	103.4%	103.9%	112.7%	112.5%	111.2%
consumption tax revenues	$\tau^c \cdot C$	100%	111.2%	101.3%	134.8%	138.8%	141.3%

Note: ISS = Initial Steady State. FSS = Final Steady State. This table reports results analogous to Table 3, with the main difference that $\gamma_{ISS} = 1.01\% \neq \gamma_{FSS} = 1.54\%$.

Figure F.1: Saving regret, welfare in the spirit of Imrohoroğlu et al. (2003), $\gamma_{FSS} = 1.54\%$

(a) initial steady state



(b) final baseline steady state

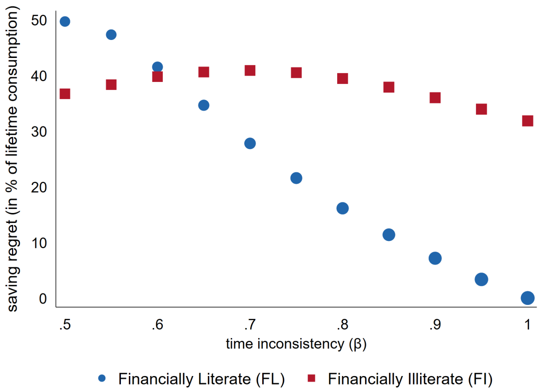
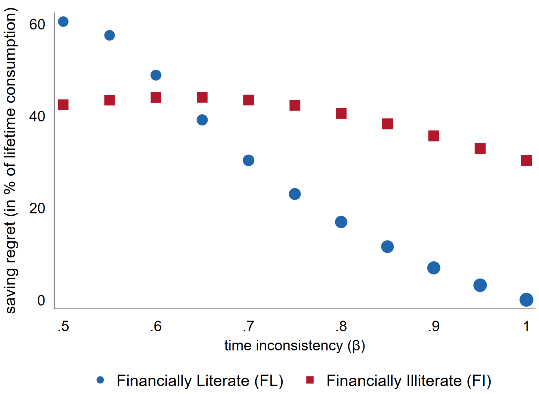


Figure F.2: Saving regret, backward-looking measure, $\gamma_{FSS} = 1.54\%$

(a) initial steady state



(b) final baseline steady state

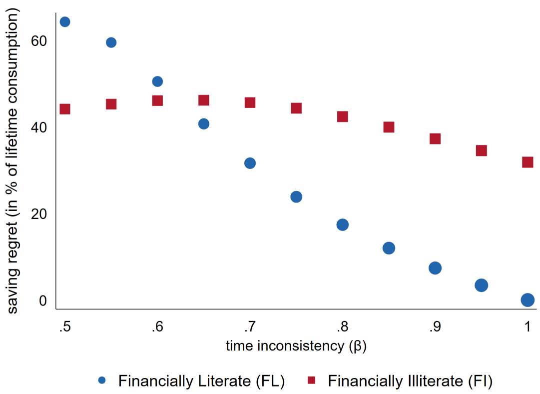
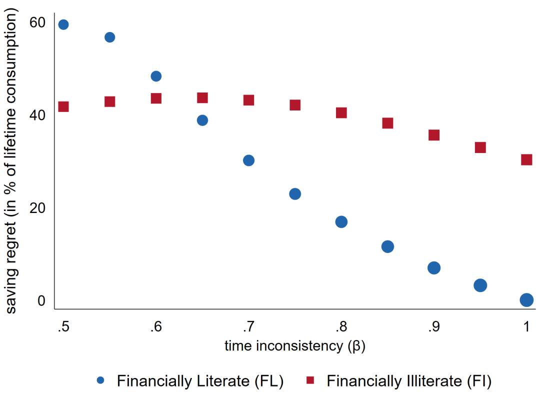
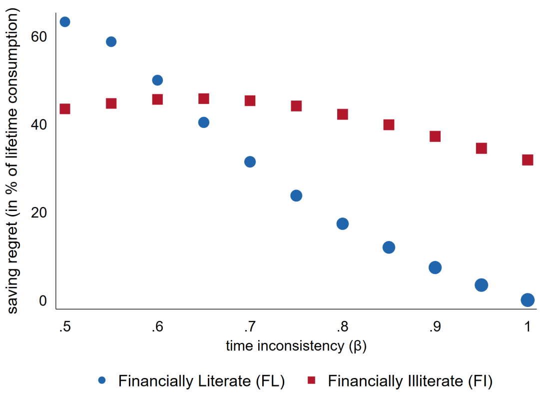


Figure F.3: Saving regret, forward-looking measure, $\gamma_{FSS} = 1.54\%$

(a) initial steady state



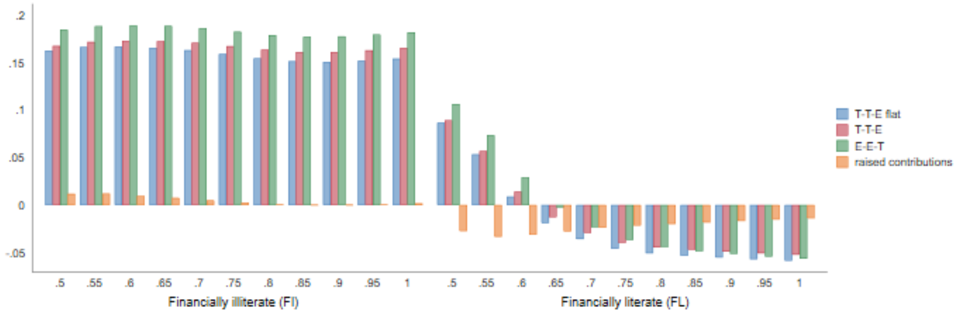
(b) final baseline steady state



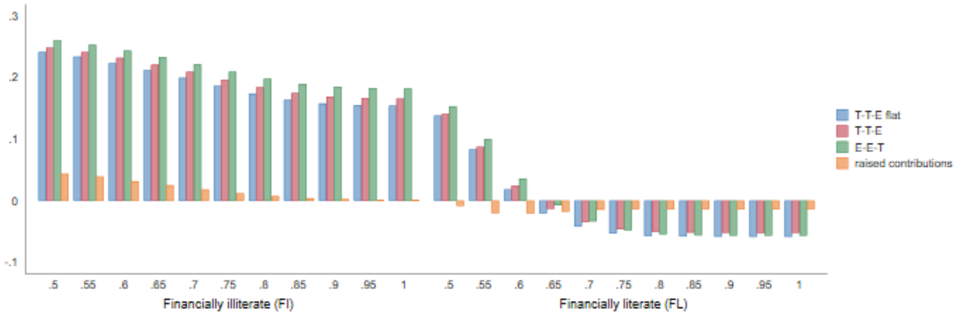
Note: saving regret computed following the procedure described in Appendix C.4. Saving regret expressed in consumption equivalent terms (% of lifetime consumption). Baseline scenario assumes pension decline to maintain pension system balance in the final steady state.

Figure F.4: Welfare effects of the reform – TFP increase ($\gamma_{FSS} = 1.54\%$)

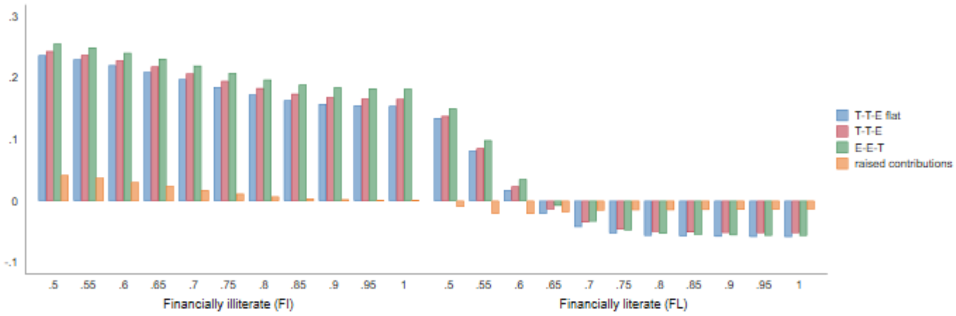
(a) Imrohoroğlu et al. (2003)



(b) backward-looking

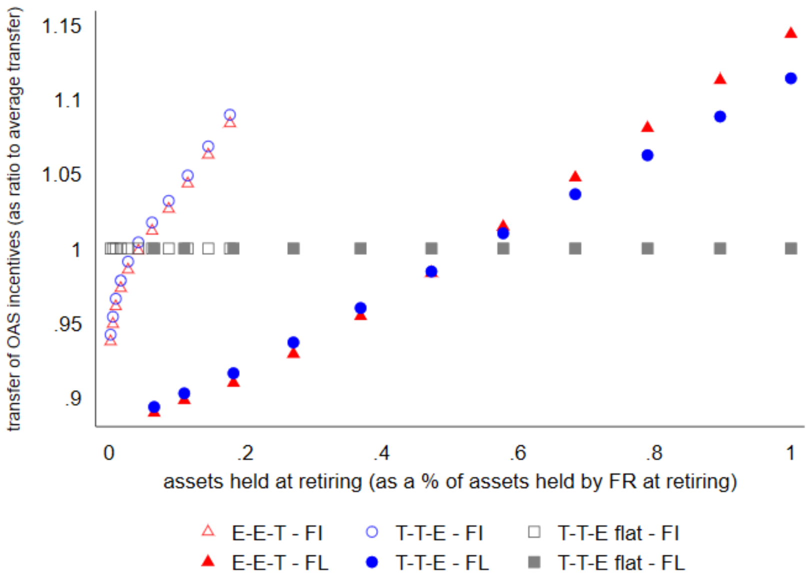


(c) forward-looking



Note: see Figure 1.

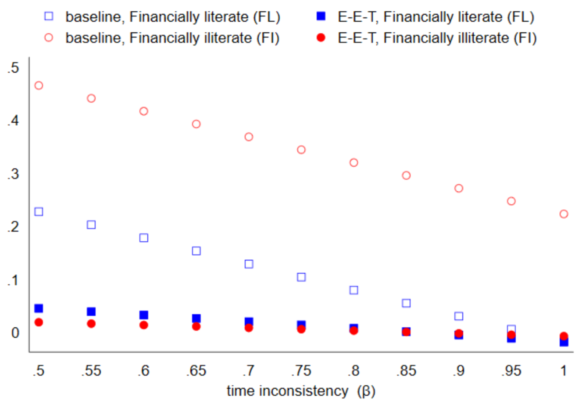
Figure F.5: Transfers for OAS incentives – TFP increase ($\gamma_{FSS} = 1.54\%$)



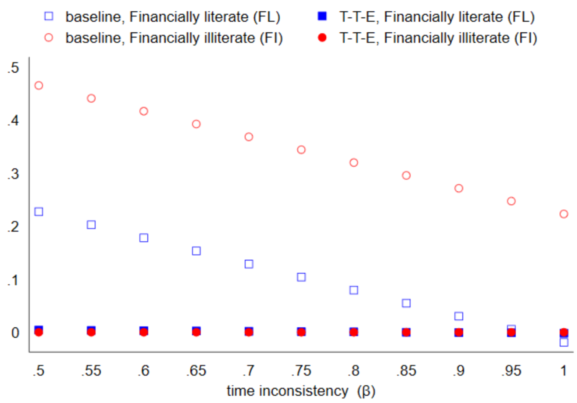
Note: see Figure 2.

Figure F.6: Age-adjusted incidence of poverty – TFP increase ($\gamma_{FSS} = 1.54\%$)

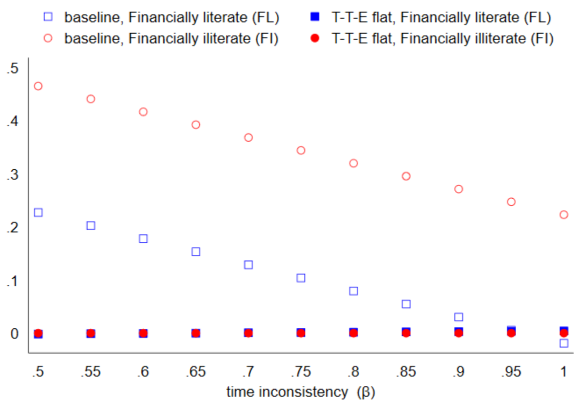
(a) E-E-T



(b) T-T-E



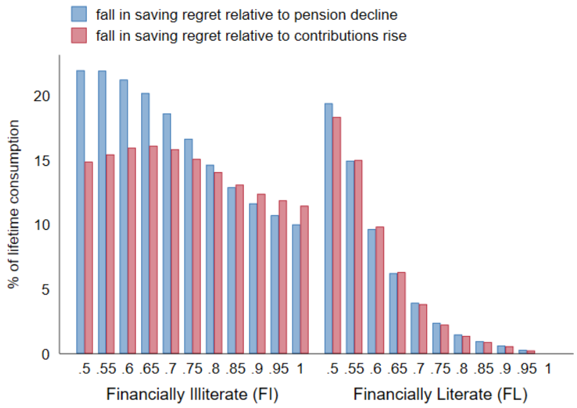
(c) T-T-E flat



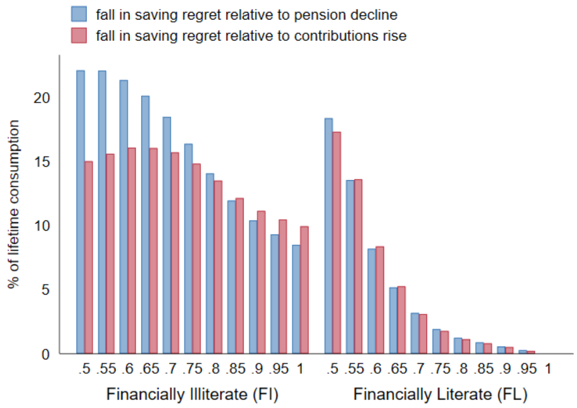
Note: see Figure 3.

Figure F.7: Saving regret – TFP increase ($\gamma_{FSS} = 1.54\%$)

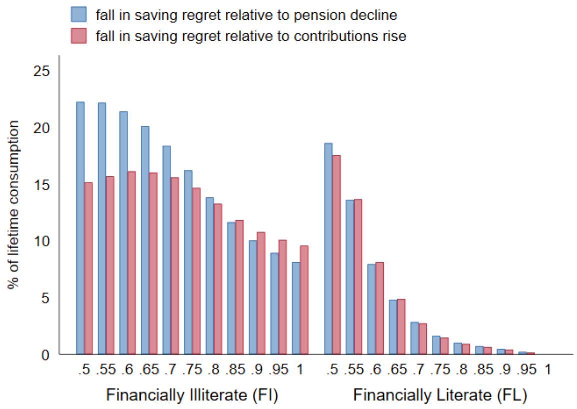
(a) E-E-T



(b) T-T-E



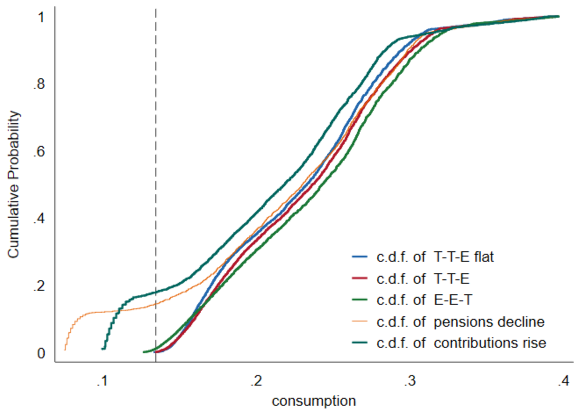
(c) T-T-E flat



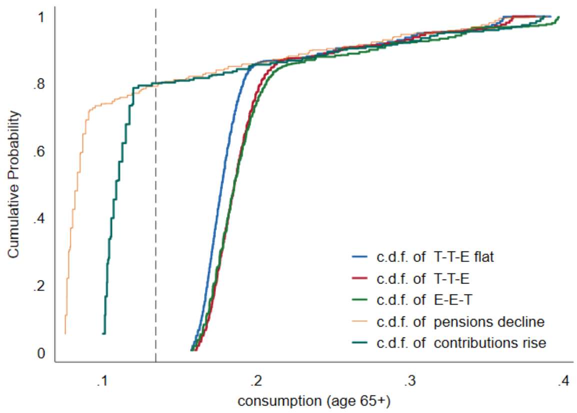
Note: see Figure 4

Figure F.8: Poverty – TFP increase ($\gamma_{FSS} = 1.54\%$)

(a) total population

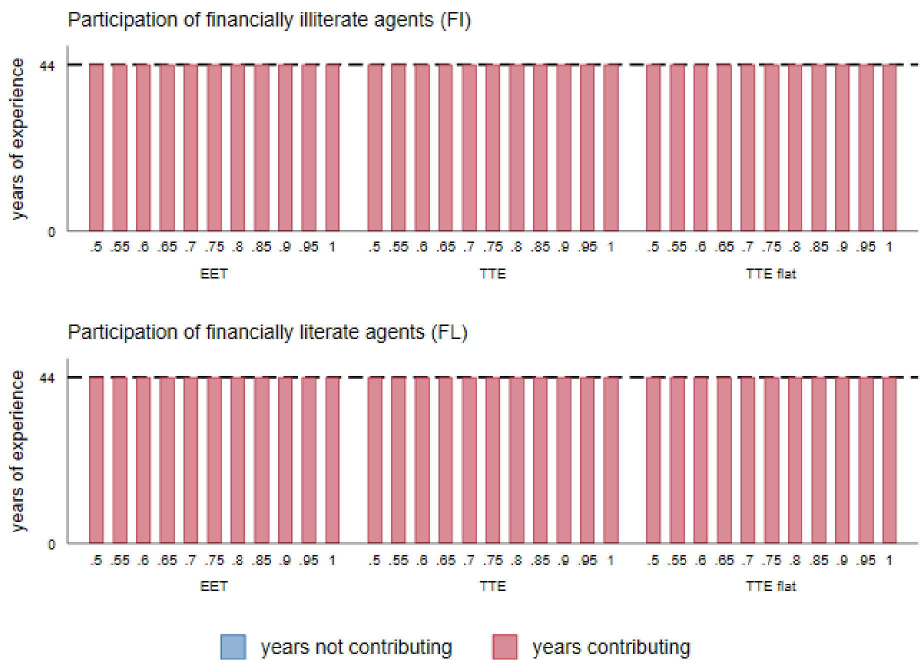


(b) population aged 65+



Note: see Figure 5.

Figure F.9: Participation in incentivized OAS schemes – TFP increase ($\gamma_{FSS} = 1.54\%$)

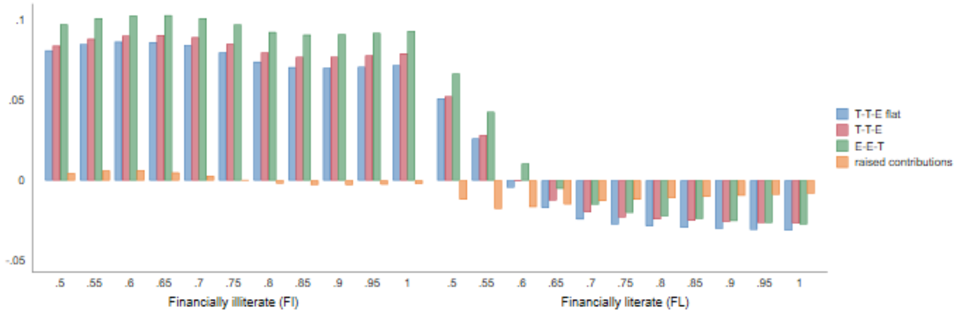


Note: see Figure D.6.

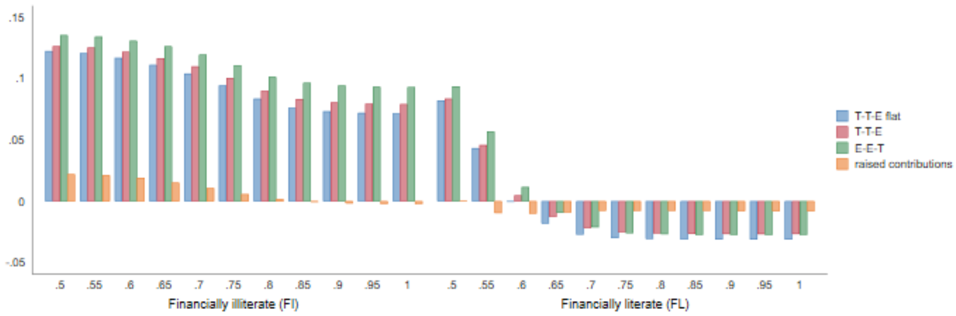
G Sensitivity: higher pension eligibility age ($\bar{J}_{FSS} = \bar{J}_{ISS} + 3$)

Figure G.1: Welfare effects of the reform – rise in retirement eligiblity age

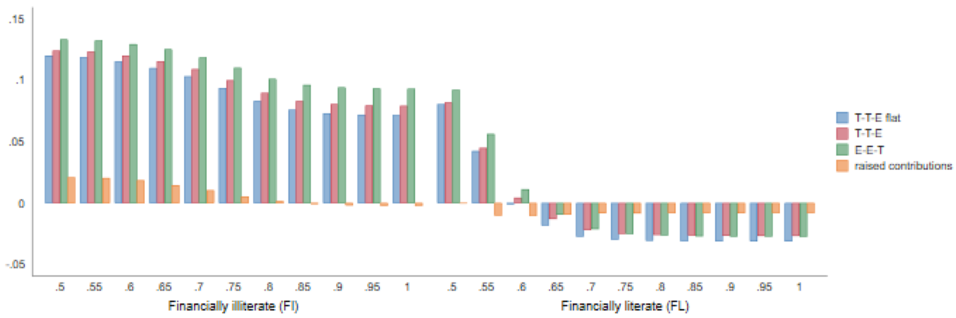
(a) Imrohoroğlu et al. (2003)



(b) backward-looking

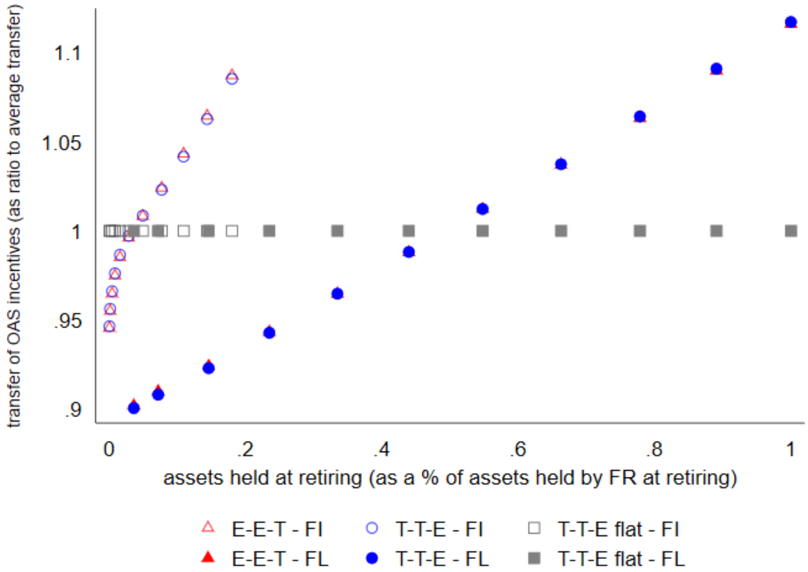


(c) forward-looking



Note: see Figure 1.

Figure G.2: Transfers for OAS incentives – rise in retirement eligiblity age



Note: see Figure 2. The transfers are a similar ratio to the average transfer for E-E-T and T-T-E under the current calibration, but they are not identical.

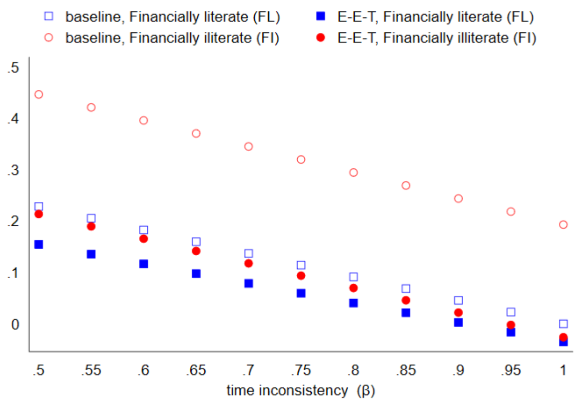
Table G.1: Macroeconomic summary – rise in retirement eligiblity age

		ISS	FSS				
			raise τ	reduce ρ	E-E-T	T-T-E	T-T-E flat
		(1)	(2)	(3)	(4)	(5)	(6)
pensions (replacement)	ρ/ρ_{ISS}	1.00	1.00	0.84	0.84	0.84	0.84
contributions rate (%)	τ	14.32	17.13	14.32	14.32	14.32	14.32
OAS contribution rate (%)	κ	-	-	-	2.13	2.13	2.13
consumption tax (%)	τ^c	15.00	14.81	14.08	16.45	16.9	17.28
OAS transfers per worker		-	-	-	0.0234	0.0231	0.0231
labor	$L = \sum_{j,m} \omega_j l_{j,m}$	100%	108.9%	109.4%	110.7%	110.5%	109.4%
aggregate product	Y	100%	111.5%	113.2%	116.5%	115.1%	113.9%
wages	w	100%	102.4%	103.5%	105.2%	104.2%	104.2%
income tax revenues	$\tau^l \cdot wL$	100%	111.5%	113.2%	101%	115.1%	113.9%
pension tax revenue	$\tau^l \cdot B$	100%	133.3%	113.1%	116.4%	115%	113.8%
aggregate capital	A	100%	116.9%	121.3%	129%	125%	123.8%
of which							
voluntary		100%	116.9%	121.3%	85%	89.1%	88.3%
in OAS scheme		-	-	-	44%	36%	35.6%
interest rate (%)	r	5.18	4.63	4.39	4.03	4.24	4.23
capital tax revenues	$\tau^k \cdot \sum_{j,m} \mathcal{K}$	100%	104.6%	102.8%	66.2%	102.3%	101.2%
aggregate gross consumption	C	100%	109.3%	109.6%	115.4%	115.1%	114.2%
consumption tax revenues	$\tau^c \cdot C$	100%	107.9%	102.8%	126.6%	129.7%	131.5%

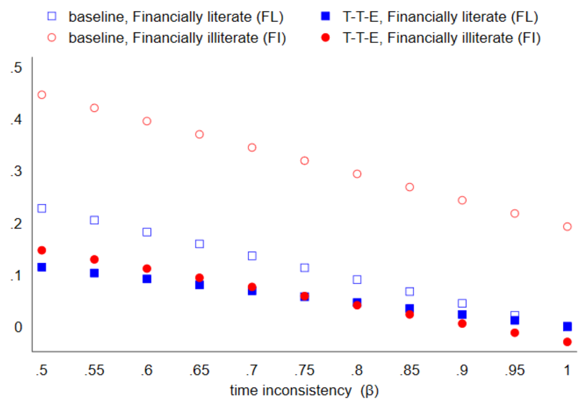
Note: ISS = Initial Steady State. FSS = Final Steady State. This table reports results analogous to Table 3, with the main difference that $\bar{J}_{FSS} = \bar{J}_{ISS} + 3$.

Figure G.3: Age-adjusted incidence of poverty – rise in retirement eligiblity age

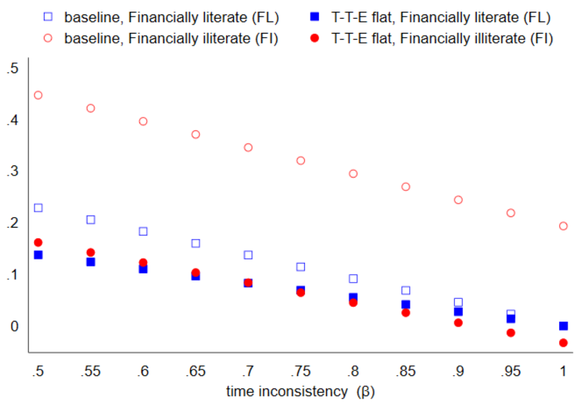
(a) E-E-T



(b) T-T-E



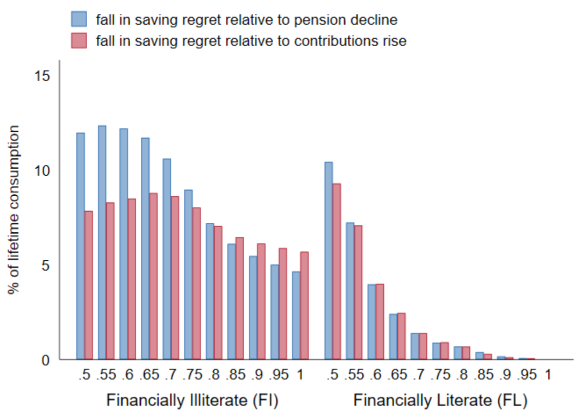
(c) T-T-E flat



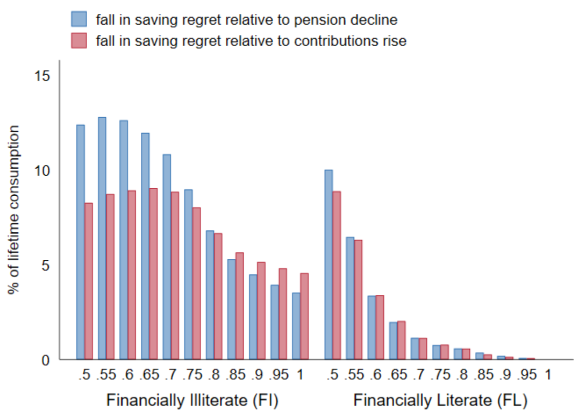
Note: see Figure 3.

Figure G.4: Saving regret – rise in retirement eligiblity age

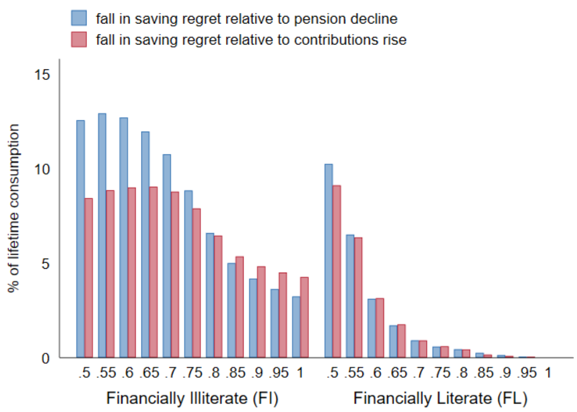
(a) E-E-T



(b) T-T-E



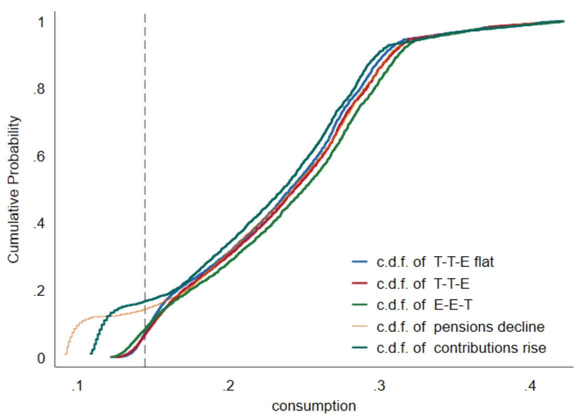
(c) T-T-E flat



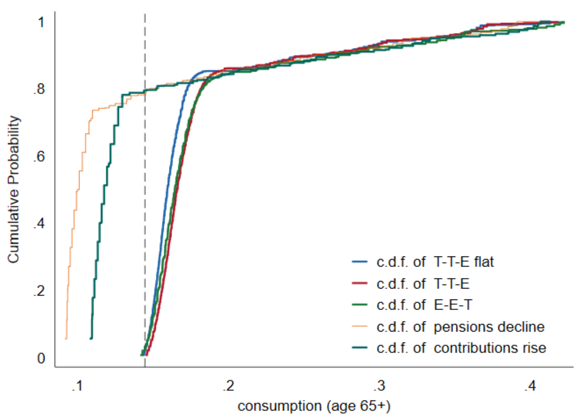
Note: see Figure 4

Figure G.5: Poverty – rise in retirement eligiblity age

(a) total population

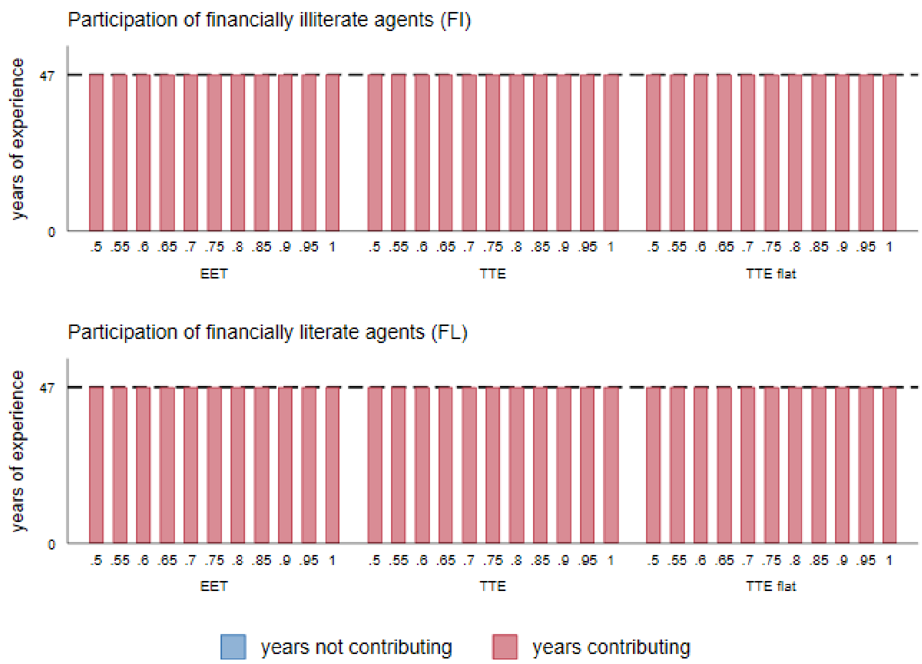


(b) population aged 65+



Note: see Figure 5.

Figure G.6: Participation in incentivized OAS schemes – rise in retirement eligiblity age



Note: see Figure D.6.