The Life Cycle Effects of Pension Reforms: A Structural Approach

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Abstract

This paper proposes a combination of ex-ante and ex-post evaluation methods to conduct pension policy analysis. We exploit exogenous variation coming from pension reforms introduced in Italy in the nineties to validate a structural life-cycle model for the joint interplay of social security, consumption, portfolio choice and endogenous retirement. We estimate the structural parameters of the model by matching the effects of the reform on consumption, asset accumulation and participation to the financial markets estimated from actual data employing a diff-in-diff identification strategy, with the corresponding effects from simulated data. The estimated model is used to conduct welfare analysis and an ex-ante policy experiment.

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1 Introduction

A body of recent economic research considers the evaluation of a social program before its actual introduction, as part of the problem of studying the effect of policy changes without the availability of ex-post information first stated by Marshak (1953). In this literature, ex-ante evaluation of social programs is not considered as a substitute for ex-post policy evaluation, which relies on methods of the program evaluation literature to identify and estimate the causal impact of a policy change after the reform is introduced.[1]

As discussed in Todd and Wolpin (2006b), ex ante evaluation of social programs is important because it can provide a number of useful prescriptions to the policy maker, shedding light into the understanding of which range of effects to expect from the introduction of hypothetical policy changes, to help avoid the implementation of programs that are later found to be ineffective, or inducing undesired effects. Moreover, the estimation of dynamic economic models to conduct policy analysis allows to provide forecasts for a range of widely different policies.[2]

In this paper we describe how we can use the estimated reduce form effects of a major wave of pension reforms introduced in Italy in the early 90s to estimate a dynamic economic model of household behavior, with the aim of providing a framework to shed some light into the understanding of how alternative pension policies could impact households decisions over the life-cycle.

We are not the first to validate an economic model using the effects obtained by randomized experiments with the aim of conducting ex ante policy evaluation. Todd and Wolpin (2006a) and Attanasio et al. (2012) develop and estimate two different dynamic models of education choices to study the impact of the PROGRESA program on childrens' schooling attendance.[3] Compared to these works, we consider a more complicated dynamic model of households behavior with savings, portfolio choice and retirement decisions, and explicitly target the effects estimated using a

[1] See Imbens and Wooldridge (2009) for a good review.

[2] Heckman (2010) discusses the response of the literature on structural models to the perceived failures of 1970s and 1980s structural models, highlighting weaknesses and strengths of the recent developments in this field of research to conduct policy analysis

[3] Lise et al. (2005) also compare their models' forecasts on job search to the effects of social programs obtained using an experimental design.

diff-in-diff identification strategy to estimate the structural parameters of the model.

We focus on Italy and use data from the Survey on Household Income and Wealth (SHIW) collected by the Bank of Italy. Italy is an interesting case because the reforms we consider dramatically changed the pension system, altering the pension award formula for the new cohorts of workers and introducing a contributive scheme to incentivize workers to postpone retirement. In particular, while for individuals belonging to older cohorts pension benefits are computed using an earnings model, a less generous contribution model is employed to compute pension benefits for young cohorts. Furthermore, while the age of retirement was exogenously determined by the legislator for a particular individual belonging to older cohorts, young workers can decide when to retire between 57 and 65 years of age in the new regime.

The mechanisms at play in this context are not trivial. On the one hand, households facing an exogenous reduction in expected pension wealth, for a given age of retirement, might not only decide to work longer but also decrease consumption today in oder to substitute social security wealth with private wealth. On the other hand, these policy changes might induce households to increase their participation to the financial markets, with privately managed funds partially substituting the public pension system. The success of these policy interventions depends then on the joint interplay between social security wealth and households' responses with respect to consumption, portfolio allocation and retirement behavior.

Starting from Feldstein (1974), the literature investigated the substitution effect between pension and discretionary wealth. In the simplest life-cycle framework without uncertainty and frictions, the displacement effect between private and social security wealth should be equal to one, that is, households should react to an exogenous reduction of pension wealth by increasing savings of the same amount. However, as discussed in Attanasio and Brugiavini (2003), there are several reasons why pension wealth might not a be a good substitute for financial savings, including the existence of borrowing constraints against pension wealth and liquidity constraints, and differential rate of returns between pension wealth and private wealth. Attanasio and Brugiavini (2003), Bottazzi et al. (2006) and Bottazzi et al. (2011) exploit the exogenous variation coming from different waves of pension reforms introduced in Italy in the '90s, to credibly identify its effect on saving and portfolio decisions and provide a measure of the offset between social security and private wealth.

Our research strategy builds on the idea that if a dynamic model of household behavior is able to mimic the effects we estimate exploiting a robust reduce-form identification strategy, then it is reliable in shedding light into the mechanisms behind the observed effects and is a useful tool to conduct ex ante policy evaluation. This analysis is especially interesting when major reforms of the pension systems are actually being considered in many developed countries. Indeed, during the last decades, most developed countries have experienced expected inadequacy of their pension systems because of both too generous existing pension provisions and the overall aging of population. The optimal design of pension reforms should consider the impact of these interventions on households' well being and inequality, since some groups of households could pay at higher costs the rebalancing of fiscal policy.

The main contribution of this work is to employ a structural evaluation approach to study a major pension reform, by matching the reduce form effects of the reform on consumption, asset accumulation and participation estimated using a diff-in-diff identification strategy, with the corresponding effects from simulated data generated by the dynamic model. We shall see that our strategy also ensures the model to generate concordant pre intervention data. We do this by carefully replicating the observed data, allowing heterogeneity with respect to the sector of employment (because the definition of treatment and control groups in the population relies on the pension reform hitting in different ways workers employed in different sectors) and education (since the evolution of earnings over the life-cycle plays a crucial role in the accumulation of wealth). Moreover, because the pension reform targeted only workers with more than 18 years of contribution in 1995, we also consider six cohorts of households born between 1940 and 1970, which will differ for their treatment status depending on the number of years of contribution when the pension reform was introduced.

We draw from the existing literature on dynamic stochastic life-cycle models to specify a structural model in which households maximize expected lifetime utility choosing consumption, the allocation of wealth to risky assets and the age of retirement and face uncertainty with respect to wages, returns from the risky assets and mortality risk. The introduction of endogenous retirement in the model is motivated by the institutional framework under investigation, since households facing an exogenous reduction in social security wealth might both increase the saving rate and work longer. French (2005) first introduced retirement decision in a life-cycle model of labor supply and saving behavior to explain what causes retirement decisions of households. In contrast to his work, where retirement is modeled as a labor supply decision and households can reenter the labor market, we explicitly introduce retirement as an absorbing state.

The model we consider cannot be solved analytically and we employ a modification of the Endogenous Grid Method (EGM) proposed by Carroll (2006), by nesting the EGM within a Value Function Iteration (VFI) approach to compute the discrete portfolio and retirement choices. Compared to the standard VFI approach mostly employed in the literature, this modification allows us to greatly reduce the time required to achieve the solution. The structural parameters of the model are estimated with an indirect inference approach, where we use a diff-in-diff regression as auxiliary model.

Provided with a set of values for the structural parameters allowing us to mimic the effects of the reform estimated from the data, we will be able to provide evidence about the channels through which the reform impacted households decisions. The structural framework will also allow us to perform some welfare analysis, which might help us to understand whether some groups suffered more than others the introduction of the reform. Finally, the model shall be used to conduct simulations and shed some light into the consequences of alternative pension policies.

The rest of the work is organized as follows. Section 2 presents the main features of the institutional framework we consider and the research strategy. In Section 3 we describe the dynamic life-cycle model used to capture the behavior of households before and after the introduction of the pension reforms. Section 4 presents stylized facts from the data, the diff-in-diff estimation of the effects of the reform and the Indirect Inference Approach we use to estimate the structural parameters. In Section

5 we present the estimation results, draw implications about the life-cycle consequences of pension reforms and conduct welfare analysis. In Section 6 we perform a policy experiment. Section 7 concludes.

2 Pension reforms and a structural approach for evaluation

In this section we describe the main features of the Italian pension system before and after the introduction of the pension reforms in the 90s, and our strategy to validate the dynamic model which aims at replicating the observed effects on households decisions.

Until the early nineties, the Italian social security system experienced high levels of imbalance mainly because of too generous provisions (implying high replacement rates) and the possibility of early retirement, given the overall aging of the population. Two major reforms of the social security system were introduced in 1992 and in 1995 to make the system more sustainable by increasing the retirement age and the minimum years of contributions for pension eligibility, and introducing a contributive model for pension benefits. Attanasio and Brugiavini (2003) and Bottazzi et al. (2011) provide extensive details on how the interventions changed both the pension award formula and the eligibility rules. Here, we highlight the main features of the reforms that we exploit in our research strategy. An important characteristic of the reform is that it did not change the provisions for those workers who had at least 18 years of contribution in 1995 (old workers), while introducing different policy changes for private and public employees.[4] The reforms changed pension rules for those workers who had less than 18 years of contribution in 1995 (middle-aged workers) raising minimum retirement age for old age pensions of private employees, but not for public employees. Moreover, while old workers are subjected to an earnings-based award formula both before and after the reform, pensions are computed using a pro-rata model for the middle-aged workers: earnings-related for working years

[4]We do not consider self-employed in our analysis. Moreover, in what follows we will refer to the years before 1992 as the pre-treatment period, and to the years after 1995 as post-treatment period, this way omitting the transitional years between the two reforms.

before 1995, and contributions-related afterwards. The earnings model for pension benefits simply transforms some average of last earnings (or the last earnings, depending on the sector of employment) $\widehat{y_R}$ into pension benefits pb_R using a function of the number of years of contribution N and an accrual rate τ_e $pb_R = \tau_e N \widehat{y_R}$. The contributive model introduced by the reform is instead characterized by linking pension benefits to the entire history of earnings, and by providing incentive to postpone retirement in that total contributions (accumulated at retirement, starting after 1995) $\tau_c \sum_{t=1995}^{N-1} y_t (1+g)^{N-1-t}$, where τ_c is the contribution rate and g a 5-year moving average of the GDP growth rate, are transformed into pension benefits using coefficients τ that are increasing with the age of retirement.[5]

Our approach for evaluation builds on the idea to use a diff-in-diff identification strategy to estimate the effects of the pension reforms on actual data, similar to that employed by Attanasio and Brugiavini (2003) and Bottazzi et al. (2011), and use a dynamic model of household behavior to generate simulated data that allow to mimic the estimated effects.[6]

In order to do so, we simulate the behavior of six different cohorts of households, born between 1940 and 1970 (1940-1945;1945-1950; 1950-1955; 1955-1960; 1960-1965, 1965-1970). We will distinguish between old workers and middle-aged workers depending on the number of years of contribution in 1995. Moreover, because of the heterogeneity in the pre- and post-reform pension rules for public and private employees, we solve and simulate the models for both the two groups separately, for each cohort. Finally, we also allow for heterogeneity with respect to education level since households with different education will face different earnings processes, which might impact the pre-treatment behavior and the response to exogenous variations in lifetime resources. Heterogeneity in education will also be associated with a different number of years of contribution when the pension reform is introduced, net to cohort effects.

Therefore, in our analysis different cohorts of households will be heterogeneous

[5] More details on the pension award formula and the pension eligibility rules before and after the reforms are reported in Table 4.

[6] We describe in detail how we exploit the exogenous variation in the pension rules to identify and estimate the effects of the pension reform in 4.2

with respect to the number of years of contribution in 1995 (impacting both the treatment status and the extent of the induced effect on expected pension benefits) and the moment of the life-cycle in which households were hit by the introduction of the reform. This might be a relevant dimension in the context under investigation in that the older the household when the reform is introduced, the lower the number of years before retirement and then the lower the ability of the household to optimally accumulate assets for retirement under the new pension regime. Workers employed in different sectors and belonging to different education groups will also be characterized by different processes of earnings, yielding a large amount of heterogeneity in the replacement rate at retirement, conditional on the same pension rules.

We use the following strategy to generate the simulated dataset that we will use to match certain statistics of the actual data and the effects of the reform estimated using a diff-in-diff approach, and draw conclusions on the life-cycle effects of the pension reforms[7]:

1. we solve the dynamic programming problem for each cohort - sector - education level group under a retributive pension system, setting a group-specific exogenous retirement age, to derive policy functions for the pre-treatment period;

2. we solve the dynamic programming problem for each cohort - sector - education level group under a contributive pension regime, introducing the choice of the age of retirement, to derive policy functions for the post-treatment period.;

3. provided with the policy functions obtained in (1), we simulate the life cycle profiles for each group of households, under the assumption that the pension eligibility rules and the pension award formula remain constant over the life cycle as determined by the legislator in the pre-treatment period. The resulting life cycle profiles represent the age profiles for outcomes that would have been observed if the pension reform was not introduced, that is the counterfactual profiles;

[7]The details on the simulation of the exogenous processes, the expected replacement rates before and after the introduction of the reform and the definition of the groups of households that we consider is reported in section 4

4. starting from the life cycle profiles obtained from (3), we simulate the introduction of the reform at cohort-specific ages corresponding to year 1995. The introduction of the reform is simulated by employing the policy functions for the post-treatment period (contributive model and endogenous retirement ages) and the contributive method to compute the replacement rates. The resulting profiles represent the actual life cycle profiles for the treated households.

5. Finally, we pool the simulated actual and counterfactual profiles for each group obtained in (3) and (4) to generate a simulated dataset that we will use to compute statistics to be matched with those estimated from the actual data.

3 The model

In this section we describe the model we use to analyze the life cycle effects of pension reforms. We first present the baseline model used to simulate the behavior of the cohort of households subjected to an earning pension system and then describe how we introduce endogenous retirement under a contributive pension regime, to simulate the introduction of the pension reform.

3.1 Earnings model

In order to describe the behavior of households subjected to a retributive pension system, we use a dynamic model similar to that in Cocco et al. (2005). However, in contrast to their work where retirement income is modeled as a constant fraction of permanent labor income in the last working-year, we introduce pension benefits as an additional state variable. This allows us to capture the existing heterogeneity in the replacement rate in the pre-reform period, coming from the complexity of the pension rules for different groups of workers and the households-specific history of realized shocks to earnings.

Let there be T periods in the life-cycle. Households retire exogenously in period R, which might differ for public and private employees to capture further heterogeneity in the accumulation of wealth, and spend $T - R$ periods in retirement. For the validity of the model used to simulate the behavior of households in the pre-reform period, this assumption is less restrictive than it seems in that the cohort of old workers is observed to retire as soon as they fulfill eligibility requirements (see Brugiavini, 1999). We introduce age of retirement as a choice variable in Section 3.3. Each period they live, households derive utility from consumption C_t and disutility from work $(1 - Ret_t)$ according to an instantaneous utility function of the same form as in Attanasio et al. (2008)

$$u(c_t, R_t) = \left(\frac{C_t^{1-\gamma}}{1-\gamma}\right) \exp(\phi_1(1 - Ret_t)) - \phi_2(1 - Ret_t) \tag{1}$$

where $\gamma > 0$ is the coefficient of relative risk aversion, both ϕ_1 and ϕ_2 are constrained to be greater than zero so that participation to the labor market reduces the utility of consumption. [8] In particular, because ψ_1 is restricted to be greater than zero, working reduces the marginal utility of consumption. We set $\phi_1 = 0$ and $\phi_2 = 0$ for individuals younger than 57 years of age.

When households die, remaining assets A_T are left to heirs. Households value bequests of assets according to the simple bequest function

$$B(A_T) = \theta_b \frac{A_T^{1-\gamma}}{1-\gamma} \tag{2}$$

where θ_b is the intensity of the bequest motive. [9] The utility function is intertemporally separable. Households are assumed to maximize lifetime expected utility by choosing consumption C_t and the share of wealth invested in risky assets α_t^s

$$\max_{c,\alpha_s} V_t = E_t\left[\sum_{s=t}^{T} \beta^{s-t} d_s u(C_{t+s}, Ret_{t+s})\right] \tag{3}$$

where $\beta < 1$ is the time discount factor and d_t denotes the probability that the

[8] We restrict the disutility from work to be greater than zero only in the last years of the working life before retirement. This allows us to compute a meaningful comparison between the cohort of households retiring under an earnings model and those retiring under a contributive model.

[9] This corresponds to the bequest function in De Nardi (2004), when we set the parameter giving the curvature of the bequest function K equal to zero, implying infinite disutility of leaving non-positive bequests.

household is alive in period $t+1$, conditional on being alive in period t. During working life, households receive exogenous labor income Y_{it}, that is assumed to be decomposed into a permanent shock ϵ_t and a transitory shock v_t:

$$Y_{t+1} = P_{t+1} v_{t+1} \tag{4}$$

where P_t is the permanent component of labor income and is assumed to follow a random walk with drift

$$P_{t+1} = G_{t+1}(Z_t) P_t \epsilon_{t+1} \tag{5}$$

Thus, before retirement, log income is the sum of a deterministic component, which might depend on individual characteristics Z_t as education and sector of employment, that varies with time and will be estimated from the data to capture the hump-shape profile of earnings over the life cycle, and two random components.

Under an earnings model, individuals are entitled to receive pension benefits PB_t when they retire which depend on the last years of earnings only. In the pre-reform period, both the age of retirement and the pension award formula vary according to the sector of employment. Private employees retire at 60 years of age and the pension benefit is computed as a fraction of the average of the last five years of earnings. The multiplier for the private employees is computed as the product between 0.02 and the number of years of contribution. Public employees retired at 65 years of age and received a pension benefit equal to a fraction of the last year of earnings. This fraction is computed as 0.0233 times the number of years of contribution. Because of the heterogeneity among and within different groups of workers, we include pension benefit as a state variable in our model. We will estimate the pension benefit each household receives at retirement by simulating individual-specific life-cycle profiles for earnings, given our estimates from the data and random extraction for both the transitory and permanent shocks, and exploiting group-specific pension award formulas. Once retired, households know with certainty the amount of pension benefit they will receive while alive.

Households allocate their wealth between a riskless and a risky asset, which can be seen as a composite portfolio of risky assets. The riskless asset has a gross return of R_f and the risky asset has a stochastic return R_t, with shocks to the excess return that are assumed to be independently and identically distributed

$$R_{t+1} - R_f = \mu^s + \eta^s_{t+1} \tag{6}$$

$$\eta^s_{t+1} \sim N(0, \sigma^2_s) \tag{7}$$

We impose zero correlation between shocks to risky returns and labor income. This choice is motivated by the contradicting empirical evidence provided in the literature. Moreover, Gomes and Michaelides (2005) show that the introduction of this correlation makes little difference in the portfolio rule and thus on the households' simulated portfolio allocations.

In each period, households will choose the share of wealth invested in the risky assets. To access the excess return from risky assets, households have to pay a per-period fixed cost of participation θ_s. Different interpretations of these fixed costs have been provided in the literature (see, e.g., Jappelli and Padula, 2015). The introduction of these per-period fixed costs of participation relies on the idea that, since the financial decision has to made in each point in time it requires, in every period, the collection and processing of financial information which are associated costs in both monetary and time terms. Information costs have then to be considered on a per period basis. As in Cocco et al. (2005) we denote the euro amount of riskless assets the household holds at time t by B_t, and the euro amount the household has in risky assets at time t by S_t. We also assume a borrowing constraint, forcing the household's allocation to riskless assets to be non-negative in each period ($B_{it} >= 0$), and a short-sales constraint, ensuring no negative allocation to risky assets. The borrowing and short-sale constraints imply the share of wealth invested in the risky assets to lie between zero and one. Allowing the households to hold negative net assets would imply assuming that households would be able to borrow against future labor income or retirement wealth, while we want to capture the fact that households can be liquidity constrained in the beginning of the life cycle. In our analysis this is important in that existence of liquidity constraints impacts the extent to which households save for precautionary motives. [10]

The intertemporal budget constraint has the form

$$A_{t+1} = R^p_{t+1}(A_t - \theta_s \mathbb{1}(\alpha^s_t > 0) + y_t - c_t) \tag{8}$$

where A_t is initial period assets, $R^p_{t+1} = \alpha^s_t R_{t+1} + (1-\alpha^s_t)R_f$ is the portfolio return, θ_s is the per period fixed cost of participation to the financial market. Households retire exogenously at R, starting to draw pension benefits.

3.2 Model solution

In each period, the timing is the following: the household starts with wealth A_{it}. Then labor income is realized (or pension benefit is received, if the household is retired) and household consumes and chooses the portfolio composition. Households leave the assets remaining in the last period A_T as bequests. Optimal decisions with respect to consumption and portfolio allocation depend on the state variables (A_t, Y_t, PB_t), preference and fixed-cost parameters, and the parameters determining the data generating process for the exogenous variables. Following Deaton (1991), we redefine the problem in terms of cash-on-hand, given by $M_t = A_t + Y_t$ so that it is possible to normalize the model with respect to permanent labor income, and reduce the dimensionality of the state space. Notice that both state and control variables will be defined in terms of permanent labor income. In particular, pension benefit PB_t is now defined in terms of the permanent component of the last labor income before retirement p_{R-1}. Consumption and portfolio rules will now depend on $X_t = (m_t, pb_t) = (\frac{M_t}{p_t}, \frac{PB_t}{p_{R-1}})$.

Retired household dynamic programming problem Given this set up, retired households solve the following dynamic programming problem:

$$V_t(m_t, pb) = \max_{c_t, \alpha^s_t}[U(c_t) + \beta d_{t+1} E_t V_{t+1}(m_{t+1}, pb)] \tag{9}$$

[10]About the interactions between liquidity constraints and precautionary saving behavior, see Carroll and Kimball (2001).

subject to

$$m_{t+1} = R^p_{t+1}(m_t - c_t - \theta_s \mathbb{1}(\alpha^s_t > 0)) + pb$$

$$R^p_{t+1} = \alpha^s_t R_{t+1} + (1 - \alpha^s_t) R_f$$

After retirement, households know the replacement rate $pb = pb_t$, $t = R, R + 1, ..., T$ which remains constant over time and, in this framework, represents a sufficient statistic for the entire working life of the household once retired.

Working household dynamic programming problem In each period before retirement $t < R$, households obtain stochastic labor income and cash-on-hand from time $t - 1$. The problem can be written as:

$$V_t(m_t, pb_t) = \max_{c_t, \alpha^s_t} [U(c_t) + \beta d_{t+1} E_t V_{t+1}(m_{t+1}, pb_{t+1})] \tag{10}$$

subject to

$$m_{t+1} = \frac{(\alpha^s_t R_{t+1} + (1 - \alpha^s_t) R_f)}{G_{t+1}\epsilon_{t+1}} (m_t - c_t - \theta_s \mathbb{1}(\alpha^s_t > 0)) + v_{t+1}$$

$$R^p_{t+1} = \alpha^s_t R_{t+1} + (1 - \alpha^s_t) R_f$$

$$y_{t+1} = p_{t+1}\epsilon_{t+1}$$

$$p_{t+1} = G_{t+1} p_t v_{t+1}$$

The problem cannot be solved analytically and we derive the policy rules numerically. Our strategy is to solve the dynamic problem by backward induction for different predefined levels of the state variable pension benefit. Thus, for each level of the discretized state space for pension benefits, we employ an Endogenous Grid Method (EGM) to compute the consumption function, and a value function iteration step to compute the discrete participation choice (see A for details on the solution algorithm). [11]

[11]See Carroll (2006) for the general introduction to the Endogenous Grid Method.

3.3 Introducing endogenous retirement

The pension reforms introduced in the early '90s dramatically changed the pension award formula, with pension benefits depending now on the contributions over the entire working life, and allowed workers to choose when to retire between 57 and 65 years of age, with incentives increasing with age. In this section, we develop a life-cycle model for the joint interplay of consumption, asset accumulation, portfolio allocation and social security wealth that differs from that discussed above in that retirement is endogenous. This extension increases the complexity of the solution but allows to capture an important feature of the reform and is important in the context under investigation since households facing an exogenous reduction in pension wealth could not only increase the saving rate but also decide to work longer. We then consider the extensive margin of labor supply as a potential driver of the effect of the reform. In contrast to French (2005), where retirement is modeled as a participation choice and then households that can then reenter the labor market, we explicitly model the retirement choice as an absorbing state. We use utility function 1, thus modeling disutility from work in the spirit of Attanasio et al. (2008), and households face the same sources of uncertainty and the same processes for the exogenous variables as in section 3.1. In addition, they also face uncertainty with respect to the GDP growth which, according to the contributive model, affects the pension benefits households are entitled to. The GDP growth is assumed to evolve according to a random walk with drift and independently and identically distributed shocks

$$GDPg_{t+1} = \mu^g + \eta^g_{t+1} \tag{11}$$

Households are now assumed to maximize

$$\max_{c,\alpha_s,Ret} V_t = E_t \sum_{s=t}^{T} \beta^{s-t} d_s \frac{C_{t+s}^{1-\gamma}}{1-\gamma} \exp(\phi_1(1 - Ret_{t+s})) - \phi_2(1 - Ret_{t+s}) \tag{12}$$

where Ret is an additional choice variable, giving the optimal age of retirement. In each period between 57 and 65 years of age, if the household chooses to work, the value function is given by:

$$V_t^w(m_t, pb_t) = \max_{c,\alpha_s} \frac{c_t^{1-\gamma}}{1-\gamma} \exp(\phi_1) - \phi_2 + \beta d_{t+1} E_t \left[\max \begin{pmatrix} V_{t+1}^w(m_{t+1}, pb_{t+1}) \\ V_{t+1}^r(m_{t+1}, pb_{t+1}) \end{pmatrix} \right]$$

If the household chooses to retire, the value function is instead given by:

$$V_t^r(m_t, pb_t) = \max_{c,\alpha_s} \frac{c_t^{1-\gamma}}{1-\gamma} + \beta E_t V_{t+1}^r(m_{t+1}, pb_{t+1})$$

where the state variable pension benefits pb_t now evolves according to

$$pb_{t+1} = \left[\frac{pb_t * GDPg_{t+1}}{\tau_t} + 0.33 \right] \tau_{t+1} \tag{13}$$

The decision of whether or not to retire in period t is determined by comparing V_t^r and V_t^w. When deciding to work longer, households enjoy higher expected pension benefits through both an increase of total contribution and a higher transformation coefficient τ_t. On the other hand, households face disutility from working an additional year, as given by the parameters ϕ_1 and ϕ_2. We will estimate these structural parameters in order to match observed effects of the reform and draw implications for expected retirement behavior.

4 Life cycle profiles and the reduced form effects of the pension reforms

This section presents stylized facts and the reduced form evidence of the effect of the reforms that our model aims at reproducing. We will use some conditional age means for consumption and assets in the pre-treatment period, and the estimated reduced form effects of the reform as target moments in the structural estimation of the dynamic model.

4.1 Life cycle profiles

In this section we present some observed stylized facts about consumption, assets and participation to the financial markets, that we use to sketch the main features our model needs to exhibit and as target moments in our estimation strategy.

We use the Survey on Household Income and Wealth (SHIW) for the years 1986-2010. SHIW collects information on a representative sample of the Italian population of around 8,000 households. In addition to income, data and demographics, SHIW collects detailed information on income, consumption expenditures and asset holdings. As the focus is a life cycle model, we consider cohorts of individuals over the observed part of their life cycle because different cohorts have access to different lifetime resources, as discussed in Attanasio and Weber (2010).

These data allow us to investigate the effect of Italian pension reforms introduced in the early '90s. The pension reforms we are studying indeed altered the pension eligibility rules and the pension award formula of those workers with less than 18 years of contribution in 1995, that we define as middle-aged (already working in 1995 but with less than 18 years of contribution) and young workers (which entered the labor force after 1995), as in Bottazzi et al. (2006). Throughout this work, we will focus on older workers and middle-aged workers, since we cannot observe young workers in the pre-treatment period.

Since we employ a unitary model for household's behavior, we use only observations referring to the head of household and household-level information data. We also drop households born before 1940 and after 1970. To be consistent with our structural analysis, we keep information on households whose head is employed. We also drop observations for the self-employed. Our data allow us to split the sample between middle-aged and older workers by using a question asking to report the number of years of contribution. The group of treated is on average much younger than the untreated, with an average age of 38 years compared to the 46 of the untreated, and more educated. In the life-cycle framework that we consider, differential educational attainments play a major role in that they are associated with different age profiles of earnings, different ages of entry in the labor market and then a different number of years of contribution when the policy change occurs.

The measure of total assets that we use rely on the definition on the SHIW data. This includes real assets and financial assets, net to financial liabilities. Then we define households as participating to the financial markets if they have non zero investments in bonds, mutual funds, equity, shares in private limited companies and partnerships, foreign securities, loans to cooperatives. According to this definition, the share of wealth invested in risky assets will then simply be the ratio between the euro amount invested in those asset classes and the total net wealth. [12] We consider here life-cycle profiles for decision variables. We will analyze earnings in Section 4.3.

In Figure 1 we report the observed life cycle profiles of non durable consumption, total assets and participation to the financial markets, for middle-aged and older workers. As discussed in Attanasio et al. (2008), the overlaps between the life-cycle profiles of each cohort, at some ages, can be informative about possible differences in life-cycle profiles. Anyway this comparison can only provide some insights about differences in life cycle profiles of middle-aged and older workers, with the important caveat that the two cohorts are observed at the same age at different points in time and it is not possible to disentangle, without additional information, year, age and cohort effects.

In a life-cycle framework, households should react to an expected permanent reduction in lifetime resources by adjusting consumption today in order to keep the marginal utility of consumption constant. As well discussed in Attanasio and Brugiavini (2003), given that the pension reforms under investigation have indeed exogenously reduced households' lifetime resources through a reduction of social security wealth, one would expect to observe treated households lowering consumption during their working lives and increasing the stock of accumulated wealth. [13] In a frictionless life cycle model for consumption and savings, the displacement effect between pension and private wealth should be equal to one, that is, a reduction of 1 euro in pension wealth should be compensated by an increase of private wealth of

[12] All the monetary values were adjusted to take the currency shift from thousands of Italian Lire (until 2000) to Euro (from 2002) into account, and also reported to 2014 euros.

[13] See Bottazzi et al. (2006) and Section 4.3 for the simulated replacement rate for each group, before and after the reform

the same amount. A departure of this effect from one might come from the introduction of imperfect markets, uncertainty about the stream of future earnings and the possibility to participate to the financial markets.

Previous literature also considered the effect of pension reforms to the portfolio choice of households. Indeed, the introduction of pension reforms could induce a substitution between public pension system and privately managed pension funds through the financial markets. Bottazzi et al. (2006) consider the Italian case and a reduced-form approach to study whether the pension reforms under investigation in this work had an impact on the portfolio choice of Italian households. Their findings confirm an increase in financial wealth for both private and public employees induced by the reform.

Without drawing any conclusion about causal effects of the pension reforms at this point, in what follows we show selected descriptives with the aim of providing some insights into the possible changes in households' behavior associated to treatment status. We will adopt a more rigorous evaluation approach in Section 4.2. We construct the conditional age-variable profiles by computing the median value per each age, and track the two cohorts of individuals defined by their treatment status. Figure 1.a reports the life-cycle profiles of non durable consumption. The consumption-age profile shows a hump-shape profile, with a peak during the last working years, as in Gourinchas and Parker (2002), among others. Figure 1.b reports the life-cycle profile for the ratio of consumption to total household income. During the working life, the profiles are decreasing with age, providing some evidence of liquidity constraints in early ages. Moreover, the younger cohort of treated households consumes a lower share of household income than the untreated households, below 45 years of age. Since savings are defined as the difference between total household income and household consumption, this evidence might be informative of higher saving rates for treated households.

Net wealth over the life cycle, reported in Figure 1.c shows the well-known hump-shape profile, with a peak at the end of the working life and slow dissaving during retirement. Several studies focused on the explanation of why asset holdings decrease during retirement slower than predicted by a standard life-cycle framework.

An important literature consider the existence of a bequest motive and uncertainty about future health and medical expenses as major explanations for this fact (see French, 2005 and De Nardi et al., 2010). In this paper we show how our model, with the introduction of a bequest motive, is able to reproduce the main features of the observed patterns in the SHIW data, with reasonable values of the structural parameters. The figure provides evidence that middle-aged workers are associated higher values of assets, at each age, than older workers. This evidence is confirmed when considering the ratio of assets to income, suggesting that this change in behavior is not due to differences in earnings faced by the two cohorts during their working lives.

The participation-age profile reported in Figure 1 shows that the share of households participating to the financial markets increases with age during the working life, while households slowly reduce participation when approaching retirement. This finding is consistent with the empirical evidence provided by Ameriks and Zeldes (2004). The two cohorts of workers differ significantly also with respect to their portfolio choices. Indeed, the comparison between the life-cycle profiles of middle-aged and older workers shows a remarkably higher participation rate among households hit by the reform before 50 years of age (between 30 and 50 years of age, the average participation is as low as 10 percent for older workers while around 22 percent of middle-aged households have some positive share of their wealth invested in the risky assets). In contrast, data do not show striking differences in the conditional share of wealth invested in risky assets between the two cohorts of households, with average shares of around 15 and 17 percent among older and middle-aged workers participating to the financial markets, respectively.

Of course, observed differences in life-cycle patterns among households' belonging to middle-aged and older workers could be just the result of compositional differences with respect to characteristics that shape consumption, saving and portfolio decisions different from earnings and, without further analysis, we cannot conclude it is rather an effect of the pension reforms. In Section 4.2, we adopt a more rigorous approach to investigate whether it is possible to assign causal meaning to the descriptive evidence discussed above.

4.2 Reduced form effects of the pension reforms

In this section we describe how we exploit the exogenous variation in the pension rules coming from the pension reforms introduced in the early '90s in Italy to estimate their effects from the data. As anticipated above, we draw from the existing literature that considered these reforms to provide reduced form estimates of their effects. In particular, Attanasio and Brugiavini (2003) consider the Italian pension reform introduced in 1992 to study the degree of substitutability between private and pension wealth, finding evidence that saving rates increased as a result of the reduction in expected pension wealth. Bottazzi et al. (2011) focus on the effect on asset accumulation and portfolio composition, finding a high displacement effect between social security wealth and private wealth, and an increase in financial wealth. Miniaci and Weber (1999) analyze the recession episode that took place in 1993 in Italy, and identify the pension reform introduced in 1992 as one of the main forces behind the observed fall in consumer expenditures. Previous works exploit a diff-in-diff approach to estimate the effect of the reform on the expected Social Security Wealth, and thus its effect on the outcome of interest. In contrast, we do not estimate a measure of the substitutability between pension and financial wealth but exploit a diff-in-diff (DID) strategy to study the effect of the reform on consumption expenditures and net wealth.

The framework under investigation is well suited to be studied adopting a DID strategy. First, the introduction of the two major reforms in 1992 and 1995 allows us to split the sample in a pre-treatment period before 1992, $T = 0$, and in a post-treatment period after 1995, $T = 1$. Moreover, as largely discussed in Bottazzi et al. (2011), these reforms induced exogenous changes in the pension system that were systematically different across different groups. We follow their identification strategy to identify the effects of the reforms. Hence, exploiting the variability coming from the institutional framework, we further split the sample by the sector of employment, in that the group of older private employees was unaffected by the reform, while the groups of middle-aged private employees and public employees were targeted by the reform. We apply the baseline sample selection described in Section 4.1. Here, we also drop household whose head is older than 60. Following from this discussion, our identification strategy to identify the effect of the reform on consumption, assets and participation choice uses a standard DID approach with multiple treatment groups, where the control group is the group of old, private employees. [14] Then we model the relevant outcome variable y as a linear function of a time dummy T, taking value one in the period after the reform, employment dummies, PUB and PRI, taking value one if the head of household is employed in the public or private sector, respectively, and a treatment dummy, taking value one if the household head had more than 18 years of contributions in 1995, and interactions of these.

$$\begin{aligned} y_i = \alpha &+ \gamma_1 T_i * D_i * PRIV_i + \gamma_2 T_i * D_i * PUB_i \\ &+ \delta_1 PUB_i + \delta_2 D_i + \delta_3 D_i * PUB_i \\ &+ \phi_1 T_i + \phi_2 Ti * PUBi + X_{it}\beta + c_i + t_t + \eta_{it} \end{aligned} \tag{14}$$

The coefficients γ_1 and γ_2 associated to the interaction of time dummy T, treatment dummy D and sector of activity dummy, $PRIV$ or PUB, represent the DID parameters of interest, capturing the variation in y induced by the reform to the group of middle-aged private and public employees. The crucial identifying assumption for the conventional DID estimator γ to provide a consistent estimate of the effect of interest is that, in the absence of the treatment, the average outcomes for the treated and control groups would have followed parallel paths over time. That is, we are assuming that both middle-aged private and public employees would have experienced trends in consumption behavior and asset accumulation over time and over the life-cycle, in absence of the reform, which are parallel to those experienced by old private employees. This assumption would be violated if, for instance, between the pre-treatment and post-treatment period, the economy was hit by a macro shock affecting treatment and control groups in different ways. There is anyway no reason to believe that the recession episode that the Italian economy experienced in the early '90s had differential consequences between the two groups, as discussed in Attanasio and Brugiavini (2003). A second violation of the identifying assumption would be the presence of non-parallel trends in the outcomes for the different

[14] We estimate the equation for participation using a Probit model.

groups. In a life cycle framework this is a major concern, in that both differential available resources among cohorts and compositional differences of groups with respect to age can potentially imply differential trends for the outcome in the absence of the reform. Consider net wealth for instance. As shown in section 4.1, its life cycle profile has a well-known hump-shape with a peak just before retirement and then steepness which depends on age. So, depending on the observed window of the life cycle observed in the data, the stock of net wealth of treated and controls with different ages in the pre-treatment period might have experienced non-parallel trends over time. Indeed, age is unbalanced in the pre-treatment period between old private (with average age equal to 38.6) and middle-aged employees (with average age equal to 28.3 and 30.5 for private and public employees, respectively). Because individuals belonging to the treatment group are workers with at least 18 years of contributions in 1995, they are also on average younger than those belonging to the control group.

To partially overcome this identifying issues, we include in the regressions, as in Attanasio and Brugiavini (2003), various demographic variables and cohort dummies to control for permanent differences in consumption and asset accumulation behavior induced by differences in earning profiles or preferences. Moreover, to capture macroeconomic shocks, we also allow for year dummies. [15]

We would like to highlight that these limitations do not undermine the validity of the strategy we employ in this work to analyze the life-cycle consequences of the introduction of the pension reforms. Indeed the indirect inference approach used to estimate the structural parameters of the model will use a corresponding diff-in-diff model on simulated, allowing us to get unbiased estimates of the structural parameters independently on the unbiasedness of the parameters of the auxiliary model. [16]

The estimation results for the diff-in-diff regressions are reported in Table 1. They provides evidence that the introduction of the pension reforms in the early

[15] In addition, because of the importance of age effects in shaping counterfactual profiles, we include a second-order polynomial in age, allowing for flexible consumption in age within the same cohort.

[16] See Section 4.3 for the description of how we implement this technique

'90s had a negative effect on consumption expenditures and induced households to increase the accumulation of wealth to compensate the reduction of pension wealth coming from the reform. The effect is more significant for the public employees, with a reduction of household non durable consumption of 2.7 percent, and an increase in net wealth of around 40 percent. Moreover, the pension reform induced an increase in participation to the financial market among the public employees of around 16 percent. The estimated effects of the pension reforms for the group of public employees are significant, at every standard confidence level. The estimated effects for middle-aged private employers are consistent with our discussion about the expected effects of the reform. Indeed, because the group of private employees suffered a lower reduction of expected pension wealth due to the reform, the magnitude of the behavioral responses of this group is smaller than that of the public employees. In particular, we find no statistically significant effect on consumption for private, middle-aged employees, but estimate an increase in asset holdings of 26 percent, with the latter effect being significant at every standard significance level. This result is controversial, but might be explained by the presence of measurement error in consumption. The results for the private middle-aged workers provide also a quite noisy evidence about the effect of the pension reform on participation to the financial market, which is estimated to be positive and relevant (around 7 percent) but not statistically significant.

4.3 Estimation

This section describes the strategy used to estimate the structural parameters of the model. In particular, we adopt a two-step strategy similar to that employed by Gourinchas and Parker (2002). In the first step we estimate the exogenous parameters of the model, that is those parameters that can be estimated without the usage of the model. In the second step, we estimate the preference and fixed-costs parameters $\Delta(\beta,\, \rho,\, \theta_b,\, \theta_s,\, \phi_1,\, \phi_2)$ using an indirect inference approach and a simulating annealing algorithm to minimize the distance between the estimated diff-in-diff effects of the pension reform and the corresponding effects estimated using simulated data, taking as given the values of the exogenous parameters estimated in the first step. [17]

Exogenous processes and parameters In this section we present the estimation of the exogenous parameters and describe the stochastic processes that we use in the solution of the dynamic programming model.

The components of the earnings process are crucial inputs of our life cycle model. Both the time varying growth rate of earnings and the level of uncertainty affect the accumulation of assets over the working life, thus impacting retirement decisions of households and then both the amount of pension benefits and the consumption behavior over the entire life-cycle. Heterogeneity with respect to the features of the earnings process among groups is then crucial in explaining observed differences in the outcome over the life cycle. A particularly important role is assigned in this context to the variance of permanent shocks. Indeed, on the one hand, higher standard deviations of permanent shocks translates into greater heterogeneity late in life and, on the other hand, higher standard deviations have significant impact on the accumulation of assets to insurance against possible future negative shocks to earnings. Moreover, in this framework, the shape of the earnings profile is important since it determines the magnitude of asset accumulation over the life cycle (net to other factors, the higher the growth rate of earnings, the lower the accumulation of assets) and the replacement rates. This consideration is particularly relevant in the context under investigation because households facing decreasing earnings at the end of the working life will have higher replacement rates than households facing steeper earnings processes, influencing both the choices in terms of consumption and then asset accumulation, and the optimal reaction to an exogenous variation in the replacement rates coming from the reform. In particular, steeper earnings profiles will be associated with lower replacement rates both under a retributive pension system in the pre-reform period, and a higher decrease in the expected pension benefits following the introduction of the contributive pension regime. For these reasons, the characterization of the components of the income process for different groups is

[17] See Gourieroux et al. (1993) for the description of indirect inference approach, and Kirpatrick et al. (1983) for a general introduction to simulating annealing as a probabilistic method for finding the global minimum of a cost function.

critical to the success of our attempt to replicate the effects of the reform estimated from the data. Considering the importance of the joint interplay between income process and pension wealth, the heterogeneity of pension rules between private and public employees, and well-documented evidence in the literature about the heterogeneity in the hump-shape profiles associated to differential educational attainment, we estimate the growth rate of earnings separately for each sector of employment-education level group[18]. In particular, we estimate a second-order polynomial in age separately for each sector-education level group. The estimation controls for time and cohort fixed effects. The group-specific parameters β_1, β_2 are estimated using data coming from the 1986-2010 SHIW, by running the following household model of log earnings with OLS

$$\log(y_{it}) = \alpha + \beta_1 AGE_i + \beta_2 AGE_i^2 + t_i + c_i + \epsilon_{it} \tag{15}$$

where y_{it} is the observed earnings of the household i, AGE_i is the age of the household head, t_i represent time dummies and c_i are cohort dummies.

The estimated coefficients are reported in Table 2. All the group-specific coefficients associated to the second-order polynomial in age are strongly significant and the obtained profiles match findings from previous literature (see Gourinchas and Parker, 2002 and Attanasio and Weber, 2010). Figure 2 reports the estimated age-income profiles, separately for private (top panel) and public employees (bottom panel). Each panel contains estimated life-cycle profiles for earnings for different education levels. The age profiles for earnings are hump-shaped for most groups, with a peak before retirement. An exemption is given by the age profile for households with a high school degree, for which the curvature of the earnings profile is significant but less relevant. The graphs in Figure 2 show how private employees face steeper age profiles of earnings than public employees with the same level of education. Moreover the latter are also characterized by a more pronounced hump-shape, with higher negative growth rates after around 50 years of age. The assumptions behind

[18]The hump-shape profiles for earnings vary substantially across different cohorts (see for instance Attanasio and Weber, 2010), but in our sample this heterogeneity seems to reflect compositional differences with respect to education. In fact, differences between cohorts are not significant within the same education group

the life-cycle model we consider imply that public employees should be associated, net to other factors, a greater wealth to income ratio than private employees. Furthermore, these results confirm previous findings (see Attanasio and Weber, 2010) highlighting the importance of education in determining the shape of life cycle profiles for earnings.

Furthermore, we estimate the variance of both transitory and permanent shocks to earnings using the second order moments for Δy_{it} and a GMM procedure, following an approach similar to that in Blundell et al. (2012). Considering the institutional framework under investigation, characterized by a different employment protection between sectors of activity and then the different uncertainty that private and public employees face during working life, we estimate this set of parameters separately for the two groups. Results are reported in the bottom panel of Table 2 and confirm these priors. The variability of the transitory component is greater for private employees (0.047, while we estimate it equal to 0.021 for public employees), perhaps reflecting both lower insurance against temporary health shocks and a larger influence of turnover. The estimated variances of permanent shocks are 0.022 and 0.017, respectively. Then, also the variance of the more structural component is larger for private employees, reflecting the higher exposure of marketable skills of these workers to technological shocks. These values compare to those of 0.044 and 0.021, respectively for the variance of transitory and permanent shocks, estimated by citegourinparker using data from the PSID and the methodology in Carroll and Samwick (1997). Blundell et al. (2012) estimate transitory and permanent variances to wages to be 0.033 and 0.032 for male workers using the same methodology we employ, and data coming from the PSID.

In Table 3, we report the set of exogenous parameters that we use, together with the estimated parameters of the earnings process, to solve and simulate our model. Adult age coincides with the age at which the household enters the labor force. We allow this to vary among education group according to the conditional mean starting age of work observed in the SHIW data. Then, households whose head attained primary education start to work at age 17, high school achievers start to work at 21 years of age, while households whose head holds a college degree enter the labor market at age 25. The households die with probability one at age 80. In the previous periods households face mortality risk. We take the conditional survival probabilities of being alive at age $t+1$, given being alive at age t, from the National Institute of Statistics (Istat).

The interplay between the value of the risk-free rate, the expected equity premium, and the standard deviation of innovations to the risky returns is crucial to determine the households' portfolio composition and the extent of asset accumulation. We set these values as estimated for the Italian financial market by Campbell (2003), who uses time series data for the sample period 1971-1998, which we think representative for the households in our SHIW sample to form expectations about market returns. In addition, in the process for expected risky return, we introduce a subjective probability of a disastrous event of 1.5 percent, similar to that in Guiso et al. (2012)[19]. The expected real GDP growth is set equal to 1.5 percent.

The pension rules we model are summarized in Tabel 4. In the pre-treatment period, the age of retirement is set for low, middle and high education achievers at 59, 60 and 61 years of age respectively, for both private and public workers. After the pension reform, the age of retirement is exogenously increased of two years for older workers, [20] while both public and private middle-aged workers choose when to retire between 57 and 65 years of age. The heterogeneity in the growth rates of earnings among different sector of employment-education groups has implications on both the replacement rate in the pre-reform period and the expected variation in replacement rates which follows the reform. Provided with the pension rules and the estimated parameters of the earnings process, we simulate the replacement rate for 2000 households, before and after the introduction of the reform. Table 5 reports average simulated replacement rates for each sub-group of three selected cohorts we consider and shows how different values of the earnings parameters and

[19]They consider different values for the probability of this tail event in the range 1.30 to 1.75 percent. This feature of the process of risky returns captures the extent to which investors anticipate the possibility to lose the entire wealth invested in the risky assets and helps to explain the low participation rates to the financial markets that we observe in the SHIW data.

[20]Retirement age was progressively increased after the reform at 65 years of age for older workers, so that they could actually still enjoy an earlier retirement. The two years exogenous increase is set here to match expectations about future age of retirement of this group of households, as measured in the SHIW data for this group after 1995.

heterogeneity in pension rules among groups imply a large degree of heterogeneity in the reduction on expected pension benefits following the introduction of the reform. We highlight how, within the same sector-education strata, younger cohorts of households experienced much higher reductions in expected replacement rates. This follows from the pension reform, according to which middle-aged workers will have enjoyed pension benefits computed using a pro-rata model. Then, keeping other factors constant, the lower the number of years of contribution in 1995, the higher the reduction in expected pension benefits for that group following the pension reform. The simulations are informative of the degree of heterogeneity in expected replacement rates, within the same cohort, between groups working in different sectors and with different education levels. Indeed, on the one hand, while public employees enjoy higher replacement rates before the introduction of the reform, they also suffer a larger reduction in expected pension benefits because of the reform. Also, there is substantial variability in expected replacement rates after the reform between groups who attained different education level. In particular, the steeper age profile of earnings of high school achievers implies a lower replacement rate under a contributive pension regime, and a much larger variation between pre-and post-treatment periods. Moreover, lower educated households benefit from the pro-rata model in that they had accumulated, within the same cohort, a higher number of years of contributions at 1995. This explains the relatively high replacement rates for low educated households after the reform.

Structural parameters estimation Given the exogenous parameters reported in Table 2 and 3, we estimate the additional critical parameters of the model using an indirect inference approach. We use information on consumption expenditures, asset holdings and financial market participation coming from SHIW 1986-2010 and the estimated effects of the reform presented in Section 4.2 to pin down these additional parameters. The parameters of the model we estimate are the discount factor β, the inverse of the intertemporal elasticity of substitution ρ, the strength of the bequest motive θ_b, the per-year fixed cost of participating to the financial markets θ_s and the utility cost of working (given by the two parameters ϕ_1, ϕ_2).

As anticipated in Section 2, the estimation strategy is the following: for each sector of employment - education level - cohort group, we solve the dynamic programming problem under the retributive pension system, given a set of structural parameters. Then, using the same values for the structural parameters, we solve the problem under the contributive pension regime, with households choosing now also the age of retirement. The parameters-specific policy functions for the retributive model are employed to simulate the life cycle profiles for the decision variables in the pre-treatment period. The pension reform is introduced at different ages depending on the year of birth of the particular cohort the group belongs to. This allows to introduce potential heterogeneity in the behavioral response of households hit by the reform in different moments of the life cycle. The resulting life-cycle profiles for consumption, assets and participation represent the simulated counterpart of the observed life cycle profiles in the data. We can now build the simulated dataset using the life cycle profiles for each simulated household. This contains panel data information on 2000 households the outcomes of whom were simulated in different parts of their life-cycle, depending on the year of birth of the cohort they belong to, so that we have simulated information for the years 1986-2010, as in the observed data from SHIW. Also, the simulated dataset is generated to have a composition with respect to sector of employment - education level - cohort as per figures computed by SHIW 1986-2010. [21]

Our aim is to match simulated moments with moments we observe in the data. In particular, we match:

[21] We simulate the behavior of 2000 households. For each sector of employment - education level - cohort group, we take group-specific policy functions (before and after the introduction of the pension reform) and the household-specific realization of shocks to earnings and returns from risky assets to simulate the corresponding behavior over the life-cycle (introducing the policy change at cohort-specific ages). Then, for each group, we pool information about the decision variables over time (noticing that observational year is simply given by the year of birth plus age) for a number of households corresponding to that observed in the data from SHIW 1986-2010. The remaining variables that we need in our simulated dataset to run the auxiliary diff-in-diff model (treatment status, pre- or post-treatment period, their interactions with the sector of employment, cohort and education dummies) can be computed using the group-specific information about year of birth, education and sector of employment. Finally, we pool information for the different groups to create a dataset that tracks the cohorts over their entire life-cycle. By keeping observations between 1986 and 2010, and applying the additional sample selection described in Section 4.1, we obtain simulated data with composition and information corresponding to that coming from SHIW 1986-2010.

1. The average net wealth to income ratio for untreated households employed in the public sector, in the pre-treatment period, between the ages of 55 and 60.
2. The average net wealth to income ratio for untreated households employed in the private sector, in the pre-treatment period, between the ages of 55 and 60.
3. The average participation rate to the financial markets for untreated households employed in the public sector, in the pre-treatment period, between the ages of 55 and 60.
4. The average participation rate to the financial markets for untreated households employed in the private sector, in the pre-treatment period, between the ages of 55 and 60.
5. The effect of the pension reforms on consumption to income ratio for households employed in the public sector.
6. The effect of the pension reforms on consumption to income ratio for households employed in the private sector.
7. The effect of the pension reforms on assets to income ratio for households employed in the public sector.
8. The effect of the pension reforms on assets to income ratio for households employed in the private sector.
9. The effect of the pension reforms on the participation to the financial markets for households employed in the public sector.
10. The effect of the pension reforms on the participation to the financial markets for households employed in the private sector.

The indirect inference approach uses an auxiliary diff-in-diff model, which is the simulated counterpart of the empirical diff-in-diff model described in section 4.2 to estimate the causal effects of the pension reforms. In particular, we run the following

OLS regressions using simulated data

$$
\begin{aligned}
y_i = \widetilde{\alpha} + \widetilde{\gamma}_1 T_i * D_i * PRIV_i + \widetilde{\gamma}_2 T_i * D_i * PUB_i \\
+ \widetilde{\delta}_1 PUB_i + \widetilde{\delta}_2 D_i + \widetilde{\delta}_3 D_i * PUB_i \\
+ \widetilde{\phi}_1 T_i + \widetilde{\phi}_2 Ti * PUBi + X_{it}\widetilde{\beta} + \eta_{it}
\end{aligned}
\tag{16}
$$

where $\widetilde{\gamma}_1$ and $\widetilde{\gamma}_2$ are the parameters of interest, providing the simulated diff-in-diff effects of the pension reforms for private and public employees, respectively. Also, we simply take conditional means using the simulated dataset to compute simulated moments (1-4). We indicate the collection of the parameters estimated for log simulated consumption (to income ratio), log simulated assets (to income ratio) and participation to the financial market and the conditional means for assets and participation rates with $\widetilde{\theta}$. Notice that $\widetilde{\theta}$ have been estimated using simulated data generated by the dynamic model for a particular set of values of the structural model Δ. We can then write $\widetilde{\theta}(\Delta)$. The central idea of indirect inference is to choose Δ in order to minimize some distance between $\widetilde{\theta}(\Delta)$ and $\hat{\theta}$, where $\hat{\theta}$ is the estimated parameter vector.

We employ a Simulated Annealing Algorithm (SAA) approach to minimize the distance between the moments (1-10) estimated using data from SHIW and those estimated using simulated data generated by the dynamic model. Our model is overidentified since we estimate six parameters to match ten moments. [22]

As discussed also in Scholz and Seshadri (2012), in order to pin down the structural parameters of our model we implicitly assume that households belonging to the same group are identical in terms of preferences and technology but face different constraints due to the evolution of shocks in the face of incomplete markets. Households belonging to different groups, defined by sector and treatment status, also differ with respect to the features of the earnings process, the baseline pension regime and the variations in the policy rules introduced by the pension reforms. In

[22] The cost function of the SAA uses a metric for the distance between $\widetilde{\theta}(\Delta)$ and $\hat{\theta}$ where the assigned weights are inversely proportional to the absolute value of the associated target moments. The temperature of the system, which controls the neighboring function, is reduced of 10 percent at each iteration, to avoid the algorithm to converge at local minima. For the role of the temperature of the system and the neighboring function in the SAA see Kirpatrick et al. (1983).

particular, we are assuming that the pension reforms introduced in the early '90s in Italy did not impact the preference parameters and the cost of participating to the financial markets.

5 Estimation results

The set of estimated parameters are reported in Table 6. In the bottom panel of Table 6 are also reported the values of the target moments estimated using data from SHIW and using simulated data generated by the dynamic model, given the set of estimated structural parameters.

The coefficient of relative risk aversion (or the inverse of the intertemporal elasticity of substitution) plays a major role in this framework. A small value for the coefficient of relative risk aversion implies a low saving rate against income uncertainty, while more risk averse households would save more in order to buffer themselves against negative income draws in the future periods (see e.g Carroll, 1997). The level of risk aversion impacts also households' portfolio choice, with higher risk averse households investing a lower share of wealth to risky assets, keeping other factors constant, or being less likely to participate to the financial market over the life cycle (as in Cocco et al., 2005). Furthermore, the relative risk aversion estimate is likely to influence the ability of our life cycle model to reproduce the observed effects of the pension reforms on asset accumulation and participation choice. Indeed, households hit by an exogenous reduction of lifetime wealth coming from the policy reform will react differently depending on the level of risk aversion. We estimate a coefficient of relative risk aversion equal to 3.9968. Estimate of this parameter in the literature range from 1.3 to 6 (see Attanasio and Weber, 2010 for a good review of existing studies). Even higher values have been employed in the calibration of life-cycle models when trying to match participation rates to the financial markets over the life-cycle (see e.g. Guiso et al., 2012). French (2005) estimates a rich model that differs from ours in that it also considers the endogenous intensive margin of labor supply and health shocks. An influential literature considers health shocks and the risk of out-of-pocket expenditures as an important determinant of asset accumulation over the life cycle. However, French's estimate of the coefficient of relative risk aversion ranges between 2.2 and 5, depending on the specification employed.

The estimate of the time discount factor, β is equal to 0.9917, lying on the upper part of the range of values estimated in previous studies, but in line with French (2005) who estimates an even higher value. An important remark to be made here is that we explicitly introduce mortality risk in our model, in contrast to most of the studies that find lower values of the time discount factor. Hence, our estimate of β does not include mortality risk and this is clear from the Euler Equation for consumption: $u^{'}(c_t) = E_t[R_{t+1}\beta d_{t+1}u^{'}(c_{t+1})]$ where d_{t+1} represents the probability of death at time $t+1$, conditional on being alive at time t.

One key parameter in our model to match the participation rates to the financial market that we observe in the data is the per period fixed cost of participation θ_s. As shown in Ameriks and Zeldes (2004), the standard household portfolio choice model without any fixed cost considerations implies one hundred percent participation at all ages, which we do not see in the data. Other works consider a low fixed costs of participation which is estimated or calibrated around 1 percent (see e.g. Gomes and Michaelides, 2005) but most of them fail to match either the participation rates or the average asset accumulation. We find a per period cost of participation of 0.017. As discussed in Section 3, this transaction cost is defined in proportion to the permanent component of income, meaning that the annual costs associated with participation are equal to 1.7 percent of the annual income. When looking at this value for the participation cost, one should consider how it is meant to include also costs of gathering information and the cost of time to be spent on trading financial securities. Furthermore, previous studies considering lower values for the costs of participation need to set very high values for the relative risk aversion coefficient in order to match observed participation rates, Guiso et al. (2012) estimate relative risk aversion in the range 7.5 - 17). The bequest intensity that we estimate is also in the ballpark of previous estimates. In particular, French (2005) and De Nardi et al. (2010) find values ranging from 1.69 and 2.5. As in Attanasio et al. (2008) the ψ_2 parameter reflects the direct utility cost of participating to the labor force.

In our case, this reflects in particular the utility cost of deciding to not retire and work one year longer. Our estimate for this value is 0.932. This high value of direct utility cost is necessary to induce a retirement behavior that enables the model to match observed responses to the reform in terms of consumption, savings and participation to the financial market. Considering the incentive scheme introduced with the contributive pension system, with higher pension benefits the higher the age of retirement, households need to associate high value to leisure when taking the decision to retire or not in order to not work one year longer. The ψ_1 parameter reflects the reduction in the utility of consumption caused by participation. Our estimate of ψ_1 is equal to 0.036, similar to that in Attanasio et al. (2008), which calibrate a value of 0.038 for this parameter. Since we find $\psi_1 > 0$ and $\rho > 1$, also find consumption and leisure to be substitutes in utility, since the marginal utility of consumption is greater when working then when retiring.

The estimated model is able to replicate quite well both the pre-reform statistics and the effects of the introduction of the pension reform estimated from actual data. Furthermore, the model mimics satisfactorily the heterogeneity in the behavior of households employed in different sectors. The median assets-to-income ratio before retirement (computed between 55 and 60 years of age) in the pre-reform period is 4.34 and 5.43 in the SHIW data, and 4.69 and 5.20 in the simulated data, for private and public employees respectively. The heterogeneity in accumulated asset for retirement between employment groups comes from the interplay between different age profiles of earnings (conditioning on the same level of education), the instability of the earnings process and the pension rules. First, the steeper age profile of earnings induce private employees to have lower saving rates than public employees. On the other hand, private employees face higher labor income risk so that, conditional on other factors, they would accumulate more assets to buffer against future income shocks. Finally, the pension system also plays an important role in that, in the pre-reform period, public employees were enjoying higher replacement rates than private employees, inducing the latter to save more for retirement, net to other factors. The model matches also the participation rates to the financial market in the pre-reform period (computed between 40 and 60 years of age), which are very similar between employment groups.

The effects of the pension reform estimated by running the diff-in-diff model 16 on simulated data match the effects estimated by running the corresponding model on SHIW data, as presented in Section 4.2. An exception is represented by the effect of the reforms on consumption for the groups of private employees. The model delivers a negative effect on consumption of 3.8 percent for this group, while the same effect estimated on actual data is marginally positive and not significant.

5.1 Simulated life-cycle profiles

Given the collection of parameters in Table 2, 3 and 6, we can solve and simulate the model for each group of households, and generate the simulated data. In this section we will first compare the simulated life-cycle profiles for the outcomes of interest with those observed in the data from SHIW 1986-2010, to give some insights into the ability of the model to match observed patterns. [23] We will then consider the life-cycle profiles for each sector-education-cohort group and draw the group-specific counterfactuals in the absence of the reform. This will allow us to draw conclusions about the life cycle-effects of the pension reforms and their potential heterogeneity.

Figure 3 shows both the SHIW profiles and the simulated life-cycle profiles of the decision variables that we target. Notice that the reported age profiles come from averaging the simulated life cycle profiles of different cohorts (and sector-education groups, weighting for the proportions we observe in the data) observed in different moments of the life-cycle. Consistently with the data from SHIW 1986-2010, different cohorts of households contribute to the life-cycle profiles differently at different ages.

Simulations capture some key features of the distributions observed in the data. In particular, assets exhibit the well-known hump-shape profile, with a peak around retirement age. Moreover, the model in the presence of income uncertainty, mortality risk and a bequest motive is able to generate substantial asset accumulation for retirement with reasonable values of the structural parameters. Average par-

[23]We do not perform a formal overidentification test but rather show the model's ability to match the main patterns of the decision variables observed in the data

ticipation in simulated data during working life (between 40 and 60 years age) is around 23 percent, very similar to the average participation rate in the SHIW data, showing how the introduction of a fixed cost generates limited participation as suggested in previous studies. Even though our simulation results capture the decrease in participation that data show when households approach retirement, the per year participation cost introduces a wealth threshold for participation that keeps young households from participating in the financial market, while data show higher participation rates for young households. [24] However, the simulated participation rates suggest that we can rationalize the limited participation of Italian households to the financial market (compared for instance to US data which provide evidence of average participation around 50 percent) with the introduction of a reasonable fixed cost of participation and degree of risk aversion. Even though we do not directly target consumption levels in our estimation procedure, the model generates simulated consumption profiles. The age profile of consumption tracks the age profile of income for each education group, consistently with previous findings (see Attanasio and Weber, 2010 for a review). Moreover the age profile of consumption is hump-shaped with a peak around retirement and a slow decrease in the years during retirement, following permanent income as suggested in Gourinchas and Parker (2002). The model also generates the endogenous share of wealth the households invest to risky assets. The Figure 4 plots the age profile of the average simulated conditional risky share. Even though we do not target the conditional share of wealth invested to risky assets for participants, the simulated age profile is similar to that observed in the SHIW, even though the simulated shares are higher at most ages than those observed in the data.

The presented behavior in terms of consumption, asset accumulation and financial market participation depends in turn also on the expected retirement behavior, conditional on the information about pension rules available to the households during working life. Even though the simulated dataset contains information on households belonging to cohorts subjected to the contributive pension system after the reform during working life only, the model generates an endogenous retirement

[24] As described in Guiso et al. (2012)

behavior for the different groups of households that is implied by the observed responses to the reform. Indeed, provided with the information about the new pension regime, households optimally choose the age of retirement to maximize lifetime utility. As discussed in Section model, the choice of when to retire depends on the joint interplay between the generosity of the incentive scheme, the utility cost of work, the accumulated wealth at the end of the working life and the expected pension benefit, which in turn depends on the history of realized earnings. In our framework, variability in the generosity of the incentive scheme comes from exogenous pension reforms, and earnings are also exogenous conditional on participating to the labor market. Hence, the key parameters for determining the age of retirement are the parameters giving the utility cost of work. Heterogeneity in the retirement age comes from different realized histories for the income process, education and the sector of employment, which affect the accumulation of wealth over the life cycle, portfolio choice (and then the ability to access excess returns from risky assets) and the expected pension benefit.

Because we match the effects of the reform, we can simulate the implied expected retirement behavior of these cohorts. The simulated retirement behavior of middle-aged workers is reported in Figure 5. By matching the estimated effects of the pension reforms, the model generates an average expected retirement age of 62.5, quite similar to the expected retirement age of the cohort of middle-aged workers in SHIW.

5.2 The life cycle effects of the reforms

The reduce-form effects estimated using a diff-in-diff identification strategy, that we find consistent to previous findings in the literature, are informative of an average reduction of consumption and an increase in the saving rate and asset accumulation following the exogenous variation in social security wealth coming from the pension reforms introduced in Italy in the '90s. These effects are more economically significant for the public workers, which suffered a higher reduction of expected pension benefits.

However, the diff-in-diff approach can say little about the mechanisms behind the estimated effects. In particular, one might be interested in understanding who reacted more to the reform and which are the channels explaining the observed behavior. Indeed, households differing for the sector of employment, the education level (impacting both on the earnings process and on the starting work age), and age at which they acquire knowledge about the pension reform, are likely to have reacted differently. The structural framework we are considering allows to gain some insights into the understanding of the age effects of the reform, the heterogeneity behind the average observed effects and the underlying mechanisms at work. It is important to notice that the optimal asset accumulation for retirement implied by the life-cycle model cannot be reached when households are hit by an exogenous reduction of lifetime resources later in life. The extent to which households are able to accumulate an optimal amount of savings for retirement depends on the different dimensions we consider in the analysis that follows: the age at which households start to work, the age of households when the reform hits, the education level and the sector of employment.

In this section we use the estimated structural parameters which generate the simulated statistics that match those observed in the data from SHIW as discussed in the previous section, and simulate the counterfactual life-cycle profiles for consumption, assets and participation in the absence of the pension reform. The comparison with the actual simulated life cycle profiles will be informative of the age effects of the reform for each group, and shed some lights into the mechanisms at play.

Figure 6 reports the simulated life cycle profiles for assets and their counterfactuals for the cohort born in 1945-1950 of old workers (top panel), the cohort born in 1955-1960 of middle-aged workers which were hit by the reform late in the working life (central panel) and the cohort born in 1965-1970 of middle-age workers which was hit by the reform earlier in the working life (bottom panel). The life cycle profiles are reported separately for private employees (left panels) and public employees (right panels), for different levels of education. The graphs show the importance of life cycle effects in understanding the implications of the pension reforms. Indeed, because the reform introduced in 1995 hit the cohorts in different moments of the life cycle, the optimal reaction of different cohorts has different implications in terms of consumption behavior, portfolio choice and asset accumulation for retirement. Some results are particularly worth underlying. First, as already suggested by the evidence coming from the diff-in-diff reduced form estimates, public employees reduce consumption and increase the accumulation of private wealth following the introduction of the reform more than private employees, with higher resulting effects of the reform at all ages. Second, life cycle effects do matter in explaining the observed effects in the data coming from the reform. Indeed, the extent to which one household is able to optimally save for retirement under the new policy regime depends on the number of remaining periods in the working life. Therefore, the younger the households when the reform was introduced in 1995, the higher the response in terms of increase in asset accumulation. Third, because high school dropouts face a less decreasing age profile of earnings than both low educated and college graduates at the end of the working life, yielding a lower replacement rate, these households are those changing more drastically their behavior in terms of asset accumulation for retirement. Finally, middle-aged workers do use the extensive margin of labor supply at retirement to compensate for the reduction, at a given retirement age, of expected pension benefits. Indeed, households which did not accumulate an optimal amount of savings for retirement postpone the retirement decision to enjoy higher expected pension benefits.

5.2.1 Welfare analysis

The structural framework allows to say something about the implications in terms of welfare of the pension reforms. Starting from the counterfactual life-cycle profiles simulated as described above, we can draw some conclusions in terms of inequality. Let us start by computing the percentage decrease in consumption around retirement for different groups of households induced by the reform. Indicating with c_i^A the actual consumption profile resulting from household i choices following the introducing of the reform, and with c_i^C the counterfactual consumption household i would have chosen if the reform was not introduced, we can compute the household-specific effect of the reform, at a given age, as:

$$TE_i = \frac{\log c_i^A}{\log c_i^C} \tag{17}$$

In Table 7 we report the average effect on consumption around retirement (we compute the average consumption between 55 and 65 years of age, in that each household chooses when to retire depending on the accumulated assets and the pension benefit she would get), by cohort-education-sector of employment group, for selected cohorts. We can notice that, while within older cohorts public employees reduce consumption more than private employees because of the reform, the effect is higher for private employees within younger cohorts. This result is explained by differential growth rates of earnings at the end of the working life. Indeed, while old public employees reduce consumption significantly because of the particularly generous provisions they were enjoying in the pre-reform period, private employees face steeper age profiles of earnings, reflected in lower replacement rates at retirement under the new contributive pension system.

In order to better explore the consequences in terms of welfare of the pension reform, we consider now the effect of its introduction into lifetime utility of households. This is important because while households draw utility from consumption, they pay a utility cost of work while approaching retirement and deciding to work longer in order to enjoy higher pension benefits. Similarly to the analysis for consumption, we compute the counterfactuals indirect utility functions (in the presence of the pension reform V_i^A, and that they would have had in case the reform was not introduced V_i^C) for each household, as follows:

$$\begin{aligned} V_i^A &= \sum_{t=s_0}^{T} \left[\left(\frac{C_{i,t}^{A^{1-\widehat{\gamma}}}}{1-\widehat{\gamma}} \right) \exp(\widehat{\psi_1}(1 - \widehat{Ret_{i,t}^A})) - \widehat{\psi_2}(1 - \widehat{Ret_{i,t}^A}) \right] \\ V_i^C &= \sum_{t=s_0}^{T} \left[\left(\frac{C_{i,t}^{C^{1-\widehat{\gamma}}}}{1-\widehat{\gamma}} \right) \exp(\widehat{\psi_1}(1 - \widehat{Ret_{i,t}^C})) - \widehat{\psi_2}(1 - \widehat{Ret_{i,t}^C}) \right] \end{aligned} \tag{18}$$

Table 8 reports the variation in lifetime utility due to the pension reform ($\frac{V_i^A - V_i^C}{V_i^C}$), for each cohort-education-sector of employment group. Because of the exogenous variation in expected lifetime resources due to the introduction of the pension reform, all groups experience a welfare loss. The Table shows how the particular characteristics of each group imply different welfare consequences of the pension reform. First, private employees suffer a larger welfare loss than public employees in that they are associated lower replacement rates under the new contributive scheme, net to other factors. Furthermore, because of the steeper age profile of earnings they face, high school dropouts also experience the largest welfare loss due to the reform.

One result is worth underlying. The estimated model suggests households to use labor supply at retirement as an insurance mechanism against the exogenous reduction in the expected pension benefit, for a given age of retirement. In fact, results in Table 8 show that younger cohorts experience a lower welfare loss than intermediate treated cohorts because they can access higher replacement rates by increasing labor supply at retirement. These results suggest that intermediate cohorts, hit by the pension reform in a late stage of the working life, are those suffering the highest welfare loss.

6 Policy experiment

The estimated model can be used to conduct a number of policy experiments. In this section we consider the behavior over the life-cycle of a cohort of young workers (entered in the labor market after 1995, thus subjected to a contributive pension scheme). In particular, using the estimated structural parameters, we simulate the life-cycle profiles for assets of this cohort under the contributive regime they are subjected, and then conduct a policy experiment consisting in the reduction of the transformation coefficients of 10 percent. This policy experiment aims at investigating the consequences of a potential further decrease in the generosity of the public pension system following the increase in life expectancy. Because the actual contributive pension system does not prescribe different pension rules between workers employed in different sectors, for simplicity we consider here only the private employees.

Figure 7 reports simulated counterfactual profiles of assets for the cohort of young workers. As expected, a reduction of the generosity of the pension system further increases the accumulation of private wealth for retirement, for all education groups. The exogenous reduction in the transformation coefficients of 10 percent reduces, for a given age of retirement, expected pension wealth of 10 percent. Households increase savings of around 5 percent (4 percent in the high school dropouts).

What is interesting here is that retirement decision plays a major role in the dynamics of households responses to a pension policy change. Indeed, as shown in Figure fig:polexpret, even if the window within which households can choose when to retire is not modified by the legislator, households will react to the exogenous reduction in pension wealth by increasing labor supply at retirement, in each education group.

7 Conclusions

This paper proposes a structural evaluation approach to conduct pension policy analysis combining ex-post and ex-ante evaluation methods. We use a dynamic life-cycle model of consumption, portfolio choice and retirement to describe households' behavior before and after the introduction of a wave of major pension reforms introduced in Italy in the nineties. The structural model is validated by matching the effects of the pension reforms estimated from actual data exploiting a diff-in-diff identification strategy, with the corresponding effects from simulated data.

We find that by carefully replicating the composition of actual data, the model is able to mimic pre-reform statistics and the estimated effects on asset accumulation and participation rates to the financial markets. Furthermore, the estimated model implies households to use labor supply at retirement to insure against the exogenous reduction in expected pension wealth following the introduction of the reforms. We quantitatively assess the welfare losses induced by the reform and show that older treated households experienced the greater loss.

The model is used to conduct a policy experiment, consisting in the reduction of the transformation coefficients under the actual defined-contribution scheme of 10 percent. The model predicts households to further increase the saving rates, to substitute social security with private wealth, and to increase the age of retirement to access higher replacement rates. The effects of the policy change are heterogeneous among households facing different age profiles of earnings over the life-cycle. This simple counterfactual exercise shows how to use the model to conduct pension policy evaluation and forecast the consequences of alternative pension policies.

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Appendix A Solution algorithm

The dynamic programming problem of the households we consider has no analytical solution, and it is solved numerically by backward induction from the terminal period. At each age, we compute the optimal policy rules and the value function, given the current state variables, the optimal policy rules and value function in the next period, using a modification of the Endogenous Grid Point Method (EGM) developed by Carroll (2006). In his seminal work, the author introduces the method to solve a standard dynamic model for consumption and asset accumulation as in Gourinchas and Parker (2002). Our numerical solution considers to nest a Value Function Iteration Step (VFI) within the EGM algorithm. Barillas and Fernandez-Villaverde (2007) were the first to propose this kind of nesting to generalize the algorithm proposed by Carrol to more than one continuous control variable. While Hintermaier and Koeniger (2010) further generalize the algorithm to consider multiple endogenous state variables and occasionally binding constraints for problems with a concave and differentiable value function, Fella (2014) also considers the introduction of a discrete choice. Our proposed solution method is more similar to this last contribution. Indeed, the complication in our model compared to the standard dynamic model for consumption la Gourinchas and Parker arises from the inclusion of a discrete choice (whether to participate to the financial market or not) and the bequest motive. Furthermore, we introduce the endogenous discrete retirement choice for households targeted by the pension reform to capture a key feature of the pension reforms.

Let us start considering the problem of a household which maximizes her lifetime expected utility under a retributive pension system. The value function during retirement is given by

$$V_t(M_t, PB_t) = \max_{C_t, \alpha_t^s} [U(C_t) + \beta E_t V_{t+1}(M_{t+1}, PB_{t+1})] \tag{19}$$

subject to

$$M_{t+1} = R_{t+1}^p (M_t - C_t - \theta_s \mathbb{1}(\alpha_t^s > 0)) + PB_{t+1}$$

$$R_{t+1}^p = \alpha_t^s R_{t+1} + (1 - \alpha_t^s) R_f$$

Since we solve the model by backward induction, and pension benefits a household receives do not vary after retirement, we can solve the dynamic problem for each level of a pre-defined grid for the state variable pension benefits. Given a level of pension benefit, and normalizing the problem by the permanent component of income at time t, the value function is given by

$$V_t^{pb}(m_t) = \max_{c_t,\alpha_t^s}[u(c_t) + \beta d_{t+1} E_t V_{t+1}^{pb}(m_{t+1})] \tag{20}$$

The terminal value for the problem is given by the bequest motive, that is

$$V_{T+1}^{pb}(m_{T+1}) = \theta_b \frac{(R_f(m_t - c_t))_t^{1-\gamma}}{1-\gamma} \tag{21}$$

Following the idea in Carroll (2006), we compute the terminal value associated to bequests for each level of a pre-defined exogenous grid for the end-of-period net wealth $a_t = m_t - c_t$. Given the terminal value function obtained this way, we use a numerical rootfinding algorithm to search for the c_T[25] that maximizes

$$V_T^{pb}(m_T) = \max_{c_T}[u(c_T) + \beta E_t V_{T+1}^{pb}(m_{T+1})] \tag{22}$$

Starting from $T-1$, the algorithm uses EGM and standard Value Function Iteration to compute policy functions and value functions until the beginning of households' working life, proceeding in two steps. Compared to the standard Value Function Iteration approach usually employed in the literature, employing the EGM step allows us to dramatically reduce the time required for the algorithm to find the optimal solution.

In the first step, given the value function $V_{t+1}^{pb}(m_t)$ and the optimal future consumption function $c_{t+1}^{pb}(m_{t+1})$, we condition on a subset of the current discrete choice $\alpha_t^{pb}(m_t)$ and exploit the first-order derivative conditions with respect to c_t to compute the conditional optimal consumption function at time t. In step 2, we use the conditional consumption functions obtained in step 1 to compute the value functions at time t associated to the different levels of the discrete choice. We compare the conditional value functions at time t and employ a Value Function Iteration step with numerical root finding to compute the optimal policy functions and the

[25] Households are assumed to not allocate part of the wealth to risky assets in the last period.

associated value function at time t.

In particular, the first step can be seen as an EGM conditional on a given level of the state variable pension benefit and the discrete portfolio choice. We thus define a function

$$\mathfrak{v}_t^{pb,\alpha^s}(a_t) = E_t[\beta V_{t+1}((\alpha_t^s R_{t+1} + (1-\alpha_t^s)R_f)a_t + v_{t+1})] \tag{23}$$

and, since the first order condition for 20 with respect to c_t is

$$u_c^{pb,\alpha^s}(c_t) = E_t[R_{t+1}\beta d_{t+1}V_{t+1}^{'}(m_{t+1})] \tag{24}$$

we can still write

$$u_c^{pb,\alpha^s}(c_t) = \mathfrak{v}_t^{'pb,\alpha^s}(m_t - c_t) \tag{25}$$

As in Carroll (2006), it is then trivial to find the value of consumption that yields the same marginal valuation as of the end-of-period wealth, using the first order condition. Since we assume non separability between consumption and leisure and, as in Attanasio et al. (2008), we use a utility function of the form $u(c_t, Ret_t) = (c_t^{1-\gamma}/(1-\gamma))\exp(\psi_1(1-Ret_t)) - \psi_2(1-Ret_t)$ we will have

$$c_t^{pb,\alpha_d^s} = \left(\frac{\mathfrak{v}_t^{'pb,\alpha^s}(a_t)}{\exp(\psi_1)}\right)^{-1/\gamma} \tag{26}$$

Optimal values of consumption and end-of-period wealth for a given state of the problem allow us to obtain the endogenous cash-on-hand

$$m_t^{pb,\alpha_d^s} = c_t^{pb,\alpha_d^s} + a_t^{pb,\alpha_d^s} \tag{27}$$

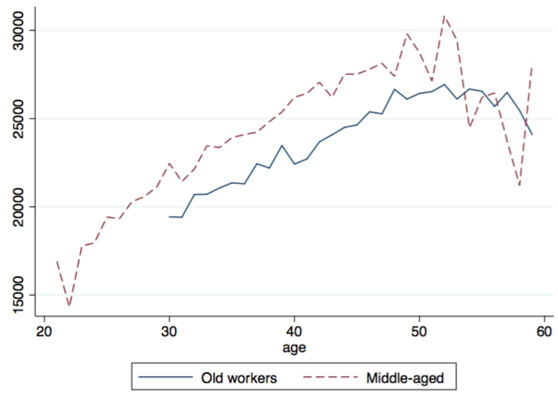
Provided with the portfolio choice-specific consumption functions $c_t^{pb,\alpha_d^s}(m_t)$, we can compute the d-conditional value functions (step 2)

$$V_t^{pb,\alpha_d^s}(m_t) = \max_{c_t}[u(c_t^{pb,\alpha_d^s}) + \beta E_t V_{t+1}^{pb}(m_{t+1})] \tag{28}$$

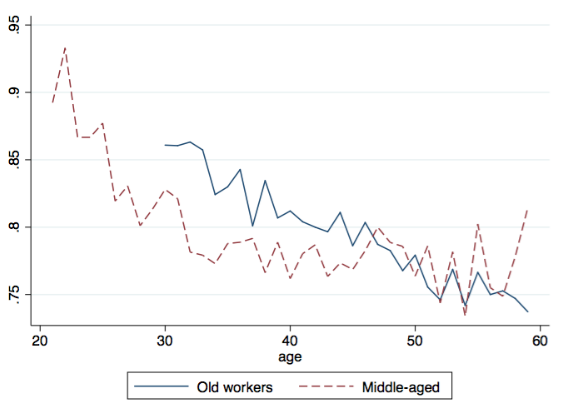
The portfolio choice in period t is then determined by comparing the conditional value functions associated with different levels of the discrete choice α^s, and the value function $V_t^{pb}(m_t)$. Once the discrete choice is computed, it is straightforward to derive the corresponding consumption functions $c_t^{pb}(m_t)$, for each element of the state space. We report in the main text how we include the additional choice of the age of retirement.

The set of admissible values for the discrete portfolio choice and the pension benefit were discretized using equally spaced grids, while we use a triple exponential grid for the end-of-period wealth. To perform the numerical integrations, as in the density functions for permanent and transitory shocks to earnings, the returns in the risky asset and the growth of Gross Domestic Product were approximated, following Tauchen (1986), using a 5-points gaussian quadrature method.

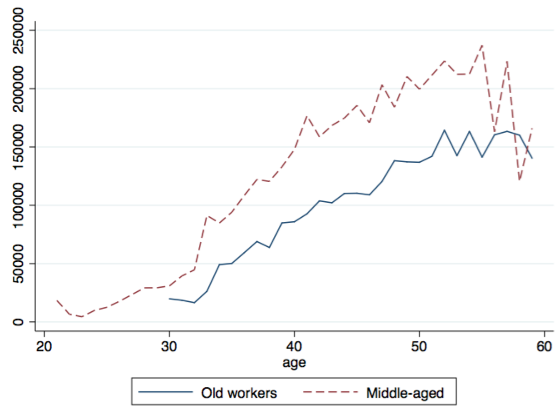
In order to evaluate the next-period consumption associated to values of cash-on-hand that do not lie in the the endogenously determined grid we use a cubic spline interpolation. Similarly we use cubic spline interpolation to evaluate the value functions corresponding to values of cash-on-hand that do not lie in the grid. This approach is standard (see e.g. Cocco et al., 2005, among others).



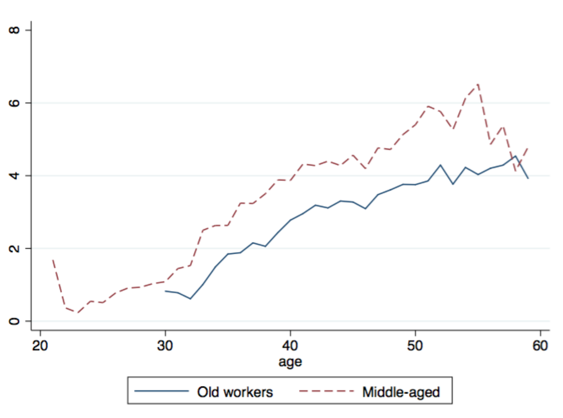
(a) Consumption expeditures



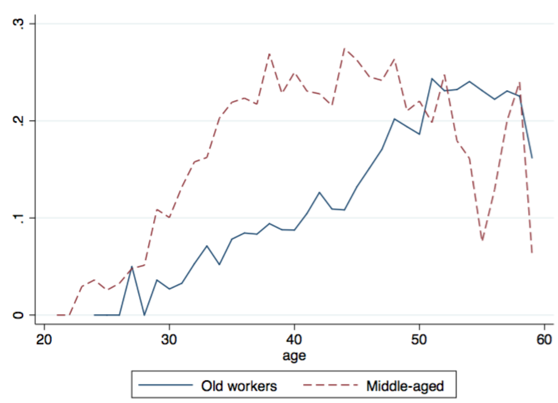
(b) Consumption to income ratio



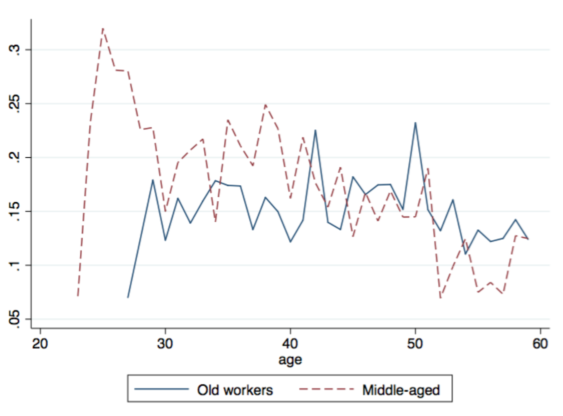
(c) Total Assets



(d) Assets to income ratio

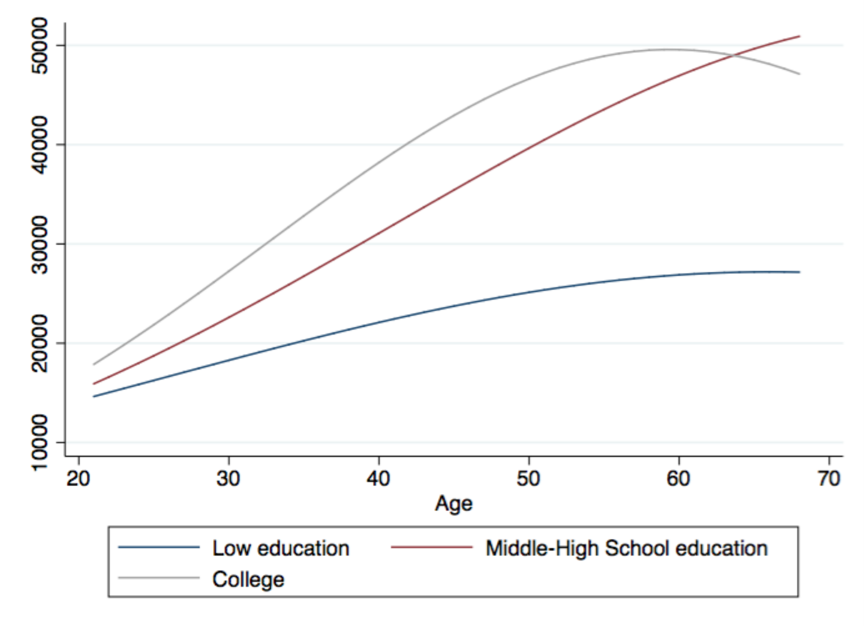


(e) Participation to the financial markets

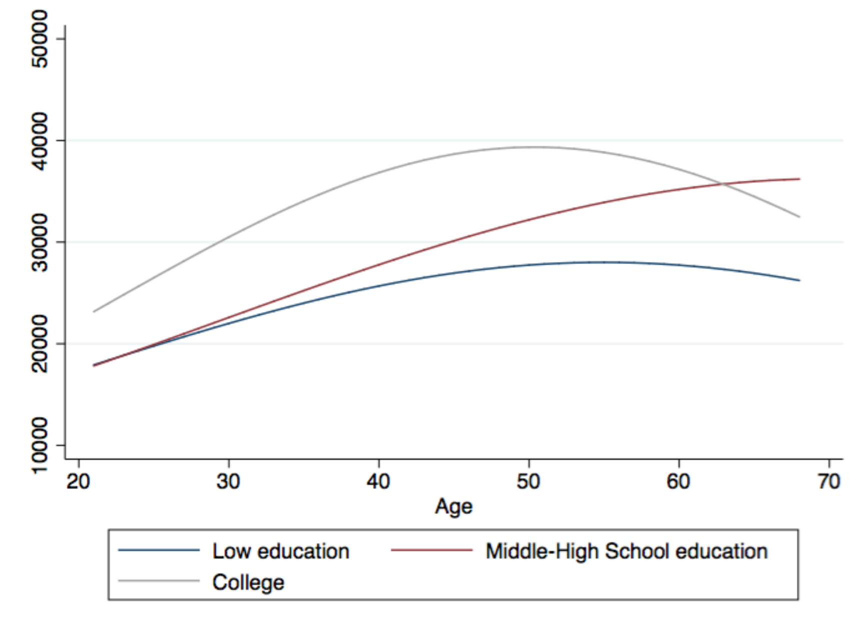


(f) Share of wealth invested to risky assets

Figure 1: Life cycle profiles for outcomes in the data



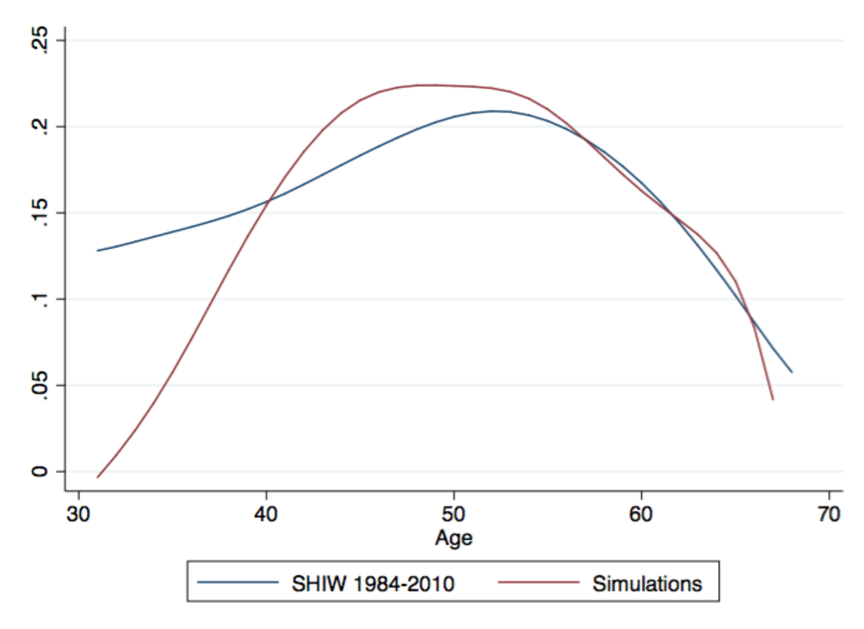
(a) Private employees



(b) Public employees

Figure 2: Estimated life cycle profiles for earnings, by sector of employment and education

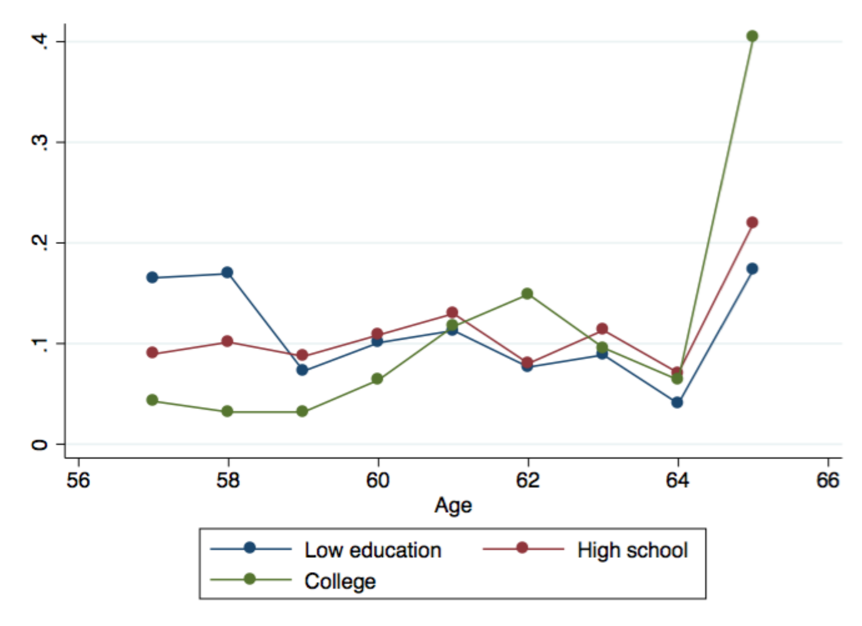
(a) Age Profile for Mean Assets



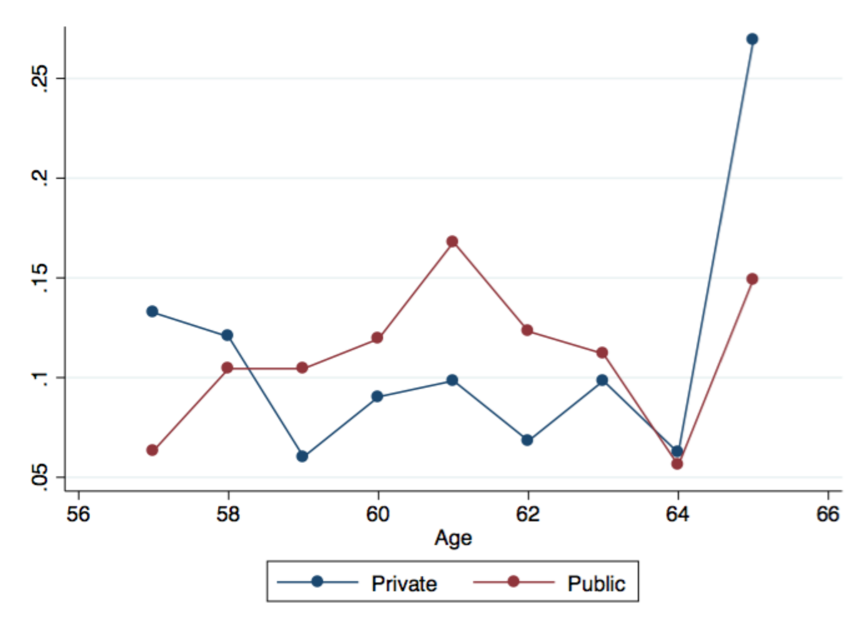
(b) Financial market Participation rates

Figure 3: Target Simulated profiles vs. Data from SHIW 1998-2010

Figure 4: Conditional risky share over the life cycle

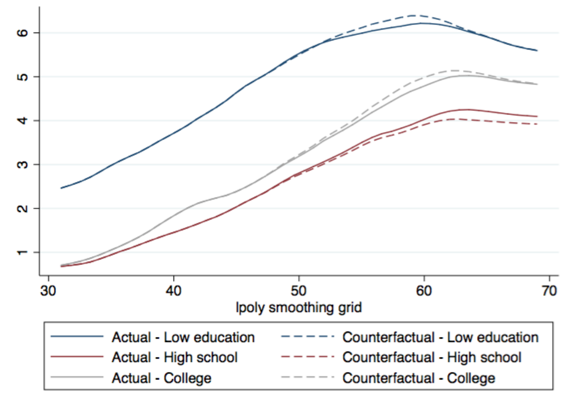


(a) By education

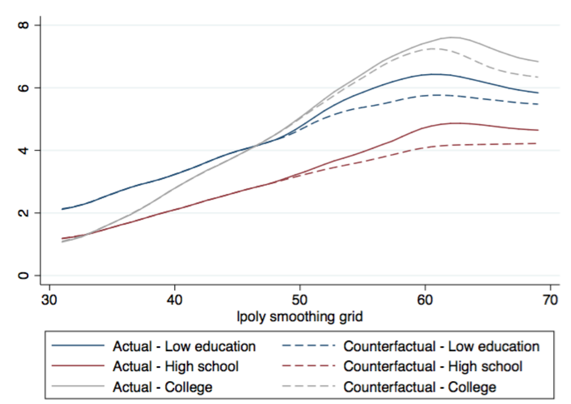


(b) By sector of employment

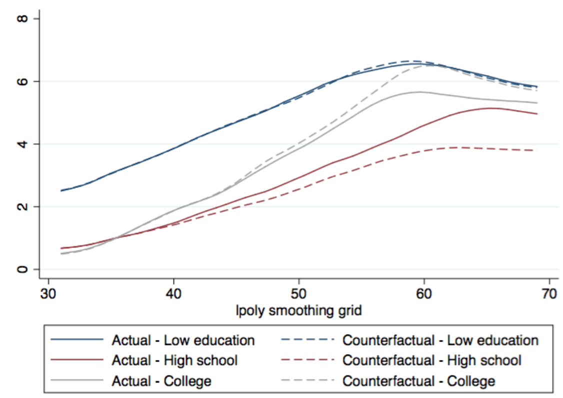
Figure 5: Simulated Retirement Behavior



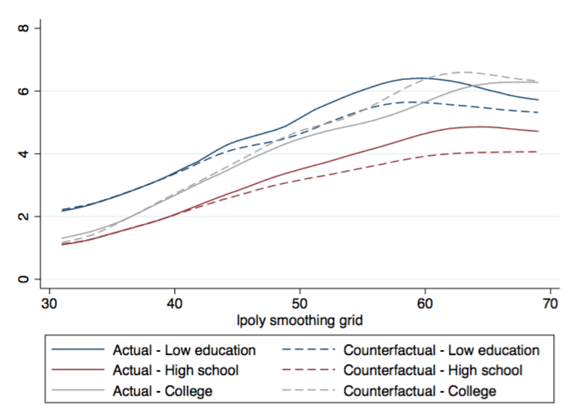
(a) Cohort 1945-1950, Private employees



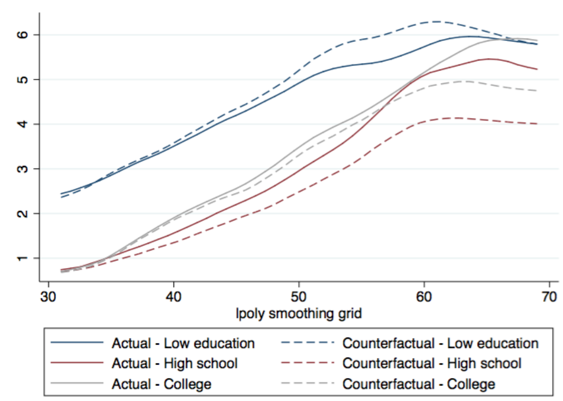
(b) Cohort 1945-1950, Public employees



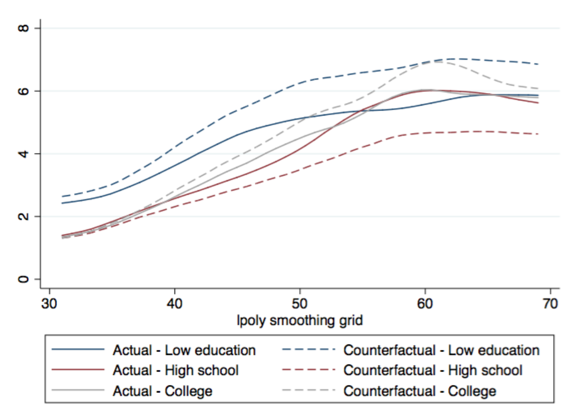
(c) Cohort 1955-1960, Private employees



(d) Cohort 1955-1960, Public employees



(e) Cohort 1965-1970, Private employees



(f) Cohort 1965-1970, Public employees

Figure 6: Counterfactual Age profiles for Assets

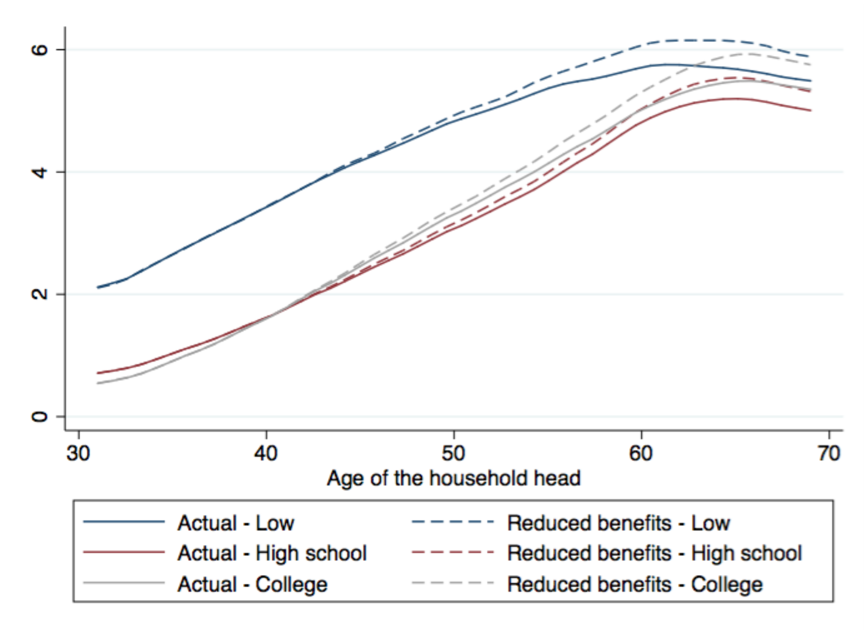


Figure 7: Policy experiment - effect on asset accumulation

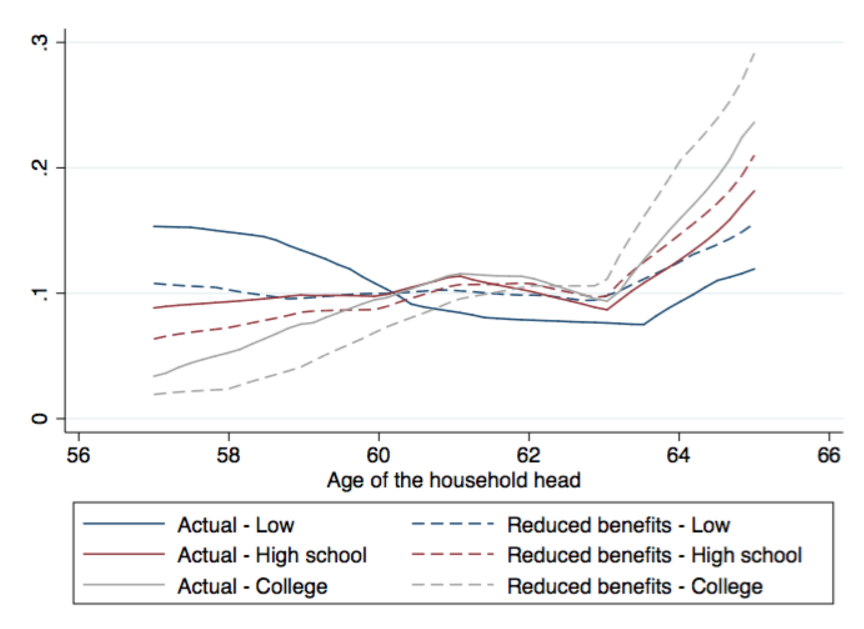


Figure 8: Policy experiment - effect on retirement behavior

Table 1: Estimation results for Diff-in-Diff regressions

	(1) Log Consumption to income ratio	(2) Log Net Wealth to income ratio	(3) Participation
Private employees, middle-age,	0.008	0.260***	0.067
after the reform	(0.014)	(0.072)	(0.091)
Public employees, middle-age,	-0.027*	0.391***	0.158*
after the reform	(0.014)	(0.076)	(0.108)
Middle-age	0.079***	-0.071	0.096
	(0.014)	(0.068)	(0.088)
Post-reform	0.001	0.557**	0.285*
	(0.043)	(0.173)	(0.160)
Public employees	0.004	0.019	-0.002
	(0.008)	(0.040)	(0.057)
Public, middle-aged	0.027	-0.101	-0.149
	(0.020)	(0.092)	(0.131)
Public, after the reform	-0.021*	0.147**	-0.006
	(0.012)	(0.050)	(0.065)
Age	-0.001	0.028***	-0.268
	(0.002)	(0.007)	(0.018)
Low education	0.031***	-0.531***	-0.655***
	(0.008)	(0.036)	(0.045)
College degree	-0.032***	0.344***	0.487***
	(0.009)	(0.027)	(0.033)
Female head	0.182***	-0.199***	-0.143
	(0.008)	(0.027)	(0.027)
Constant	-0.889***	-0.825**	-3.668***
	(0.081)	(0.32)	(0.018)
Regional dummies	YES	YES	YES
Cohort dummies	YES	YES	YES
Time dummies	YES	YES	YES
Observations	22,603	21,879	22,603
R-squared	0.294	0.096	0.139

Note: Standard errors for the estimated coefficients in parenthesis. Three stars indicate statistical significance at the 1 percent confidence level, two stars at the 5 percent level and one start at the 10 percent. Column 1 reports OLS estimates of the regression model for log equivalent consumption to income ratio. In column 2 are reported OLS estimates for log wealth to income ratio, while column 3 shows results of the PROBIT estimation for participation to the financial market. We use data from SHIW 1986-2010, where we drop transitional year 1993, households which head is above 60 years of age or out of the labor force. Moreover we only keep information on households which year of birth is between 1940 and 1970.

Table 2: Estimated parameters of the earnings process

Age coefficients		Primary education	High school education	College education
Private	Age	0.040256**	0.0581009**	0.0821825**
		(0.00557)	(0.00719)	(0.02016)
	Age^2	-0.0003045**	-0.0003748**	-0.0006916*
		(0.00005)	(0.00007)	(0.00021)
Public	Age	0.0425787**	0.0413638**	0.061978**
		(0.0096)	(0.00813)	(0.01425)
	Age^2	-0.0003873**	-0.0002954**	-0.00061**
		(0.00010)	(0.00008)	(0.00014)

Variances of shocks to earnings			
Private	Transitory	σ_t^2	0.04689**
			(0.00310)
	Permanent	σ_p^2	0.02079**
			(0.00308)
Public	Transitory	σ_t^2	0.02247**
			(0.00269)
	Permanent	σ_p^2	0.01679**
			(0.00286)

Note: The group-specific coefficients of the polynomial in age for earnings have been estimated using OLS with the inclusion of cohort and year fixed effects. Earning process variances estimated using GMM. Baseline sample selection as in section 4.2 is applied. In addition, we keep households the head of which is unemployed and in working age (we drop retired) for the estimation of the instability of the earnings process. Standard errors for the estimated coefficients in parenthesis. Two stars indicate statistical significance at the 1 percent confidence level, one star at the 5 percent level.

Table 3: Other exogenous Parameters

Parameters		Value
Risk free rate	R_f	1.023
Excess return from risky assets	μ^s	0.015
Std deviation of risky returns	σ_s	0.27
Probability of disastrous event	p_{tail}	0.015
Mean GDP growth	$E[GDP^g_{t+1}]$	0.01
Initial age in the model, Primary education	Age_0^L	17
Initial age in the model, High school degree	Age_0^M	21
Initial age in the model, College degree	Age_0^H	25
Terminal age in the life cycle	T	80

Note: This Table shows the values of the structural parameters that are set outside the model or taken from previous studies.

Table 4: Parameters from pension rules

	Pre-reform	Post-reform
Retirement age		
Old workers		
Low education	59	61
High school degree	60	62
College graduates	61	63
Middle-aged workers		
Low education	59	Choice between [57-66]
High school degree	60	Choice between [57-66]
College degree	61	Choice between [57-66]
Pension award formula		
Old, private workers	Mean last five earnings* 0.02*years of contributions	Mean last ten earnings* 0.02*years of contributions
Old, public workers	Last earning* 0.023*years of contributions	Mean last ten earnings* 0.02*years of contributions
Middle-aged, private workers	Mean last five earnings* 0.02*years of contributions	Retributive until 1995, then total contribution*τ_r
Middle-aged, public workers	Last earning* 0.023*years of contributions	Retributive until 1995, then total contribution*τ_r
Transformation coefficients τ_r		
Retirement at 57 years of age		0.04304
Retirement at 58 years of age		0.04416
Retirement at 59 years of age		0.04535
Retirement at 60 years of age		0.04661
Retirement at 61 years of age		0.04796
Retirement at 62 years of age		0.04940
Retirement at 63 years of age		0.05094
Retirement at 64 years of age		0.05259
Retirement at 65 years of age		0.05435
Retirement at 66 years of age		0.05700

Note: This Table reports the main features of the pension systems in Italy before and after the introduction of the reforms in the nineties, which I exploit to identify the model. In the Table is also reported the age of retirement for the group of old workers and middle-aged workers before the reform which we set as the average retirement age in SHIW data. Middle-aged workers are allowed to choose the age of retirement after the introduction of the reform. The pension award formula for old workers and middle-age workers before the reform uses an earnings model, while a pro-rata model is employed for middle-aged workers after the introduction of the reform: earnings model until 1995 and contribution-based afterwards. Total contribution at each possible retirement age is transformed into pension benefits applying the age-specific coefficients τ reported in Table.

Table 5: Mean simulated replacement rate before and after the pension reforms

		Pre-reform	Post-reform								
			Retirement age								
			57	58	59	60	61	62	63	64	65
	Cohort 45-50										
	Low education	0.79					0.80				
Private	High school degree	0.77						0.76			
	College degree	0.80							0.84		
	Low education	0.89					0.84				
Public	High school degree	0.89						0.78			
	College degree	0.89							0.85		
	Cohort 55-60										
	Low education	0.79					0.80				
Private	High school degree	0.77	0.58	0.59	0.59	0.60	0.61	0.61	0.63	0.64	0.66
	College degree	0.80	0.65	0.67	0.69	0.71	0.74	0.76	0.80	0.84	0.88
	Low education	0.89					0.84				
Public	High school degree	0.89	0.71	0.72	0.73	0.74	0.76	0.77	0.79	0.81	0.83
	College degree	0.89	0.70	0.73	0.75	0.77	0.80	0.83	0.88	0.92	0.97
	Cohort 65-70										
	Low education	0.79	0.65	0.67	0.68	0.70	0.72	0.74	0.77	0.80	0.83
Private	High school degree	0.77	0.51	0.52	0.53	0.54	0.55	0.56	0.58	0.60	0.62
	College degree	0.80	0.59	0.62	0.64	0.66	0.70	0.73	0.77	0.81	0.86
	Low education	0.89	0.72	0.74	0.77	0.80	0.83	0.86	0.91	0.96	1.00
Public	High school degree	0.89	0.60	0.61	0.62	0.64	0.66	0.67	0.70	0.72	0.75
	College degree	0.89	0.65	0.67	0.70	0.73	0.77	0.80	0.86	0.90	0.96

Note: Replacement rates for selected cohorts of households we consider in the analysis. The replacement rate is simulated considering pension rules in Table 4. Moreover, we use growth rate of earnings for each group as estimated in section 4.2, real GDP growth of 1.0 percent and assume workers contribute over the working life for 40 years. We assume the year of birth of each household belonging to a particular cohort to be median year in the year of birth group. Head of households born in 1945-1950 are old workers, for every education level, and then subject to a retributive pension system. Low educated workers belonging to cohort 1955-1960 accumulated more than 18 years of contribution in 1995 and are still subject to a retributive pension regime after the reform. Other groups reported in Table (high school and college degree achievers belonging to cohort 1955-1960 and the 1965-1970 cohort) are middle-aged workers in our definition and the expected pension benefit is simulated using a pro-rata model, with relative weight of retributive vs contributive model that is proportional to the number of years of contribution in 1995 for that particular group.

Table 6: Calibrated parameters and target moments

Parameters		Value
Coefficient of relative risk aversion	ρ	3.9968
Time discount factor	β	0.9917
Bequest weight	θ_b	1.4426
Cost of participation to the financial market	θ_s	0.0179
Utility cost of work	ψ_1	0.0366
	ψ_2	0.9324

Target moments	Actual		Simulated	
	Private	Public	Private	Public
Median assets pre-reform (55-60)	4.34	5.43	4.69	5.20
Participation rate pre-reform (40-60)	0.229	0.233	0.236	0.219
Effect on Consumption	0.008	-0.027	-0.038	-0.053
	(0.014)	(0.015)	(0.006)	(0.008)
Effect on net Wealth	0.260	0.391	0.279	0.409
	(0.072)	(0.076)	(0.010)	(0.013)
Effect on Participation	0.067	0.158	0.048	0.129
	(0.092)	(0.109)	(0.009)	(0.011)

Note: The Table reports the set of preference and fixed-cost parameters estimated using an indirect inference approach and a simulated annealing algorithm, and a comparison between target moments in the SHIW data and in the simulated data. In the Table, the cost of participation to the financial market is expressed as a ratio to the income level. Assets pre-reform are the average ratio of assets over income before retirement (between 55 and 60 years of age). The effects of the reform are expressed as percentual variations.

Table 7: Heterogeneous Effects of the Reform on Consumption at Retirement

		Cohort		
		1945-1950	1955-1960	1965-1970
Private	Low education	-0.001	-0.002	-0.003
	High school dropouts	-0.007	-0.044	-0.037
	College graduates	+0.014	-0.001	-0.029
Public	Low education	-0.047	-0.050	+0.03
	High school dropouts	-0.058	-0.049	-0.033
	College graduates	-0.027	-0.039	-0.011

Note: The Table reports the average effect of the reform on consumption at retirement, by group. The individual effect is obtain the talking the logarithm of the ratio between the actual consumption profile resulting from household i's choices following the introducing of the reform, and the counterfactual consumption household i would have chosen if the reform was not introduced.

Table 8: Effect on indirect utility function, by group

		Cohort		
		1945-1950	1955-1960	1965-1970
Private	Low education	-0.26	-0.17	-0.16
	High school dropouts	-0.23	-0.27	-0.17
	College graduates	-0.06	-0.2	-0.18
Public	Low education	-0.37	-0.27	-0.02
	High school dropouts	-0.33	-0.22	-0.17
	College graduates	-0.27	-0.23	-0.06

Note: The Table reports the average effect on indirect utility function of the pension reform, by group. We use individual counterfactual consumption life-cycle profiles and the simulated retirement behavior under the contributive pension system to compute the indirect utility function in the presence and in the absence of the pension reform.