Taxation of Consumption and Labor Income: a Quantitative Approach *

Francesca Parodi †

Abstract

I quantitatively characterize optimal consumption and labor income taxes in a general framework that allows for partially irreversible durable goods, preference heterogeneity, and horizontal equity goals of the social planner. To do so, I develop and estimate a structural life-cycle model of household consumption, saving, and employment choices. I find that durables should be subsidized in presence of adjustment costs and that heterogeneity in risk aversion leads to non-uniform consumption taxes. Allowing for government's equity concerns, I show that the model rationalizes the tax practice and that differentiated consumption taxes serve a redistributive purpose jointly with progressive labor income taxes.

JEL Codes: D10, D30, D63, E20, H20, H31, J22

Keywords: Intertemporal Household Choice, Consumption, Durable goods, Saving, Labor Supply, Efficiency, Optimal Taxation, Inequality, Welfare

*I am grateful to Richard Blundell, Mariacristina De Nardi, and Orazio Attanasio for their invaluable advice and support. I also thank Monica Costa Dias, Eric French, Hamish Low, Costas Meghir, Cormac O'Dea, Luigi Pistaferri, Kjietil Storesletten, Alessandra Voena, as well as seminar participants at UCL, IFS, CCA, EIEF, Stockholm IIES, NYU, NYU Stern, New York Fed, McGill, Wisconsin-Madison, Bank of Spain, and University of Oxford for their helpful comments. I gratefully acknowledge financial support from the ESRC (PhD Studentship). The views expressed in this paper are those of the author and do not involve the responsibility of the Bank of Italy and ISTAT. This paper was previously circulated under the title "Taxation of Durables, Non-durables and Earnings with Heterogeneous Preferences". All errors are my own.

†Collegio Carlo Alberto, University of Turin, Institute for Fiscal Studies. francesca.parodi@carloalberto.org

1 Introduction

Consumption and personal income taxes are key policy instruments. They are the two major sources of government revenues, raising about 21% and 24% of total revenues on average in OECD countries, with substantial differences across nations. On the one hand, these instruments are defining elements of governments' redistribution and social insurance policies. By lowering the tax rates on basic consumption goods and increasing the progressivity of personal income taxes, governments aim to diminish inequality and to protect households against adverse economic shocks. On the other hand, differential consumption tax rates, together with the level and progressivity of income taxes, distort consumption choices among different categories of goods and change the incentives to work, especially for the second earner of the household[1]. Moreover, from an intertemporal perspective, both consumption and labor income taxes affect credit constraints and distort saving decisions.

Given the relevance of these two tax instruments and the incentive-insurance trade-offs that they generate, how should the government tax households' expenditures in different consumption goods and labor income? The prescriptions of optimal taxation theory in terms of direct and indirect taxation are in sharp contrast with the tax systems implemented in reality. The uniform commodity taxation theorem by Atkinson and Stiglitz (1976), one of the most influential results in Public Economics, implies that differentiated consumption tax rates are not needed if an optimal non linear income tax is in place. Yet, in practice, most countries heavily rely on differentiated commodity taxation even if they have sophisticated progressive income tax systems.

In order to bridge this gap between tax theory and tax practice, in this paper I quantitatively characterize the optimal consumption and income tax rates in a general framework that relaxes the key assumptions of the Atkinson-Stiglitz theorem that could be driving the uniform commodity taxation result. My empirical framework deviates from the original Atkinson-Stiglitz setting along three main dimensions. First, I allow for multiple consumption goods with different degrees of necessity and durability. In particular, I include durable goods that are partially irreversible and enter the borrowing constraint. Second, I consider rich preference heterogeneity. Third, I take into account horizontal equity objectives of the social planner.

Taking these aspects of reality into account is crucial for studying the design of direct and indirect taxation in a meaningful way. Indeed, household consumption consists of different categories of goods and expenditures in these different consumption goods varies over the life-cycle and across income levels. Specifically, durables represent both a consumption good, from which the household derives utility over time, and a saving device, that can be used to smooth consumption against uncertainty. Depending on the composition of their consumption

[1]See Bick and Fuchs-Schündeln (2018) for a cross-country comparison of consumption taxes and non-linear labor income taxes and their impact on households' labor supply decisions.

basket, households are differently affected by taxation. Moreover, even conditionally on having the same income, different households may react very differently to the same tax reform because they have heterogeneous preferences, such as patience and risk aversion, that drive their consumption, saving and labor supply choices. Lastly, governments might take fairness concerns into consideration and, therefore, choose the mix of direct and indirect taxation that redistributes in favour of the group that is deemed as the most deserving according to certain characteristics, such as coming from a disadvantaged background or having low disposable income, that are endogenous to the tax system itself.

In order to conduct this quantitative analysis, I develop a structural life-cycle model that features the key elements needed, while preserving computational tractability. In the model, households consume two categories of non-durable goods - necessities and luxuries - and consumer durables that are partially irreversible. Households also make an extensive margin labor supply choice for the second earner that affects the utility derived from consumption. Households make their decisions in a context of uncertainty in earnings of both spouses and fertility dynamics. To self-insure against these shocks, they save and borrow in risk free financial assets subject to credit constraints, buy and sell consumer durables and use them as collateral for borrowing, and adjust the labor market participation of the second earner. These self-insurance channels are complemented by publicly provided social insurance through a progressive labor income tax and proportional consumption taxes with differentiated rates.

The model is estimated on survey micro data for a representative sample of Italian household using a two step procedure. In the first step, I estimate preferences for the intratemporal static choice among different categories of non-durables. While, in the second step, I estimate preferences for intertemporal consumption, saving, and labor supply choices, as well as parameters governing durables' dynamics. Households are ex ante heterogeneous in their education level, as a proxy of their socio economic status, which affects their intra- and intertemporal preferences and the stochastic processes for earnings and fertility that they face over the life cycle. A further source of heterogeneity comes from households' initial endowments of durables, assets and income, which are drawn from the empirical distribution observed in the micro data.

Using the estimated model, I conduct a quantitative normative analysis of the optimal tax rates on different consumption goods and labor income. Similarly to Heathcote et al. (2017), I restrict the social planner's search for optimal tax rates to four parameters – tax rates on the three different consumption categories and either level or progressivity of income tax – for computational tractability. This approach allows me to empirically test the robustness of the uniform commodity taxation in a more general and realistic framework, to quantify the relative importance of competing mechanisms suggested by the public finance theory, and to rationalize the tax practice.

The optimal tax system is derived under three alternative scenarios. In the first scenario, the social planner is utilitarian and household preferences are homogeneous. In the second scenario, the planner is utilitarian, but household preferences are heterogeneous. In the third scenario, household preferences are heterogeneous, but the planner maximizes a social welfare function that takes into account inequality aversion in the spirit of generalized social marginal welfare weights by Saez and Stantcheva (2016). More informative than the numbers obtained from this quantitative normative exercise – which should be interpreted as approximations as they are based on estimated parameters – are the qualitative results and the quantitative mechanisms that emerge from the analysis.

I find that under utilitarian scenarios the uniform commodity taxation result fails for durables that turn out to be subsidized, and therefore taxed differently from other consumption goods, both under homogeneous and under heterogeneous preferences. The role of durables is twofold and, therefore, theory makes contrasting predictions regarding their optimal taxation. On the one hand, durables are a saving tool that can be used to smooth consumption, similar to capital. As such, they should be taxed according to both Ramsey literature (Conesa et al. (2009)), where capital taxation is an imperfect substitute for missing age-dependent taxation, and to Mirrleesian literature, where capital is taxed so to incentivize labor supply in context of imperfect information about effort.

On the other hand, durables are consumption goods to which agents have to commit to before the realization of future shocks. Given this feature, Cremer and Gahvari (1995) suggest they should be subsidized so to incentivize risk averse agents to consume them in presence of uncertainty, while Koehne (2018) finds they should be taxed less than non-durables, if they are complement to them, so to provide intertemporal incentive to supply labor. Thanks to my empirical framework, I can conclude that the pre-commitment consumption good mechanism quantitatively prevails on the saving tool mechanism under utilitarian scenario.

Allowing for preference heterogeneity, I show that the uniform commodity taxation result fails also for non-durable goods. The implicit social welfare weights that the utilitarian social planner attaches to individuals' utility coincide with the marginal utility of consumption – or expected marginal value of wealth in an intertemporal setting. Therefore, consumption-saving preference heterogeneity changes the ranking of utilitarian social welfare weights along the income distribution and the direction of redistribution, that depends on the correlation between preferences and education (as a determinant of income). While existing literature focused on one-dimensional heterogeneity in consumption-saving preferences[2], the rich preference heterogeneity in my estimated model allows me to assess the relative importance of multiple dimensions of heterogeneity and to show that heterogeneity in risk aversion is quantitatively more important in driving the failure of the uniform commodity taxation result.

[2]For instance, Golosov et al. (2013) look at the impact of heterogeneity in discount factor on optimal capital income taxation.

Lastly, departing from the assumption of utilitarian planner and allowing for a social welfare function that takes into account horizontal equity objectives by weighing households' expected lifetime utilities with weights that are decreasing in households' expected lifetime disposable income, I can rationalize the current tax systems implemented across countries and show that differentiated commodity taxes, and in particular higher tax rates on durables, play a redistributive role jointly with progressive income taxes.

This paper relates to three main strands of the literature. The model builds on the extensive Micro and Macro literature on dynamic life cycle models. On the one hand, I borrow elements from structural life cycle models of consumption and female labor supply decisions in presence of uncertainty (Blundell et al. (2016b), Blundell et al. (2016a), Attanasio et al. (2018)). On the other hand, my model is closely related to the literature on two-asset life cycle models. In particular, my framework is similar to the liquid-illiquid assets model in Kaplan and Violante (2014) and to the models of Fernandez-Villaverde and Krueger (2011) and Berger and Vavra (2015) that allow for saving in financial assets and durables. To my knowledge, this is the first paper that combines a two-asset structure with endogenous labor supply choice within an estimated life cycle model.

The quantitative normative analysis contributes to the Ramsey-style literature that concerns the design of optimal tax systems in heterogeneous-agents incomplete-markets economies. İmrohoroğlu (1998) conducts a quantitative analysis of optimal capital income taxation. Benabou (2002) investigates the effects of progressive income taxes and redistributive education finance on efficiency and inequality. Conesa et al. (2009) quantitatively characterize optimal income and capital taxation over the life cycle. More recently, Heathcote et al. (2017, 2020) focus on the optimal degree of progressivity of labor income taxes. This literature has so far neglected the interaction between differentiated consumption tax rates and progressive labor income taxes that I focus on.

The quantitative approach to optimal taxation adopted in this paper complements the vast public finance Mirrleesian static, and more recently dynamic, literature on the optimal mix of direct and indirect taxation. Studies in this literature have extended the Atkinson-Stiglitz framework in various alternative directions. Among others, Cremer et al. (2001) allow individuals to differ in their initial endowments. Golosov et al. (2003) consider a dynamic setting in which skills evolve stochastically over time. Cremer and Gahvari (1995) and, more recently, Koehne (2018) look at pre-committment goods. Saez (2002), Diamond and Spinnewijn (2011) and Golosov et al. (2013) focus on preference heterogeneity. Thanks to the estimate model in this paper, I am able to quantify the effects of the mechanisms at play and relate them to existing theoretical predictions.

The remainder of the paper proceeds as follows. Section 2 outlines the model. Section 3 describes the data and the policy environment. Section 4 explains the estimation procedure and presents the estimated parameters. Model fit and validation are discussed in Section 5 together with simulated elasticities. In Section 6, I use the estimated model to perform the quantitative optimal tax policy analysis. Section 7 concludes.

2 The model

The model features consumption, saving, and female labor supply decisions in a unitary life-cycle framework. Households, denoted by i, start their economic life at age $t_0 = 30$, the first time period in the model. Retirement is exogenous and takes place with certainty at age $T_{ret} = 60$. After retirement, households face an exogenous age-education specific probability of death up to the maximum age $T = 85$[3]. Each household can consist of two spouses or of two spouses with one or more children. I do not model singles and changes in marital status, but I allow for the family composition to change as a consequence of the birth of a child.

One period in the model corresponds to one year in real life and the timing of events goes as follows. Households of working age start each period with a stock of assets and a stock of durable goods. They draw realisations of the stochastic processes for husband's wages, wife's wages and family composition for the current period[4]. Then, they choose whether or not the wife should participate to the labor market and they make the consumption-saving decision. During retirement, households face no idiosyncratic shocks and make no participation decisions.

Households in the model belong to three different types, based on their education level at the start of working life: secondary or high school drop out, high school, college. Type is exogenously determined by age 30, when they enter the model, and remains fixed over the life cycle. Husband and wife in the household are assumed to be of the same education level[5]. Both intra- and intertemporal preferences for consumption, saving and work are heterogeneous across education types. The stochastic processes for husband's and wife's labor income and for family composition are also education-specific[6].

[3]For computational simplicity, husband and wife are assumed to be of the same age and to die together.

[4]For computational simplicity, these three idiosyncratic stochastic processes are assumed to be independent of each other, except for correlation in the initial conditions.

[5]This assumption is justified by the data, where more than 70% of women in the sample are married to a man with their same education level. Allowing for spouses of different education levels would add complexity to the model.

[6]An additional source of heterogeneity across households comes from the fact that their initial endowments of education, financial assets, durables, wages and family composition are drawn from the empirical distribution, as described in Appendix D.

2.1 Household problem and Preferences

One of the distinctive features of the model is the consistent integration of an intratemporal static demand analysis for multiple non-durables with an intertemporal dynamic model for durables. The idea of nesting a static demand system within an intertemporal substitution problem has been introduced by Blundell et al. (1994). Here I extend this approach by applying it to a heterogeneous-agent structural life-cycle model. I now turn to describing in detail the household's decision problem and preferences.

In each period, households maximize life-time expected utility and choose wife's labor supply, l_t, consumption of non-durables necessities, $c_{1,t}$, consumption of non-durable luxuries, $c_{2,t}$, next period durables stock, d_t, and next period financial assets stock, a_t:

$$\max_{l_t, c_{1,t}, c_{2,t}, d_t, a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} U(c_{1,t}, c_{2,t}, d_t, l_t) \tag{1}$$

Assuming that preferences are weakly separable between non-durables and durables, on the one hand, and between non-durables and female participation, on the other hand, I can model the consumption-saving decision as consisting of two stages. First, households decide how to allocate their total resources among non-durable bundle, durables, and financial asset savings. Second, they choose how to divide the total expenditure on non-durables between the two non-durable categories: necessities and luxuries. The first stage of the consumption-saving decision exclusively depends on intertemporal preferences as the non-durable consumption choice is jointly determined with durables and assets, that are inherently dynamic choices. On the other hand, the second stage is static and depends only on intratemporal preferences between the two non-durables.

Gorman (1971) two-stage budgeting result implies that the intratemporal non-durable problem is completely characterized by the consumer indirect utility function - the maximum level of utility achieved by optimally allocating a given level of total expenditure on non-durables (c_t) between two non-durable categories for a given vector of non-durable prices (P_t) - up to a monotonic transformation. Therefore, the household problem can be restated so that the direct utility from the two non-durables is replaced by the corresponding indirect utility, $v(c_t, P_t)$, thus linking intra- and intertemporal decisions in a coherent way:

$$\max_{l_t, c_t, d_t, a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} U(v(c_t, P_t), d_t, l_t) \tag{2}$$

The assumption of weak separability simplifies the solution and estimation of the model, but imposes that the effect of durables and female participation on the demand for non-durable subcategories is completely captured by non-durable total expenditure. I will test this implication in the estimation section of the paper.

Intertemporal preferences. Life cycle utility is intertemporally separable and instantaneous utility at each period t is a CRRA:

$$U(v(c_t, P_t), d_t, l_t) = \frac{[(v(c_t/n(k_t), P_t))^{\theta}(\delta d_t - \epsilon^d)^{1-\theta}]^{1-\gamma}}{1-\gamma} exp(\Psi(l_t, k_t)) \tag{3}$$

Where, $v(c_t, P_t)$ is the indirect utility capturing the optimal decisions of the intratemporal non-durable stage of the model as a function of equivalized total expenditure and prices.

In order to capture household's changing needs over time and economies of scale in consumption depending on the number of households' members, total non-durable consumption expenditure is adjusted by an equivalence scale that is a function of stochastic family composition $n(k_t)$[7]. The parameter γ is the coefficient of relative risk aversion and θ is the weight of non-durable goods in utility.

Per period preferences are assumed to be non homothetic in non-durables and durables. In particular, I choose a Stone-Geary specification which allows for the introduction of additional heterogeneity, as suggested by Hoynes (1996). By allowing durables and non-durables expenditure shares to change as total expenditure varies, the parameter ϵ^d captures the degree to which durables are luxury goods. A negative value of ϵ^d, as the one I will find in estimation, implies that utility is well defined even when the service flow of durables is zero. The more negative ϵ^d is, the more of a luxury durables are. The household derives utility from the service flow of durables, which, as common in this literature, is assumed to be a constant proportion, δ, of the durables stock in each period.

The marginal utility from consumption of non-durables and from the service flow of durables depends on whether the wife works ($l_t = E$) or not ($l_t = NE$) in the current period[8]. Since $(1-\gamma)$ will be negative, a positive Ψ implies that having the wife working reduces household's utility from consumption, both non-durable and durable, and that consumption and female labor supply are complement. The degree of complementarity between consumption and female participation varies depending on whether there are children in the household and on whether the youngest child is of pre-school age, as captured by the dummy k (0 if no children, 1 if youngest child is 0 to 5 years old, 2 if youngest child is older than 5). Hence, Ψ is specified as follows:

[7]The equivalence scale adopted (from Italian National Statistical Institute) takes value .60 for household of 1 member, 1 for 2 members, 1.33 for 3 members, 1.63 for 4 members, 1.90 for 5 members, 2.16 for 6 members and 2.40 for more.

[8]I chose not to model the intensive margin labor supply decision of the wife because in the SHIW data less than 14% of working women work part-time.

$$\Psi(l_t, k_t)) = \begin{cases} 0 & \text{if } l_t = NE \\ \psi_0 \times \mathbf{1}(k_t = 0) + \psi_1 \times \mathbf{1}(k_t = 1) + \psi_2 \times \mathbf{1}(k_t = 2) & \text{if } l_t = E \end{cases} \quad (4)$$

This specification is similar to that in Blundell et al. (2016a) and is justified by existing literature suggesting that the evolution in family composition influences preferences for consumption, wealth and, especially, female labor supply over the life cycle (Attanasio et al. (1999)). Also, there is empirical evidence showing that, at all education levels, women's labor force participation sharply drops during the first five years after childbirth (Costa Dias et al. (2018)).

Intratemporal preferences. I do not impose a specific functional form on the intratemporal direct utility from non-durable consumption. Instead, I model the indirect utility, $v(.)$, of the dual problem[9] following Deaton and Muellbauer (1980) Almost Ideal Demand System (AIDS) formulation. The advantage of this demand system rests in its great flexibility. Indeed, AIDS can nest different types of preferences, including non-homothetic preferences that are needed to classify goods as necessities or luxuries, without imposing restrictions on the direct utility functional form. A more detailed description of this model is reported in Appendix A. The AIDS functional form for the indirect utility function in the intratemporal problem is:

$$v(c, P) = exp\left\{\frac{ln(c) - ln(a(P))}{b(P)}\right\} \quad (5)$$

$$ln(a(P)) = \alpha_0 + \sum_{i=1}^{n} \alpha_i lnp_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \eta_{ij} lnp_i lnp_j \quad (6)$$

$$b(P) = \prod_{i=1}^{n} p_i^{\beta_i} \quad (7)$$

where, c is (equivalized) total budget for non-durable consumption in the two $(n = 2)$ non-durable categories. P is the vector of prices including taxes. $a(P)$ is the price index and is homogeneous of degree one. $b(P)$ is the Cobb-Douglas price aggregator and is homogeneous of degree zero.

[9] the corresponding primal problem is:

$$\max_{c_1, c_2} u(c_1, c_2) \qquad s.t. \qquad (1 + \tau_1^n)\tilde{p_1}c_1 + (1 + \tau_2^n)\tilde{p_2}c_2 = c$$

where, $p_1 = (1 + \tau_1^n)\tilde{p_1}$, $p_2 = (1 + \tau_2^n)\tilde{p_2}$ and $P = [p_1, p_2]$ is the vector of non-durable prices inclusive of the consumption tax rates.

2.2 The environment

Durables. Households can adjust their durables stock d by buying or selling[10]. When the household buys, it has a positive durables' flow and must pay the consumption tax on durables τ^d. When the household sells, it experiences a negative flow and faces a proportional adjustment cost $1-\pi$. This adjustment cost captures the fact that a fraction $1-\pi$ of the durable stock is an irreversible investment for the household as it has no second hand market due to Akerlof's Lemons problem[11]. This feature of the model allows to capture the varying degree of irreversibility of the different components of the durables stock that is observed in the data and, therefore, to better represent the constraints faced by households. To capture this non-convexity in durables price I specify:

$$D(x_t) = \begin{cases} (1+\tau_c^d) & \text{if } x_t \geq 0 \\ \pi & \text{if } x_t < 0 \end{cases} \tag{8}$$

Where, x represents durables' flow. Durables stock depreciates at the constant rate δ [12]. I assume the absence of a rental market for durable goods. This is a reasonable assumption, given that I only model consumer durables and abstract from housing. Hence, the durables law of motion is:

$$d_t = (1-\delta)d_{t-1} + x_t \tag{9}$$

Financial assets. Households can also save and borrow in a risk-free financial asset whose associated interest rate is r. As in the setup of Aaronson et al. (2012), agents can borrow up to a fraction χ of their durables stock in each period, implying a role of durables as collateral, in particular for consumer credit and car loans. Unlike durables, the stock of financial assets can be adjusted at any time without paying any transaction costs. Hence, similar to Kaplan and Violante (2014), households can store wealth in two types of instruments: liquid financial assets and partially illiquid durables, that also provide consumption utility.

Earning processes. The processes governing the two spouses' labor income are assumed to differ across education level of the household. The logarithm of gross earnings at age t of spouse g is modelled in the following way:

$$lny_t^s = f^g(X,t) + \tilde{y}_t^g \tag{10}$$

[10]For simplicity I assume that each household is either a net seller or a net buyer (with the limit case of inaction) in each period. This assumption is supported by the data (see Appendix B.5).

[11]While for precious objects and, partly, for cars it is easy to have an external appraisal, this is not the case for furniture and household appliances

[12] In this model the rate of durables depreciation and the rate of durables service flow must coincide as they both represent the loss of value of durables stock due to usage, but not the loss of value for resale or collateral purposes represented by π and χ in the budget and borrowing constraints, respectively.

$$\tilde{y}_t^g = z_t^g + \varepsilon_t^g \tag{11}$$

$$z_t^g = \rho^g z_{t-1}^g + u_t^g \tag{12}$$

$$\varepsilon_t^g \sim N(0, \sigma_{\varepsilon^g}^2), \qquad u_t^g \sim N(0, \sigma_{u^g}^2), \qquad z_0^g \sim N(0, \sigma_{z_0^g}^2)$$

where, f captures the deterministic component as a function of age and demographic characteristics of the household, X, and $\tilde{y}$ is the stochastic component, which accounts for the dynamics in earnings that remain unexplained after removing the deterministic component. The stochastic component consists itself of a persistent shock, z, that is modelled as an AR(1) with persistency ρ and innovation u, and of a transitory shock, ε, that is assumed to be measurement error and does not affect household's decisions. The transitory shock, the innovation to the AR(1) process and the initial productivity shock are assumed to be iid Normal with zero mean and estimated variances. During retirement, the two spouses face no labor income shocks and the household receives a yearly pension benefit that is a fixed proportion, ζ, of husband's earnings in the last period of work.

Family composition. The presence and age of children in the household is driven by an exogenous stochastic process that can take three possible realisations - no children, youngest child is 0 to 5 years old, youngest child is older than 5 - and evolves according to education-age specific transition probabilities estimated from the data. The transition probability during working age is given by

$$Prob[k_t | k_{t-1}, t, s] \quad \forall t < T_{ret}$$

During retirement, there are no dependent children in the household and all uncertainty about family composition is resolved. This parsimonious way of modelling household's composition allows me to embed uncertainty from unanticipated family dynamics into the model while keeping it computationally tractable.

2.3 The government

The government levies proportional consumption taxes and non linear progressive labor income taxes at the individual level. Proportional consumption taxes – τ^{n1}, τ^{n2}, τ^d – can differ across consumption categories. The progressive labor income tax regime is approximated by the non linear tax-transfer function proposed by Benabou (2002) and is allowed to depend on family composition, as follows:

$$y^{net} = T(y^{gross}, k) = \lambda_k (y^{gross})^{1-\tau_k^y} \tag{13}$$

Where λ captures the level of taxation and τ^y the degree of progressivity. If $\tau^y > 0$ the tax is progressive, if $\tau^y < 0$ the tax is regressive and $\tau^y = 0$ corresponds to a flat tax with rate $1-\lambda$.

2.4 Recursive formulation

Working age. The state space of the problem during working age has seven dimensions: age, education, financial assets, durables, woman's productivity, man's productivity, family composition. I denote by $F(.)$ the joint distribution of the stochastic exogenous state variables - woman's productivity shocks, man's productivity shock, and family composition shocks - over which the expected value of future utility is computed. Hence, the recursive formulation of the household's problem is:

$$\mathbb{S}_t = \{s, a_{t-1}, d_{t-1}, y_t^f, y_t^m, k_t\}$$

$$V_t(\mathbb{S}_t) = \max_{l_t, c_t, d_t, a_t} \{U(v(c_t, P_t), d_t, l_t) + \beta \int V_{t+1}(\mathbb{S}_{t+1}) dF(y_{t+1}^f, y_{t+1}^m, k_{t+1} | y_t^f, y_t^m, k_t)\} \tag{14}$$

Subject to the durables law of motion, the budget constraint and the borrowing constraint:

$$c_t + D(x_t)x_t + a_t = (1+r)a_{t-1} + T(y_t^m, k_t) + T(y_t^f, k_t) \times \mathbf{1}(l_t = E) \tag{15}$$

$$d_t = (1-\delta)d_{t-1} + x_t \tag{16}$$

$$a_t \geq -\chi d_t \tag{17}$$

Retirement. Retired households do not receive any productivity or family composition shocks, therefore, their state space includes: age, education, financial assets, durables. After age T_{ret}, households face an exogenous survival probability denoted by ϕ. Hence, the recursive formulation is:

$$\mathbb{S}_t^r = \{s, a_{t-1}, d_{t-1}\}$$

$$V_t^r(\mathbb{S}_t^r) = \max_{c_t, d_t, a_t} \{U(v(c_t, P_t), d_t) + \beta\phi V_{t+1}^r(\mathbb{S}_{t+1}^r)\} \tag{18}$$

Subject to (16) and (17) and to the retirement specific budget constraint:

$$c_t + D(x_t)x_t + a_t = (1+r)a_{t-1} + T(\zeta y_{T_{ret}-1}^m, 0) \tag{19}$$

3 Data and Policy environment

3.1 The Data

I use two data sets: the Bank of Italy Survey on Household Income and Wealth (SHIW) and the Italian National Institute of Statistics Household Budget Survey (ISTAT HBS). Details on both dataset and on sample selection are are in Appendix B.

The SHIW is a longitudinal dataset collecting information on income, wealth and consumption for a representative sample of Italian households. The non-durable consumption measure definition includes expenditures in food, clothing, entertainment, medical expenses, housing repairs and imputed rents[13]. SHIW collects information on three categories of durable goods: vehicles (such as cars, caravans, motorbikes, bicycles, boats), furniture (such as household electrical appliances and furnishings), jewellery (including jewellery, antiques, old coins and other precious objects). Households are asked to report the value of the stock and of the flow for each category (except for furniture).

Table 1: Mean durables flows and stocks (euros), SHIW

	Value of stock	Value of purchase	Value of sale
Vehicles	10,669.80	1,894.62	221.67
	(11,984.44)	(5,961.74)	(1,498.30)
Furniture	14,289.48	827.86	
	(16,767.61)	(2,816.99)	
Jewelry	4,884.12	168.31	16.02
	(17,537.89)	(1,999.85)	(560.71)

standard deviations in parentheses

ISTAT HBS is the most comprehensive cross sectional expenditure survey in Italy. It collects detailed information on the consumption of all commodities at the level of each single item purchased by the household during an average week and allows me to disaggregate non-durable consumption into its subcomponents according to their differential treatment in terms of consumption tax rates. I classify as non-durable necessities those goods that are currently taxed at the lowest rate (4%) and as non-durable luxuries those that are taxed at the intermediate rate (10%)[14]. Necessities include food at home, books and newspapers and some medical expenses. Luxuries include food away from home, hotels and holidays, housing repairs and additions, entertainment and personal care services and goods .

[13]while the PSID only started collecting data on non-durable consumption other than food since 1999, the non-durable consumption measure definition in SHIW has remained the same since its very first wave.

[14]The composition of the groups of goods taxed at the different rates was not subject to any relevant reforms over the period covered in the data.

Table 2: Average expenditure shares (%) in main non-durables categories, HBS

necessities		luxuries	
1. Food at home	90.04	1. Food away from home	63.28
2. Books and newspapers	8.62	2. Housing repairs	21.11
3. Medical expenses	1.34	3. Personal care	8.65
		4. Holiday and travel	4.61
		5. Entertainment	2.36
total	34.40	total	65.60

3.2 Policy environment

Here I describe the tax instruments of the Italian policy environment in year 2014 (the last wave of my data) that represents the baseline scenario for the estimation and the quantitative optimal taxation experiments in the next sections.

Consumption taxation. The value added tax (VAT) is the most important indirect tax in the Italian system. The tax base of VAT is the total business value added minus investment expenses, and therefore coincides with the value of final consumption. The tax regime consists of three rates: a reduced rate of 4% which applies to non-durable necessities, such as food consumed at home, books and newspapers and medical expenses; an intermediate rate of 10% applying to other non-durables and services such as food away from home, housing repairs, personal care, holidays and travel and entertainment; a standard rate of 22% on all other goods, mainly durables (e.g. cars and household appliances) and semi durables (e.g. clothing). Also, some exemptions apply for health and educational services.

Unlike in the US system, where sales taxes are not salient, the VAT is salient as it is included in all posted prices. In my analysis I assume full pass-through of changes in value added tax rates to the final consumer. This assumption simplifies the computational experiments and is supported by empirical evidence (see, for instance, Poterba (1996)).

Labor income taxation. The personal income tax is the main direct tax. Its tax base includes labor income from employment and self-employment, pensions, property incomes, agricultural income, and other non-work and non-pension incomes (e.g. unemployment benefits). Some tax allowances can be deducted from the tax base. They include social security contributions, contributions to private pension plans by employees and self-employed individuals, and the cadastral value of the main residence.

The tax unit is the individual and the tax schedule - applied to the tax base net of tax allowances - is progressive, with higher tax rates applying to higher income brackets (see Appendix C). Although the same tax rates apply to all individuals, different tax credits are granted to different individuals depending on their family composition and income sources. Tax credits for dependent family members are decreasing in individual gross income and depend on the presence of spouse and other family members in the household and on the age and number of dependent children. Tax credits for income sources apply differently to employees, self-employed workers and pensioners. They decrease linearly with individual gross income and are zero above 55,000 euros of annual income. These tax credits increase the progressivity of the system and are based on horizontal equity concerns. Differently from the US and UK systems, all tax credits are non-refundable, therefore the tax liability cannot be negative.

The income tax system also features some means-tested benefits. The most important class of benefits are family allowances that are paid to families of employees and pensioners below a certain threshold of family income that depends on family composition and size. In this study, I adopt an approximation to the actual income tax-benefit system and I focus on taxation of labor income only. Hence, my measure of gross income consists of labor income net of deductible allowances and before taxes, while my measure of net income coincides with gross income net of taxes and inclusive of family allowances.

4 Estimation

I follow a two-step procedure to estimate the parameters of the model[15]. In the first step, I estimate the preference parameters governing the within-period static household's decision problem of how to optimally allocate non-durable expenditure among different subcategories. In the first step, I also estimate the predetermined elements of the model: male earning process, family composition dynamics, and non linear labor income tax function. Given the estimates of the first step, in the second step I estimate the structural parameters determining household's intertemporal preferences, the wife's earning process, and durables dynamics using the method of simulated moments (MSM).

4.1 First step

Here, I focus on the estimation of the intratemporal demand system. The other first step estimation procedures and results are standard in this literature and are reported in Appendix F.1.

Intratemporal demand system. To estimate the preference parameters that rationalize households' intratemporal allocation decision among different non-durable subcategories, I estimate the Almost Ideal Demand System defined in Section 2. Applying Roy's identity to

[15]This procedure is commonly adopted in the estimation of structural life cycle models to reduce computational complexity, see for instance Gourinchas and Parker (2002) and French (2005).

the indirect utility function in (5), the following demand system estimation equations can be derived:

$$w_{it} = \alpha_i + \sum_{j=1}^{k} \eta_{ij} ln p_{jt} + \beta_i ln \left\{ \frac{c_t}{a(p)} \right\} + e_{it} \tag{20}$$

Where, i denotes the i^{th} good and t indexes the observation. The expenditure share in good i, w_{it}, is a function of prices inclusive of taxes, p_{jt}, total non-durable expenditure in equivalent terms, c_t, and the preference parameters α, β and η to be estimated. the term e_{it} captures unobservable components in demand and I assume it to be measurement error. Some restrictions on the estimating parameters must hold in order for the demand system to be consistent with utility maximization. $\sum_{i=1}^{k} \alpha_i = 1$, $\sum_{i=1}^{k} \beta_i = 0$, $\sum_{j=1}^{k} \eta_{ji} = 0$ must hold to satisfy adding-up, while $\sum_{j=1}^{k} \eta_{ij} = 0$ is required to satisfy homogeneity.

Equations in (20) are estimated by education on HBS repeated cross sections data[16] using the iterated linear least squares estimation strategy suggested by Blundell and Robin (1999). Total expenditure in non-durables on the right hand side of (20) is likely to be correlated with the error term as the dependent variable, which is correlated to the error term by construction, features total expenditure at the denominator. To correct for this potential endogeneity problem, I use a grouping estimator strategy[17]. I use demographics (year, region of residence and age of the head of household) as grouping variables and assume that group membership affects expenditure shares only indirectly through its effect on total expenditure.

Given the model assumption of weak separability in preferences between non-durable consumption and female labor supply and between non-durable consumption and durable consumption, conditioning variables for female participation and durables stock are excluded from the regression equations in (20). Following Browning and Meghir (1991), I test for separability between non-durable consumption and female participation and find that, once controlling for education, the unconditional demand system is not rejected (results in Appendix F.3)[18]. This result supports the model assumption that the effect of participation and durables on non-durable subcategories is completely captured by non-durable total expenditure.

Tables 3 and 4 show that β parameters are highly significant, suggesting rejection of homotheticity. Indeed, non-durables taxed at 4%, c_1, are confirmed to be necessities and non-durables taxed at 10%, c_2, to be luxuries because their budget elasticities are smaller and greater than one, respectively. Compensated own-price elasticities are negative for both goods as predicted by the theory. Looking across education levels, expenditure shares and budget elasticities of

[16]The price data, that are not included in HBS household consumption survey, are obtained from ISTAT Consumer Price Index database. I use price data disaggregated at the regional level in order to create further variability.

[17]Ideally, one would correct this endogeneity problem by instrumenting total expenditure with earnings. Unfortunately, HBS does not contain information on household earnings or income.

[18]I cannot test for non separability between non-durable bundle and durable consumption because of lack of data on durables stock in HBS.

Table 3: AIDS estimated parameters by education

	Secondary	High School	College
α_1	0.5774	0.6156	0.7918
	(0.0312)	(0.0314)	(0.0350)
β_1	-0.0269	-0.0319	-0.0516
	(0.0036)	(0.0036)	(0.0039)
η_{11}	0.0087	0.0179	0.0564
	(0.0186)	(0.0195)	(0.0279)
N	2,238	2,260	2,110

Standard errors in parentheses

Table 4: Predicted expenditure shares, budget and price elasticities

	shares	budget elasticity	p_1 elasticity	p_2 elasticity
Secondary				
share c_1	0.344	0.922	-0.613	0.613
	(0.001)	(0.010)	(0.053)	(0.053)
share c_2	0.656	1.041	0.321	-0.321
	(0.001)	(0.005)	(0.028)	(0.028)
High school				
share c_1	0.332	0.904	-0.587	0.587
	(0.001)	(0.011)	(0.058)	(0.058)
share c_2	0.668	1.048	0.292	-0.292
	(0.001)	(0.005)	(0.029)	(0.029)
College				
share c_1	0.326	0.842	-0.428	0.428
	(0.001)	(0.012)	(0.084)	(0.084)
share c_2	0.674	1.077	0.207	-0.207
	(0.001)	(0.006)	(0.041)	(0.041)

Standard errors in parentheses

non-durable luxuries are higher for more educated households. Own price compensated elasticities are larger for low education households, suggesting that their demand for both non-durable categories are more responsive to price changes.

The estimation of the parameters of the demand system on the two non-durable subcategories provides estimates of the price indices in (6) and (7), which are the arguments of the indirect utility of the intratemporal consumption problem together with the total expenditure in non-durables chosen in the intertemporal model. Therefore, they represent the link between the within-period choice and the between-period choice.

4.2 Second step

Method of simulated moments estimation. Parameters of Household's intertemporal preferences, women earning process and durables dynamics are estimated on SHIW data using the MSM[19]. Interest rate is exogenously set at 2%.

The second step estimation procedure is the following. For a given set of initial values of the estimating parameters, I solve the life cycle model and obtain optimal decision rules for non-durable consumption, durable consumption, saving in financial assets and female participation. I then use these decision rules to simulate life cycle choices of households. I initialize the simulations drawing values of the relevant state variables from the data distribution (details on solution and simulation are in Appendix D). I compute the same set of moments in the data and in the simulated panel and iteratively search for the parameter values that minimize the weighted distance between empirical and simulated targeted moments. More precisely, the estimated parameters, $\hat{\Theta}$, are the solution to the following GMM minimization problem[20]:

$$\hat{\Theta} = \arg\min_{\Theta} \left\{ \sum_{k=1}^{K} \left[(m_k^{data} - m_k^{sim}(\Theta))^2 / Var(m_k^{data}) \right] \right\} = \arg\min_{\Theta} \{ g(\Theta)' \Omega g(\Theta) \} \tag{21}$$

where, m_k^{data} denotes the k^{th} data moment computed over N observations in the sample, $m_k^{sim}(\Theta)$ represents the k^{th} simulated moment computed over S simulations as a function of the set of parameters values Θ. $g(\Theta)$ is the Kx1 vector collecting all distances between empirical and simulated targeted moments. These squared distances are weighted by the diagonal matrix Ω whose entries on the main diagonal are the inverse of the variances of the empirical moments. I do not use the asymptotically optimal weighting matrix because of its poor small sample properties, as suggested by Altonji and Segal (1996). Asymptotic standard errors are computed following Gourieroux et al. (1993)[21].

The vector of estimating parameters, Θ, contains education-specific consumption preference parameters $(\theta, \gamma, \beta, \epsilon^d)$, education-specific work preference parameters (ψ_0, ψ_1, ψ_2), education-specific parameters governing wife's earnings process $(f_0, f_1, f_2, \rho, \sigma_u, \sigma_{z_0}, \sigma_\epsilon)$, and parameters governing durables dynamics (δ, π, χ). The moments targeted in estimation are: mean life-cycle profiles (age 30-60) of non-durable consumption, durables, financial assets and female employment rate by education group; OLS coefficients of a regression of female gross earnings

[19]References for this estimation method are Lerman and Manski (1981), McFadden (1989) and Pakes and Pollard (1989).

[20]Minimization is implemented by quadratic approximation (routine e04jcf from NAG library). I experimented starting the algorithm from various initial values to ensure that the minimum found is global.

[21]Estimation of the standard errors of the second step structural parameters takes the parameters estimated in the first step as fixed. Taking into account the variation in first step in estimating second step standard errors is prohibitively demanding in terms of computation time.

on a polynomial in age and moments from the variance covariance matrix of the residuals from this regression by education group; mean ratios between current period durables stock net of durables flow and previous period durables stock, separately for the sub sample of net sellers and net buyers. Overall, I target 383 moments for 45 estimating parameters. Identification is discussed in Appendix E.2.

Parameter estimates. Table 5 reports the estimates of the intertemporal preference parameters. The weight of non-durable consumption in utility, θ, ranges from .79 to .84 across education groups in line with values in the literature (see Aaronson et al. (2012)). High school and college graduates place higher weight on non-durable relative to durable consumption than the lowest education group. This might be explained by the fact that households with higher education have higher initial endowments of durables than the less educated, therefore, ceteris paribus, their marginal utility from an additional unit of durables is lower.

The coefficient of relative risk aversion, γ, varies within the range suggested by the literature for models with non separable utility between consumption and labor (Conesa et al. (2009)). Also, it decreases with education in line with existing empirical evidence [22] suggesting that risk aversion is negatively correlated with higher education. The estimates for the discount factor, β, support the common finding (see Cagetti (2003), among others) that more educated agents are more patient.

The negative values of the Stone Geary coefficient, ϵ^d, suggest that durables are luxury goods and more so for households with lower education. Indeed, a higher (in absolute value) ϵ^d implies a flatter curvature of households' intertemporal preferences for durables, that is, a slower growth of durables consumption share as wealth increases.

The parameters relative to women's participation choice, ψ, are all positive, meaning that working involves a utility cost at all education levels (recall that, according to my specification, utility from consumption is negative). This utility cost is higher for low education households and for households with children.

Unlike the male earning process, the female earning process is estimated inside the structural model, together with the other parameters. Given the low female employment rate in the data and the fact that I only observe wage offers for those women who decided to participate, non-random self selection into employment is a serious concern when it comes to estimating the earning process faced by women. However, the structural approach allows me to account for this problem by replicating the same selection that affects the actual data set in the simulated panel. Hence, in estimation I compare empirical moments computed on the selected sub sample of working women to analogous simulated moments computed on the sub sample of simulated

[22] See Outreville (2015) for a survey of empirical studies on the relationship between relative risk aversion and level of education.

Table 5: estimated preference parameters

	Sec	HS	College	
θ	.7941	.8414	.8217	non-durable consumption share
	(.0024)	(.0023)	(.0031)	
γ	3.56	3.1941	2.7971	coeff. of relative risk aversion
	(.0099)	(.0112)	(.0163)	
β	.9802	.9899	.9955	discount factor
	(.0011)	(.0006)	(.0010)	
ϵ^d	-976	-353	-90	Stone-Geary coeff for durables
	(9.54)	(20.16)	(4.67)	
ψ_0	3.0263	.7741	.4100	female participation: no children
	(14.01)	(.0179)	(.0367)	
ψ_1	.9734	.8226	.6270	female participation: youngest child 0-5
	(.0090)	(.0062)	(.0105)	
ψ_2	.9445	.9426	.6811	female participation: youngest child 6+
	(.0097)	(.0051)	(.0101)	

women who endogenously choose to participate in the model.

Table 6 shows the estimated parameters. The first three parameters, f_0, $f_1$and f_2, characterize the deterministic component of female wage process specified in (10). Interestingly, mean wage at age 30, captured by the intercept f_0, is higher for secondary educated women than for college graduates. This can be rationalized by the fact that at age 30 secondary educated women are likely to have accumulated more experience than college graduates and, therefore, to be offered higher wages. The negative sign of the coefficients on age squared indicates a concave age-efficiency profile of wages at all education levels. The rest of the parameters in Table 6 refer to the stochastic component of the wage process. More educated women face an AR(1) unobserved productivity process with lower persistency, ρ, and higher variance, σ_u, than the less educated.

The estimates of the parameters governing durables' dynamics in Table 7 imply that durables depreciate at the rate of 3% and that about 45% of durables' stock can be sold on the second hand market, while only 9% has collateral value. These three parameters jointly determine the dynamics of durables accumulation over the life-cycle in my model. The higher is the depreciation, the slower is durables accumulation, but also the higher is the frequency of adjustments to the stock. The higher is reversibility and collateral value, the stronger is the incentive to accumulate durables as a smoothing device, and, again, the higher is the frequency of adjustments.

Tables 5, 6 and 7 show that parameters are overall statistically significant. Only parameter ψ_0, capturing disutility from participation for secondary educated non parent women, is not significant at any confidence level due to lack of observations for this subgroup in the sample.

Table 6: estimated female earning process parameters

	Sec	HS	College	
f_0	8.5953	9.1434	8.9207	deterministic component: intercept
	(.0239)	(.0070)	(.0121)	
f_1	0.04	0.022	0.04	deterministic component: age
	(.0003)	(.0004)	(.0008)	
f_2	-0.0005	-0.00015	-0.00035	deterministic component: age squared
	(.000007)	(.00002)	(.00002)	
ρ	0.9801	0.9426	0.8817	AR(1) persistency
	(.0046)	(.0028)	(.0106)	
σ_u	0.1057	0.1180	0.1710	std dev of AR(1) innovation
	(.0068)	(.0018)	(.0100)	
σ_{z0}	0.3684	0.4244	0.40	std dev of initial realization
	(.0128)	(.0092)	(.0272)	
σ_ϵ	0.35	0.26	0.2363	std dev of transitoty shock
	(.0177)	(.0174)	(.0341)	

Table 7: estimated durable dynamics parameters

	All education levels	
δ	.0344	durables depreciation rate
	(.0007)	
π	.4532	fraction of non irreversible durables
	(.0030)	
χ	.0917	fraction of collateralizable durables
	(.0048)	

5 Model fit and implications

5.1 Model fit

The estimated model performs well in reproducing the most important features of the data. First, let us look at the profiles of households' economic choices unconditional of education in Figure 1. The model accurately replicates the mean profiles of durables, non-durable consumption, financial assets and women's employment rate that are observed in the data.

Figure 2 reports profiles by education. Consistently with the data, the simulated paths of accumulation of durables and financial assets over the life-cycle are steeper for higher education groups. The model slightly over predicts non-durable consumption for college educated in the first part of life and under predicts it for secondary educated in middle age. In terms of female employment rate, the model does a good job in replicating the data and shows that participation starts declining around age 40 for all education groups and that more educated women have higher employment rates.

Figure 1: mean life cycle profiles, data vs model

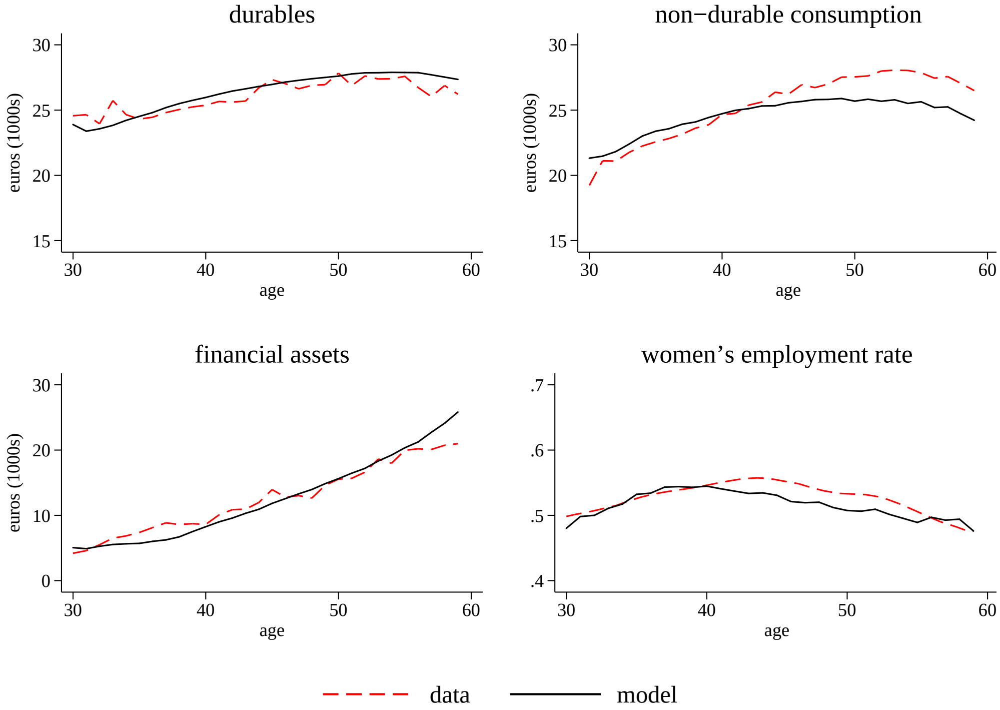


Figure 2: mean life cycle profiles by education, data vs model

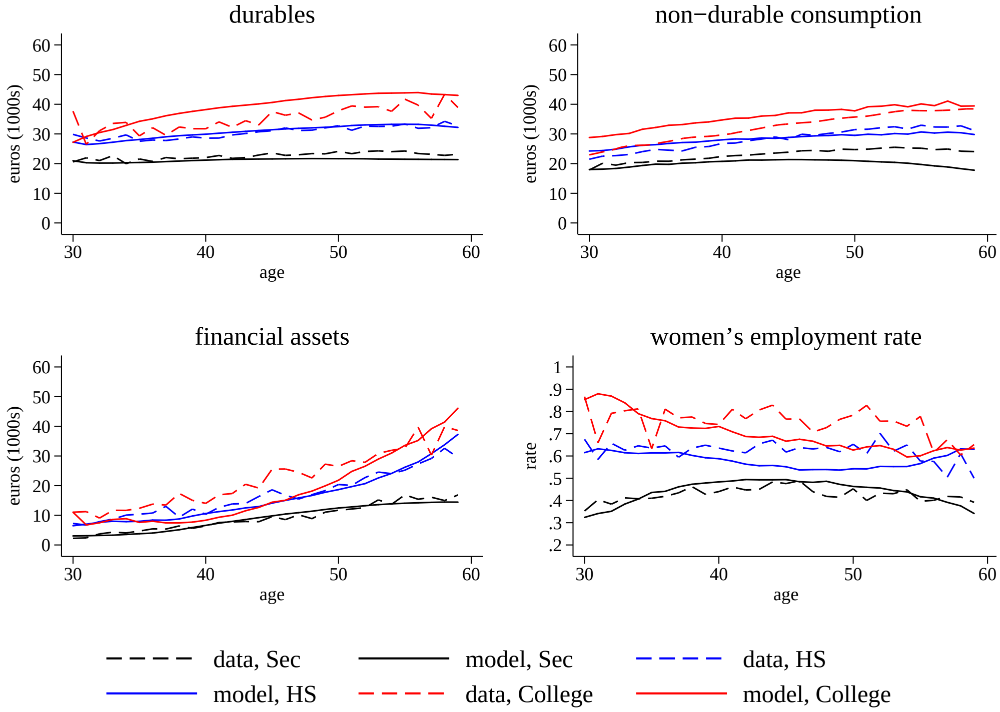


Figure 3: distributions, data vs model

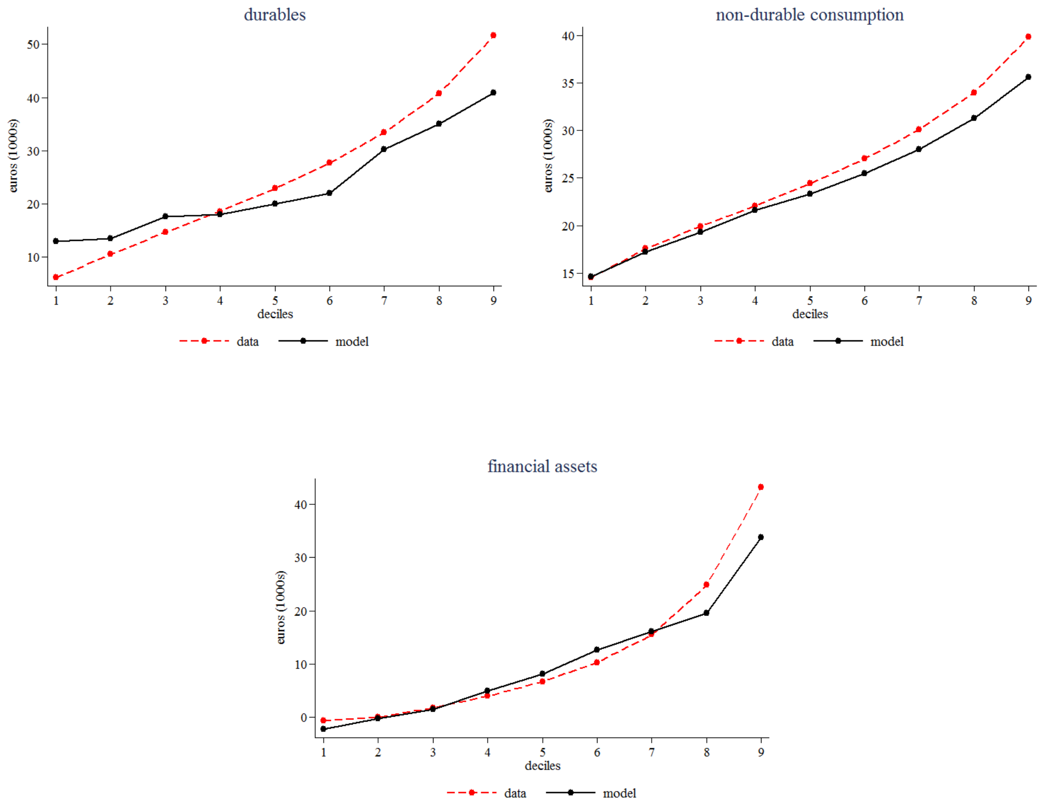


Figure 3 compares the empirical and simulated distributions of durables, non-durable consumption, and financial assets among households of all ages and education levels. These moments are not estimation targets, however the model fits them well too. This is an important validation check for the estimation strategy and it shows that the model generates substantial and realistic heterogeneity across households within and between different socio-economic groups. This heterogeneity is key given that the aim of the paper is to evaluate the redistributive impact of tax policies. Further evidence of fit and validation checks are reported in Appendixes G.3 and G.4.

5.2 Life-Cycle Marshallian Elasticities

I now use the estimated model to simulate elasticities of households' consumption and female participation choices to an increase in prices or net wages. These own and cross price elasticities help me highlighting the main mechanisms of the model and will also guide the discussion of the normative analysis results in the next section. In particular, I focus on life cycle Marshallian elasticities[23] that capture the response to a permanent increase in prices or wages when house-

[23]Marshallian (or uncompensated) elasticities are fundamentally static concepts, but, as discussed by Attanasio et al. (2018) and by Blundell and MaCurdy (1999), they can be adapted to a life-cycle framework if

holds are allowed to save, that is, accounting for wealth effects. Since my aim is to evaluate the long run effects of permanent reforms to consumption and labor income taxes, Marshallian elasticities seem to be the most adequate measure. Also, given the important role of both financial assets and durables as smoothing devices in the model, wealth effects must be taken into consideration when measuring the impact of these reforms.

Table 8: simulated marshallian elasticities

		All		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.60	0.50	0.60	0.76
male net wage	-1.62	0.33	0.38	0.48
price of necessities	0.04	-0.85	-0.05	-0.00
price of luxuries	-0.05	-0.04	-0.99	0.01
price of durables	-0.06	0.00	0.00	-1.21
		Secondary		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.50	0.43	0.49	0.73
male net wage	-1.36	0.46	0.53	0.69
price of necessities	0.02	-0.91	-0.03	-0.01
price of luxuries	-0.07	-0.01	-1.01	0.02
price of durables	-0.13	-0.03	-0.04	-0.98
		High School		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.84	0.60	0.70	0.94
male net wage	-2.04	0.20	0.23	0.29
price of necessities	0.07	-0.85	-0.04	0.01
price of luxuries	-0.04	-0.03	-0.99	0.00
price of durables	0.01	0.05	0.05	-1.59
		College		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.15	0.45	0.60	0.33
male net wage	-1.16	0.32	0.43	0.47
price of necessities	0.02	-0.63	-0.13	-0.00
price of luxuries	-0.04	-0.18	-0.94	-0.01
price of durables	-0.00	-0.04	-0.05	-0.73

Marshallian elasticities are computed by increasing, one at a time, prices (inclusive of taxes) of different goods and net female and male earnings profiles by 1% and then comparing simulated outcomes between the baseline scenario and each of the perturbed scenarios. Percentage changes in outcomes are computed at the mean and pooling all ages together. Looking at Table 8, we notice that there is substantial heterogeneity in elasticities across education groups.

Column 1 of Table 8 shows extensive margin female labor supply elasticities. Elasticities of female participation to own net earnings are on the upper bound of the range suggested by

intertemporal allocations are allowed to adjust from period to period.

the literature. College educated women (with college educated husbands) are less responsive to earnings changes than high school and secondary educated ones. Elasticities to spouse's net earnings are negative and similar in magnitude to own earnings elasticities, suggesting the existence of strong income effects on second earner's participation decision, as found in previous literature (Aaberge et al. (1999) and Borella et al. (2019))[24].

Columns 2 to 4 of Table 8 report demand elasticities for non-durables necessities, non-durable luxuries and durable goods, respectively. non-durables demand elasticities to changes in both spouses' wages range from 0.20% to 0.70% and confirm that the demand for necessities is less responsive than that for luxuries across all education groups. Elasticity of consumer durables with respect to changes in wages is on average higher than the corresponding elasticities for non-durables. As expected, durable goods are more of a luxury than both non-durable categories for all education groups with the exception of college educated. Own price demand elasticities for all consumption goods have the expected negative sign and range from -0.63% to -1.59%.

Own price elasticity of demand for non-durable necessities is smaller than that of demand for non-durable luxuries which, in turn, is smaller than that of demand for durables. Again college educated households represent an exception: their demand for durables is less elastic to a change in own price than their demand for non-durable luxuries.

Moreover, own price elasticities for non-durables are decreasing in education level as households at the bottom of the wealth distribution are more liquidity constrained and adjust non-durable consumption more frequently in response to income shocks. Cross price elasticities are small in magnitude and suggest weak complementarity[25] between non-durable necessities and luxuries.

6 Quantitative normative analysis

In this section I use the estimated life cycle model to conduct normative analysis and determine the optimal tax rates on non-durable goods, durables and labor income. Starting from the classical Atkinson-Stiglitz result of uselessness of commodity taxation in presence of optimal non linear labor income tax, a vast theoretical literature about the direct-indirect tax debate has developed. Studies in this literature have extended the Atkinson-Stiglitz framework in various alternative directions. Among others, Cremer and Gahvari (1995) looked at pre-commitment

[24]The model assumptions of inelastic male labor supply and no intensive margin decision for women imply that the only channel through which the household can adjust labor supply as a response to changes in wages or prices is the employment decision of the wife. This mechanism of the model might slightly inflate the magnitudes of simulated elasticities of female participation.

[25]Note that the definitions of complementarity and substitutability used here may not be symmetric as they derive from uncompensated Marshallian elasticities. Only compensated complementarity and substitutability are guaranteed to be symmetric.

goods, Cremer et al. (2001) allowed individuals to differ in their initial endowments, Saez (2002) focused on preference heterogeneity and Golosov et al. (2003) considered a dynamic setting in which skills evolve stochastically over time.

The rich dynamic structure of my model allows me to contribute to this debate by relaxing three key assumptions behind the Atkinson-Stiglitz theorem. Specifically, my general framework allows for partially irreversible durable goods that enter the borrowing constraint of the household, for consumption-saving preference heterogeneity, and for horizontal equity concerns of the social planner. In addition, to make the setting more flexible, I also account for heterogeneous endowments, and stochastically evolving productivities and family composition. Reassured by the fact that the estimated model closely aligns with the micro data, I rely on model's simulations to quantitatively characterize the optimal tax system. With this approach, I am able to quantify the effects of the mechanisms at play and relate them to existing theoretical predictions, thus reconciling tax theory and tax practice.

In the rest of the section I describe the government problem and I conduct three computational experiments. First, the optimal tax system is derived using a restricted version of the model in which only endowments and preferences for work are heterogeneous across education groups (estimates and elasticities for this restricted version of the model are in Appendix F.2) and under the assumption of utilitarian social planner. Second, the analysis is extended to the fully specified model that allows for additional heterogeneity in consumption-saving preferences, keeping the utilitarian assumption. Third, the optimal tax system is obtained in a more general scenario in which, not only household preferences are heterogeneous, but also horizontal equity objectives of the social planner are taken into account.

6.1 The government problem

The government chooses the tax instruments that maximize a social welfare criterion. I first assume the social planner employs a utilitarian approach. I will extend the analysis to a more general social welfare criterion in subsection 6.4. Specifically, in order to take into account the dynamic and stochastic nature of the problem, the government's objective function consists of the sum of households' ex ante expected lifetime utilities under a given fiscal policy regime (similar to Conesa et al. (2009) and Erosa and Gervais (2002)). Thus, agents' utilities are evaluated at the start of their (working) life before uncertainty about their specific realizations of idiosyncratic shocks is resolved.

Ideally, one would want to allow the government to choose from an unrestricted set of tax instruments, however, given the complexity of my model, this is computationally infeasible. Therefore, I restrict the set of tax parameters to the three consumption tax rates, $\tau^{n1}, \tau^{n2}, \tau^{d}$, and the parameter capturing either the level of labor income tax, λ, or its progressivity, τ. I assume that the planner compares different tax scenarios in steady state without taking into account transitional dynamics.

The government problem is subject to the constraint that, under any evaluated reform, total tax revenues must be equal to their pre reform level[26]. Retirees are assumed to be affected by the same tax reforms as the working age population and the tax revenues collected from them are included in the public budget. Hence, the government problem is specified as follows:

$$\max_{\tau^{n1},\tau^{n2},\tau^{d},\lambda} \sum_{i} EV_0^i(\tau^{n1}, \tau^{n2}, \tau^d, \lambda) \tag{22}$$

s.t

$$\sum_t \sum_i Tax_t^i(\tau^{n1}, \tau^{n2}, \tau^d, \lambda) = R^{pre}$$

Where, EV_0^i is ex ante expected utility of household i, Tax_t^i is the amount of taxes - on both consumption and labor income - paid by household i at age t and R^{pre} represents total tax revenues in the pre reform scenario[27].

6.2 Homogeneous preferences and utilitarian planner

As a first step of the normative analysis, I quantitatively characterize the optimal tax rates on commodities and labor income under the assumption of homogeneous preferences for consumption and savings. I find that the tax policy that maximizes the utilitarian social welfare function implies tax exemption of non-durable goods, both necessities and luxuries, subsidization of consumer durables and increase in the level of labor income tax. Under the optimal tax scenario, tax rates on non-durable necessities and luxuries drop from 4% and 10%, respectively, to 0%, durables are no longer taxed at 22% rate but subsidized at 7% rate. Also, optimal marginal and average labor income tax rates increase at all earnings levels with respect to the baseline scenario. In particular, at the mean level of annual gross earnings in the sample (around 28,000 euros), marginal labor income tax increases from 35% to 41% and average labor income tax increases from 26% to 33%.

Overall, this first normative exercise implies a shift of the taxation burden from consumption taxes toward labor income taxes with respect to the baseline scenario. In particular, optimal exemption of non-durables suggests that the Atkinson-Stiglitz uniform commodity taxation result holds true, in regards to non-durables, even in a general dynamic setting, provided that

[26]when computing total revenues I sum over all simulated households and periods, assuming that revenue neutrality must hold over the cross section of simulated households.

[27]The government problem is solved numerically by finding the three consumption tax rates that maximize the social welfare function and using either the level or the progressivity of the income tax to ensure revenue neutrality is satisfied. After checking the regularity of the objective function via grid search, the optimization is solved with a quadratic approximation algorithm. Results are approximated to the closest integer.

Table 9: consumption tax rates, MTR and ATR at mean gross earnings (%)

	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR
pre	4	10	22	35	26
post	0	0	-7	41	33

preferences for commodities are homogeneous and that the planner is utilitarian.

The mechanism behind this finding relies on the assumption of weakly separable preferences between total non-durable consumption and labor supply. Weak separability implies that individuals' marginal rate of substitution between the two non-durable goods is independent of labor supply choice, conditional on a given level of income. As suggested by Laroque (2005) and Kaplow (2006), under weak separability and homogeneity, differential commodity taxation is not optimal because it creates distortions in consumption choices and cannot mitigate the labor-leisure distortions caused by labor income taxes. It is, therefore, more efficient for the social planner to eliminate indirect taxes - or use uniform indirect tax rates - and rely on income taxes only.

However, the uniform commodity taxation result quantitatively fails for consumer durables that turn out not to be taxed at the same rate of non-durables, but to be subsidized. Durables in the model, and in reality, have two characteristics: on the one hand, they are a saving technology similar to financial assets, as they enter the borrowing constraint and can be used to smooth consumption; on the other hand, due to their partial irreversibility, they are pre-commitment consumption goods to which households have to commit to before the realization of future shocks. Given their twofold role, theory makes contrasting predictions regarding their optimal taxation.

If durables are treated as capital, then according to both Ramsey and Mirrleesian literatures they should be taxed. Indeed, Conesa et al. (2009) suggest that capital should be taxed as an imperfect substitute for missing age-dependent taxes and transfers. While, in the dynamic Mirrleesian approach (Kocherlakota (2010)), capital is taxed to provide an incentive to supply labor in absence of perfect information about effort.

If, instead, they are seen as pre-commitment consumption goods, then theory prescribes to subsidize them. According to Cremer and Gahvari (1995), risk averse households tend to under consume pre-commitment goods, such as durables, in presence of uncertainty and so it is efficient for the planner to subsidize them in order to balance different kinds of consumption across good and bad states of the world. Whereas Koehne (2018), in a dynamic Mirrleesian framework with durables' adjustment costs, finds that durables, should be taxed less than non-durables, or even subsidized, so to provide intertemporal incentive to work. More precisely, if durables are complement to non-durables and are normal goods, having a larger stock of them, that is partially irreversible, incentivizes labor supply in current and following periods as it increases the future marginal value of consumption.

Which of these two competing mechanisms prevails is an empirical question that crucially depends on preference parameters and on durables' dynamics. Using my estimated model, I show that the pre-commitment good channel quantitatively prevails on the saving tool channel in a utilitarian scenario.

Table 10: changes (%) in households' choices and lifetime welfare

	All	Sec	HS	College
financial assets	-28.45	-30.08	-25.66	-31.95
durables stock	17.30	20.09	14.44	18.95
non-durable consumption	-2.09	-2.29	-1.77	-2.50
non-durable consumption, necessities	-5.07	-5.21	-4.83	-5.34
non-durable consumption, luxuries	-0.86	-0.99	-0.54	-1.45
durables flow	32.03	33.06	29.73	37.12
female participation	1.05	1.06	1.20	0.51
Expected lifetime income	-8.82	-8.86	-8.74	-8.90
CEV	0.76	0.46	1.08	1.19
Expected lifetime utility	1.50	0.91	2.14	2.35
Gini on expected lifetime income	0.18	1.00	0.05	0.00

Table 10 shows mean percentage changes in the main simulated outcomes between pre and post reform scenarios. The subsidy on durables has a large positive effect on durables purchases and on durables stock, which more than offsets the negative income effect due to higher labor income taxes. Insurance provided by the government through durables subsidies implies a large decrease of savings in financial assets as durables become a more convenient smoothing device.

The negative income effect from higher labor income taxes together with the substitution effect in favor of durables cause a reduction of demand for non-durables. In particular, the demand for necessities decreases more than that for luxuries. The reason for this result is that the decrease in price of necessities is smaller than that in price of luxuries and that Marshallian own price elasticity of demand are smaller for necessities than for luxuries. Therefore, the effect of the price reduction, which implies an increase in demand and counteracts the substitution toward durables and the negative income effect, is stronger for luxuries than for necessities.

In terms of labor supply effects, female participation increases as a consequence of the reform across all education groups. Husbands' lower net earnings together with their inelastic labor supply drive women into the labor market in order to compensate for the negative income shock that hit the household.

The bottom lines of Table 10 show lifetime welfare implications of the optimal tax system. Expected lifetime disposable income decreases at all education levels. This suggests that the decrease in net earnings of the main earner, due to higher labor income tax rates, offsets the effect of higher female participation. The reform brings an overall welfare gain equivalent to a 0.76% increase in per-period non-durable consumption. Also, it increases lifetime expected utility of all education groups. This shows the effect of cheaper non-durable consumption and increased insurance.

From columns 2-4 of Table 10, it is evident that richer households gain more from the reform. This result holds true even when CEVs are disaggregated at a finer level by deciles of income distribution (See Appendix H). Also, as shown by the change in Gini indexes, the distribution of disposable income is more unequal after the reform, especially among the less educated. This is a consequence of the subsidy on durables that are consumed disproportionately more by wealthier households. All in all, the optimal tax system found under this first experiment results into an increase in both efficiency and inequality with respect to the status quo.

6.3 Heterogeneous preferences and utilitarian planner

Large empirical evidence shows the existence of heterogeneity in households' intertemporal preferences (among others, see Lawrance (1991) and Cagetti (2003)). Indeed, allowing for richer intertemporal consumption preference heterogeneity helps in matching the main features of the data (see Appendix G.5 for a comparison of fit of the model with and without additional heterogeneity). Moreover, theory suggests that preference heterogeneity can have important implications on optimal taxation results (Kaplow (2008)). In particular, Saez (2002) suggests that, in a dynamic setting, the key assumption behind the uniform commodity taxation result is not the weak separability between consumption and labor, but rather the homogeneity of consumption preferences among individuals, implying that saving behavior is the same for all agents and independent of their skills.

The goal of this second computational experiment is to quantitatively characterize the optimal tax system in a context of additional preference heterogeneity and compare it to the one found under homogeneous consumption-saving preferences. Specifically, households in the model are now heterogeneous not only in endowments and taste for work, but also with respect to discount rate, risk aversion, weight of non-durable consumption in utility, preferences for consumer durables and for different non-durable categories.

I find that the set of tax instruments that maximizes the utilitarian social welfare function in this setting is an increase in taxation of non-durables, a large subsidy on durables and a decrease in labor income tax levels. Optimal taxation of consumption requires an increase in the tax rate on non-durables necessities from 4% to 22% and an increase in the tax rate on non-durable luxuries from 10% to 18%. The optimal subsidy rate on durables is 22%. Optimal marginal and average labor income tax rates decrease at all earnings level. In particular, marginal tax rate at the mean decreases from 35% to 28% and average tax rate at the mean drops from 26% to 19%.

Table 11: consumption tax rates, MTR and ATR at mean gross earnings (%)

	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR
pre	4	10	22	35	26
post	22	18	-22	28	19

Optimal tax rates obtained from this second numerical experiment imply a shift from labor income taxes to non-durable consumption taxes and a scope for differentiated rates of commodity taxation, even in presence of a non-linear labor income tax. These results are strikingly different from the ones found under consumption preference homogeneity and suggest that the uniform commodity taxation result fails for all consumption types under preference heterogeneity.

The explanation behind this results lies in the fact that, in a utilitarian framework, the implicit social welfare weights assigned by the government to each agent coincide with the agent's marginal utility from consumption – or expected marginal value of wealth in a dynamic setting. Therefore, heterogeneity in consumption-saving preferences changes the ranking of social welfare weights along the income distribution with respect to the one obtained in the homogeneous preference scenario. In particular, in my model, the extent and direction of redistribution under preference heterogeneity differ from the ones under homogeneity depending on the sign of the correlation between education – as a determinant of income – and consumption-saving preferences.

This mechanism has previously been investigated in the theoretical literature. Blomquist and Christiansen (2008) find a role for differentiated commodity taxation, even in presence of non-linear income taxes, when high-skilled agents have heterogeneous preferences for leisure. Kleven et al. (2009) study optimal income taxation of couples with heterogeneity either in home production abilities or in market opportunities. Choné and Laroque (2010) show how heterogeneity in the opportunity cost of work can justify negative marginal tax rates at low incomes. Diamond and Spinnewijn (2011) and Golosov et al. (2013) focus on optimal differentiated capital taxation with heterogeneous discount factor.

While the theory has focused on one-dimensional preference heterogeneity, I exploit the rich preference heterogeneity in my estimated model to explore the relative importance of multiple dimensions of preference heterogeneity. To do so, I add heterogeneity in the different dimensions of the set of model's parameters one step at a time and I derive the optimal tax system in each step. Results are presented in Table 12: in the first row, I start from the baseline scenario of fully homogeneous preferences, in the second row, only the AIDS parameter are heterogeneous across education groups, in the third row heterogeneity in the risk aversion is added, in the fourth row also heterogeneity in the Stone-Geary parameter is allowed for, in the fifth row the discount factors are heterogeneous too. Finally, to restore the fully heterogeneous version of the model, I allow for heterogeneity in the share of non-durable consumption in utility function.

Table 12: Optimal tax rates under alternative scenarios of preference heterogeneity

	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR
fully homog.	0	0	-7	41	33
heterog. AIDS	0	3	-5	40	32
heterog. AIDS, γ	12	8	-9	36	28
heterog. AIDS, γ, ϵ^d	19	13	-17	34	25
heterog. AIDS, γ, ϵ^d, β	24	17	-18	31	22
fully heterog.	22	18	-22	28	19

I find that heterogeneity in risk aversion is quantitatively the most important driver of the failure of the uniform commodity taxation result. When only heterogeneity in intratemporal consumption preferences (AIDS parameters) is allowed for, optimal rates are not very different from the ones found under full homogeneity. And, once heterogeneity in risk aversion has been accounted for, allowing for heterogeneity in further dimensions does not qualitatively change the results.

More precisely, according to the estimates with full heterogeneity, more educated households are less risk averse than less educated counterparts. Given the assumption of CRRA utility, this implies higher marginal utility from consumption for college educated and, therefore, larger utilitarian implicit social welfare weight on them. Moreover, the consumption share of non-durable necessities decreases as the education level increases, as shown by the estimated intratemporal preference parameters. Hence, it is more efficient for the utilitarian planner to tax luxuries less than necessities and, at the same time, decrease the tax burden on labor income.

As for consumer durables, the result of optimal subsidization found in the previous experiment is confirmed and magnified. On top of the pre-commitment goods mechanism, the additional channel of preference heterogeneity is now at play. More educated households have stronger preferences for durables and they weigh more in the social welfare function due to their lower risk aversion.

Table 13 presents mean percentage changes in the main simulated outcomes between pre and post reform scenarios. It shows the long run effects of the optimal tax system on household behavior, taking into account life cycle dynamics and insurance mechanisms. The subsidy on durables has a large positive effect on durables stock across all education groups. This effect is also reinforced by the increase in households disposable income due to lower rates of labor income tax. Publicly provided insurance in the form of durables subsidies also implies a large decrease in the stock of financial assets. Households have an incentive to run down their financial assets wealth and to invest in durables as a more convenient smoothing device. This change in portfolio composition in favor of durable goods is stronger for more educated

Table 13: changes (%) in households' choices and lifetime welfare

	All	Sec	HS	College
financial assets	-39.26	-29.78	-44.88	-46.74
durables stock	57.53	52.60	59.29	67.85
non-durable consumption	-8.20	-8.09	-8.05	-9.08
non-durable consumption, necessities	-11.83	-12.16	-11.79	-10.61
non-durable consumption, luxuries	-6.50	-6.04	-6.34	-8.49
durables flow	123.27	112.68	131.72	126.34
female participation	4.49	4.09	5.11	3.80
Expected lifetime income	4.87	4.68	5.14	4.82
CEV	0.23	-0.64	0.75	3.23
Expected lifetime utility	0.20	-1.33	1.36	4.56
Gini on expected lifetime income	0.87	1.81	1.37	0.89

households who are the least liquidity constrained.

In terms of consumption, the sharp increase in tax rates on non-durables together with the large subsidy on durables shift households expenditure away from non-durables toward durables for all households types. The effect is again stronger for college educated who have stronger preferences for durables. In particular, consumption of necessities decreases more than consumption of luxuries across all education groups with respect to the pre reform scenario. This is due to the fact that the price of necessities increases relatively more than the price of luxuries as a consequence of the reform. Also, budget elasticities are lower for necessities than for luxuries at all education levels and, therefore, the positive income effect is weaker for necessities. The larger decrease in non-durable necessities' purchases for lower education groups reflects the larger simulated own price demand elasticities for more constrained households.

As for the long run effects of the optimal reform on labor supply, I find that female participation to the labor market increases. This is driven by the lower taxation on labor earnings that incentivizes female employment. Higher female participation is also a result of the need for household insurance and consumption smoothing against the post reform sharp increase in non-durable consumption prices. These two mechanisms prevail on the income effect of higher net wage of the main earner, which discourages participation of the second earner. In line with simulated elasticities, participation decision is less responsive to changes in net income for college educated women than for lower educated ones.

Lifetime welfare effects of the optimal tax system are shown in the bottom panel of Table 13. Expected lifetime disposable income increases for all education groups as a consequence of the lower labor income taxes and of the increased female participation that increase the flow of household's net earnings over the whole life cycle. As a consequence of durables subsidies and lower labor income taxes, overall welfare increases by 0.23% of per-period non-durable consumption with respect to the baseline.

However, the optimal tax system redistributes in favor of the more wealthy and imposes a welfare loss on the poorer groups of the population (not only across, but also within education groups, as shown in Appendix H). This is because the decrease in non-durable consumption and the higher female participation impose a larger disutility on households at the bottom of the wealth distribution. Also, the Gini index on lifetime disposable income increases by 0.87% with respect to the status quo, while it increased only by 0.18% in the experiment of the previous section. This supports the common theoretical intuition that preference heterogeneity lowers optimal redistribution (see Lockwood and Weinzierl (2015) for a recent discussion) and shows how large the effect can be.

6.4 Heterogeneous preferences and horizontal equity

When preferences are heterogeneous, utilitarianism implies taxing agents on the basis of their preferences. This results in efficiency gains, but, at the same time, raises important horizontal equity concerns[28]. Moreover, from a political economy point of view, utilitarianism prescribes optimal tax policies that are hard to implement in practice. Public debate together with recent cross country surveys[29] suggest that voters are in general against redistribution based on people's different preferences for effort versus leisure and consumption enjoyment rather than on social fairness principles.

In order to bridge the gap between optimal taxation results and actual tax practice, in this section I introduce a flexible generalization of the government social welfare function and test the robustness of the uniform commodity taxation result to it. Along the lines of generalized social marginal welfare weights proposed by Saez and Stantcheva (2016), I allow the social planner to take into account observed agents' characteristics that capture society's concern for horizontal equity while being orthogonal to agents' preferences. Specifically, I assume that the weights assigned by the planner to households' expected lifetime utility (EV) are decreasing in households' expected lifetime disposable income (EI). As stressed by Krusell et al. (1996) in a related study, the distribution of agents over income and wealth can be an important factor determining economic policies.

In particular, two characteristics of the generalized welfare weights that I adopt are worth mentioning. First, given that the government problem is solved ex ante with respect to the realization of shocks, weights are computed on expected rather than realized lifetime income. Second, weights are endogenous as they are allowed to change at each evaluated tax scenario. This implies that government optimization is not constrained to marginal tax changes around the baseline and that horizontal equity concerns are taken into account. Hence, the government

[28]See the prominent work of Fleurbaey and Maniquet (2004, 2006) on this topic.

[29]Saez and Stantcheva (2016) and Alesina et al. (2018) recently conducted on-line surveys where questions are designed to elicit people's preferences for redistribution.

problem under revenue neutrality constraint becomes:

$$\max_{\tau^{n1},\tau^{n2},\tau^{d},\lambda} \sum_i g(EI_0^i(\tau^{n1},\tau^{n2},\tau^{d},\lambda))EV_0^i(\tau^{n1},\tau^{n2},\tau^{d},\lambda) \tag{23}$$

where, the weights are:

$$g(EI_0^i) = \frac{(EI_0^i)^{1-\epsilon}}{\sum_i (EI_0^i)^{1-\epsilon}}$$

The degree of government inequality aversion, ϵ, determines how fast the welfare weights decrease along the distribution of lifetime disposable income. In an intertemporal setting with heterogeneous initial endowments, expected lifetime disposable income captures the probability of coming from a disadvantaged background. Hence, by increasing the degree of government inequality aversion, I allow the policy maker to attach progressively less importance to households' preferences and more to their actual lifetime socio-economic status and background. When ϵ is equal to one, the standard utilitarian criterion applies, where redistribution is driven by heterogeneous households' preferences. If, on the other hand, ϵ is very large, the social planner redistributes in favor of households – or the single household in the extreme Rawlsian case – with lower expected lifetime income, regardless of differences in preferences.

Table 14: Optimal tax rates and welfare effects, alternative values of ineq. aversion

Inequality Aversion	Optimal tax rates					$\Delta EV(\%)$			
$1-\epsilon$	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR	All	Sec	HS	College
0	22	18	-22	28	19	0.20	-1.33	1.36	4.56
-2	22	6	-14	36	28	-0.13	-1.50	0.96	3.51
-4	4	10	21	35	26	0.03	0.01	0.05	0.10
-20	0	8	22	36	28	-0.02	0.08	-0.08	-0.32

Table 14 shows a set of results that help to reconcile the discrepancies between the outcome of the utilitarian normative analysis and actual tax practice. First, under government inequality aversion scenarios (rows 2 to 4), the optimal tax system results in lower efficiency and higher equity with respect to the utilitarian scenario (first row). Specifically, if ϵ increases beyond a given threshold, equity concerns offset efficiency concerns so that non-durable necessities are taxed less than non-durable luxuries and the subsidy on durable goods turns into a tax.

Second, the tax systems implemented in most developed countries can be rationalized under high degrees of government inequality aversion. In particular, the model justifies the tax system currently in place in Italy under a level of government inequality aversion corresponding to ϵ equal to 5. This level of inequality aversion implies that the government social welfare function weighs households in the second decile of the income distribution about six times more than households in the eighth decile. While, tax systems as those observed in Scandinavian countries, where labor income taxes are high and rather flat and the ordinary rate of consumption tax reaches 25%, are obtained under the assumption of even stronger horizontal equity concerns of the policy maker.

Third, in order for the poorer group to gain at the expense of the richer groups of the population, the rates of consumption taxes have to be highly differentiated. However, this outcome is costly from the efficiency point of view. These results suggest that differentiated consumption tax rates contribute to redistribution jointly with the progressivity of labor income taxes, thus justifying their pervasiveness in practice.

6.5 Income tax progressivity as instrument for revenue neutrality

In the normative analysis presented so far, I assumed that revenue neutrality was guaranteed by adjustments in the level of labor income tax, holding progressivity constant. Table 15 shows analogous results obtained when, instead, the budget is balanced by varying the degree of progressivity, while keeping the level unchanged with respect to pre reform scenario.

Table 15: Optimal tax rates and welfare effects, alternative values of ineq. aversion

Inequality Aversion	Optimal tax rates					$\Delta EV(\%)$			
$1-\epsilon$	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR	All	Sec	HS	College
Homogeneous pref.									
0	0	0	-10	41	33	2.10	1.74	2.56	2.36
Heterogeneous pref.									
0	24	19	-20	31	23	0.30	-1.37	1.59	4.93
-2	23	17	-4	30	22	0.15	-0.99	1.02	3.39
-4	4	12	22	34	26	-0.07	-0.09	-0.04	0.00
-20	0	0	22	40	32	0.26	0.56	0.04	-0.59

The first two rows of Table 15 present the results under utilitarian social welfare function. When consumption preferences are homogeneous (first row), the optimal commodity tax rates and the marginal and average tax rates on labor income of the mean earner are very similar to the ones previously derived. Some differences are observed in terms of effects on lifetime welfare. The increase in progressivity of labor income tax only marginally affects tax payers at the low end of the income distribution. Hence, it leads to a higher overall welfare gain and lower inequality with respect to the case in which the level of tax is increased along the whole income distribution. In the case of heterogeneity in consumption preferences (second row), the results of positive and differentiated tax rates on non-durables and of subsidy on durables are confirmed. Here revenue neutrality implies that labor income tax becomes flatter.

Looking at the results obtained under heterogeneous preferences and generalized social welfare criterion (rows 3 to 5), one main difference appears with respect to the case in which the level of labor income tax is used as revenue neutrality instrument. When the government is highly averse to inequality (last row) and is allowed to increase the progressivity of the labor income tax, the result of uniform non-durable commodity taxation obtains even with heterogeneous consumption preferences. However, it is now combined with a high tax on durables and increased progressivity of income tax. Differently from the previous scenario, where the only way for the government to increase the progressivity of the tax system was to apply differentiated rates of consumption tax, in this setting it can do so also by adjusting the labor income tax schedule. This latter channel proves to be more effective than the differential tax rates on non-durables when the aim of the policy maker is to specifically target the less wealthy groups. Nonetheless, high taxation of durables still plays an important redistributive role on top of progressive labor income tax.

7 Conclusions

In this paper, I develop and estimate a rich structural life-cycle model of household consumption, saving and labor supply decisions with direct and indirect taxation. The model combines many realistic elements such as multiple consumption goods, partially irreversible durables, and preference heterogeneity. I show that the interaction among these features is crucial in matching the life-cycle patterns of households' behavior observed in the micro data.

I use the estimated model to conduct a quantitative normative analysis of the optimal taxation of consumption and income in a general framework that relaxes the key assumptions behind the uniform commodity taxation result of Atkinson and Stiglitz (1976), thus bridging the gap between tax theory and tax practice.

I find that the uniform commodity taxation result fails for durable goods entering the borrowing constraint and subject to adjustment costs. Indeed, the pre-commitment feature characterizing the durable investment decision in an environment with uncertainty justifies an optimal subsidy on durables' purchases. I also show that heterogeneity in intertemporal preferences, especially risk aversion, affects the ranking of utilitarian social welfare weights, thus driving consumption tax rates on non-durables away from uniformity, even in presence of non-linear labor income taxes.

Departing from the assumption of a utilitarian social planner and allowing for a more flexible social welfare criterion that accounts for society's horizontal equity concerns, I show that the model can rationalize the tax systems implemented in reality under high degrees of government inequality aversion. In particular, quantitative simulations suggest that differentiated consumption taxes - with substantially higher rates on durables - play a role as redistributive tools jointly with progressive labor income taxes.

References

Aaberge, R., Colombino, U., and Strom, S. (1999). Labour supply in Italy: an empirical analysis of joint household decisions, with taxes and quantity constraints. *Journal of Applied Econometrics*, 14(4):403–422.

Aaronson, D., Agarwal, S., and French, E. (2012). The spending and debt response to minimum wage hikes. *American Economic Review*, 102(7):3111–39.

Alesina, A., Stantcheva, S., and Teso, E. (2018). Intergenerational mobility and preferences for redistribution. *American Economic Review*, 108(2):521–54.

Altonji, J. G. and Segal, L. M. (1996). Small-sample bias in gmm estimation of co-variance structures. *Journal of Business and Economic Statistics*, 14(3):353–366.

Atkinson, A. B. and Stiglitz, J. E. (1976). The design of tax structure: direct versus indirect taxation. *Journal of Public Economics*, 6(1-2):55–75.

Attanasio, O., Levell, P., Low, H., and Sánchez-Marcos, V. (2018). Aggregating elasticities: Intensive and extensive margins of women's labor supply. *Econometrica*, 86(6):2049–2082.

Attanasio, O. P., Banks, J., Meghir, C., and Weber, G. (1999). Humps and bumps in lifetime consumption. *Journal of Business and Economic Statistics*, 17(1):22–35.

Benabou, R. (2002). Tax and education policy in a heterogeneous-agent economy: What levels of redistribution maximize growth and efficiency? *Econometrica*, 70(2):481–517.

Berger, D. and Vavra, J. (2015). Consumption dynamics during recessions. *Econometrica*, 83(1):101–154.

Bick, A. and Fuchs-Schündeln, N. (2018). Taxation and labour supply of married couples across countries: A macroeconomic analysis. *The Review of Economic Studies*, 85(3):1543–1576.

Blomquist, S. and Christiansen, V. (2008). Taxation and heterogeneous preferences. *FinanzArchiv: Public Finance Analysis*, 64(2):218–244.

Blundell, R., Browning, M., and Meghir, C. (1994). Consumer demand and the life-cycle allocation of household expenditures. *The Review of Economic Studies*, 61(1):57–80.

Blundell, R., Costa Dias, M., Meghir, C., and Shaw, J. (2016a). Female labor supply, human capital, and welfare reform. *Econometrica*, 84(5):1705–1753.

Blundell, R. and MaCurdy, T. (1999). Labor supply: A review of alternative approaches. In *Handbook of Labor Economics*, volume 3, pages 1559–1695. Elsevier.

Blundell, R., Pistaferri, L., and Saporta-Eksten, I. (2016b). Consumption inequality and family labor supply. *American Economic Review*, 106(2):387–435.

Blundell, R. and Robin, J. M. (1999). Estimation in large and disaggregated demand systems: An estimator for conditionally linear systems. *Journal of Applied Econometrics*, 14(3):209–232.

Borella, M., De Nardi, M., and Yang, F. (2019). Are marriage-related taxes and social security benefits holding back female labor supply? *NBER Working Paper no. 26097*.

Browning, M. and Meghir, C. (1991). The effects of male and female labor supply on commodity demands. *Econometrica: Journal of the Econometric Society*, 59(4):925–951.

Cagetti, M. (2003). Wealth accumulation over the life cycle and precautionary savings. *Journal of Business and Economic Statistics*, 21(3):339–353.

Choné, P. and Laroque, G. (2010). Negative marginal tax rates and heterogeneity. *American Economic Review*, 100(5):2532–47.

Conesa, J. C., Kitao, S., and Krueger, D. (2009). Taxing capital? not a bad idea after all! *American Economic Review*, 99(1):25–48.

Costa Dias, M., Joyce, R., and Parodi, F. (2018). The gender pay gap in the uk: children and experience in work. *IFS Working Paper 18/02*.

Cremer, H. and Gahvari, F. (1995). Uncertainty and optimal taxation: In defense of commodity taxes. *Journal of Public Economics*, 56(2):291–310.

Cremer, H., Pestieau, P., and Rochet, J.-C. (2001). Direct versus indirect taxation: the design of the tax structure revisited. *International Economic Review*, 42(3):781–800.

Curci, N., Savegnago, M., and Cioffi, M. (2017). BIMic: The Bank of Italy microsimulation model for the Italian tax and benefit system. *Bank of Italy Occasional Papers no.394*.

Deaton, A. and Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review*, 70(3):312–326.

Diamond, P. and Spinnewijn, J. (2011). Capital income taxes with heterogeneous discount rates. *American Economic Journal: Economic Policy*, 3(4):52–76.

Erosa, A. and Gervais, M. (2002). Optimal taxation in life-cycle economies. *Journal of Economic Theory*, 105(2):338–369.

Fernandez-Villaverde, J. and Krueger, D. (2011). Consumption and saving over the life cycle: How important are consumer durables? *Macroeconomic Dynamics*, 15(5):725–770.

Fleurbaey, M. and Maniquet, F. (2004). Compensation and responsibility. In *Handbook of Social Choice and Welfare*.

Fleurbaey, M. and Maniquet, F. (2006). Fair income tax. *The Review of Economic Studies*, 73(1):55–83.

French, E. (2005). The effects of health, wealth, and wages on labour supply and retirement behaviour. *The Review of Economic Studies*, 72(2):395–427.

Golosov, M., Kocherlakota, N., and Tsyvinski, A. (2003). Optimal indirect and capital taxation. *The Review of Economic Studies*, 70(3):569–587.

Golosov, M., Troshkin, M., Tsyvinski, A., and Weinzierl, M. (2013). Preference heterogeneity and optimal capital income taxation. *Journal of Public Economics*, 97:160–175.

Gorman, W. M. (1971). Two-stage budgeting. *Mimeo*.

Gourieroux, C., Monfort, A., and Renault, E. (1993). Indirect inference. *Journal of Applied Econometrics*, 8(S1):S85–S118.

Gourinchas, P. O. and Parker, J. A. (2002). Consumption over the life cycle. *Econometrica*, 70(1):47–89.

Guvenen, F. (2009). An empirical investigation of labor income processes. *Review of Economic Dynamics*, 12(1):58–79.

Heathcote, J., Storesletten, K., and Violante, G. L. (2017). Optimal tax progressivity: An analytical framework. *The Quarterly Journal of Economics*, 132(4):1693–1754.

Heathcote, J., Storesletten, K., and Violante, G. L. (2020). Optimal progressivity with age-dependent taxation. *Journal of Public Economics*, page 104074.

Hoynes, H. (1996). Welfare transfers in two-parent families: Labor supply and welfare participation under AFDC-UP. *Econometrica*, 64(2):295–332.

İmrohoroğlu, S. (1998). A quantitative analysis of capital income taxation. *International Economic Review*, pages 307–328.

Jappelli, T. and Pistaferri, L. (2000). The dynamics of household wealth accumulation in Italy. *Fiscal Studies*, 21(2):269–295.

Kaplan, G. and Violante, G. L. (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica*, 82(4):1199–1239.

Kaplow, L. (2006). On the undesirability of commodity taxation even when income taxation is not optimal. *Journal of Public Economics*, 90(6-7):1235–1250.

Kaplow, L. (2008). Optimal policy with heterogeneous preferences. *The BE Journal of Economic Analysis & Policy*, 8(1).

Kleven, H. J., Kreiner, C. T., and Saez, E. (2009). The optimal income taxation of couples. *Econometrica*, 77(2):537–560.

Kocherlakota, N. R. (2010). *The new dynamic public finance*. Princeton University Press.

Koehne, S. (2018). On the taxation of durable goods. *International Economic Review*, 59(2):825–857.

Krusell, P., Quadrini, V., and Rios-Rull, J. V. (1996). Are consumption taxes really better than income taxes? *Journal of Monetary Economics*, 37(3):475–503.

Laroque, G. R. (2005). Indirect taxation is superfluous under separability and taste homogeneity: a simple proof. *Economics Letters*, 87(1):141–144.

Lawrance, E. C. (1991). Poverty and the rate of time preference: evidence from panel data. *Journal of Political Economy*, 99(1):54–77.

Lerman, S. and Manski, C. (1981). On the use of simulated frequencies to approximate choice probabilities. *Structural analysis of discrete data with econometric applications*, 10:305–319.

Lockwood, B. B. and Weinzierl, M. (2015). De gustibus non est taxandum: Heterogeneity in preferences and optimal redistribution. *Journal of Public Economics*, 124:74–80.

McFadden, D. (1989). A method of simulated moments for estimation of discrete response models without numerical integration. *Econometrica*, 57(5):995–1026.

Outreville, J. F. (2015). The relationship between relative risk aversion and the level of education: a survey and implications for the demand for life insurance. *Journal of Economic Surveys*, 29(1):97–111.

Pakes, A. and Pollard, D. (1989). Simulation and the asymptotics of optimization estimators. *Econometrica*, 57(5):1027–1057.

Poterba, J. M. (1996). Retail price reactions to changes in state and local sales taxes. *National Tax Journal*, pages 165–176.

Saez, E. (2002). The desirability of commodity taxation under non-linear income taxation and heterogeneous tastes. *Journal of Public Economics*, 83(2):217–230.

Saez, E. and Stantcheva, S. (2016). Generalized social marginal welfare weights for optimal tax theory. *American Economic Review*, 106(1):24–45.

Tauchen, G. (1986). Finite state markov-chain approximations to univariate and vector autoregressions. *Economics letters*, 20(2):177–181.

Appendices for online publication

A Almost Ideal Demand System

AIDS is a special case of the general class of PIGLOG preferences. PIGLOG preferences are characterized by an expenditure function formulation that ensures that the resulting demand functions are first-order approximations to any set of demand functions derived from utility-maximizing behavior. Specifically, the PIGLOG expenditure function - the minimum expenditure as a function of given level of utility and prices - is the following:

$$log(c(u,p)) = (1-u)log(a(p)) + (u)log(b(p)) \qquad u \in [0,1]$$

where, $a(p)$ represents cost of subsistence ($u = 0$) and $b(p)$ represents cost of bliss ($u = 1$).

When specific functional forms for $log(a(p))$ and $log(b(p))$ are assumed, AIDS expenditure function obtains:

$$log(c(u,p)) = \alpha_0 + \sum_k \alpha_k log p_k + \frac{1}{2}\sum_k \sum_j \gamma^*_{k,j} log p_k log p_j + u\beta_0 \prod_k p_k^{\beta_k} \tag{24}$$

Provided that $\sum_i \alpha_i = 0$ and $\sum_j \gamma^*_{k,j} = \sum_k \gamma^*_{k,j} = \sum_j \beta_j = 0$, equation (24) has enough parameters to be a flexible functional form.

For a utility-maximizing consumer, total expenditure x coincides with the value of the expenditure function $c(u,p)$ and this equality can be inverted so to obtain u as a function of x and p, which is precisely the AIDS indirect utility function specification used in the model:

$$v(x,p) = exp\left[\frac{log(x) - log(a(p))}{b(p)}\right]$$

B Data

B.1 SHIW dataset

The SHIW was first conducted in 1965 and then repeated annually with time-independent samples (repeated cross sections) of households up to 1987. Since 1987 the Survey was conducted every other year (except for a three year interval between 1995 and 1998) and, starting from the 1989 wave, each wave includes households interviewed in previous years (panel households) in the sample. The overall sample comprises around 8000 households in each wave since 1987 and is representative of the Italian resident households population. The unit of analysis is the household, defined as the group of persons residing in the same dwelling who are related by blood, marriage or adoption. Institutional population is not included. The numerosity of the panel component has increased gradually over time and is now roughly 57% of the overall sample.

More in detail, SHIW collects the following information: socio-economic and demographic characteristics of the household; current occupational status and past employment history of adult household members; different sources of income including payroll and self-employment income, pensions, transfers, and property income of adult household members; household's wealth at the end of the year in terms of properties lived in or owned by the household, imputed rents, household financial and real assets and liabilities; household's expenditure in non-durables and durables during the year.

The sample for the survey is drawn in two stages: first, the municipalities (stratified by region and population) are selected; second, the households to be interviewed are selected within each municipality from civic registers. Panel households are selected according to a rotating-panel sampling design: households that had participated in at least two earlier surveys are all included in the sample, plus a fraction of those interviewed only in the previous wave are randomly selected to be interviewed again in the current wave, while a fresh sample is drawn in every wave. The adoption of this rotating-panel strategy allows to minimize dropout problems and therefore reduces the problem of non random sample attrition. In the most recent wave of the survey the rate of response among contacted households was much higher for panel households (82,2%) than for non panel ones (35,8%) and non random attrition is reportedly not a major problem in the SHIW data. Appendix A.3 reports more details on panel structure and non random attrition in the SHIW.

Table 16 shows in some more detail the structure and numerosity of the the SHIW rotating panel by reporting the number of households interviewed in more than one wave. For instance, among the 8156 households in the last wave (2014), 13 participate since 1987, 64 since 1989, 166 since 1991 and so on. Table 16 also allows to pin down how many households are observed for, say, three subsequent waves in each year: in 2014 there are 579 households that have been interviewed in three subsequent waves, 806 households in 2012 wave, 856 households in 2010 wave, 995 households in the 2008 sample and so on.

Table 16: Structure of SHIW

Year first interview	Year of survey 1987	1989	1991	1993	1995	1998	2000	2002	2004	2006	2008	2010	2012	2014
1987	8027	1206	350	173	126	85	61	44	33	30	28	23	21	13
1989		7068	1837	877	701	459	343	263	197	159	146	123	102	64
1991			6001	2420	1752	1169	832	613	464	393	347	293	244	166
1993				4619	1066	583	399	270	199	157	141	124	106	78
1995					4490	373	245	177	117	101	84	75	62	46
1998						4478	1993	1224	845	636	538	450	380	267
2000							4128	1014	667	475	398	330	256	170
2002								4406	1082	672	525	416	340	221
2004									4408	1334	995	786	631	395
2006										3811	1143	856	648	414
2008											3632	1145	806	481
2010												3330	1015	579
2012													3540	1565
2014														3697
sample size	8027	8274	8188	8089	8135	7147	8001	8011	8012	7768	7977	7951	8151	8156
% panel hhs		14.6	26.7	42.9	44.8	37.3	48.4	45.0	45.0	50.9	54.4	58.1	56.6	54.7

Table 17 shows that panel and non panel households are similar in terms of demographic and socio-economic characteristics, thus suggesting that nonrandom attrition is not a major problem in the SHIW data.

Table 17: Comparison of means and standard deviations

Variable	hhs in 2010 sample only	hhs in 2010 and 2012 samples	hhs in 2012 sample only
consumption	25299.21	26381.97	24180.87
	(16200.07)	(15376.81)	(14579.85)
durable consumption	1627.81	1233.78	952.76
	(5086.05)	(4300.55)	(3596.78)
non-durable consumption	23671.40	25148.18	23228.106
	(14515.29)	(14069.37)	(13409.34)
disposable income	33146.58	31788.48	29289.21
	(25129.62)	(22629.14)	(22604.65)
gender of head of hh	1.46	1.45	1.46
	(0.5)	(0.5)	(0.5)
age of head of hh	55.10	53.09	55.81
	(17.18)	(15.37)	(17.21)
education of head of hh	3.25	3.43	3.19
	(1.07)	(1.04)	(1.07)
family size	2.49	2.60	2.43
	(1.28)	(1.32)	(1.31)
geographic area	1.81	1.85	1.80
	(0.85)	(0.88)	(0.87)
observations	2315	1015	3540

B.2 HBS

HBS sampling scheme is organized in two-stages: firstly, municipalities are selected among two groups according to the size of population; chief towns of provinces are fully included and selected to take part to the survey every month, while the remaining are grouped in strata according to some economic and geographic characteristics and are extracted every 3 months; second, households are randomly selected within the stratum from the registry office records. As a result, the survey unit is the legal family recorded by the registry office. Sample size is around 28,000 households from 480 municipalities and weights allowing for a recalibration of population in each stratum and for the distribution by household size within region are also provided for.

Data are recorded by means of two complementary methods: a diary (Libretto degli Acquisti) where the household keeps track of expenditures made and of quantities of internally produced goods consumed in the previous 7 days (Taccuino degli Autoconsumi); a proper interview for the remaining purchases done in the previous month and for durables bought in the previous 3 months. It has to be remarked that expenditure is provided on a monthly basis, so commodities recorded on a wider recording period are made monthly in the survey by dividing the amount for the number of months they are recorded for.

B.3 Sample selection

I use the SHIW waves 1989 to 2014 and HBS waves 2003 to 2012. Sample selection in both data sets satisfies the following criteria. Given that the model focuses on households' economic choices during working age, only households whose head is aged 30-59 are kept in the sample. Most young people still live with their parents around age 20 in Italy. Moreover, there is a well known (Jappelli and Pistaferri (2000)) head of household bias in SHIW data at early ages due to a strong positive correlation between wealth and young household headship.

As the model does not allow for singles and family transitions, such as marriage, divorce and widowhood, single households or households whose head reports changing marital status at a given wave are dropped from all waves in which they are observed. In SHIW, this means dropping about 20% of observations in the original sample of households in the selected age range (15% of the dropped observations are singles). Hence, the final SHIW dataset is an unbalanced panel of around 43,000 household-year observations, where about 25% of households are observed for at least five subsequent waves (i.e. ten years).

All monetary values are CPI adjusted (base year 2014). Variables for durables stock and flow, non-durable consumption and financial assets are all trimmed at the 95th percentile of the age specific distribution in order to mitigate the impact of misreporting. The variable for financial assets includes bank and postal accounts, government bonds and stocks net of consumption debt, but, for consistency with the model, it excludes housing and mortgages[30].

The variable for individual's net earnings is defined as the sum of compensation of employees and net income from self-employment and entrepreneurial income. It excludes pensions and income from property and assets, but includes government transfers. It is trimmed at the 1st and 98th percentiles of the education specific distribution. SHIW only collects data on net earnings of households' members. The corresponding gross earnings are obtained by means of a grossing-up procedure that uses the Bank of Italy microsimulation model for the Italian tax and benefit system (Curci et al. (2017))[31].

B.4 Financial assets measure

I adjust the financial assets variable in the SHIW data so to net out down payment for non-homeowners. Specifically, the financial assets measure that I use is net of downpayment for non-homeowners with non-negative assets, who are assumed to become homeowners at some point in the future, while it coincides with the original measure of financial assets for home-owners and for non-homeowners with negative assets. The downpayment for households that only appear in the data as non-homeowners is not observed and, therefore, it is imputed on

[30]In order to be fully consistent with the choice of modelling financial assets as completely liquid, the data measure for net financial assets is adjusted for down payment for non home owners. Details in Appendix B.4.

[31]Results kindly provided by the Bank of Italy.

the basis of the downpayment accumulated by those households who have same demographic characteristics (age, region, education)and are observed before and after the purchase of the first house. This adjustment allows to account for the fact that some households, especially young ones, might be saving towards the purchase of their first house and, therefore, might perceive part of the financial wealth they report in the survey as effectively illiquid.

In the adjustment procedure I take into account the following observed and derived measures:

- X_a : proportion of homeowners aged a. As a consequence, $(1 - X_a)$ is the proportion of those who still do not have a house at age a and $(0.75 - X_a)$ is the proportion of those who do not have a house and are saving towards buying one, given that by age 60 around 0.75 of households in the data are homeowners
- $Y_a(1 - X_a)$: proportion of non-homeowners with positive assets at age a
- A_a^H: average assets of homeowners at age a
- A_a^{NH}: average assets of non-homeowners at age a
- A_a^{NH+} and A_a^{NH-}: average assets of non-homeowners with positive and negative assets at age a

Savings towards downpayment is a proportion $\frac{Dp}{A+Dp}$ of the savings of the $(0.75-X_a)$ fraction of households who aim to buy a house in the future. Hence, the final adjusted assets measure capturing liquid assets only is:

$$\tilde{A}_a = \begin{cases} X_a A_a^H + (1 - Y_a)(1 - X_a)A_a^{NH-} + Y_a(1 - X_a)\left(1 - \frac{0.75-X_a}{Y_a(1-X_a)}\frac{Dp}{A+Dp}\right)A_a^{NH+} & \text{if } Y_a(1 - X_a) > (0.75 - X_a) \\ X_a A_a^H + (1 - Y_a)(1 - X_a)A_a^{NH-} + Y_a(1 - X_a)\left(1 - \frac{Dp}{A+Dp}\right)A_a^{NH+} & \text{otherwise} \end{cases}$$

B.5 Durables measure

In the SHIW data, the net flow is computed as the difference between purchases and sales of durables at their respective prices, as reported by households. In solving and simulating the model, instead, I can only assign different prices to the durables net flow chosen by the agents in each period (x_t) depending on whether it is positive of negative. The following tables show that this is a reasonable approximation. Indeed, in my sample only 5% of net buyers also sell and about 25% of net sellers also buy, but the sub sample of net sellers is much smaller than the sub sample of net buyers.

Table 18: Net buyers

	1%	5%	10 %	25%	50%	75%	90%	95%	99%
% purchases	62.2	82.8	100	100	100	100	100	100	100
% sales	0	0	0	0	0	0	0	17.2	34.8

$N = 19,957$

Table 19: Net sellers

	1%	5%	10 %	25%	50%	75%	90%	95%	99%
% purchases	0	0	0	0	0	12.1	37.5	44	47.4
% sales	52.63	56	62.5	87.9	100	100	100	100	100

$N = 462$

C Income Tax schedule

Table 20: Personal income tax rates

Income brackets (annual gross income (euros))	tax rates (%)
$\leq$ 15,000	23
15,000-28,000	27
28,000-55,000	38
55,000-75,000	41
$\geq$ 75,000	43

D Computational details

Solution. The household maximisation problem described in Section 2 has no analytical solution. I solve it numerically by backward iteration starting from the final period of life (age 85). I obtain decision rules for household's non-durable consumption, investment in durables, investment in financial assets and women's participation decisions as functions of the information set (state variables) of the household in each period of the life cycle. During working life, the set of state variables consists of age, education, durables, financial assets, male productivity, female productivity and family composition. During retirement, instead, it consists of age, education, durables and financial assets. The two endogenous continuous state variables, stock of durables and stock of financial assets, are discretized on two logarithmically spaced grids of 30 points each. Following Tauchen (1986), the two continuous exogenous stochastic AR(1) processes for spouses' productivities are discretized and approximated using Markov chains over two grids of five points each. The exogenous state variable for family composition, instead, is defined as discrete and has three possible realizations. The model combines continuous choices of next period durables and financial assets stocks with the discrete employment choice of the wife. Moreover, the model features non-convexities due to the partial irreversibility of durable goods. To deal with these simultaneous discrete and continuous choices and with the non-convexities in durables choice, I discretize the space of continuous choices and solve the optimisation problem by grid search choosing the combination of grid points that maximizes households' expected utility in each period. Households' expected lifetime utility is computed by integrating the value function over the distributions of the three exogenous stochastic state variables for male productivity, female productivity and family composition. Given the optimal decision rules for employment, next period durables stock and next period financial assets, optimal choices for non-durable consumption and durables' flow are obtained as residual from the budget constraint and from the durables law of motion[32].

Simulation. Once obtained the optimal decision rules as functions of the state variables, I simulate the life-cycle economic behavior of 12,790 households. I initialize the simulations by drawing values of the state variables (education type, financial assets, durables, both spouses' earnings and family composition) from the data distribution in the sub sample of households in age range 25-30. This procedure implies that households' initial endowments not only differ across education groups, but also across households within the same education group. I simulate ten replications for each of the households observed in the data. Over the life-cycle, each simulated household draws specific profiles of realizations of productivities and family composition random shocks. Based on the initial set of information at the beginning of each period, optimal choices are computed starting from the first period in the model (age 31) and moving forward so that the durables and financial assets decisions made by the household in period t enter the state space on which period $t+1$ choices depend.

[32] The solution is computed in Fortra90 using parallelization on multiple nodes.

E Identification

E.1 Identification of male earning process parameters

Given that I assumed the stochastic component of earnings, $\tilde{y}$, to be the sum of a persistent shock (AR(1) process with non constant variance) and of a transitory shock, the theoretical variance-covariance matrix of $\tilde{y}$ consists of the following theoretical moments[33]

$$var(\tilde{y}_{i,t}) = var(z_{i,t}) + var(\varepsilon_{i,t}) = \rho^{2t}\sigma^2_{z_0} + (1-\rho^{2t})\frac{\sigma^2_u}{1-\rho^2} + \sigma^2_\varepsilon \tag{25}$$

$$cov(\tilde{y}_{i,t}, \tilde{y}_{i,t-j}) = cov(z_{i,t}, z_{i,t-j}) = \rho^j var(z_{i,t-j}) \qquad if \qquad j > 0 \tag{26}$$

The predicted residuals from the estimation of the determinisitc component of y are consistent estimators of $\tilde{y}$, hence, to construct the empirical counterparts of the theoretical moments, the corresponding empirical moments are computed on the predicted residuals so to build the empirical variance-covariance matrix.

Identification of the four parameters of interest follows the following steps:

- ρ is identified from the slope of the covariance at lags greater than zero:

$$\frac{cov(\tilde{y}_{i,t}, \tilde{y}_{i,t-4})}{cov(\tilde{y}_{i,t-2}, \tilde{y}_{i,t-4})} = \frac{\rho^4 var(z_{i,t-4})}{\rho^2 var(z_{i,t-4})}$$

- σ^2_ε is identified from difference between variance and covariance at first lag:

$$var(\tilde{y}_{i,t-2}) - \frac{1}{\rho^2}cov(\tilde{y}_{i,t}, \tilde{y}_{i,t-2}) = var(z_{i,t-2}) + \sigma^2_\varepsilon - \frac{1}{\rho^2}\rho^2 var(z_{i,t-2})$$

- $\sigma^2_{z_0}$ is identified residually from variance at age zero:

$$var(\tilde{y}_{i,0}) - \sigma^2_\varepsilon$$

- σ^2_u is identified from difference between variance and covariance at second lag :

$$var(\tilde{y}_{i,t-2}) - cov(\tilde{y}_{i,t}, \tilde{y}_{i,t-4}) - \sigma^2_\varepsilon = \rho^4 var(z_{i,t-4}) + \sigma^2_u + \sigma^2_\varepsilon - \rho^4 var(z_{i,t-4}) - \sigma^2_\varepsilon$$

Full identification is achieved with two lags of the current age $(t, t-2, t-4)$, therefore the same houshold must be interviewed for at least three subsequent waves of SHIW in order to be

[33] Given that SHIW is conducted every other year, I do not observe household earnings at every age, but only at age $t, t+2, t+4...$ and have to adjust the model accordingly.

included in the earning process' estimation sample.

Let $\mathbf{f}(\psi)$ be the vector of the unique moments of the symmetric theoretical variance-covariance matrix, which are functions of the parameters $\psi = \{\rho, \sigma_u^2, \sigma_\epsilon^2, \sigma_{z_0}^2\}$ to be estimated, and $\mathbf{m}$ be the vector of the corresponding empirical moments. The estimators of the parameters in ψ are found by minimizing the weighted (diagonal weighting matrix W) distance between theoretical and empirical moments:

$$\hat{\psi} = \arg\min_{\psi} [\mathbf{m} - \mathbf{f}(\psi)]' \mathbf{W} [\mathbf{m} - \mathbf{f}(\psi)] \tag{27}$$

Standard errors of estimating parameters are computed by repeating the estimation procedure above on 500 bootstrapped samples.

In principle the term $\varepsilon_{i,t}$ might be thought of as a mix between transitory shock and measurement error, however, as already mentioned, I assume that all estimated transitory shocks to wages represent measurement error. In SHIW the fundamental cause of measurement error for income data is under reporting of earnings. It has been shown (Biancotti et al., 2008) that income and wealth are voluntarily underestimated by the respondents more severely in the South and when the head of the household is self employed, poorly educated or older. If under reporting is not systematic the tendency to under report can be a relevant cause of additional variance of the measurement error. This might partially explain the large magnitude of the variance of the stochastic transitory component of earnings that I find.

E.2 Identification of second step parameters

Identification of each preference parameter hinges on all the moments targeted in estimation. However, some moments contribute more heavily to the identification of particular parameters. Mean life-cycle profiles of financial assets and non-durable consumption contribute to the identification of the coefficient of relative risk aversion, as suggested by other studies (Cagetti (2003), Gourinchas and Parker (2002)). A higher level of assets and a smoother life cycle consumption path imply a larger γ. Savings in durables and financial assets influence the identification of the discount factor β, larger holdings of wealth suggest that households are more patient and discount the future less. In particular, γ and β can be separately identified because thay have different quantitative implications at different ages, depending on the relative importance of precautionary savings (risk aversion) and life cycle-savings for retirement (discount factor). Mean profiles of non-durable and durable consumption together inform the identification of θ and ϵ^d. Indeed, a higher ratio of durable to non-durable consumption implies that households value non-durable consumption relatively more with respect to durables and that they perceive durables as luxury goods.

Mean female employment rate over the life cycle, in particular around the birth of the first child, help identifying disutility from work parameters. Lower participation at the beginning of life implies that working is more costly when there are young children in the households and therefore ψ_1 and ψ_2 are higher. The fraction of durables stock that is collateralizable, χ, is identified by the mean patterns of financial assets and durables at beginning of working life, when individuals are more likely to borrow. The higher the ratio between assets liabilities and durables, the higher is the collateral value of durables.

The rest of the structural parameters can be cleanly identified by exploiting the longitudinal structure of SHIW data. The parameters of the deterministic and stochastic components of female earning process are identified by the mean age profile of wages and by the elements of the variance covariance matrix of the time series of unobserved productivity shocks, respectively.

The identification strategy for durables depreciation rate, δ, and reversibility rate, π, relies on the availability of reported measures for value of durables stock and value of durables flow in each wave of the panel data. Specifically, δ and π are separately identified by the relationship between the end of period value of the stock net of the period value of the flow and the previous period value of the stock. Identification of δ exploits the fact that the values of both durables stocks and flows reported by net sellers in the data embed irreversibility. Thus, it is possible to isolate the effect of depreciation from that of irreversibility by expressing the durables law of motion in terms of observables for the sub sample of net sellers. Once δ is identified, identification of π follows a similar reasoning and hinges on the fact that, among net buyers, only the observed stock - but not the observed flow - includes irreversibility.

The formal proof starts from durables law of motion: $d_t = (1-\delta)d_{t-1}+x_t$ and goes as follows:

- For net sellers, $\tilde{d} = \pi d$ and $\tilde{x} = \pi x$ are observed in data and the durables law of motion can be rewritten in terms of observables:

$$\pi d_t = (1-\delta)\pi d_{t-1} + \pi x_t \rightarrow \tilde{d}_t = (1-\delta)\tilde{d}_{t-1} + \tilde{x}_t$$

$$1-\delta = \frac{\tilde{d}_t - \tilde{x}_t}{\tilde{d}_{t-1}}$$

  hence, δ is identified in the subsample of households who are net sellers between two subsequent waves.

- For net buyers, $\tilde{d} = \pi d$ and $\tilde{x} = (1+\tau^d)x$ are observed and the transformed durables law of motion in terms of observables is:

$$\begin{aligned}(1+\tau^d)\pi d_t = (1-\delta)(1+\tau^d)\pi d_{t-1} + (1+\tau^d)\pi x_t \rightarrow \\ (1+\tau^d)\tilde{d}_t = (1-\delta)(1+\tau^d)\tilde{d}_{t-1} + \pi \tilde{x}_t\end{aligned}$$

$$1-\delta = \frac{\tilde{d}_t - \frac{\pi}{1+\tau^d}\tilde{x}_t}{\tilde{d}_{t-1}}$$

$$\pi = (1+\tau^d)\frac{\tilde{d}_t - (1-\delta)\tilde{d}_{t-1}}{\tilde{x}_t}$$

once δ has been identified, also π is identified in the subsample of households who are net buyers between two subsequent waves.

The moments that I target in estimation are tractable approximations of the above theoretical relationships:

$$\frac{1}{N_s T}\sum_{i=1}^{N_s}\sum_{t=1}^{T}\left[\frac{\tilde{D}_{i,t}-\tilde{X}_{i,t}}{\tilde{D}_{i,t-1}}\right] \qquad \text{and} \qquad \frac{1}{N_b T}\sum_{i=1}^{N_b}\sum_{t=1}^{T}\left[\frac{\tilde{D}_{i,t}-\tilde{X}_{i,t}}{\tilde{D}_{i,t-1}}\right]$$

computed separately over the subsamples of net sellers (N_s) and net buyers (N_b).

F Estimation

F.1 First step estimation procedures

Male earning process. I treat male earning process as exogenous to the structural model by assuming absence of non random selection into employment for men[34]. I estimate the process' parameters on gross earnings panel data from SHIW, following a standard estimation procedure (see Guvenen (2009)). As shown in equations (10)-(12), I specify gross labor income as the sum of a deterministic component and of a stochastic component. I first estimate the parameters of the deterministic component as the coefficients of a regression of logarithm gross wages on a set of year dummies, a polynomial in age and a region fixed effect. I then predict the residuals from this regression and estimate the parameters of the stochastic component as the ones that minimize the distance between the empirical variance covariance matrix computed on the predicted residuals and the theoretical variance covariance matrix. In particular, I estimate the persistency of the AR(1) productivity shock, ρ, the variance of the innovation to the AR(1) productivity shock, σ^2_u, the variance of the initial productivity shock, $\sigma^2_{z_0}$, and the variance of

[34]This assumption is standard in the literature and is supported by the fact that employment rate of married men is close to 100% in the data.

the transitory shock σ^2_ε. All estimates are education specific. Details on estimation procedure and identification are in Appendix E.1.

Table 21: Estimated parameters of the stochastic component of male earnings

	Education level		
	Secondary	High School	College
ρ	0.9351	0.9483	0.9667
	(0.0310)	(0.0385)	(0.1008)
σ^2_u	0.0128	0.0119	0.0092
	(0.0068)	(0.0101)	(0.0126)
$\sigma^2_{z_0}$	0.0379	0.0488	0.1464
	(0.0167)	(0.0278)	(0.0885)
σ^2_ε	0.0980	0.0653	0.0799
	(0.0152)	(0.0184)	(0.0271)
N	2,156	1,254	410

Bootstrapped standard errors in parentheses

Family composition dynamics. Family composition evolves stochastically and can assume one of three possible values: 0 for no children in household, 1 for youngest child of pre school age (0-5), 2 for youngest child of school age (6+). The probabilities of transitioning from one state to the other are estimated from SHIW panel data as functions of age and education level of the household. Figure 4 in Appendix G.1 shows that the estimated life cycle mean profiles of family composition line up very well with the ones observed in the data for working age households. The average probability of having at least one child in the household at the starting age of 30 is decreasing in household's education.

Tax function. To estimate the parameters of the non linear labor income tax function in (13), I take its logarithmic transformation:

$$ln(y^{net}) = ln(\lambda) + (1-\tau)ln(y^{gross}) \tag{28}$$

The chosen tax base is labor income, therefore, y^{net} represents wage net of taxes and inclusive of transfers and y^{gross} measures wage before taxes and transfers. As taxation of labor income is levied at the individual rather than at the household level in Italy, I estimate (28) on gross and net wages of each spouse from SHIW data. To take into account the fact that tax credits and family allowances depend on family composition and income sources, I estimate different tax functions for parents, non-parents and retirees. Estimates in Table 22 confirm that the level of taxation is lower for retirees than for working age households and is higher for non-parents than for parents with dependent children. Progressivity, instead, does not significantly differ by employment and family status.

Table 22: estimated parameters of labor income tax function

	dependent child(ren)	no dependent child(ren)	retirees
λ	2.39	2.23	2.98
τ	0.12	0.11	0.13

The estimated tax function in (28) provides a good approximation to the actual tax system with a R-squared of 0.96. Figure 5 in Appendix G.2 shows the actual and approximated relationship between gross and net earnings in the three sub groups of parents, non-parents and retirees.

F.2 Estimates and elasticities for restricted version of the model

Table 23: AIDS estimated parameters

	α_1	β_1	η_{11}
share c_1	0.8513	-0.0587	-0.0101
	(0.0125)	(0.0014)	(0.0127)

$N = 13,989$

Standard errors in parentheses

Table 24: Predicted expenditure shares and elasticities at the means

	shares	budget elasticity	p_1 elasticity	p_2 elasticity
share c_1	0.337	0.826	-0.603	0.603
	(0.001)	(0.004)	(0.037)	(0.037)
share c_2	0.663	1.088	0.307	-0.307
	(0.001)	(0.002)	(0.019)	(0.019)

Standard errors in parentheses

Table 25: estimated preference parameters

	Sec	HS	College	
	All education levels			
θ		.85		non-durable consumption share
		(.0018)		
γ		3.36		coeff. of relative risk aversion
		(.0071)		
β		.99		discount factor
		(.0006)		
ϵ^d		-300		Stone-Geary coeff for durables
		(3.4852)		
ψ_0	3.0494	.7946	.4610	female participation: no children
	(14.7319)	(.0299)	(.0391)	
ψ_1	.9761	.9528	.9128	female participation: youngest child 0-5
	(.0072)	(.0099)	(.0132)	
ψ_2	.9410	.99	.80	female participation: youngest child 6+
	(.0047)	(.0086)	(.0163)	

Table 26: estimated durable dynamics parameters

	All education levels	
δ	.04	durables depreciation rate
	(.0011)	
π	.50	fraction of non irreversible durables
	(.0041)	
χ	.09	fraction of collateralizable ddurables
	(.0043)	

Table 27: simulated marshallian elasticities, All and by education

		All		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.38	0.42	0.58	0.80
male net wage	-1.59	0.34	0.45	0.25
price of necessities	0.08	-0.84	-0.03	0.00
price of luxuries	-0.07	0.05	-1.03	0.01
price of durables	-0.04	0.03	0.05	-1.65
		Secondary		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.46	0.37	0.51	0.61
male net wage	-1.68	0.40	0.53	0.31
price of necessities	0.07	-0.85	-0.04	0.00
price of luxuries	-0.05	0.06	-1.02	0.02
price of durables	-0.02	0.02	0.03	-1.44
		High School		
1% increase in	employment	necessities	luxuries	durables
female net wage	1.43	0.48	0.66	0.98
male net wage	-1.70	0.26	0.36	0.18
price of necessities	0.11	-0.82	-0.02	0.01
price of luxuries	-0.11	0.05	-1.04	0.01
price of durables	-0.06	0.07	0.10	-2.08
		College		
1% increase in	employment	necessities	luxuries	durables
female net wage	0.93	0.40	0.57	0.68
male net wage	-0.87	0.36	0.51	0.33
price of necessities	0.01	-0.83	-0.05	-0.01
price of luxuries	-0.00	0.07	-1.02	-0.03
price of durables	-0.01	-0.03	-0.05	-0.76

F.3 Test of non separability assumption in AIDS

$$w_i = \alpha_{0i} + \alpha_{1i}df + \sum_{j=1}^{k} \eta_{ij} lnp_j + (\beta_{0i} + \beta_{1i}df) ln \left\{ \frac{c}{a(p)} \right\} + e_i$$

where,

$$ln(a(P)) = \sum_{i=1}^{n} (\alpha_{0i} + \alpha_{1i}df) lnp_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \eta_{ij} lnp_i lnp_j$$

Table 28: AIDS estimated parameters by education

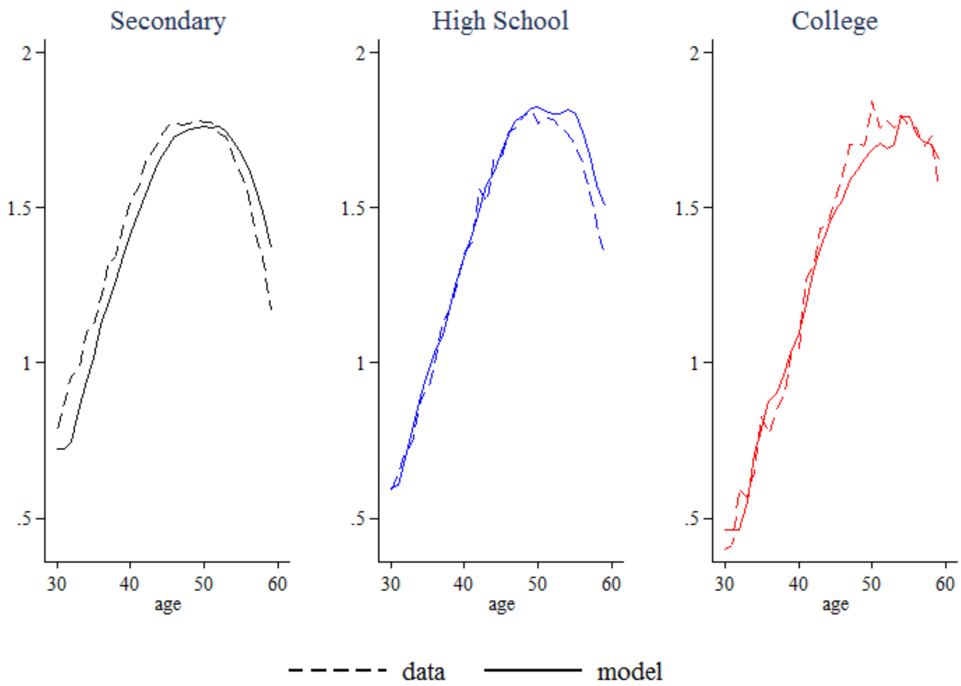
	Secondary	High School	College
α_0	0.4573	0.7003	0.8786
	(0.0333)	(0.0348)	(0.0390)
α_1	0.0429	-0.2107	-0.0501
	(0.0612)	(0.0665)	(0.0666)
β_0	-0.0108	-0.0381	-0.0581
	(0.0039)	(0.0039)	(0.0043)
β_1	-0.0112	0.0162	-0.0003
	(0.0071)	(0.0075)	(0.0074)
η_{11}	- 0.0136	0.0047	0.0870
	(0.0113)	(0.0115)	(0.0183)
N	2,193	2,185	1,999

Standard errors in parentheses

G Model Fit

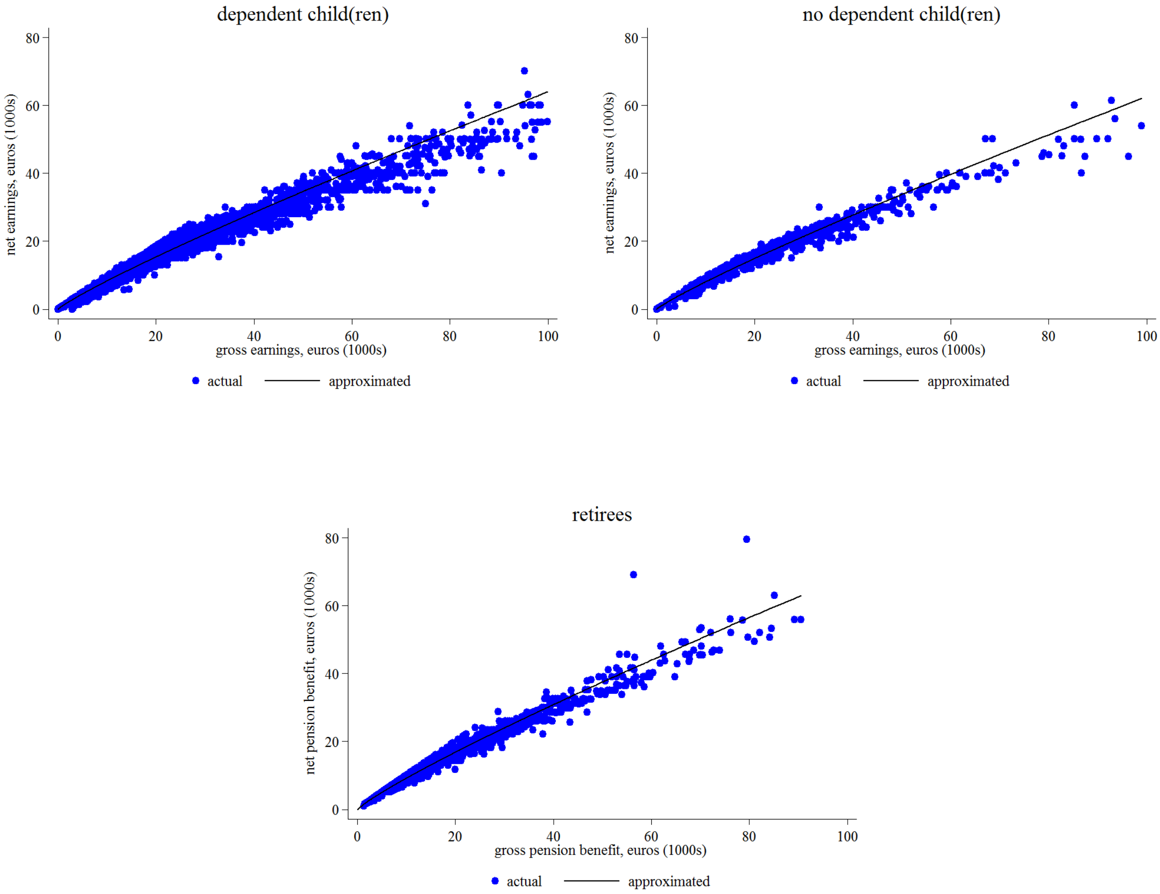
G.1 Family composition

Figure 4: family composition profiles



G.2 Tax function

Figure 5: labor income tax, actual vs approximated



G.3 Additional model fit

Figure 6: mean net earnings by education, data vs model

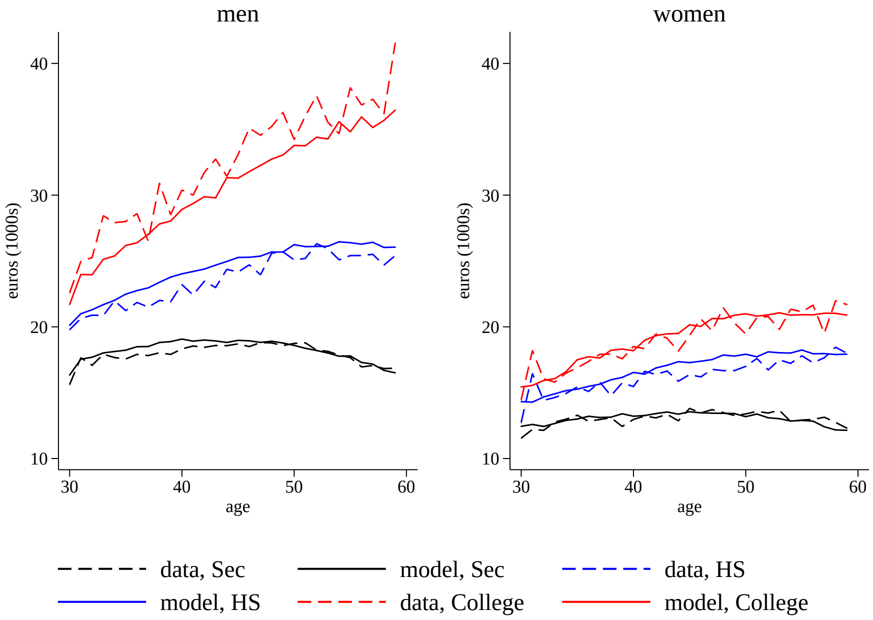


Table 29: Means at age 40-50 by education, data vs model

	Secondary		High School		College	
	Data	Model	Data	Model	Data	Model
non-durable consumption	23,828	21,163	28,984	28,891	33,070	36,729
women employment rate	0.43	0.48	0.63	0.59	0.75	0.73
durables	22,937	21,191	30,759	30,711	34,959	39,017
financial assets	9,002	9,696	15,819	14,293	21,888	14,386
men net wage	18,605	18,883	24,167	25,071	33,228	31,288
women net wage	13,337	13,390	16,397	17,260	19,516	19,854

G.4 Additional validation checks

Figure 7: distributions, data vs model

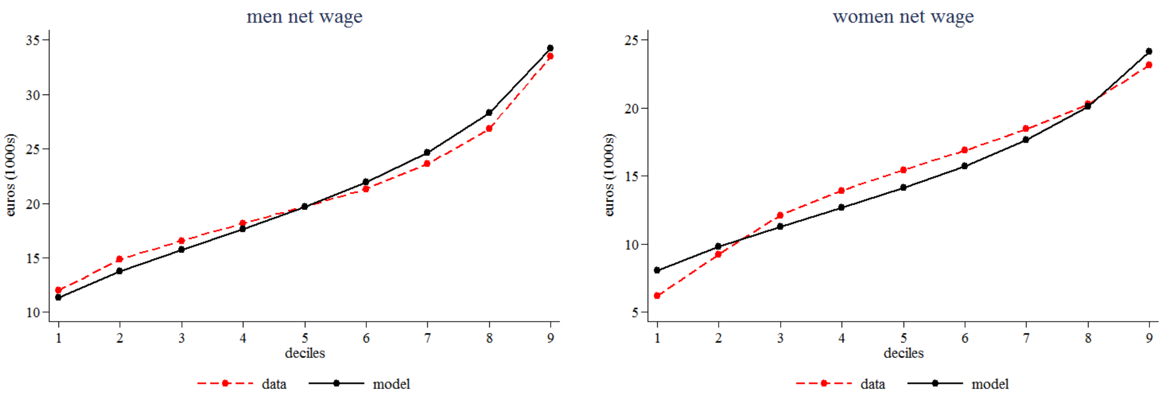
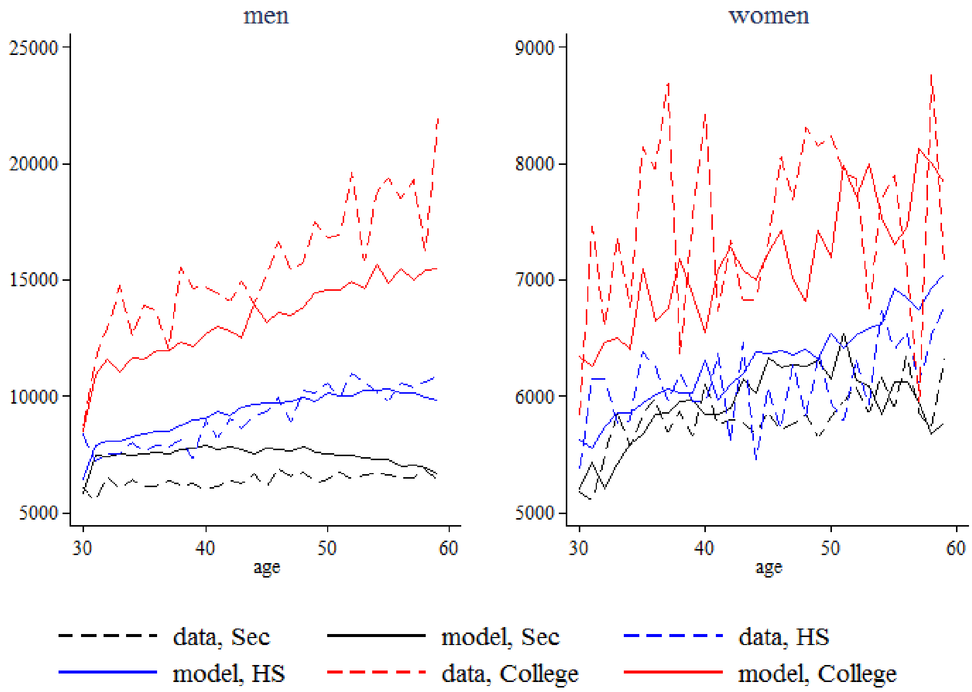


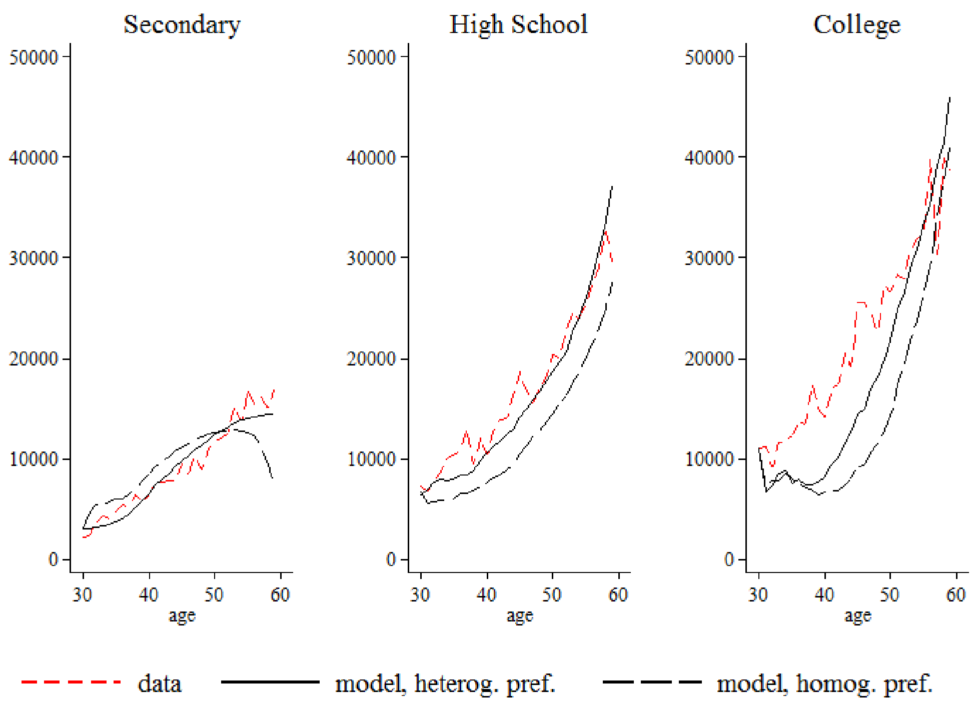
Figure 8: std. dev. of net wages by education, data vs model



G.5 Homogeneous versus heterogeneous consumption preferences

Figure 9 compares the performances of the two versions of the model- with and without heterogeneous consumption preferences across education groups - in reproducing the education-specific life-cycle profiles of financial assets observed in the data. Allowing for heterogeneous preferences for consumption and savings improves the fit to the data.

Figure 9: mean life cycle profiles of assets, data vs model



H Additional welfare implications of tax reforms

Figure 10 and 11 shed more light on the welfare implications of the optimal tax systems found under homogeneous and heterogeneous preferences scenarios, respectively, by disaggregating the welfare gains/losses by deciles of (education specific) pre-reform expected lifetime disposable income distributions.

Figure 10: CEV by education and by deciles of pre reform expected lifetime disposable income

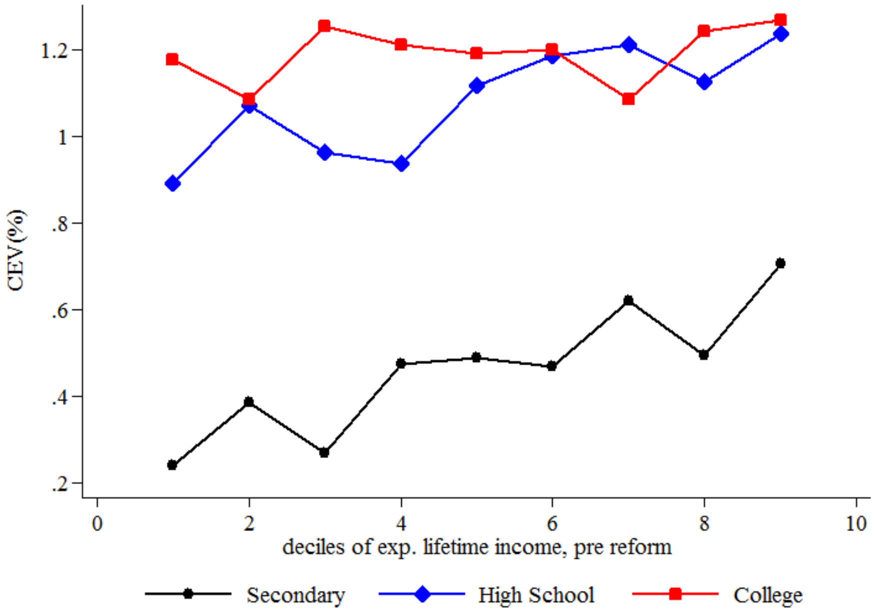


Figure 11: CEV by education and by deciles of pre reform expected lifetime disposable income