Essays in Public Finance and Household Life Cycle Behavior

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I, Francesca Parodi, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the work.

Abstract

This PhD thesis investigates the impact of direct and indirect taxation on households' consumption, saving and labor supply decisions over the life cycle.

Chapter 1 focuses on indirect taxation. A dynamic model of households saving, durable and non-durable consumption decisions in a context of income uncertainty and borrowing constraints is set up. A novel feature of the model is the consistent integration of an intratemporal static demand analysis for different categories of non-durables - necessities and luxuries - with an intertemporal dynamic model for durables and savings. Simulated counterfactuals based on the estimated model show that revenue neutral reforms changing value added tax rates towards uniformity would be welfare improving, however, they would redistribute in favor of the wealthiest groups.

Chapters 2 and 3 analyze direct and indirect taxation jointly. Chapter 2 extends the model in Chapter 1 by allowing for endogenous labor supply decisions, heterogeneous preferences and uncertainty in family dynamics. The model is estimated on micro-data and its rich structure is shown to be crucial in reproducing the empirical patterns of households' life cycle economic behavior. Marshallian elasticities are then simulated along several dimensions and show that the model accounts for mechanisms of interaction between households' economic behavior and the tax system that have not been considered together in previous studies.

Chapter 3 applies the model of Chapter 2 to conduct a quantitative normative analysis. Under a utilitarian framework, it is found that durables should be subsidized in presence of pre-commitment and uncertainty and that the optimal combination of taxes on non-durables and labor income crucially depends on the degree of

preference heterogeneity. Allowing for a generalized social welfare criterion with varying degrees of government inequality aversion, it is shown that the model can rationalize the tax systems observed in reality.

Impact Statement

Consumption and personal income taxes are key policy instruments. They are the two major sources of government revenues 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 in the absence of perfect private insurance market. On the other hand, differential tax rates distort consumption choices among different categories of goods, while the level and progressivity of income taxes change the incentives to work of the household. Moreover, from an intertemporal perspective, both consumption and labor income taxes affect credit constraints and distort saving decisions.

Given the importance of these two tax instruments and the incentive-insurance trade-off that policy makers face when deciding about their mix and design, this PhD thesis investigates the impact of direct and indirect taxation on households' consumption, saving and labor supply decisions over the life cycle and how the policy maker should optimally design these taxes.

In order to realistically address this topic, this research develops an empirical framework that combines all the dimensions that are crucial for the study of direct and indirect taxation and, at the same time, remains computationally tractable in order to provide quantitative results that help in guiding the public policy debate and in bridging the gap between tax theory and tax practice.

The model presented in this thesis features several elements affecting households consumption, saving and labor supply decisions that have not been considered together in previous literature: multiple consumption goods, partially irreversible durables, credit constraints, preference heterogeneity, and uncertainty about the evolution of earnings and family dynamics. The interaction among these features is shown to be crucial in matching the life-cycle patterns of households' economic behavior observed in the micro data and, in particular, in reproducing the empirical distributions of consumption, savings and earnings.

The estimated model is used to conduct a series of computational experiments. The analysis highlights the importance of taking into account durable goods and intertemporal preference heterogeneity for conducting optimal taxation analysis. Moreover, to overcome the limitations of the utilitarian approach to social welfare in a context of multidimensional preference heterogeneity, the analysis is generalized to a social welfare criterion allowing for society's fairness concerns. This framework reconciles the discrepancy between theoretical optimal taxation results and actual tax practice and shows that the model in this thesis can rationalize the tax systems implemented in reality under high degrees of policy makers' inequality aversion. Quantitative simulations also suggest that differentiated consumption taxes - with substantially higher rates on durables - can play a crucial role as redistributive tools jointly with progressive labor income taxes.

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Contents

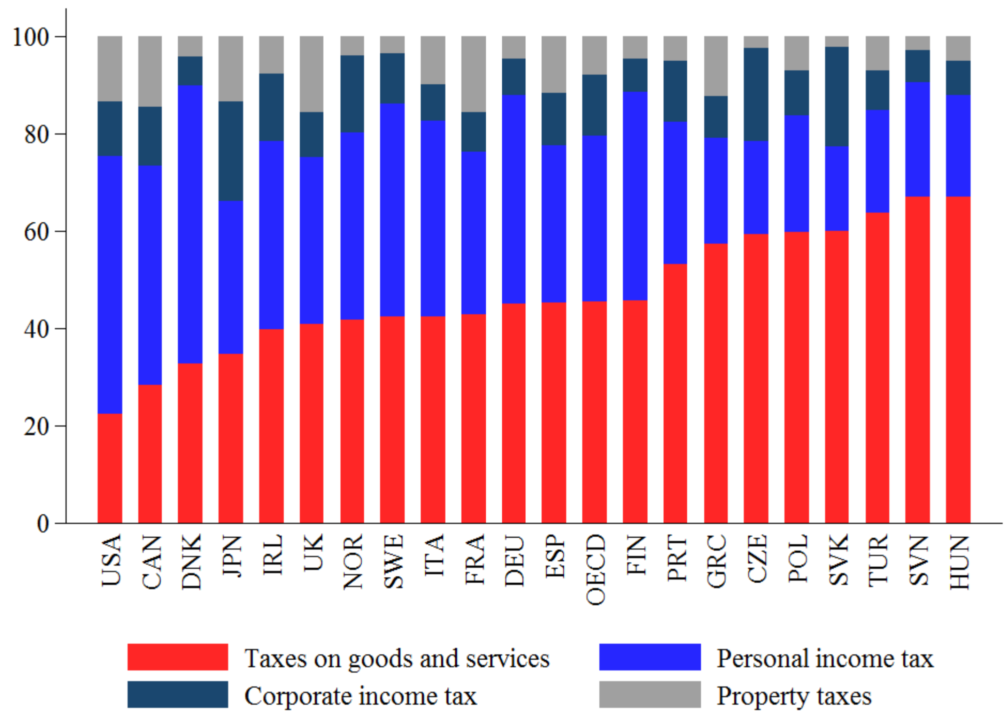
List of Figures

List of Tables

Introduction

Consumption and personal income taxes are key policy instruments. They are the two major sources of government revenues in OECD countries, with substantial differences across nations, as shown in Figure 1.

Figure 1: Shares of total tax revenues across countries



Source: Author's elaboration with data from OECD.Stat.

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 in the absence of perfect private insurance market. On the other hand, differential tax rates distort consumption choices among different categories of goods, while the level and progressivity of income taxes change the incentives to work of the household. Moreover, from an intertemporal perspective, both consumption and labor income taxes affect credit constraints and distort saving decisions.

Given the importance of these two tax instruments and the incentive-insurance trade-off that policy makers face when deciding about their mix and design, this PhD thesis investigates the impact of direct and indirect taxation on households' consumption, saving and labor supply decisions over the life cycle and how the policy maker should optimally design taxes on different commodities and labor income.

In order to realistically address this topic, there are three key elements to be taken into account. First, households' consumption consists of different categories of goods that can be taxed at different rates: non-durables with different degrees of necessity and durables that represent both a consumption and an investment decision for the household. Consumption choices among these goods vary over the course of life and differ across income levels. Second, these consumption choices interact with labor supply decisions that are very sensitive to tax incentives, especially for the second earner in the household. Third, even conditional on their income, households differ in their responses to the tax system because they face different lifetime shocks and constraints and have heterogeneous preferences.

The broad aim of this research is to develop an empirical framework that features all the dimensions that are crucial for the study of direct and indirect taxation described above and, at the same time, remains computationally tractable in order to provide quantitative results that can help in guiding the debate on the joint design of direct and indirect taxation and bridge the gap between tax theory and tax practice.

Chapter 1 focuses on indirect taxes. In this chapter, I set-up a dynamic model of households durable and non-durable consumption decisions in a context of income uncertainty and borrowing constraints. A novel feature of the model is the consistent integration of an intratemporal static demand analysis for different categories of non-durables with an intertemporal dynamic model for durables. The model is estimated on a combination of cross-sectional and panel data and then exploited to simulate the effects of hypothetical reforms of value added tax (VAT) on consumption choices over the life cycle and on redistribution across different groups of households. I find that revenue neutral reforms changing VAT rates towards uniformity would be welfare improving, however, they would redistribute in favour of the wealthiest groups.

Chapters 2 and 3 investigate direct and indirect taxation jointly. Chapter 2 extends the model presented in Chapter 1 by allowing for endogenous labor supply decision of the second earner in the household and heterogeneous preferences across education groups. The model is estimated on micro-data and its rich structure is shown to be crucial in reproducing the empirical patterns of households' life cycle economic behavior. I then use the model to simulate life cycle Marshallian elasticities along several dimensions and show that the model implies several mechanisms of interaction between households' economic choices and the tax system that have not been considered together in previous studies.

First, the disaggregation of consumption into sub components implies that consumption goods are differently affected by changes in consumption and labor income taxation depending on their degree of necessity and durability. In particular, the fact that households have to commit to their durable investment decisions before future shocks are realized calls for additional social insurance.

Second, the model allows for interactions between instruments of private insurance and the tax system. Specifically, consumption taxes on durables change the attractiveness of financial assets relative to durables as saving instruments and, therefore, shift the composition of households portfolio over time. Moreover, the presence of credit constraints creates further heterogeneity in the response to tax changes across the population; more constrained households react differently to tax reforms as opposed to unconstrained ones. The labor supply choice of the second earner is affected by the tax system both directly, through incentives from the labor income tax, and indirectly, as a device to smooth household consumption against changes in the tax burden.

Third, heterogeneity in preferences across education groups translates into heterogeneity in the elasticities of consumption demand and labor market participation to changes in prices and wages. This has important implications for the redistributive effect of taxation.

Chapter 3 applies the rich empirical framework developed in Chapter 2 to conduct a quantitative normative analysis of the optimal tax rates on different commodities and on labor income in a utilitarian framework and under alternative scenarios of preference heterogeneity. I find that durables should be subsidized in presence of pre-commitment and uncertainty and that the optimal combination of taxes on non-durables and labor income crucially depends on the degree of preference heterogeneity. Allowing for a more general social welfare criterion with varying degrees of government inequality aversion, I show that the model can rationalize the tax systems observed in reality and that differentiated consumption taxes - with higher rates on durables - serve a redistributive purpose jointly with the progressivity of labor income taxes.

This thesis contributes to different streams of the economic literature on household life cycle behavior and Public Finance. The models developed in Chapters 1 and 2 relate to the empirical and theoretical literature on households' consumption choices among multiple categories of commodities over the life cycle (Aguiar and Hurst, 2013). In particular, given the focus on durables dynamics, this research draws insights from papers on consumer durables adjustments over the life cycle such as Eberly (1994) and Attanasio (2000). In terms of methodology, the consistent integration of static demand system governing the intratemporal decision among different categories of non-durables within the dynamic life cycle model for durables builds on Blundell et al. (1994).

The rich framework presented in Chapter 2 combines elements of the extensive Microeconomic and Macroeconomic literature on dynamic life cycle models. On the one hand, it borrows features from the Labor and Household Economics literature on structural life cycle models of consumption, female labor supply decisions and family insurance in presence of uncertainty (Blundell et al. (2016a), Blundell et al. (2016b), Attanasio et al. (2018)). On the other hand, the model is closely related to the Macro literature on two-asset life cycle models. In particular, the framework is similar to the liquid-illiquid assets model in Kaplan and Violante (2014), to the models of Fernandez-Villaverde and Krueger (2011) and Berger and Vavra (2015) that allow for saving in financial assets and durables, and to the model in Aaronson et al. (2012), in which households can use durables as collateral for borrowing and face durables adjustment costs. To my knowledge, this is the first paper that combines a two-asset structure with endogenous labor supply choice within an estimated structural life cycle model.

The quantitative normative analysis conducted in Chapter 3 contributes to the literature that concerns the quantitative characterization 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) 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 is the focus of Chapter 3 .

Lastly, the analysis in Chapter 3 complements the vast Public Finance theoretical literature on the optimal mix of direct and indirect taxation. Starting from the seminal Atkinson and Stiglitz (1976) result of uselessness of commodity taxation in presence of optimal non linear labor income tax, a large body of literature has developed. Studies in this literature challenged the conclusions of Atkinson and Stiglitz by extending their framework in various alternative directions. Among others, Cremer and Gahvari (1995a) looked at pre-commitment 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 the framework that is developed in this thesis allows to contribute to this debate in a more general environment that combines many of the dimensions previously considered in these extensions.

Moreover, the empirical approach of this study fills a gap in the Public Finance literature as it allows to quantify the importance of the mechanisms suggested by the theory and, therefore, to obtain data-based policy implications regarding direct and indirect taxation in a realistic dynamic stochastic context. In particular, the results in Chapter 3 help in bridging the existing gap between data and theory by evaluating how optimal taxes compare to the actual tax codes implemented across countries.

Chapter 1

Value-Added Tax, Household Consumption Dynamics, and Redistribution

1.1 Introduction

Most European countries apply differentiated rates of Value-Added Tax (VAT) to different categories of goods, depending on their degree of necessity, with the aim of reducing household consumption inequality. However, the desirability of this structure of the indirect tax system has become object of debate among economists and policy makers. Opponents of the current systems believe it would be more efficient to apply a uniform standard tax rate on all consumption goods and to redistribute through other fiscal tools, such as benefits. In the light of this debate, the aim of this Chapter is to study the impact on households of potential reforms of the current Italian differentiated VAT schedule towards more uniformity. In particular, the analysis will focus on the effects of such VAT reforms on households' consumption and saving choices over the life cycle and on redistribution across heterogeneous households.

I investigate these mechanisms by means of a structural life cycle model of non-durable consumption, durables and savings with indirect taxation, income uncertainty and borrowing constraints. The distinctive feature of the model is the integration of an intratemporal static demand analysis for multiple non-durable goods -necessities and luxuries - within an intertemporal dynamic model for durables and assets. I analyze household consumption decisions within each period of life as well as over the life-cycle.

I estimate the model on micro data using the method of simulated moments and a two-step estimation procedure. In the first step, I estimate the preference parameters of the Almost Ideal Demand System (Deaton and Muellbauer (1980)) that governs the intratemporal choice among different non-durable commodities. In the second step, I estimate the parameters that determine durables dynamics and the intertemporal consumption and saving decisions. I use a unique micro dataset containing longitudinal information on non-durable consumption, durables, and wealth for a representative sample of Italian households.

Studying the dynamics and interaction between durable and non-durable components of household's consumption over the life time is crucial for the assessment of the welfare effects of the reforms under analysis because there are key differences in tax rates and consumption behaviour between the two types of goods. The life-cycle pattern of durable consumption influences the life-cycle dynamics of non durables expenditure and savings because durable goods are not only a form of consumption, but also an alternative way of saving from one period of life to the next with respect to financial assets. Expenditure in durables influences households' lifetime utility both in a direct way, as current consumption, and in an indirect way, as a means of saving for future consumption.

Surprisingly, very little attention has been devoted to these aspects in the existing Public and Household Finance literature. Therefore, the present paper aims at contributing to this stream of research by enriching a dynamic life-cycle framework with features that help to analyse the long run consumption and saving behaviour of households in presence of alternative indirect taxation scenarios. The main findings from this exercise show that it is possible to improve efficiency of the current VAT design by applying less differentiated rates, however, this would result in redistribution towards the wealthiest groups of the population.

Related literature. This Chapter is most closely related to the Public Finance literature looking at the design of tax-benefit systems and at their impact on households' economic choices. In particular, this research has been greatly influenced by the Mirrlees Review (Mirrlees et al. (2010), Mirrlees et al. (2011)), a project which brought together international experts with the aim of identifying the main characteristics of a good tax system in developed countries and suggesting reforms to the existing systems that take into account their influence on people's behaviour. One of the main insights of the Review is that a good tax system should be as simple and transparent as possible. The reforms in favour of a non differentiated consumption tax rate that are being discussed nowadays in Europe, and that are the focus of this Chapter, are precisely inspired by these principles.

The model developed in this first Chapter is grounded in the large and growing literature about structural life-cycle models of household consumption and saving. Attanasio and Weber (2010) conduct a survey of models of intertemporal consumption and savings choice and discuss numerous public policy implications. Brewer et al. (2012) study lifetime inequality and investigate the progressivity and the redistribution properties of the existing UK tax-benefit system by means of a dynamic life-cycle model. In various papers Jappelli and Pistaferri (2006, 2010, 2014) study the issues of intertemporal consumption choice, income and consumption inequality and, especially, heterogeneity in marginal propensity to consume an income shock among different kinds of Italian households. While the dynamic life-cycle models in the existing literature deal with reforms to personal income taxes, social security and benefits and look at their impact on labour supply incentives, in this Chapter I focus exclusively on changes to indirect taxes on consumption and on their effect on household expenditure and saving choices over lifetime.

The model in this Chapter also draws insights from the empirical and theoretical literature studying consumer durables adjustment and households' choice among different types of consumption goods. Among these, the seminal studies by Eberly (1994) and Attanasio (2000) estimate the parameters of (S,s) rules governing the dynamics of durables stock in presence of non-convex adjustment costs using US micro data on car purchases. More recently, Bertola et al. (2005) adopt a semi structural approach to study consumer durables adjustments under idiosyncratic income uncertainty using Italian micro data about different categories of durables. Fernandez-Villaverde and Krueger (2011) investigate durable and non-durable consumption over the life-cycle in the US by means of a semi non-parametric statistical model. Aguiar and Hurst (2013) study the disaggregated life-cycle consumption profiles using US data about sub-components of non-durable consumption. I expand on this literature by enriching a dynamic model of non-durable and durable consumption choice with some additional features. I model non-durable consumption as a non-homogeneous bundle of goods that differ in their degree of necessity so that I allow for non-durable necessities and non-durable luxuries. I also account for the fact that some durable goods, once bought, are irreversible, meaning that they cannot be sold on a second-hand market and have no role as collateral for borrowing, while others have some degree of reversibility. In particular, differently from existing literature, I look at how the presence of non irreversible durable goods, that have an insurance value as consumption smoothing device and collateral for borrowing, influences the consumption-saving decision of the household in an economic context featuring indirect taxes, income uncertainty and borrowing constraints.

Lastly, in terms of methodology, the main new contribution of this Chapter with respect to the existing literature is the consistent integration of a static demand system into a dynamic life-cycle model of household consumption and saving choices. As a result of this set-up, intratemporal and intertemporal preference parameters can be estimated relying on two different sets of moments from two separate data sources. This idea of embedding a static demand system into an intertemporal substitution problem builds on Blundell et al. (1994) and Attanasio and Browning (1995), who adopt a representation of period specific household preferences featuring a conditional indirect utility function. However, while they condition on demographic characteristics of the households in order to test the validity of the life-cycle model, I condition on household's expenditure in durable consumption goods in order to take into account the existence of important differences in consumption behaviour and tax rates between durables and non-durables.

The rest of this Chapter is structured as follows. Section 1.2 describes the current VAT system in Italy and reports some introductory evidence that motivates this study. Section 1.3 outlines the model. Section 1.4 describes the data. Section 1.5 explains the estimation strategy and its results. Section 1.6 implements counterfactual analysis. Section 1.7 concludes.

1.2 Value-Added Tax System in Italy

The consumption tax schedule currently in place in Italy is highly differentiated. There is a reduced rate of 4% applying to non-durable necessities such as medicines and most food goods, an intermediate rate of 10% applying to other non-durables and services which are not considered necessities (e.g. restaurants and hotels), a standard rate of 22% on all other goods, mainly semi durables and durables. Also, few exemptions apply for medical and educational expenditures. As a result of this differentiation, Italy has the third lowest VAT-Revenue Ratio (VRR) among all OECD countries as reported by recent statistics ((OECD, 2014)). This index measures the amount of actual VAT revenues raised as a fraction of the amount of VAT revenues that would ideally be raised if the standard VAT rate was applied to all consumption. The lower the VRR, the less efficient is the VAT system of the country.

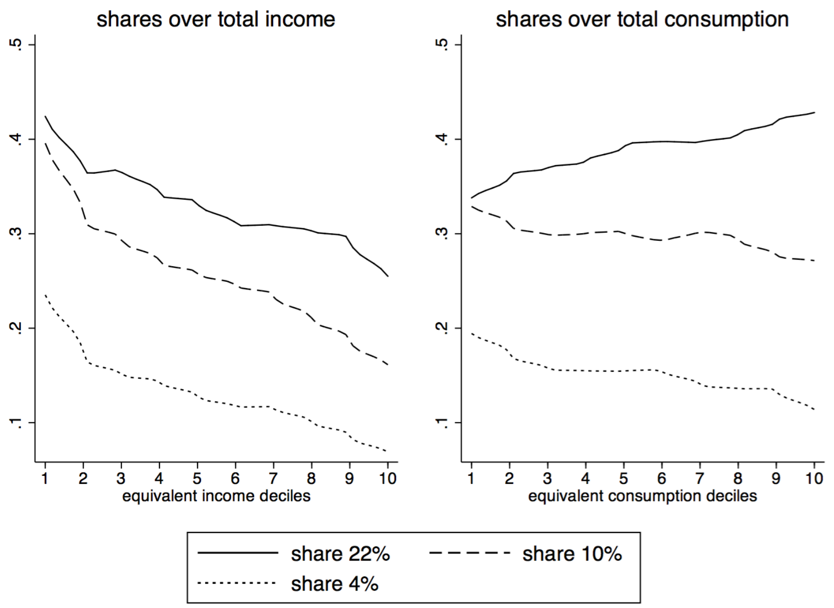
The reason why it is interesting to study the potential effects of a reform towards a less differentiated VAT schedule is twofold. From the equity point of view, even if reduced tax rates were originally introduced for equity reasons, evidence from the data about the effectiveness of VAT reduced as a redistribution device is not decisive. Figure 1.1 shows the graphical representations of Engel curves describing how household's expenditure on a particular category of goods varies with total income or total consumption in equivalent terms (equivalence scale in Appendix B.3).

In the left panel, VAT burden is assessed over total income, which corresponds to taking a current tax period perspective where household's economic possibilities and constraints are captured at a specific point in time without considering past and future choices. Under this perspective, VAT turns out to be overall highly regressive because households in the lower tail of the income distribution pay relatively more VAT than households in the upper tail at all rates.

The right panel, instead, measures VAT burden as a fraction of total consumption expenditure, thus taking an intertemporal, life-cycle perspective. This implicitly takes into account that the propensity to save is higher for richer people who therefore consume only a fraction of their income and also that younger or older households may consume more than their current income in certain periods of life because they are borrowing against their future income or dissaving past savings, respectively. According to this second approach, a different result appears: VAT has some redistributive power because households consuming overall more, also pay relatively more ordinary VAT rate, however reduced rates again do not succeed in targeting the poor who happen to pay relatively more VAT at reduced rates than their richer counterparts.

From the efficiency point of view, optimal taxation theorems (Atkinson and Stiglitz, 1976) tell us that imposing differentiated tax rates on different consumption goods is inefficient and costly in welfare terms because it distorts households' consumption decisions with respect to what they would be in an efficient equilibrium based on the relative prices of goods that, in turn, reflect their relative cost of production (equality between marginal rate of substitution and marginal rate of transformation). Under the assumption of separability of the utility function between consumption and labour, no differentiated consumption taxes need to be employed if non linear income taxation can be used by the government to redistribute. The assumptions of separable utility function and availability of other redistributive devices, on which the theorems rely, are admittedly strong and their validity might

Figure 1.1: VAT burden ranked over total equivalent consumption and total equivalent income



be questioned in a context, such as the Italian one, where tax evasion and income under reporting may hinder the feasibility of redistribution via income tax and benefits. In the present paper I will assume them to hold, leaving further investigation to the next chapters of this thesis.

Hence, the empirical evidence together with the predictions from the optimal taxation theory, cast doubts on the effectiveness, both in terms of equity and efficiency, of the current indirect tax schedule and calls for an investigation on whether there might be room for improvement of the tax system if the highly differentiated rates of VAT were to be replaced by more uniform ones and possibly complemented with other redistributive policy tools, such as government transfers. Whether it is actually possible to design a reform that is not only welfare increasing overall, reducing inefficiency, but also effective at redistributing towards the less wealthy groups of the population, improving on equity, is an open question that can only be answered by taking into account the set of incentives and constraints under which households make economic decisions. The aim of this paper is precisely to try and answer this question by developing a quantitative model that allows for interactions between taxation and the dynamics of households' consumption-savings behaviour over the life-cycle in a context of income uncertainty and borrowing constraints.

1.3 The Model

I set up a dynamic life-cycle model of household consumption and savings decisions that allows to account separately for durable and non-durable consumption in a partial equilibrium framework with income uncertainty and borrowing constraints.

Demographics. Households are born as working adults at age $t_0 = 30$, the first time period in the model. Retirement is exogenous and takes place with certainty at age $T_{ret} = 60$, so that working life lasts from period t_0 until period $T_{ret} - 1$. From age T_{ret} the household is retired, receives a flat pension benefit from the government and faces an education specific, exogenous probability of death until age $T = 85$, at which everyone dies with certainty.

Timing. Households start each period (a year) with a stock of assets and a stock of durable goods from the previous period and get an income realization for the current period. At the beginning of each period households make their consumption-saving choices. First, they decide how to allocate their total resources among non-durables, durables and financial asset savings. Then they decide how to allocate the total expenditure on non-durables between the two non-durables categories, the one taxed at 4% and the one taxed at 10%. The first decision depends on intertemporal preferences, as the non-durable consumption choice is jointly determined with durables and assets dynamic choices. While, the second problem is entirely static, it depends only on intratemporal preferences between the two non-durables and is independent of the first step, once the amount of total expenditure on non-durables has been chosen. Lastly, during the period households derive utility from consumption of non-durables and from service flows of durables.

Durables market. When making their durable consumption decision, households take into account that durables can be bought and sold on the second-hand market. Hence, they decide whether to sell, buy or keep their durable stock invariant. I make the simplifying assumption that each household is either a net seller or a net buyer (with the limit case of inaction) in each period, this assumption seems to be largely supported by the data (see Appendix B.1.2). If households are not inactive, they also decide how much to buy (or sell) of durables, where x_t represents the positive (or negative) variation in the amount of durable goods stock.

If the household decides to buy new durables ($x_t > 0$), it must pay the relative price of durables to non durables , q, times the VAT rate on durables, τ^d, for each unit of durables purchased. As a reasonable stylised representation of the tax rules currently in place, the rate on durables, τ^d is strictly greater than the rates on the two non-durable categories, τ^{n1}, τ^{n2}. I assume that when households buy durables they always pay VAT on them, regardless of whether they buy on the first-hand or on the second-hand market. This corresponds to assuming that when durables are sold on the second-hand market they must go through an intermediate dealer which provides some services and therefore charges VAT on the good again before reselling it (e.g. second-hand cars dealer provide insurance on used cars before reselling them). Given the evidence that in Italy the on-line second-hand market with direct seller-buyer contact is thinner than in other countries, this assumption is plausible and it reduces the dimensions of the dynamic problem making it more tractable.

If, instead, the household decides to decrease its stock of durables by selling ($x_t < 0$), there is no expenditure on durables, but there are proceeds from selling durables on the second hand market at the relative price q that can be used to finance current non-durable consumption. However, households can actually sell at a value on the market only a fraction π of the amount of durable stock they would like to get rid of. Indeed, a fraction $1 - \pi$ of the durable stock represents those durable goods that are an irreversible investment for the household as they have virtually no second hand market due to the well-known Akerlof's Lemons problem. 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. Because of asymmetric information about the actual quality of the good between the seller and the buyer, agents believe that certain durable goods offered on second-hand markets are on average such bad quality that they are only willing to pay very low prices for them so that the sellers with the good quality used durables are driven out of the market. Sellers of decreasing quality remain in the market until the willingness to pay of the potential buyers is driven down to zero and the market shuts down. 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 in reality.

The durables stock depreciates at the constant rate δ, which coincides with the proportion of the stock that captures the service flow of durables from which the household derives utility. For simplicity, I assume that there is no durable goods rental market and I abstract from housing as a durable good .

Financial assets market. Households can also save and borrow in a risk free financial asset whose associated constant interest rate is r. Only collateralized debt is allowed, in particular agents can borrow up to a fraction χ of their durables stock in each period implying a limited role of some durables categories as collateral. Differently from durables, financial assets are modelled as completely liquid, therefore households can access and adjust their financial assets stock at any time without paying any transaction costs.

Household problem. The household solves the dynamic optimization problem:

$$\max_{c_{1,t},c_{2,t},d_t,a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} \tilde{u}(c_{1,t}, c_{2,t}, d_t) \tag{1.1}$$

In each period they decide how to optimally allocate their total resources among the two non-durables, those taxed at 4% and those taxed at 10% ($c_{1,t}, c_{2,t}$), durables (d_t) and savings in financial assets (a_t). I model the non-homogeneous non-durable consumption bundle (c_t) as consisting of two groups of goods as dictated by the need to represent the current Italian VAT schedule as accurately as possible, but it is worth noting that this model is easily generalizable to the case of n non-durable subcategories. The main assumption underlying my model is that there exist a form of separability between the non-durable bundle and the durables: each of the two non-durables is related to the durables in the same way in terms of elasticity of demand with respect to the price of durables. Under this assumption the household lifetime utility can be rewritten so that the intratemporal utility derived from consumption of the non-durables enters the intertemporal utility separately from the durables. Hence, the households problem becomes:

$$\max_{c_{1,t},c_{2,t},d_t,a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} U(u(c_{1,t},c_{2,t}),d_t) \tag{1.2}$$

Subject to a set of three constraints: the law of motion for durable stock, the budget constraint and the borrowing constraint.

$$d_t = (1-\delta)d_{t-1} + x_t \tag{1.3}$$

$$c_t + D(x_t)x_t + a_t = (1+r)a_{t-1} + y_t \tag{1.4}$$

where, $D(x_t)$ is the non-linear price function for durables:

$$D(x_t) = \begin{cases} (1+\tau_c^d)q & \text{if } x_t \geq 0 \\ \pi q & \text{if } x_t < 0 \end{cases} \tag{1.5}$$

$$a_t \geq -\chi q d_t \tag{1.6}$$

It is worth noting that in general the depreciation rate in the durables law of motion and the fraction of durables stock that represents the flow of services from which households derive utility would not necessarily coincide. Indeed, the depreciation rate in the durables law of motion would account both for actual depreciation due to usage and for loss of value due to irreversibility of certain durable goods that, once used, have virtually no second hand market and therefore it would not coincide with the fraction of durables stock that gets used each period and that delivers utility from flow of services to households. However, given that in my model the irreversibility feature is taken explicitly into account in the budget constraint separately from and in addition to depreciation solely due to usage, then the depreciation rate in (1.3) and the fraction of the stock from which households derive utility in each period must be the same as they both represent the loss of value of durables stock due to usage, but not the loss of value for resale purposes represented by χ in the budget and borrowing constraints. In other words, in this model households can still derive utility from durables that are not completely depreciated even if these have no resale value because of their complete irreversibility.

Solution. Following Gorman (1971) and Blundell et al. (1994), I solve the model exploiting the fact that the intratemporal non-durable problem is completely characterized by the indirect utility function, which is the maximum level of utility achieved by optimally choosing how to allocate a given level of total expenditure on non-durables (c) between two non-durable categories at a given vector of non-durable prices (P) , up to a monotonic transformation. Therefore, the original life cycle problem can be restated by replacing the direct utility from non-durable consumption with the corresponding indirect utility, thus linking intra and intertemporal decisions in a coherent way:

$$\max_{c_t,d_t,a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} U(v(c_t,P_t),d_t) \qquad s.t. \tag{1.7}$$

Subject to constraints (1.3), (1.4) and (1.6).

Intertemporal choice. The life-cycle intertemporal utility is a standard CRRA featuring Stone-Geary preferences between durables and non-durables:

$$U(v(c_t,P_t),d_t) = \frac{[(v(c_t/n_t,P_t))^{\theta}(\delta d_t - \varepsilon^d)^{1-\theta}]^{1-\gamma}}{1-\gamma} \tag{1.8}$$

Where, $v(c_t, P_t)$ is the indirect utility capturing the optimal decisions of the intertemporal non-durable stage of the model as a function of total expenditure and prices. $\frac{1}{\gamma}$ is the elasticity of intertemporal substitution of consumption and θ is the expenditure share in non-durable goods. Non-durable consumption is adjusted by an equivalence scale n_t in order to capture changing needs over time and economies of scale in consumption depending on the number of members living in the household. The equivalence scale changes over time as the household ages, but it is assumed to be deterministic (Appendix B.3). ε^d is the Stone-Geary parameter that makes within period preferences non homothetic in non-durables and durables and captures the extent to which durables are to be considered as a luxury good with respect to the non-durable bundle. Assuming $\varepsilon^d < 0$ allows well defined utility even in periods when the service flow of durables is zero or low and a larger absolute value of ε^d implies that durables are consumed only by wealthier households. In principle, the household derives utility from the service flow of durables rather than from the durable stock itself. As common in this literature, I assume for simplicity that the service flow is a constant proportion, δ, of the stock in each period and therefore allow for the stock of durables to enter the utility function directly.

Intratemporal choice. Conditional on the optimal total expenditure on non-durables chosen in the intertemporal problem, households decide on the optimal consumption quantities of the non-durables taxed at 4% and non-durables taxed at 10% by solving a static utility maximization problem:

$$\max_{c_1, c_2} u(c_1, c_2) \qquad s.t. \qquad (1+\tau^{n1})\tilde{p_1}c_1 + (1+\tau^{n2})\tilde{p_2}c_2 = c \tag{1.9}$$

where, $p_1 = (1+\tau^{n1})\tilde{p_1}$, $p_2 = (1+\tau^{n2})\tilde{p_2}$ and $P = [p_1, p_2]$ is the vector of non-durable prices inclusive of the VAT rates. I do not impose a specific functional form on the intratemporal direct utility $u(.)$. Instead, I model the indirect utility, $v(.)$, as the one resulting from the Almost Ideal Demand System (AIDS) model by Deaton and Muellbauer (1980).

Earning process. The process governing earnings from labour is assumed to be exogenous and to differ across education level achieved by the head of the household (s: secondary or less, high school, college or more). Allowing the earnings process dynamics to depend on education level, intended as a proxy for lifetime socioeconomic conditions, allows to create ex-ante heterogeneity among households in the model which is particularly needed here given the emphasis of this paper on redistributional issues. I assume that the logarithm of earnings at age t can be modelled in the following way:

$$lny_t^s = f^s(X_t, t) + \tilde{y}_t^s \tag{1.10}$$

$$\tilde{y}_t^s = z_t^s + \varepsilon_t^s \tag{1.11}$$

where, f captures the deterministic component as a function of age and demographic characteristics of the household, X_t, and y is the stochastic component which accounts for the dynamics in earnings that remain unexplained after taking into account the deterministic component. The stochastic component consists itself of a persistent shock, z, and a transitory shock, ε. Both the deterministic function and the persistency and variances of the stochastic shocks vary across education levels.

Recursive formulation. All in all, the household's problem is:

$$V_t(a_{t-1}, d_{t-1}, y_t) = \max_{a_t, d_t} \{U(v(c_t, P_t), d_t) + \beta\, \mathbb{E}_{y_{t+1}|y_t} V_{t+1}(a_t, d_t, y_{t+1})\} \tag{1.12}$$

subject to the constraints (1.3), (1.4) and (1.6).

The problem is characterized by the following two Euler Equations:

$$u'_{c_t} = \beta\,(1+r)\, E u'_{c_{t+1}} \tag{1.13}$$

$$u'_{x_t} = \beta D(x_t)(1+r)E_t u'_{c_{t+1}} - \beta E_t\left[\beta(1-\delta)D(x_{t+1})(1+r)E_{t+1}u'_{c_{t+2}} - (1-\delta)u'_{x_{t+1}}\right] \tag{1.14}$$

This model features a non convexity due to the irreversibility of a fraction of the durables stock which cannot be sold on the second-hand market and to the presence of VAT tax rate on purchases but not on sales of durables. These two characteristics make selling durables less profitable than it would otherwise be and, therefore, represent an implicit adjustment cost of selling durables stock for the household. Such non convex adjustment cost implies that the household's decision problem is not a well behaved convex dynamic programming problem and, therefore, the standard numerical approaches, relying on the differentiability of the value function, cannot be applied in this specific case.

Instead, in order to solve the model, I adopt a discrete state-space dynamic programming technique. I discretize the two endogenous states (financial assets and durables) over two finite logarithmically spaced grids. I first find and store the set of optimal choices of next period financial assets for each possible value of next period durables by maximizing the objective function over the assets grid conditional on durables. I then find the optimal choice of next period durables by picking the point on the durables grid that, together with the corresponding optimal asset choice, delivers the highest value of the objective function.

The continuous stochastic AR(1) process for the exogenous state, stochastic component of earnings, is discretized and approximated using a Markov chain over five grid points closely following Tauchen (1986). Finally, non durable consumption choice and durables investment/disinvestment flow are implied by the budget constraint and by the durables law of motion. Given a terminal value function equal to zero for the time period in which the household is dead, I iterate backwards in time and find the age-dependent optimal policy and value functions for each period of the household's life. Then, using these policy functions, I simulate life cycle patterns of non durable consumption, durables flow, durables stock and financial assets for many possible paths of the stochastic labour income process.

1.4 The Data

In this section I describe the data that I use in this Chapter as well as in the rest of the thesis. 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).

The SHIW is conducted every other year since 1987 (with the exception of a two year gap between 1995 and 1998 waves) and since 1989 has a panel dimension. Each wave covers a representative sample of about 8,000 Italian households. Appendix B.1 describes SHIW sample design, structure and response rates. To the best of my knowledge SHIW and PSID are the only two panel data sets containing measures for non-durable consumption, durables, financial wealth and income.

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 breakdown of household's consumption expenditure into different subcomponents is particularly suited for the model's estimation.

The non-durable consumption measure definition includes expenditures in food, clothing, entertainment, medical expenses, housing repairs and imputed rents[1]. Also, the data offer 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

[1]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.

amount spent during the year for purchasing these three kinds of durable goods; the amount of revenues from sales of means of transport and precious objects (furniture do not have a proper second-hand market so it is assumed they cannot be sold) during the year; the monetary value of the stock of all durable goods belonging to the household at the end of the year. Table 1.1 reports mean flows and stocks of durables components in SHIW selected sample.

Table 1.1: 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

The second data set that I use is ISTAT HBS. This is the most comprehensive cross sectional expenditure survey in Italy. It has a sample size of about 28,000 households and collects detailed information on the consumption of all commodities at the level of each single item purchased by the household during an average week[2] (see Appendix B.2 for more details).

HBS also contains information about household's socio economic characteristics and employment status, but it lacks data on income and wealth. This second data set 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%). Necessities include food at home, books and newspapers and some medical expenses. Luxuries include food away from home, hotels and holidays, housing re-

[2]Given the high degree of detail, the survey represents the official source for the construction of cost-of-living indices and the production of poverty (absolute and relative) consumption-based statistics in Italy (Pisano and Tedeschi (2014)).

pairs and additions, entertainment and personal care services and goods. Table 1.2 summarizes the classification of non-durables components and reports the relative expenditure shares in HBS selected sample.

Table 1.2: 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

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 45,000 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[3].

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, used in Chapter 2, 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)) [4].

1.5 Estimation

In order to estimate the model, I adopt a two-step strategy similar to the one used by Gourinchas and Parker (2002), French (2005) and others in this literature. In the first step, I estimate the parameters governing the intratemporal static non-durable consumption problem and the ones determining the dynamics of the earnings process outside of the life-cycle model.

In the second step, taking the parameters estimated in the first step as given, I estimate the parameters governing intertemporal preferences and durables dynamics in the life-cycle model. Due to the set-up of the model, the parameters of household's preferences that determine the optimal allocation of resources within each period and over the life-cycle are identified and estimated consistently from two different sets of moments and exploiting two different datasets.

1.5.1 First Step: Intratemporal Consumption Model

I model the intratemporal problem of how to optimally allocate total expenditure in non-durable consumption between a non-durable necessity and a non-durable lux-

[3]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.1.1.

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

ury according to the Almost Ideal Demand System (AIDS) model by Deaton and Muellbauer (1980). The desirability of this model rests in its great flexibility: the general functional form of the PIGLOG cost function on which AIDS is based implies that the demand functions derived from it are first-order approximations to any set of demand functions derived from utility-maximizing behavior (see Appendix A.1 for more details). Hence, AIDS can nest different types of preferences, including non homothetic ones that are needed in order to be able to characterise goods as necessities or luxuries, without imposing restrictions on the direct utility functional form. The indirect utility function characterizing the intratemporal problem according to AIDS, thus, takes the following form:

$$v(c,P) = exp\left\{\frac{ln(c) - ln(a(P))}{b(P)}\right\} \tag{1.15}$$

where, c is total budget for non-durable consumption in the two ($k = 2$) non-durable goods categories, P is the vector of prices including taxes, $ln(a(P))$ and $b(P)$ are the price index and the Cobb-Douglas price aggregator, respectively:

$$ln(a(P)) = \alpha_0 + \sum_{i=1}^{k} \alpha_i lnp_i + \frac{1}{2}\sum_{i=1}^{k}\sum_{j=1}^{k} \eta_{ij} lnp_i lnp_j \tag{1.16}$$

$$b(P) = \prod_{i=1}^{k} p_i^{\beta_i} \tag{1.17}$$

Applying Roy's identity to (1.15) the Marshallian demand functions in each of the two category of goods c_i can be derived and, from there, the expenditure shares in each of the two categories, $w_i = \frac{p_i c_i}{c}$, as a function of total budget and prices are computed. These translate into the following demand system estimation equations:

$$w_{it} = \alpha_i + \sum_{j=1}^{k} \eta_{ij} lnp_{jt} + \beta_i ln\left\{\frac{c}{a(p)}\right\} + e_{it} \tag{1.18}$$

Where, t denotes the observation index and e_{it} is assumed to represent unobservable components in demand, here assumed to be measurement error for simplicity. The parameters to be estimates are α, β and η. Some restrictions on these parameters are required. $\sum_{i=1}^{k} \alpha_i = 1$, $\sum_{i=1}^{k} \beta_i = 0$, $\sum_{j=1}^{k} \eta_{ji} = 0$ must hold in order to satisfy adding-up, while $\sum_{j=1}^{k} \eta_{ij} = 0$ in order to satisfy homogeneity.

The estimation exploits ten subsequent waves of the HBS spanning years from 2003 to 2012. The price data, that are not included in the consumption survey, are obtained from ISTAT Consumer Price Index database. As the variability of prices for the same goods over time and across families is small, I use price data disaggregated at the regional level in order to create further variability. The estimation equations in (1.18) can be affected by an endogeneity problem because total expenditure in non-durables on the right hand side of the equations is likely to be correlated with the error term. Indeed, the share, which as dependent variable is correlated to the error term by construction, features the total expenditure at the denominator. Also, it might be the case that households with different levels of total expenditure in non-durables also have systematically different shares of expenditure on the two non-durable subcategories.

Ideally, one would correct this endogeneity problem by instrumenting total expenditure with earnings. However, since HBS does not contain information on household earnings or income, I have to resort to a grouping estimation strategy. I use a discrete instrument for the continuous endogenous variable total expenditure that consists of a group variable constructed as all possible combinations of the values taken by the demographic variables education, age (of head of household), year, region. So that the dataset can then be collapsed by group and the observations are no longer the single households, but the groups of similar households. This methodology is equivalent to the use of IV because estimating the regression on the grouped data effectively means changing the variation in the endogenous variable via aggregation.

Moreover, as I want to take into account the fact that the number of household components may have an impact on consumption choices of different categories of non-durables, I transform total expenditure in equivalent terms using the equivalence scale in Appendix B.3 and estimate the AIDS on the equivalized expenditure.

Table 1.3: AIDS estimated parameters

	α_1	β_1	η_{11}	η_{12}
share c_1	0.8513 ***	-0.0587***	-0.0101	0.0101
	(0.0125)	(0.0014)	(0.0127)	(0.0127)

$N = 13,989$

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Once estimated the parameters of interest, I predict the expenditure shares and derive budget elasticities and compensated own- and cross-price elasticities.

Table 1.4: 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

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.4 shows that the non-durables taxed at 4%, c_1, are indeed necessities and the non-durables taxed at 10% , c_2, are a luxuries as their budget elasticities are smaller and greater than one, respectively. Table 1.4 also suggests that the necessity non-durables and the luxury non-durables are substitute of each other as the compensated cross-price elasticities are positive and significant. Compensated own-price elasticities are negative for both goods as predicted by the theory (Negativity property).

The estimation of the parameters of the AIDS demand system on the two non-durables is an interesting exercise in itself as it allows to predict the behavioral response of the two non-durable consumption shares to price changes (and therefore VAT reforms) taking into account substitution and income effect. Most importantly for the aim of this paper, estimation of AIDS delivers estimates of the price indices in (1.16) and (1.17) to be then used to compute the estimated indirect utility of the second-stage intratemporal consumption problem conditional on the total expenditure in non-durables chosen in the first stage intertemporal model as from (1.15). These price indices are precisely what links the within-period allocation (demand system) and the between-period allocation (life-cycle model) in a coherent way.

1.5.2 First Step: Earning Process

I estimate the parameters governing the deterministic and stochastic parts of the earnings process of the household for three different education groups (secondary school or less/high school/ college or more) separately. The logarithm of earnings of household i whose head is aged t is modelled as follows :

$$lny_{i,t} = D_t + \beta_1 age_{i,t} + \beta_2 age^2_{i,t} + \beta_3 status_i + \beta_4 reg_i + \tilde{y}_{i,t} \tag{1.19}$$

$$\tilde{y}_{i,t} = z_{i,t} + \varepsilon_{i,t} \tag{1.20}$$

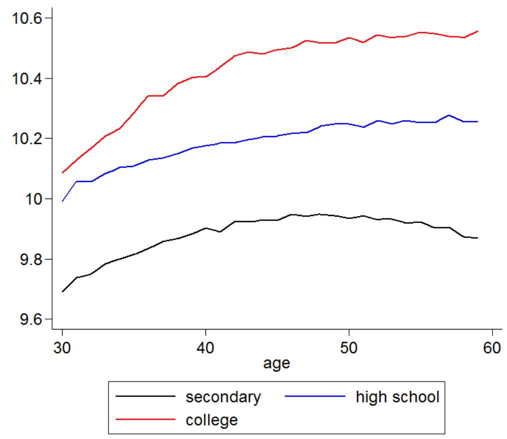
$$z_{i,t} = \rho z_{i,t-1} + u_{i,t} \tag{1.21}$$

$$\varepsilon_{i,t} \sim (0, \sigma^2_\varepsilon), \qquad u_{i,t} \sim (0, \sigma^2_u), \qquad z_{i,0} \sim (0, \sigma^2_{z0})$$

The deterministic part of the earnings process consists of year dummies and a quadratic in age conditional on marital status and region of residence. While, the stochastic part, $\tilde{y}$, that captures the effect of unobservables not included in the deterministic component, features a persistent component (z), following an AR(1) stochastic process with non constant variance, and a purely transitory component (ε) that represents measurement error.

All in all, the parameters to be estimated are $\Psi = \{\beta_1, \beta_2, \beta_3, \beta_4, \rho, \sigma^2_u, \sigma^2_\varepsilon, \sigma^2_{z0}\}$ and the approach to estimation is the one proposed by Guvenen (2009). Estimates of the coefficients obtained from regression (1.19) allow me to build education specific age-efficiency profiles of earnings displayed in Figure 1.2.

Figure 1.2: Deterministic profiles of log annual earnings by education



The predicted residuals from the first step regressions are consistent estimators of the stochastic component of the earnings process, hence I use them in order to estimate the parameters of the persistent and transitory dynamic components of the earnings process by means of minimum distance estimation. Details on estimation procedure and identification are in Appendix D.1.

Results of estimation are reported in Table 1.5 and are in line with those found in the existing literature. Two additional remarks are in order. First, my estimates are obtained on the sub sample of households in which at least one of the spouses is working, either as an employee or as a self employed. This means that I am selecting the households that participate into the labour market that could be systematically different from those that are left out of the sample due to having zero wages and this can of course result into selection bias of the estimated parameters that I am not correcting for. However, the work requirement sample selection that I apply results into dropping only around 16% of all household observations in the age range 25-59, hence applying the sample selection correction should not affect my results substantially.

Second, in principle the term $\varepsilon_{i,t}$ might be thought of as a mix between transitory shock and measurement error, however, as already mentioned before, 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.

Table 1.5: Estimates of earnings process parameters

	Education level		
	secondary	high school	college
ρ	0.9682	0.9734	0.9428
	(0.0390)	(0.0300)	(0.0873)
σ_u^2	0.0068	0.0054	0.0136
	(0.0082)	(0.0052)	(0.0309)
σ_ε^2	0.0968	0.0697	0.0512
	(0.0174)	(0.0108)	(0.0229)
$\sigma_{z_0}^2$	0.0802	0.0579	0.2168
	(0.0422)	(0.0511)	(0.1519)
N	2,678	2,052	691

Bootstrapped standard errors in parentheses

1.5.3 Second Step

The second step of the two step estimation procedure consists in the structural estimation of the parameters characterizing the life-cycle model, those related to intertemporal preferences and those related to durables dynamics, via the Method of Simulated Moments (MSM). This estimation technique, first introduced by McFadden (1989), consists in finding the parameters that minimize the weighted distance between moments computed in the data and the analogous moments computed on the simulated panel produced by the life-cycle model by means of an iterative procedure. More precisely, the vector of estimates of the parameters of interest, $\hat{\Theta}$, is the solution to the following minimization problem:

$$\hat{\Theta} = \arg\min_{\Theta} \left\{ \sum_{k=1}^{K} \left[(m_k^{data} - m_k^{sim}(\Theta))^2 / Var(m_k^{data}) \right] \right\} = \arg\min_{\Theta} \left\{ g(\Theta)' \Omega g(\Theta) \right\} \tag{1.22}$$

And the variance of the estimator is:

$$\hat{V} = (1 + \frac{N}{S})(\hat{G}' \Omega \hat{G})^{-1} \qquad with \qquad \hat{G} = \frac{\partial g(\Theta)}{\partial \Theta} \bigg|_{\Theta = \hat{\Theta}}$$

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 obtained under a specific set of parameters values Θ and $g(\Theta)$ 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 empirical variances. I do not use the asymptotically optimal weighting matrix because of its small sample properties, as suggested by Altonji and Segal (1996). The simulations are initialized to the empirical, education-specific joint distributions of the three state variables (earnings, financial assets, durables) at age 30-31. The aim is to embed in the model the initial heterogeneity among households, within and across education levels, that is observed in the data at the start of working life, also taking into account the strong correlations that exist among the three state variables.

The MSM estimation is performed by iterating back and forth between the solution of the life-cycle model and the minimization of the MSM objective function in (1.22). Starting from a given set of initial values of the parameters to be estimated, the solution of the dynamic programming problem is found and the corresponding optimal policy functions are obtained. Then, using these decision rules, the life-cycle choices of a large number of simulated agents are produced so to get a simulated panel. Targeted moments are computed in the data sample and in the simulated panel and the MSM objective function is constructed and minimized with respect to the estimating parameters. The values of the parameters that solve the minimization problem are returned. If the value of the associated minimized objective function is the minimum the routine terminates, otherwise the routine starts over again using the current values of the parameters as initial values for the next iteration [5]. Given the non-convexities in the durable choice, the MSM objective function may not be a smooth function of the model parameters everywhere in their domain. Therefore, I use the derivative-free Nelder-Mead optimisation routine [6].

The moments targeted in MSM estimation are the following. OLS coefficients on age polynomials during working life (age 30-59) of non-durable consumption, durables stock, non-durable consumption share of total consumption, financial assets, financial assets-durables ratio. Means by age at end of working life (age 55-59) of non-durable consumption, durables stock, financial assets. Covariances between non-durables and durables and covariances between financial assets and durables at ages 35, 45, 55. Two moments related to durables dynamics.

The parameters to be estimated are $\Theta = \left\{\gamma, \theta, \beta, \varepsilon^d, \pi, \chi, \delta, \zeta_1, \zeta_2, \zeta_3\right\}$. Only two parameters are exogenously assigned values suggested by the literature: the interest rate, r, is set to 2% and the relative price of durables to non-durables, q, is set to 1. This results in 50 targeted moments and 10 estimating parameters, hence the model is over identified. The second step estimated parameters are reported in Table 1.6 together with their asymptotic standard errors.

The estimates are all statistically significant.The estimated preference parameters γ, θ and β are in line with the existing literature. The large, negative value found for ε^d suggests that durables are luxury goods. The estimates of the parameters governing durables' dynamics, π, χ and δ, imply that about 50% of durables'

[5] The code for solution, simulation and estimation of the model is written in Fortran90. The solution part of the code is parallelized on 8 processors using OpenMP libraries.

[6] Implemented in Fortran using routine from NAG library. I experimented starting the algorithm from various initial values to ensure that the minimum found is global.

Table 1.6: Second step estimated parameters

Parameters	Value (annual)	Definition	SE
γ	3.72	Coeff. of relative risk aversion	1.6922
θ	0.85	Non-durable consumption share	0.0019
β	0.99	Discount factor	0.0016
ε^d	-476.42	Stone-Geary coeff. for durables	40.5815
π	0.47	Fraction of non irreversible durables	0.0089
χ	0.11	Fraction of collateralizable durables	0.0145
δ	0.01	Durables depreciation rate	0.0013
ζ_1	0.92	Pension replacement rate	0.0130
ζ_2	0.70	Pension replacement rate	0.0128
ζ_3	0.83	Pension replacement rate	0.0115

stock can be sold on the second hand market, while only 11% has collateral value and that durables depreciate slowly at the 1% rate. The estimated education-specific social security replacement rates are within reasonable values. As it is usually the case in this kind of structural life cycle models, it is not possible to provide a formal proof for the identification of each parameter separately from the others. However, it is worth investigating which aspects of the data, and therefore which empirical moments, contribute more heavily to the identification of which estimated parameters.

The coefficient of relative risk aversion, γ, is identified from the mean life-cycle profile of financial assets and non-durable consumption as suggested by other studies (Cagetti (2003), Gourinchas and Parker (2002)). The higher the level of assets and the smoother the pattern of consumption over the life-cycle, the more risk averse are households and, therefore, the higher will be the estimated γ. The weight of non-durable consumption in the utility function, θ, is identified by construction from the life-cycle profile of mean non-durable consumption share of total consumption and also from the covariances between non-durable and durable consumption.β, the discount factor, is identified from the mean life-cycle profiles of the two sources of wealth in the model (financial assets and durables). The larger the holdings of wealth at all stages of life, the more patient are households in discounting the future and the higher will be the estimated value of β.

The Stone-Geary durables parameter, ε^d, captures the extent to which durables are a luxury good and ensures that the marginal utility of consuming zero durables in each life period is finite. It is identified by the mean profile of durables over the life cycle and also by the covariances between non-durable and durable consumption at different points in life. The slower households consumption of durables with respect to non-durables increases as they become wealthier from one period to the next of the life-cycle, the more durables are perceived as luxuries and the flatter the curvature of households' preferences in durables and, therefore, the higher (in absolute value) the estimated ε^d will be.

The parameters $\zeta_1, \zeta_2, \zeta_3$, the fractions of last working period's earnings that households receive as constant pension flows for after-retirement years, are the only education specific parameters. These parameters do not simply represent social security replacement rates, but they capture the value of wealth for all years after retirement more broadly. The utility that agents derive from holding wealth during retirement years depends on agents' characteristics, such as health risk, pension arrangements and bequest preferences, that are not modelled, but are strongly correlated with education level. Relying on the Bellman's optimality principle, I claim that the education specific mean level of financial assets held in the years immediately pre-retirement (55-59) embeds the expected present discounted value of wealth after retirement and therefore identifies the corresponding education specific ζ.

The fraction of durables stock that is collateralizable, χ, is identified by the mean patterns of financial assets and of financial assets-durables ratio over the life-cycle, especially at beginning of working life when individuals are more likely to borrow. Also, covariance between assets and durables at different stages of life helps in identifying this parameter. The more negative the mean assets early in life and the higher the ratio between assets liabilities and durables, the higher is the collateral value of durables and so the higher the estimated χ will be.

Finally, durables depreciation rate δ and reversibility rate π are closely interrelated in this model as they jointly determine the dynamics of durables accumulation over the life-cycle. The higher depreciation, the slower is durables accumulation, but also the more frequent are adjustments to the stock. The higher reversibility, the higher is the incentive to accumulate durables as a smoothing device, and again the more frequent are adjustments to the stock.

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 of identification is in Appendix D.2.

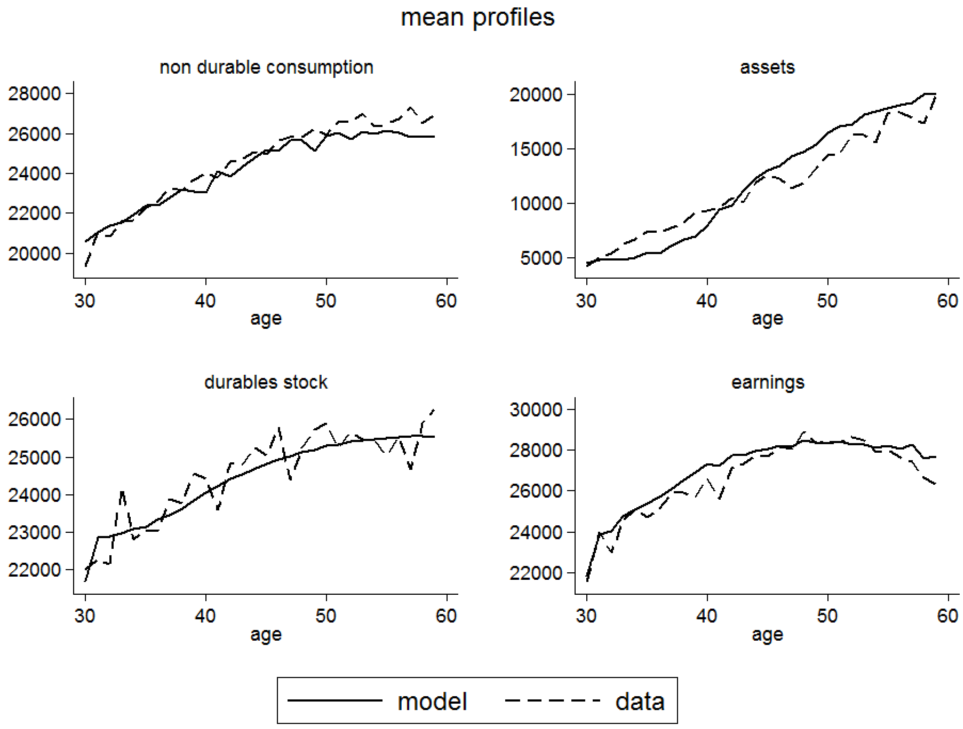
1.5.4 Model Fit

Before turning to the simulation of counterfactual scenarios, I must assess the performance of the estimated model in fitting the main features and patterns observed in the data under the existing tax system. Figure 1.3 shows that the simulations produced by the model using the optimal parameters fit the data very well in terms of mean life-cycle profiles of non-durable consumption, financial assets, durables stock and earnings. In particular, my model replicates very closely both the levels and the patterns over age observed in the data.

1.6 Counterfactual Analysis

Given that the overall fit of the estimated model to the data is good, I can now use it to simulate the effects of hypothetical reforms of the VAT rates on households' long-run economic choices and life-cycle welfare. Looking at the impact of these

Figure 1.3: Fit of targeted moments between model and data



changes on households of different education levels, I can also examine the degree of redistributive power that such reforms would imply. I focus on two groups of policy experiments that are revenue-neutral with respect to the status quo: i) changes of the three VAT rates towards higher or complete uniformity, not generating any extra tax revenues; ii) increases of the VAT reduced rates complemented with benefits that redistribute the extra revenues to keep overall revenue-neutrality of the tax-benefit system.

All hypothetical reforms are compared to the existing tax system ($\tau^{n1} = 4\%, \tau^{n2} = 10\%, \tau^{d} = 22\%$) and are assumed to be alternative states of the world that the agents face from the beginning to the end of their life-cycle. Transitions between different tax scenarios are not analyzed. Lifetime welfare effects of changes to tax-benefit system are quantified in terms of consumption equivalent variation (CEV) as it is common in this literature (see Conesa et al. (2009) and Blundell et al. (2016a) among others). CEV is the (non-durable) consumption change at pre-reform prices that is equivalent to the proposed reform in terms of its impact on lifetime expected utility [7].

The first group of simulations includes the following three hypothetical reforms. Under reform 1, all three VAT rates are set to the common value that guarantees revenue neutrality: $\tau^{n1} = \tau^{n2} = \tau^{d} = 8.4\%$. In terms of life-cycle choices, Figure 1.4 panel (a) shows that the model predicts a shift from consumption of non-durable luxuries to durables and also a tendency to save more in durables than in financial assets as a response to the sharp decrease in τ^{d} that make durables much cheaper. The expenditure in non-durable necessities, instead, is inelastic to the increase in τ^{n1}. Reform 2 leaves the ordinary rate unchanged and equalizes the two reduced rates at the level that ensures revenue neutrality: $\tau^{n1} = \tau^{n2} = 8.2\%, \tau^{d} = 22\%$.

Panel (b) of Figure 1.4 shows that the model predicts virtually no impact of this reform on long run economic choices of households. In the case of Reform 3, the reduced VAT rate on non-durable necessities is kept at the current level and the other two rates are equalized at the rate that satisfies revenue neutrality: $\tau^{n1} = 4\%, \tau^{n2} = \tau^{d} = 10.4\%$.

Panel (c) of Figure 1.4 shows that again the decrease in the ordinary rate τ^{d} causes households to smooth their consumption by accumulating more durables than financial assets over the life-cycle.

Table 1.7 summarizes the welfare effects of this first group of reforms. Reform 2 decreases the overall welfare with respect to the current scenario. Reforms 1 and 3, instead, increase the overall welfare with respect to the status quo by changing VAT rates towards uniformity. However, this requires lowering the ordinary rate and therefore redistributing in favour of the wealthier (more educated) at the expense of the poorer (less educated), who lose (Reform 1) or gain less (Reform 3) from these

[7] CEV is the change in consumption, Δ, that solves the following equation:

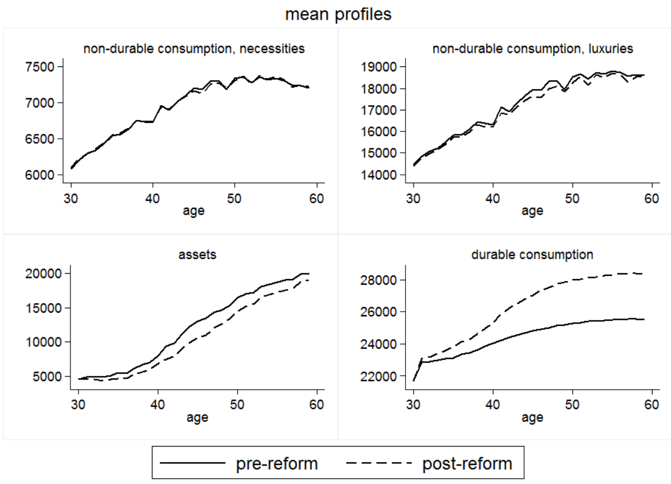
$$E_0 V^{post} \equiv E_0 \sum_t \beta^t \frac{[(v(((1+\Delta)c_t^{post})/n_t, P_t))^{\theta}(\delta d_t^{post} - \varepsilon^d)^{1-\theta}]^{1-\gamma}}{1-\gamma} = E_0 V^{pre}$$

which implies:

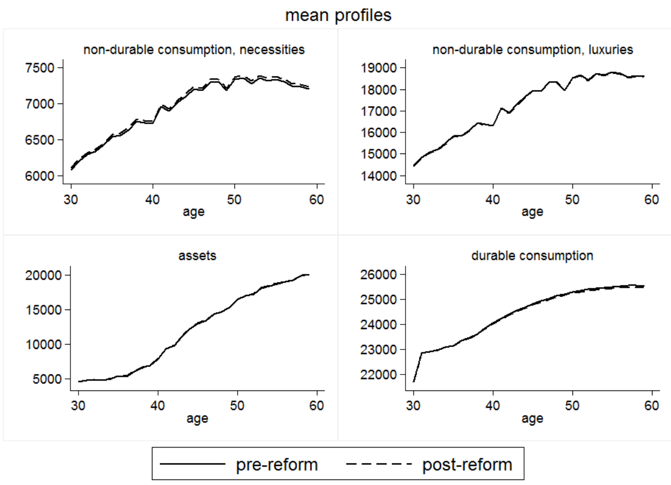
$$CEV = \Delta = \left[\frac{E_0 V^{post}}{E_0 V^{pre}}\right]^{\frac{1}{\theta(1-\gamma)}} - 1$$

Figure 1.4: Effects of reforms on life-cycle consumption and savings

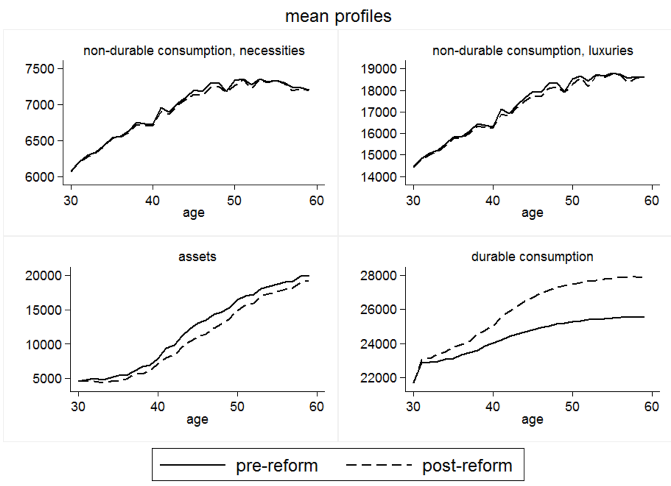
(a) Reform 1



(b) Reform 2



(c) Reform 3



changes.

Table 1.7: Effects of reforms on life-cycle welfare, percentages

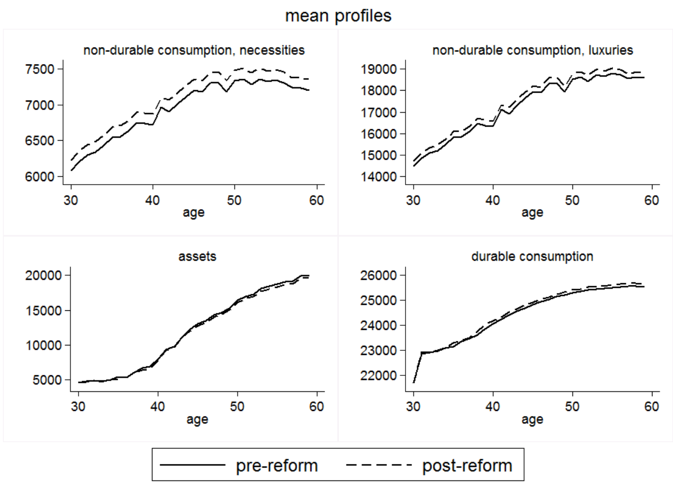
Secondary	High School	College	All
reform 1: $\tau^{n1} = \tau^{n2} = \tau^{d} = 8.4\%$			
-0.0709	+0.1072	+0.1473	+0.0220
reform 2: $\tau^{n1} = \tau^{n2} = 8.2\%, \tau^{d} = 22\%$			
-0.0671	+0.0243	+0.0523	-0.0184
reform 3: $\tau^{n1} = 4\%, \tau^{n2} = \tau^{d} = 10.4\%$			
+0.0017	+0.0662	+0.0795	+0.0352

The second group of counterfactual simulations consists of two reforms. Under Reform 4, VAT rate on non-durable necessities, τ^{n1}, is increased from 4% to 10%. Under Reform 5 complete uniformity is imposed by setting the reduced rates, τ^{n1} and τ^{n2}, at the same level of the current ordinary rate. Under both scenarios the extra revenues generated are redistributed by means of yearly cash transfers granted to all households in the same amount, regardless of their income level. The precise amount of the transfer required is calculated by solving for the value that keeps public budget (tax revenues net of transfers) unchanged with respect to the baseline scenario.

The long-run effects on households' economic choices of these two reforms are shown in Figure 1.5. The impact of Reform 5 is larger in magnitude than that of Reform 4, but the patterns are similar. Despite the increase in VAT rates, the expenditures on non-durables categories are higher over all life-cycle with respect to the baseline scenario. Hence, the model predicts that the income effect due to the transfer prevails on the substitution effect due to the increased prices. Also, consumption and saving in durables are increased as households are richer and the relative price of durables to non-durables is lower. Lastly, the reforms disincentivize accumulation of financial assets over the life-cycle as the benefits represent an additional source of insurance that households can rely upon to smooth their consumption against bad income shocks in each period.

Figure 1.5: Effects of reforms on life-cycle consumption and savings

(a) Reform 4



(b) Reform 5

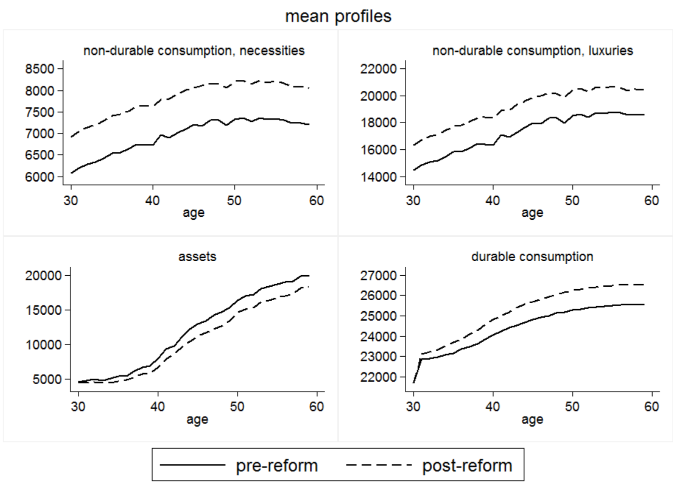


Table 1.8 collects the effects on lifetime welfare of this second group of reforms. Both reforms are overall welfare improving with respect to the current scenario. Moreover, they imply a more progressive system compared to the one in place because the same benefit matters more in relative terms for poorer households. Indeed, college educated households slightly lose, while their high school and secondary educated counterparts gain from these reforms and redistribution is in favour of the less wealthy groups of the population.

Table 1.8: Effects of reforms on life-cycle welfare, percentages

Secondary	High School	College	All
reform 4: $\tau^{n1} = \tau^{n2} = 10\%, \tau^{d} = 22\%$ and yearly transfer (375 euros)			
+0.5852	+0.1525	-0.0161	+0.3498
reform 5: $\tau^{n1} = \tau^{n2} = \tau^{d} = 22\%$ and yearly transfer (2,836 euros)			
+3.9999	+0.7131	-0.5155	+2.2189

1.7 Conclusions

In this Chapter, I set up and estimate a dynamic life-cycle model of household consumption and savings decisions that allows to account separately for durable and non-durable consumption in a context of indirect taxation, income uncertainty and borrowing constraints. From the methodological perspective, this paper offers a promising new contribution to the literature as it shows that explicitly modelling differences in tax rates and consumption behaviour between durables and non-durables and, at the same time, allowing for durables to provide an alternative way of saving in a partially collateralizable asset results in a good fit of the model to household micro data.

I use this model to investigate the effects of hypothetical reforms of VAT rates on households' consumption-savings choices over the life cycle, on the allocation of labour earnings between expenditure in durable goods and non-durable goods and on redistribution across different kinds of households.

I find that there exist revenue neutral reforms that increase overall welfare with respect to the current scenario by changing VAT rates towards uniformity, but these reforms redistribute in favour of the wealthier at the expense of the poorer. However, by complementing changes in VAT rates towards uniformity with progressive benefits, it is possible to design revenue neutral and overall welfare enhancing reforms that redistribute in favour of the less wealthy.

The analysis conducted in this first Chapter relies on various simplifications. First, it considers indirect taxes in isolation from the rest of the tax system, in particular it abstracts from the interactions between indirect and direct taxation. Second, the theoretical framework proposed here does not allow for labor supply responses, which are an important margin of adjustment to tax changes for most households. These simplifying assumptions are likely to influence the results of the analysis and, therefore, they will be relaxed in the following two chapters.

Chapter 2

Taxation of Durables, Non-durables, and Earnings with Heterogeneous Preferences: Model and Implications

2.1 Introduction

Consumption and personal income taxes are key policy instruments. They are the two major sources of government revenues in OECD countries, with substantial differences across nations[1]. 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 tax rates distort consumption choices among different categories of goods, while the level and progressivity of income taxes change the incentives to work, especially for the second earner of the household. 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 equity-efficiency trade-off that they generate, the aim of the second and third Chapters of this thesis

[1] Source: OECD (2018).

is to study their joint design and interactions by addressing the following questions. How do consumption and income taxes affect household consumption, saving and labor supply choices over the life cycle? What implications do they have for inequality and the well being of families? How should the government tax different categories of consumption goods and labor income? How does the optimal design of these taxes compare to the actual tax systems implemented in reality?

To answer these questions, I extend the model developed in Chapter 1 and set up an empirical framework that accounts for the essential features of household economic behavior that are needed to study direct and indirect taxation. First of all, households' consumption consists of different categories of goods that can be taxed at different rates: non-durables with different degrees of necessity and durables that represent both a consumption and an investment decision for the household. Consumption choices among these goods vary over the course of life and differ across income levels. Moreover, these consumption choices interact with labor supply decisions that are very sensitive to tax incentives and family dynamics, especially for the second earner in the household. In addition, even conditional on their income, households differ in their responses to the tax system because they face different lifetime shocks and constraints and have heterogeneous preferences.

The main contribution of this Chapter is, therefore, to develop and estimate a structural life cycle model of household consumption, saving, and employment choices that combines all the elements that are essential for investigating the interaction between direct ad indirect taxation and household economic behavior, while remaining computationally tractable in order to provide quantitative results that can help in guiding the policy debate. 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 and fertility. 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. Households are ex ante heterogeneous in their education level, as a proxy of their socio economic status, which affects their preferences for consumption, saving and work and the stochastic processes for earnings and fertility that they face over the life cycle.

Hence, the model in this Chapter is richer than the one of Chapter 1 along several important dimensions: endogenous labor supply decision for the second earner in the household which is non separable in preferences with respect to both non durable and durable consumption; stochastic family dynamics that influence consumption and labor supply choices ad create further scope for insurance and consumption smoothing for the household; heterogeneous intratemporal and intertemporal preferences for consumption, saving and labor supply decisions across education groups.

I estimate the model on micro data using a two-step estimation procedure. In the first step, I estimate the education-specific preference parameters governing the intratemporal choice among different non-durable commodities. In the second step, I estimate the parameters that determine durables dynamics and the heterogeneous intertemporal preference parameters for consumption, saving, and labor supply by method of simulated moments. I use the same dataset introduced in Chapter 1, which contains longitudinal information on non-durable consumption, durables, wealth, hours and wages for a representative sample of Italian households. The rich structure of this dataset is essential for my estimation strategy. Moreover, the Italian tax regime, featuring highly differentiated consumption tax rates and a progressive labor income tax, represents a convenient benchmark for the analysis. Simulations of the estimated model show that the combination of its features proves to be crucial in matching the life-cycle patterns observed in the micro data and, in particular, in reproducing the empirical distributions of consumption, savings, and earnings of both spouses.

I then use the estimated model to simulate life-cycle Marshallian elasticities along multiple dimensions. In particular, I 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 empirical implications of the model and will also guide the discussion of the normative analysis results in Chapter 3. The model encloses several mechanisms of interaction between households' economic choices and the tax system that have not been considered together in previous studies. First, the disaggregation of consumption into sub components implies that consumption goods are differently affected by changes in consumption and labor income taxation depending on their degree of necessity and durability. In particular, the fact that households have to commit to their durable investment decisions before future shocks are realized calls for additional social insurance.

Second, the model allows for interactions between instruments of private insurance and the tax system. Specifically, consumption taxes on durables change the attractiveness of financial assets relative to durables as saving instruments and, therefore, shift the composition of households' portfolio over time. Moreover, the presence of credit constraints creates further heterogeneity in the response to tax changes across the population; more constrained households react differently to tax reforms as opposed to unconstrained ones. The labor supply choice of the second earner is affected by the tax system both directly, through incentives from the labor income tax, and indirectly, as a device to smooth household consumption against changes in the tax burden. Third, heterogeneity in preferences across education groups translates into heterogeneity in the elasticities of consumption demand and labor market participation to changes in prices and wages. This has important implications for the redistributive effect of taxation.

Related literature. This paper 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), Borella et al. (2017), 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 remainder of the Chapter proceeds as follows. I briefly describe the policy environment in Section 2.2. Section 2.3 outlines the model and Section 2.4 the data. Section 2.5 explains the estimation procedure and presents the estimated parameters. Model fit and validation are discussed in Section 2.6 together with simulated elasticities. Section 2.7 concludes.

2.2 Policy Environment

In this section I briefly describe the tax instrument and Italian policy environment that constitute the focus of my analysis. They refer to year 2014 (the last wave of my data), that also represents the baseline scenario for the quantitative optimal taxation experiments in Chapter 3.

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. As explained in Chapter 1, 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 (Table 2.1). 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 Euro 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.

Table 2.1: 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

2.3 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 $T = 85$. 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. For simplicity, husband and wife are assumed to be of the same age and to die together.

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[2]. Then, they choose whether or not the wife should participate to the

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

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: i) secondary or high school drop out, ii) high school, iii) 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[3]. 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[4].

2.3.1 Household Problem and Preferences

Expanding on the model in Chapter 1, the model in this Chapter integrates an intratemporal static demand analysis for multiple non-durables within an intertemporal dynamic model for durables, savings and labor supply decisions. 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:

$$\max_{l_t, c_{1,t}, c_{2,t}, d_t, a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} U(c_{1,t}, c_{2,t}, d_t, l_t) \tag{2.1}$$

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

[3]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.

[4]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 C

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:

$$\max_{l_t, c_t, d_t, a_t} \mathbb{E}_{t_0} \sum_{t=t_0}^{T} \beta^{t-t_0} U(v(c_t, P_t), d_t, l_t) \tag{2.2}$$

The assumption of weak separability greatly simplifies the solution and estimation of the model, but imposes some restrictions. Namely, it implies 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:

$$U(v(c_t, P_t), d_t, l_t) = \frac{[(v(c_t/n(k_t), P_t))^{\theta}(\delta d_t - \varepsilon^d)^{1-\theta}]^{1-\gamma}}{1-\gamma} exp(\Psi(l_t, k_t)) \tag{2.3}$$

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 $n(k_t)$[5]. 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. 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:

[5]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.

$$\Psi(l_t,k_t)) = \begin{cases} 0 & \text{if } l_t = NE \\ \psi_0 \times \mathbf{1}(k_t=0) + \psi_1 \times \mathbf{1}(k_t=1) + \psi_2 \times \mathbf{1}(k_t=2) & \text{if } l_t = E \end{cases} \tag{2.4}$$

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. As in Chapter 1, 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[6] following Deaton and Muellbauer (1980) Almost Ideal Demand System (AIDS) formulation. A more detailed description of this model is reported in Appendix A.1. The AIDS functional form for the indirect utility function in the intratemporal problem is:

$$v(c,P) = exp\left\{\frac{ln(c) - ln(a(P))}{b(P)}\right\} \tag{2.5}$$

$$ln(a(P)) = \alpha_0 + \sum_{i=1}^{n} \alpha_i lnp_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \eta_{ij} lnp_i lnp_j \tag{2.6}$$

$$b(P) = \prod_{i=1}^{n} p_i^{\beta_i} \tag{2.7}$$

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

[6]recall from Chapter 1 that the corresponding primal problem is:

$$\max_{c_1,c_2} u(c_1,c_2) \qquad s.t. \qquad (1+\tau^{n1})\tilde{p_1}c_1 + (1+\tau^{n2})\tilde{p_2}c_2 = c$$

where, $p_1 = (1+\tau^{n1})\tilde{p_1}$, $p_2 = (1+\tau^{n2})\tilde{p_2}$ and $P = [p_1, p_2]$ is the vector of non-durable prices inclusive of the consumption tax rates.

the price index and is homogeneous of degree one. $b(P)$ is the Cobb-Douglas price aggregator and is homogeneous of degree zero.

2.3.2 The Environment

Durables. Households can adjust their durables stock d by buying or selling [7]. 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 (Akerlof (1970))[8]. 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. 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:

$$D(x_t) = \begin{cases} (1+\tau^d)q & \text{if } x_t \geq 0 \\ \pi q & \text{if } x_t < 0 \end{cases} \tag{2.8}$$

Where, x represents durables' flow and q is constant durables' price. Durables stock depreciates at the constant rate δ [9]. I assume the absence of a rental market for durable goods. This is a reasonable assumption, given that I only model consumer

[7] 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.1.2).

[8] Because of asymmetric information about the actual quality of the good between the seller and the buyer, agents believe that certain durable goods offered on second-hand markets are on average such bad quality that they are only willing to pay very low prices for them so that the sellers with the good quality used durables are driven out of the market. Sellers of decreasing quality remain in the market until the willingness to pay of the potential buyers is driven down to zero and the market shuts down.

[9] 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.

durables and abstract from housing. Hence, the durables law of motion is:

$$d_t = (1-\delta)d_{t-1} + x_t \tag{2.9}$$

Financial assets. Households can also save and borrow in a risk-free financial asset whose associated interest rate is r. 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. 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 two processes governing husband's and wife's 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 standard way:

$$lny_t^s = f^g(X,t) + \tilde{y}_t^g \tag{2.10}$$

$$\tilde{y}_t^g = z_t^g + \varepsilon_t^g \tag{2.11}$$

$$z_t^g = \rho^g z_{t-1}^g + u_t^g \tag{2.12}$$

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

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.

2.3.3 The Government

The government levies proportional consumption taxes and non linear progressive labor income taxes at the individual level. Proportional consumption taxes are $\tau^{n1} = 4\%$ on non-durable necessities, $\tau^{n2} = 10\%$ on non-durable luxuries and $\tau^{d} = 22\%$ on durables. 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:

$$y^{net} = T(y^{gross},k) = \lambda_k (y^{gross})^{1-\tau_k^y} \tag{2.13}$$

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 $1-\lambda$.

2.3.4 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:

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

$$V_t(\mathbb{S}_t) = \max_{l_t, c_t, d_t, a_t} \{U(v(c_t, P_t), d_t, l_t) + \beta \int V_{t+1}(\mathbb{S}_{t+1}) dF(y_{t+1}^f, y_{t+1}^m, k_{t+1} | y_t^f, y_t^m, k_t)\} \tag{2.14}$$

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

$$c_t + D(x_t)x_t + a_t = (1+r)a_{t-1} + T(y_t^m, k_t) + T(y_t^f, k_t) \times \mathbf{1}(l_t = E) \tag{2.15}$$

$$d_t = (1-\delta)d_{t-1} + x_t \tag{2.16}$$

$$a_t \geq -\chi q d_t \tag{2.17}$$

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:

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

$$V_t^r(\mathbb{S}_t^r) = \max_{c_t, d_t, a_t} \{U(v(c_t, P_t), d_t) + \beta \phi V_{t+1}^r(\mathbb{S}_{t+1}^r)\} \tag{2.18}$$

Subject to (2.16) and (2.17) and to the retirement specific budget constraint:

$$c_t + D(x_t)x_t + a_t = (1+r)a_{t-1} + T(\zeta y^m_{T_{ret}-1}, 0) \tag{2.19}$$

2.4 The Data

I exploit the same two data sets used in Chapter 1 the Bank of Italy Survey on Household Income and Wealth (SHIW) and the Italian National Institute of Statistics Household Budget Survey (ISTAT HBS). A detailed description of these data sources is reported in Section 1.4 of Chapter 1 and in Appendix B.1 and B.2.

2.5 Estimation

I follow a two-step procedure to estimate the parameters of the model[10]. In the first step I estimate the predetermined elements of the model including male earning process, family composition dynamics and non linear labor income tax function. In this first step I also estimate the preference parameters governing the within-period static household's decision problem of how to optimally allocate non-durable expenditure among different subcategories. 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).

2.5.1 First Step

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[11]. I estimate the process' parameters on gross earnings panel data from SHIW, following a standard estimation procedure (see Guvenen (2009)).

As shown in equations (2.10)-(2.12), I specify gross labor income as the sum of a deterministic component and of a stochastic component. I first estimate the

[10]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).

[11]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.

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_u^2, the variance of the initial productivity shock, σ_{z0}^2, and the variance of the transitory shock σ_ε^2. All estimates are education specific. Table 2.2 presents the estimated parameters of the stochastic component. Details on estimation procedure and identification are in Appendix D.1.

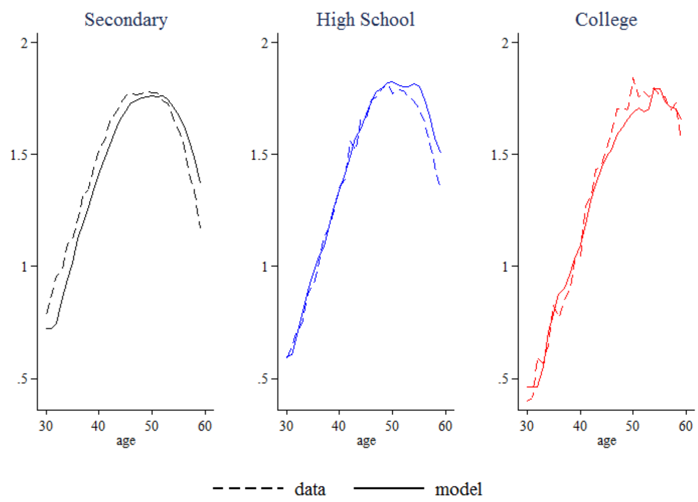
Table 2.2: Estimated parameters of the stochastic component of male earnings

	Education level		
	Secondary	High School	College
ρ	0.9351	0.9483	0.9667
	(0.0310)	(0.0385)	(0.1008)
σ_u^2	0.0128	0.0119	0.0092
	(0.0068)	(0.0101)	(0.0126)
$\sigma_{z_0}^2$	0.0379	0.0488	0.1464
	(0.0167)	(0.0278)	(0.0885)
σ_ε^2	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 2.1 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.

Figure 2.1: Family composition profiles



Tax function. To estimate the parameters of the non linear labor income tax function in (2.13), I take its logarithmic transformation:

$$ln(y^{net}) = ln(\lambda) + (1-\tau)ln(y^{gross}) \tag{2.20}$$

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 (2.20) 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 2.3 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.

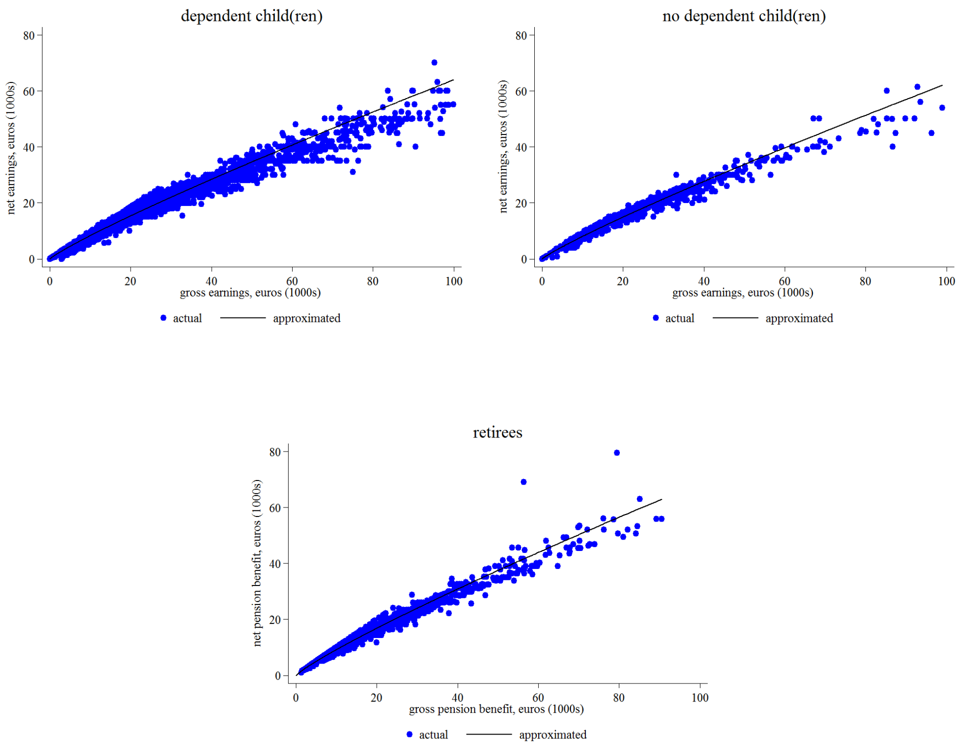
The estimated tax function in (2.20) provides a good approximation to the

Table 2.3: 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

actual tax system with a R-squared of 0.96. Figure 2.2 shows the actual and approximated relationship between gross and net earnings in the three sub groups of parents, non-parents and retirees.

Figure 2.2: Labor income tax, actual vs approximated



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 2.3. As explained in Chapter 1, applying Roy's identity to the indirect utility function in (2.5), the following demand system estimation equations can be derived:

$$w_{it} = \alpha_i + \sum_{j=1}^{k} \eta_{ij} lnp_{jt} + \beta_i ln \left\{ \frac{c_t}{a(p)} \right\} + e_{it} \tag{2.21}$$

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 (2.21) are estimated by education on HBS repeated cross sections data[12] 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 (2.21) 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 the same grouping estimator strategy adopted in Chapter 1[13]. 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 (2.21). Following Browning and Meghir (1991), I test for separability between non-durable con-

[12]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.

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

sumption and female participation and find that, once controlling for education, the unconditional demand system is not rejected (results in Appendix A.2)[14]. 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.

Table 2.4: 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

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.5: 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

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Tables 2.4 and 2.5 show that results from my demand system estimation are

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

overall sensible and in line with findings in the literature. The 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 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 (2.6) and (2.7), 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.

2.5.2 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[15]. 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 C). I compute the same set of moments in the data and in

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

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[16]:

$$\hat{\Theta} = \arg\min_{\Theta} \left\{ \sum_{k=1}^{K} \left[(m_k^{data} - m_k^{sim}(\Theta))^2 / Var(m_k^{data}) \right] \right\} = \arg\min_{\Theta} \left\{ g(\Theta)' \Omega g(\Theta) \right\} \tag{2.22}$$

And the variance of the estimator is:

$$\hat{V} = (1 + \frac{N}{S})(\hat{G}'\Omega\hat{G})^{-1} \qquad with \qquad \hat{G} = \left. \frac{\partial g(\Theta)}{\partial \Theta} \right|_{\Theta = \hat{\Theta}}$$

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).

The vector of estimating parameters, Θ, contains education-specific consumption preference parameters ($\theta, \gamma, \beta, \varepsilon^d$), education-specific work preference parameters (ψ_0, ψ_1, ψ_2), education-specific parameters governing wife's earnings process ($f_0, f_1, f_2, \rho, \sigma_u, \sigma_{z_0}, \sigma_\varepsilon$), 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 on a

[16] 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.

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. 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 they 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 of identification is in Appendix D.2.

Parameter estimates. Table 2.6 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 [17] 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.

Table 2.6: 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)	

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

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

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 women who endogenously choose to participate in the model.

Table 2.7 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 (2.10). 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 2.7 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.

Table 2.7: 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)	

The estimates of the parameters governing durables' dynamics in Table 2.8 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.

Table 2.8: 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)	

Tables 2.6, 2.7 and 2.8 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 because there are too few observations for this subgroup in the data sample.

2.6 Model Fit and Implications

2.6.1 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 2.3. 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.

Second, Figure 2.4 reports profiles conditional on 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.

Lastly, the education-specific life cycle profiles of net wages for men and women in Figure 2.5 are very similar in the model and in the data. Net earnings increase faster for college and high school educated and are much higher for men than for women of same age and education. Additional evidence of model fit is reported in Appendix F.1

Figure 2.3: Mean life cycle profiles, data vs model

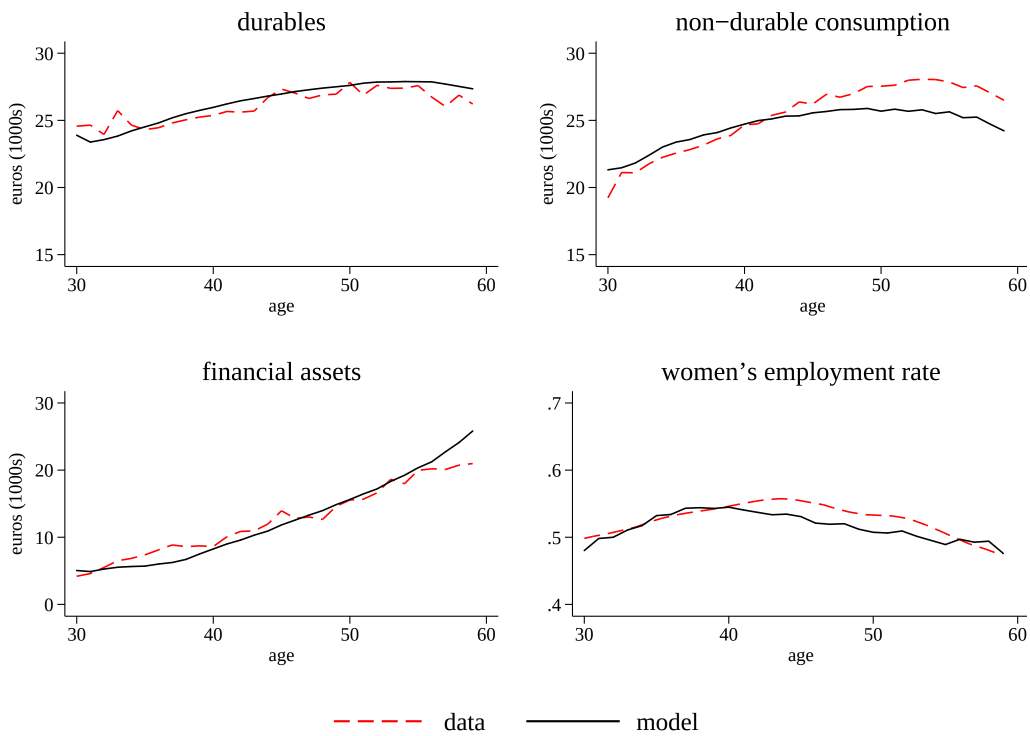


Figure 2.4: Mean life cycle profiles by education, data vs model

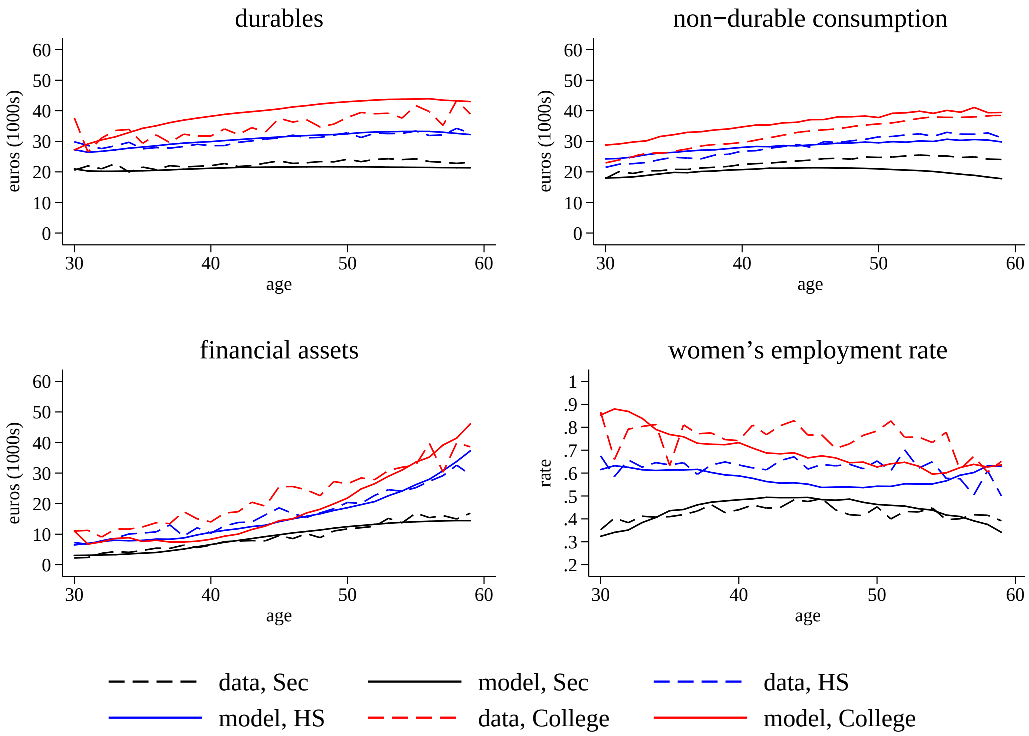


Figure 2.5: Mean net earnings by education, data vs model

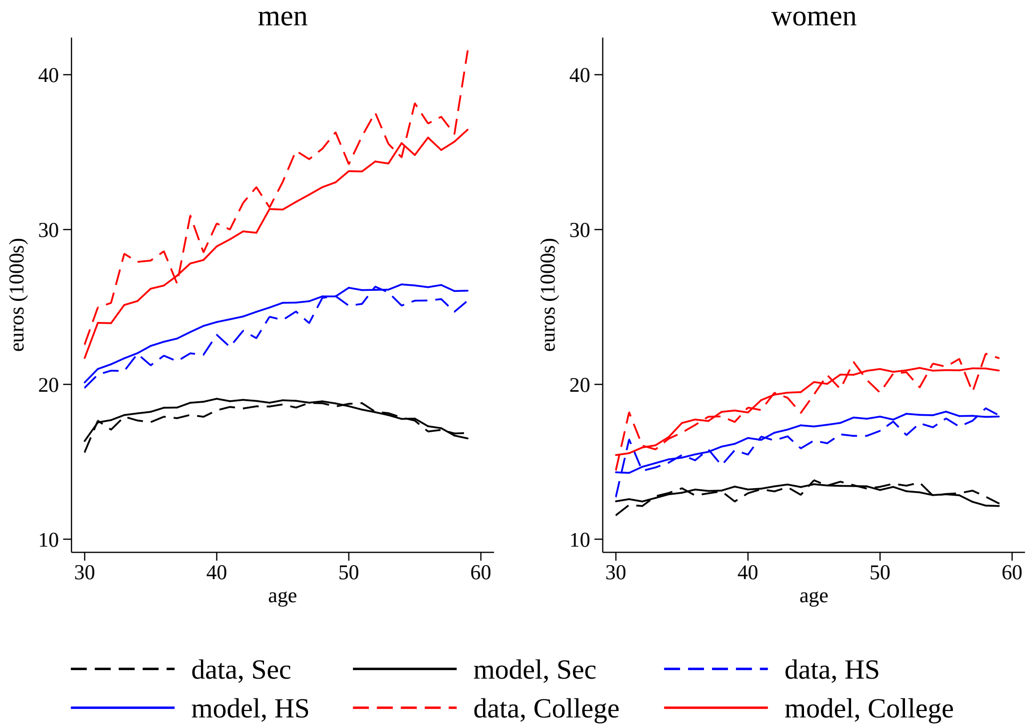


Figure 2.6 compares the empirical and simulated distributions of durables, non-durable consumption, financial assets, and net earnings among households of all ages and education levels. These moments are not estimation targets, however the model fits them well too. This is an important validation check 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 validation checks are reported in Appendix F.2.

2.6.2 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[18] that capture the response to a permanent increase in prices or wages when households 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.

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 2.9, we notice that there is substantial heterogeneity in elasticities across education groups.

Column 1 of Table 2.9 shows extensive margin female labor supply elasticities.

[18] 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 intertemporal allocations are allowed to adjust from period to period.

Figure 2.6: Distributions, data vs model

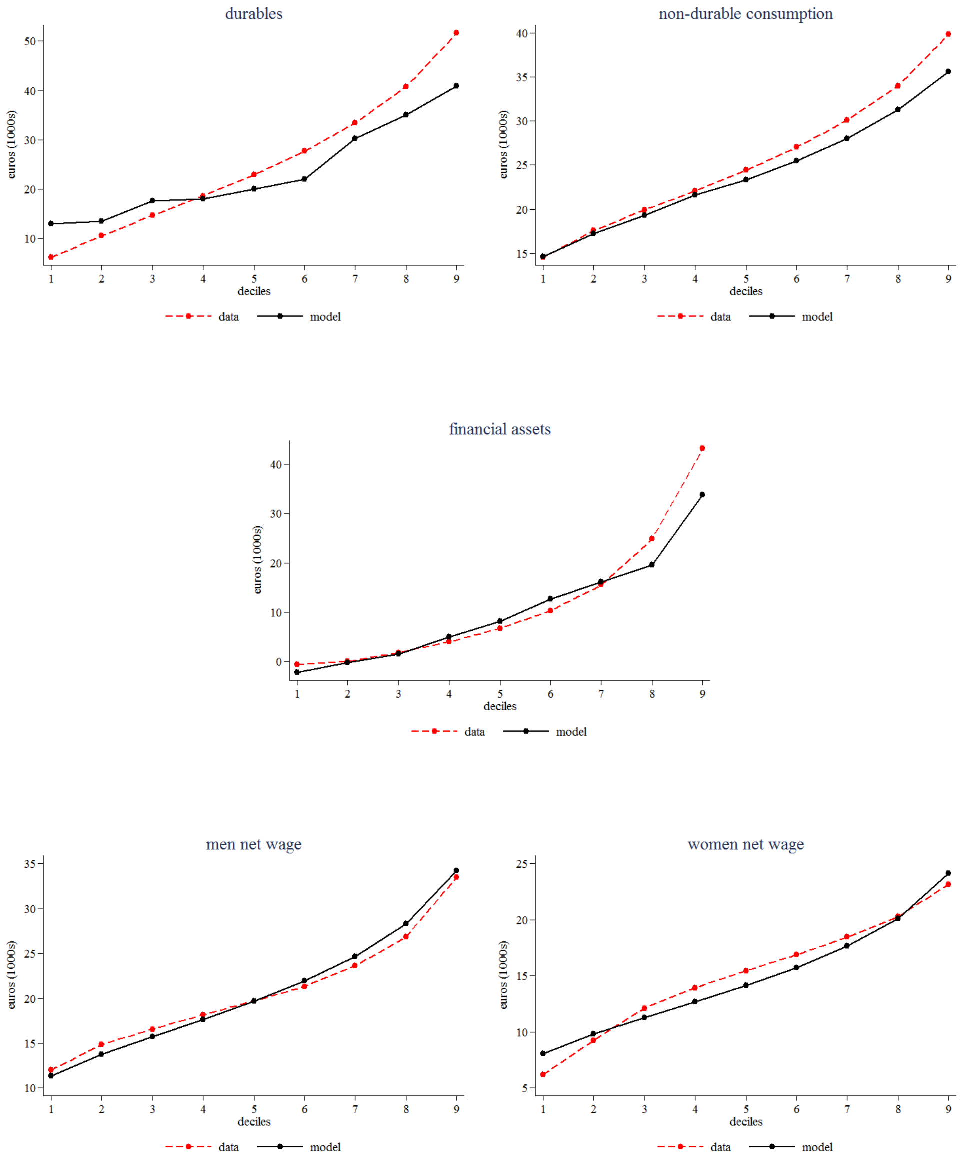


Table 2.9: Simulated marshallian elasticities

		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

Elasticities of female participation to own net earnings are on the upper bound of the range suggested by 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. (2017)).

Extensive margin elasticities to changes in prices of consumption goods are small in magnitude, suggesting no strong complementarities/substitutabilities exist between each of the consumption goods and leisure. It is worth noting that 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.

Columns 2 to 4 of Table 2.9 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[19] between non-durable necessities and luxuries.

2.7 Conclusions

In this Chapter, I develop and estimate a rich structural life-cycle model of household durable and non-durable consumption, saving and labor supply decisions and estimate it using the method of simulated moments. The model combines many realistic elements including preference heterogeneity across education groups, uncertainty about the evolution of earnings and family dynamics, multiple consumption goods, partially irreversible durables, credit constraints and endogenous participation decision of the second earner. I show that the interaction among these features is crucial in matching the life-cycle patterns observed in the micro data and, in particular, in reproducing the empirical distributions of consumption, savings and earnings of both spouses.

By simulating life cycle Marshallian elasticities along multiple dimensions, I show that the estimated model encloses several mechanisms of interaction between direct and indirect taxation and household life cycle choices that have not been considered together in previous literature.

First, taxes create relevant incentives and disincentives on labour supply of second earner suggesting the presence of strong income effects and family insurance mechanisms in the household. Second, different consumption goods are differently affected by taxes depending on their degree of necessity and durability. Third, tax changes can shift households' portfolio composition in terms of relative importance of assets versus durables. Lastly, different long run responses to tax reform can result from different credit constraints as well as from heterogeneous consumption

[19] 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.

and saving preferences of the households.

Chapter 3 of this thesis consists in the application of the empirical framework developed in this Chapter to the quantitative normative analysis of labor income taxes and consumption taxes on different categories of goods. However, the rich structure of the estimated model described in this Chapter lends itself to other promising applications. For instance, expanding on Kaplan (2012), the model could be exploited to investigate consumption inequality over the life-cycle in a realistic setting in which households can allocate their expenditure among different categories of consumption goods and can self insure against shocks not only through the standard mechanism of saving in liquid assets, but also by relying on their durable stock and by adjusting the labor supply decision of the second earner.

Chapter 3

Taxation of Durables, Non-durables, and Earnings with Heterogeneous Preferences: Quantitative Normative Analysis

3.1 Introduction

In this section I use the estimated life cycle model developed in Chapter 2 to conduct a quantitative normative analysis and determine the optimal tax rates on non-durable goods, durables and labor income. Indirect taxes on consumption expenditures and direct taxes on labor income are the two major sources of government revenues across countries. Despite their importance, there is a discrepancy between the predictions of the economic theory in terms of their optimal design and the tax regimes that are observed in reality. In particular, one of the most influential results in optimal tax theory, the Atkinson and Stiglitz (1976) theorem, suggests that differentiated commodity taxation is useless in presence of optimal non-linear income taxes. However, in reality differentiated consumption taxes are widely adopted together with income taxes across countries.

In Chapter 2, the estimated model was shown to be reliable and to closely match the lifetime patterns and distributions of households' choices observed in the micro-data. Hence, in this Chapter, I can use it to bridge the gap between theory and data by simulating alternative counterfactual tax scenarios and their impact on households' welfare.

In order to disentangle the importance of the competing mechanisms at play, the analysis in this Chapter proceeds in three subsequent steps. First, I look at the optimal tax system in a simpler framework, where the government is assumed to be utilitarian and households are assumed to have heterogeneous endowments and preference for work, but homogeneous consumption and saving preferences. Estimates and elasticities for this restricted version of the model are in Appendix E.1. Then, I move on to a second scenario in which the social welfare criterion is still utilitarian, but households are allowed to have heterogeneous preferences, as in the full-blown version of the model. Lastly, to overcome the limitations of the utilitarian welfare function in presence of heterogenous preferences, I extend the analysis to allow for a more general social welfare criterion with varying degrees of government inequality aversion. In particular, I adapt the approach of generalized social marginal welfare weights, introduced by Saez and Stantcheva (2016), to my dynamic stochastic framework: the weights attached by the government to households expected lifetime utilities are decreasing in households expected lifetime disposable income.

Under the assumption of a utilitarian social welfare criterion, I obtain two main results. First, a subsidy on durables' purchases is optimal. The reason behind this result is government's provision of efficient social insurance. In presence of uncertainty, credit constraints, and partial irreversibility of durable goods, risk averse agents tend to under consume pre-commitment goods, such as durables, and over consume non-durable goods. Therefore, by subsidizing durables, the policy maker incentivizes durable consumption and provides households with insurance by closing the gap between different consumption expenditures in good and bad states of the world.

Second, the optimal combination of taxes on non-durable consumption and labor income crucially depends on the degree of preference heterogeneity in the population. If households differ only in their preferences for work, all non-durable commodity taxes are zero and the government relies on higher level - or progressivity - of non-linear labor income tax at the optimum. If, instead, additional heterogeneity in consumption and saving preferences is introduced, optimal redistribution is lower and an optimal tax system with high and differentiated tax rates on non-durable goods and lower labor income taxes arises. The striking difference between the two scenarios is explained by the fact that heterogeneity in intertemporal preferences, and especially in risk aversion, creates a correlation between utilitarian welfare weights and consumption-saving patterns that radically changes the ordering of the social welfare weights along the income distribution.

Overall, this quantitative analysis suggests that explicitly taking into account durable goods' dynamics and heterogeneity in consumption preferences restores the role of differentiated commodity taxation, even in presence of a non-linear labor income tax schedule. This finding revives Ramsey style results and challenges the Atkinson-Stiglitz framework. Yet, this outcome is in sharp contradiction with the structure of the tax systems observed in reality.

I bridge this gap between the results of the quantitative utilitarian normative analysis and the tax practice by allowing for government inequality aversion. I show that, as government inequality aversion increases, the optimal tax system results in progressively lower efficiency and higher equity. Specifically, if inequality aversion increases beyond a given threshold, equity concerns offset efficiency concerns and the subsidy on durable goods turns into a tax.

I also find that the tax systems implemented in most developed countries, characterized by higher tax rates on luxuries and durables, are justified under high degrees of government inequality aversion. In particular, I identify the level of government inequality aversion that rationalizes the tax system currently in place in Italy and I show that, under even higher degrees of inequality aversion, tax systems similar to the ones implemented in certain Scandinavian countries, like Sweden and Norway, are obtained. Interestingly, these results contradict the traditional view that commodity taxes tend to be regressive and suggest that differentiated rates contribute to redistribution jointly with the progressivity of labor income taxes, thus justifying their pervasiveness in practice.

Lastly, I show that, when the government adjusts the progressivity of the labor income tax rather than its level, the result of zero commodity taxation on non-durables obtains even in presence of heterogeneous consumption preferences. However, it is coupled with a high tax on durables and a very progressive labor income tax. This result suggests that, although it is more efficient for the inequality averse government to target the less wealthy groups through more progressive income taxes rather than through differentiated consumption tax rates on non-durables, taxation of durable goods plays a crucial redistributive role in addition to the progressivity of labor income tax.

Related literature. The optimal mix of direct and indirect taxation is a classic topic in Public Finance. In a context of linear income taxes, two seminal studies argued in favor of differentiated commodity taxation. First, Ramsey (1927) showed that consumption tax rates should reflect differences in price elasticities. Second, Diamond and Mirrlees (1971) demonstrated that taxes should be greater on commodities that are purchased more by agents with lower social marginal utility of income. Successively, Atkinson and Stiglitz (1976) derived their powerful result on the uselessness of differential commodity taxation in presence of an optimal non-linear income tax and undermined the importance of commodity taxation as a redistributive tool. Starting from these early contributions, a vast theoretical literature challenged the validity of the Atkinson-Stiglitz result by extending its framework in various alternative directions and reached contrasting conclusions. Among others, Cremer and Gahvari (1995a,b) allow for pre-commitment goods and uncertainty and prove that differential commodity taxation remains a useful tool of optimal taxation even in presence of non-linear income taxes and separability; Cremer et al. (2001) show that the Atkinson-Stiglitz result can still hold under non separability but fails when endowments differ between individuals; Saez (2002) revisits the Atkinson-Stiglitz result in a more general set-up with heterogeneous tastes and argues in favor of commodity taxation; Golosov et al. (2003) extend to a dynamic framework with unobservable skills evolving stochastically over time and show that the uniform commodity taxation result still holds; Kaplow (2006) demonstrates that the conclusion of the Atkinson-Stiglitz theorem holds regardless of whether the income tax is optimal; Diamond and Spinnewijn (2011) and Golosov et al. (2013) find a role for differentiated commodity taxation, even in presence of non linear income taxes, in contexts of one-dimensional preference heterogeneity. The rich dynamic structure of my model allows me to contribute to this debate in a more general framework that combines many of the dimensions previously considered in these extensions. Moreover, thanks to the empirical approach of the study, I can complement the theoretical analysis by quantifying the combined effects of the mechanisms at play and relate them to existing theoretical predictions, thus bridging the gap between theory and data.

The normative analysis in this Chapter also contributes to the 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) 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 is the focus of my research.

The rest of the Chapter is structured as follows. Section 3.2 describes the government problem. Section 3.3 presents the optimal tax system under the homogeneous preference scenario. Section 3.4 extends the analysis to the heterogeneous preference scenario. Section 3.5 repeats the analysis under the generalized social welfare criterion. Section 3.6 concludes.

3.2 The Government Problem

The government chooses the tax instruments that maximize a social welfare criterion. I assume the social planner employs a utilitarian approach. 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[1]. 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:

$$\max_{\tau^{n1},\tau^{n2},\tau^{d},\lambda} \sum_{i} EV_0^i(\tau^{n1},\tau^{n2},\tau^{d},\lambda) \tag{3.1}$$

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

[1]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.

R^{pre} represents total tax revenues in the pre reform scenario.

3.3 Homogeneous Consumption Preferences

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 7.1% 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 Euro), marginal labor income tax increases from 35% to 41% and average labor income tax increases from 26% to 33%.

Table 3.1: Consumption tax rates, MTR and ATR at mean gross earnings, pre-post (%)

	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR
pre	4	10	22	35	26
post	0	0	-7.10	41	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. On the one hand, optimal exemption of non-durables suggests that the Atkinson-Stiglitz result holds true, in regards to non-durables, even in a general dynamic setting, provided that preferences for commodities are homogeneous.

The intuition 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, always possible for the social planner to generate a Pareto improvement by eliminating indirect taxes and adjusting labor income taxes.

On the other hand, optimal subsidy on consumer durables partially restores the role of differentiated commodity taxation. To understand this result, one must consider the interaction between private and social insurance in presence of uncertainty and credit constraints. In the absence of formal insurance markets, risk averse agents smooth their consumption over the life cycle against idiosyncratic shocks and tend to under consume pre-commitment goods, such as durables, and over consume post uncertainty goods, such as non-durables, with respect to the first best scenario of complete insurance. A policy maker who taxes non-durables more than durables, or even subsidizes durables, incentivizes consumption of durables over non-durables. Therefore, it provides households with some insurance against shocks by closing the gap between total consumption expenditures in good and bad states of the world.

Hence, when there are multiple sources of uncertainty and durables are highly irreversible, distortionary taxes can be welfare improving if they allow the government to provide an additional insurance channel. This result confirms the theoretical finding of optimal subsidization of pre-commitment goods in presence of uncertainty derived by Cremer and Gahvari (1995a) and is also in line with a recent related study by Koehne (2018), who finds that, when the stock of durables is subject to adjustment frictions, the optimal tax on durable purchases must be different from that on non-durables.

Table 3.2 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

Table 3.2: 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

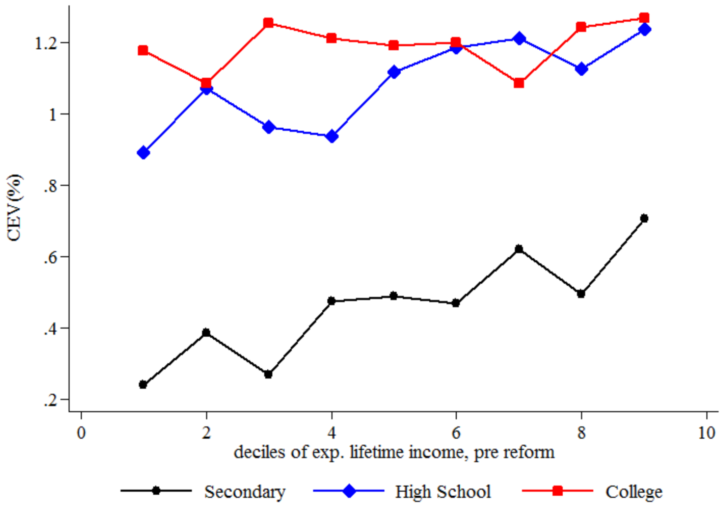
the government through durables subsidies implies a large decrease of savings in financial assets as durables become a more convenient smoothing device.

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 3.2 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

Figure 3.1: CEV by education and by deciles of pre reform expected lifetime disposable income



consumption. Also, it is Pareto improving, as 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 3.2 and from Figure 3.1, it is evident that richer households gain more within and across education groups. 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.

To summarize, this first experiment delivers two main quantitative findings that are in line with theoretical discussions. When agents' preferences are assumed to be homogeneous and weakly separable between non-durable consumption goods and labor, all non-durable commodity taxes are zero and government relies only on non-linear labor income taxes at the optimum. Agents' desire to insure against uncertainty together with pre commitment nature of durable goods imply that a subsidy on durables is optimal. The results found under the simpler quantitative model with homogeneous consumption preferences will serve as a benchmark for the following analysis.

3.4 Heterogeneous Consumption Preferences

Standard Mirrleesian optimal taxation analysis abstracts from heterogeneity in tastes over consumption and leisure. Agents are allowed to differ only in their earning abilities. However, 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 F.3 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) finds that preference heterogeneity interacts with policy instruments in complex ways and can even reverse classical results derived under preference homogeneity. In particular, as discussed by Saez (2002), 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 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 21.8%

and an increase in the tax rate on non-durable luxuries from 10% to 18.4%. The optimal subsidy rate on durables is 21.80%. 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 3.3: Consumption tax rates, MTR and ATR at mean gross earnings, pre-post (%)

	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR
pre	4	10	22	35	26
post	21.80	18.40	-21.80	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, suggesting that the no commodity taxation theorem does not hold under preference heterogeneity. In fact, these findings are more in line with Ramsey (1927) and Diamond and Mirrlees (1971) classical theories in favor of positive and differentiated tax rates on non-durable commodities.

Also, they confirm the conclusions reached by a more recent stream of theoretical research about the optimal design of consumption and labor income taxes under heterogeneity of preferences. 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. 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 consumption taxation with heterogeneous discount factor.

The intuition behind the results in this second scenario lies in the fact that heterogeneity in intertemporal preferences creates a correlation between social welfare weights and consumption-saving patterns. Indeed, 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. Therefore, heterogeneity in consumption preferences changes the ranking of social welfare weights along the income distribution. In particular, I find a slightly higher tax rate on non-durable necessities than on non-durable luxuries. The mechanism explaining this outcome hinges on the heterogeneity of risk aversion across skill groups. According to the estimates, more educated households are less risk averse than less educated counterparts. Given the assumption of CRRA utility, this implies higher marginal utility from consumption, or equivalently marginal value of wealth, 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 public insurance mechanism for pre-commitment goods, 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.

It is worth noting that, according to the estimates and in line with existing empirical findings, high ability - or high education - households are also more patient than low ability ones. Their higher discount factor counteracts the effect of their lower coefficient of risk aversion. Indeed, a high discount factor (i.e. low discount rate) implies lower marginal utility from consumption and, therefore, lower implicit utilitarian social welfare weights. In presence of heterogeneity in multiple dimensions, as it is the case in my model, which effect prevails is an empirical question. My estimates suggest that heterogeneity in discount factor is much smaller than heterogeneity in risk aversion and, therefore, the effect of the latter is stronger.

Table 3.4 presents mean percentage changes in the main simulated outcomes

Table 3.4: Changes (%) in households' choices and lifetime welfare

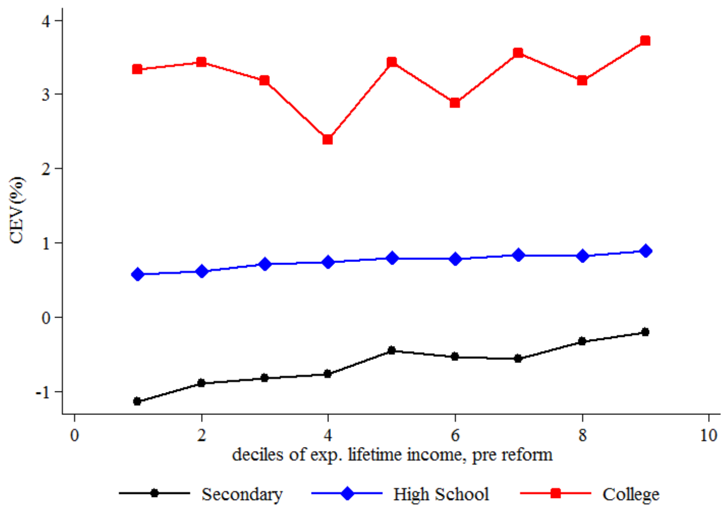
	All	Sec	HS	College
financial assets	-39.26	-29.78	-44.88	-46.74
durables stock	57.53	52.60	59.29	67.85
non-durable consumption	-8.20	-8.09	-8.05	-9.08
non-durable consumption, necessities	-11.83	-12.16	-11.79	-10.61
non-durable consumption, luxuries	-6.50	-6.04	-6.34	-8.49
durables flow	123.27	112.68	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

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 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.

Figure 3.2: CEV by education and by deciles of pre reform expected lifetime disposable income



Lifetime welfare effects of the optimal tax system are shown in the bottom panel of Table 3.4 and in Figure 3.2. 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, as shown in Figure 3.2, the optimal tax system redistributes in favor of the more wealthy and imposes a welfare loss on the poorer groups of the population. 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.

This second computational experiment confirms the relevant impact of preference heterogeneity on optimal taxation analysis. Specifically, it suggests the importance of determining the link between various dimensions of consumption preference heterogeneity and the distribution of social welfare weights. In particular, I have shown that heterogeneity in risk aversion has a substantial effect on optimal policies in dynamic and stochastic contexts.

3.5 Generalized Social Welfare Criterion

The normative analysis based on utilitarian social welfare criterion that I conducted so far allowed me to investigate the main dynamics and distortions at play when designing optimal tax systems. However, 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 equity concerns[2]. 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[3] 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.

Hence, in order to bridge the gap between optimal taxation results and ac-

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

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

tual tax practice, in this section I introduce a flexible generalization of the government social welfare function. Along the lines of generalized social marginal welfare weights proposed by Saez and Stantcheva (2016), I allow the policy maker to take into account observed agents' characteristics that capture society's concern for equity while being orthogonal to agents' preferences. Specifically, I assume that the weights assigned 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 problem under revenue neutrality constraint becomes:

$$\max_{\tau^{n1},\tau^{n2},\tau^{d},\lambda} \sum_i g(EI_0^i(\tau^{n1},\tau^{n2},\tau^{d},\lambda))EV_0^i(\tau^{n1},\tau^{n2},\tau^{d},\lambda) \tag{3.2}$$

where, the weights are:

$$g(EI_0^i) = (EI_0^i)^{1-\varepsilon}$$

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 3.5: Optimal tax rates and welfare effects under alternative values of inequality aversion

Inequality Aversion	Optimal tax rates					$\Delta EV(\%)$			
$1-\varepsilon$	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR	All	Sec	HS	College
0	21.76	18.41	-21.75	28	19	0.20	-1.33	1.36	4.56
-2	15.67	4.56	0	36	28	0.04	-0.68	0.62	1.97
-4	4.40	9.82	21.05	35	26	0.03	0.01	0.05	0.10
-20	0	7.66	22.42	36	28	-0.02	0.08	-0.08	-0.32

Table 3.5 shows a set of results that help to reconcile the discrepancies between the outcome of the utilitarian normative analysis and actual tax practice. First, as government inequality aversion increases, the optimal tax system results in progressively lower efficiency and higher equity. 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. 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 fairness 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. Interestingly, these results contradict the traditional view that commodity taxes tend to be regressive and suggest that differentiated rates contribute to redistribution jointly with the progressivity of labor income taxes, thus justifying their pervasiveness in practice.

3.5.1 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 3.6 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 3.6: Optimal tax rates and welfare effects under alternative values of inequality aversion

Inequality Aversion	Optimal tax rates					$\Delta EV(\%)$			
$1-\varepsilon$	τ^{n1}	τ^{n2}	τ^{d}	MTR	ATR	All	Sec	HS	College
Homogeneous pref.									
0	0	0	-9.8	41	33	2.10	1.74	2.56	2.36
Heterogeneous pref.									
0	15.7	24.5	-19.08	30	22	0.42	-1.05	1.54	4.54
-2	21.44	11.53	0	32	24	-0.40	-1.33	0.31	2.19
-4	5.23	13.55	22.04	33	25	-0.16	-0.26	-0.08	0.10
-20	0	0	21.75	40	32	0.26	0.56	0.04	-0.59

The first two rows of Table 3.6 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. Non-durable necessities are now taxed at a lower rate than luxuries. This is explained by noting that in this case the government can maximize welfare of high skill group more efficiently through the reduction in progressivity rather than through lower tax rates on luxuries.

Looking at the results obtained under heterogeneous preferences and generalized social welfare criterion (rows 3 to 5), two main differences appear with respect to the case in which the level of labor income tax is used as revenue neutrality instrument. First, 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 zero 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 government only way 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 together with progressive labor income tax.

The second difference with respect to the case of income tax level as revenue neutrality instrument is that the relationship between efficiency and equity is now U-shaped rather than monotonic. Efficiency is lower for intermediate degrees of government inequality aversion, while it is higher at the extremes. However, the tax system obtained under extremely high inequality aversion still implies an efficiency loss with respect to the utilitarian scenario.

3.6 Conclusions

In this Chapter, I exploit the estimated life cycle model of Chapter 2 to conduct a quantitative normative analysis of direct and indirect taxation in a dynamic stochastic framework. I conduct a series of computational experiments to characterize the optimal combination of consumption and labor income taxes under a utilitarian approach. This analysis highlights the importance of taking into account durable goods and intertemporal preference heterogeneity for conducting optimal taxation analysis in a realistic setting. The pre-commitment characterizing the durable investment decision in an environment with uncertainty justifies an optimal subsidy on durable purchases. While, heterogeneity in intertemporal preferences for consumption and saving drives the role of differentiated consumption tax rates as an optimal taxation instrument, even in presence of non-linear labor income taxes, by changing the ranking of utilitarian social welfare weights along the income distribution.

To overcome the limitations of the utilitarian approach to social welfare in a context of multidimensional preference heterogeneity, the analysis is generalized to a more flexible social welfare criterion that allows the government to redistribute on the basis of society's fairness concerns rather than on people's different preferences for effort versus leisure and consumption enjoyment. This framework bridges the gap between optimal taxation results and actual tax practice and shows that the model can rationalize the tax systems implemented in reality under high degrees of government inequality aversion. Quantitative simulations also suggest that differentiated consumption taxes - with substantially higher rates on durables - can play a crucial role as redistributive tools jointly with - and on top of - progressive labor income taxes.

The debate on how the government should tax different consumption goods and labor income over the life cycle is far from resolved. The analysis conducted in this paper has highlighted the importance of several elements including preference heterogeneity and durable goods. However, other dimension are left unexplored and represent promising avenues for future research. In particular, the dynamic model could be extended to allow for a home production function that implies full non separability in preferences between consumption and labor, as proposed by Kleven (2004) in a static setting. Modelling the complementarity and substitutability between multiple consumption categories and family labor supply in a context of preference heterogeneity might lead to different optimal taxation results and inform policy debate.

Conclusions

This thesis investigates the impact of direct and indirect taxation on households' consumption, saving and labor supply decisions over the life cycle and how the policy maker should optimally design taxes on different commodities and labor income.

In Chapter 1, I focus on indirect taxation. I set up and estimate a dynamic life-cycle model of household consumption and savings decisions that allows to account separately for durable and non-durable consumption in a context of indirect taxation, income uncertainty and borrowing constraints. I use this model to investigate the effects of hypothetical reforms of VAT rates on households' consumption-savings choices over the life cycle, on the allocation of labour earnings between expenditure in durable goods and non-durable goods and on redistribution across different kinds of households. I find that there exist revenue neutral reforms that increase overall welfare with respect to the current scenario by changing VAT rates towards uniformity, but these reforms redistribute in favour of the wealthier at the expense of the poorer. However, by complementing changes in VAT rates towards uniformity with benefits, it is possible to design revenue neutral and overall welfare enhancing reforms that redistribute in favour of the less wealthy.

In Chapters 2 and 3, I investigate direct and indirect taxation jointly. Building on the framework developed in Chapter 1, in Chapter 2 I develop a rich structural life-cycle model of household durable and non-durable consumption, saving and labor supply decisions and estimate it using the method of simulated moments. The model combines many realistic elements including preference heterogeneity across education groups, uncertainty about the evolution of earnings and family dynamics, multiple consumption goods, partially irreversible durables, credit constraints and endogenous participation decision of the second earner. I show that the interaction among these features is crucial in matching the life-cycle patterns observed in the micro data and, in particular, in reproducing the empirical distributions of consumption, savings and earnings of both spouses.

I use the estimated model to simulate life-cycle Marshallian elasticities along multiple dimensions. I show that the estimated model encloses several mechanisms of interaction between direct and indirect taxation and household life cycle choices that have not been considered together in previous literature.

First, taxes create relevant incentives and disincentives on labour supply of second earner suggesting the presence of strong family insurance and income effect mechanisms in the household. Second, different consumption goods are differently affected by taxes depending on their degree of necessity and durability. Third, tax changes can shift households' portfolio composition in terms of relative importance of assets versus durables. Lastly, different long run responses to tax reform can result from different credit constraints as well as from heterogeneous consumption and saving preferences of the households.

In Chapter 3, exploiting the estimated model of Chapter 2, I conduct a series of computational experiments to characterize the optimal combination of consumption and labor income taxes under a utilitarian approach. This analysis highlights the importance of taking into account durable goods and intertemporal preference heterogeneity for conducting optimal taxation analysis in a realistic setting. The pre-commitment characterizing the durable investment decision in an environment with uncertainty justifies an optimal subsidy on durable purchases. While, heterogeneity in intertemporal preferences for consumption and saving drives the role of differentiated consumption tax rates as an optimal taxation instrument, even in presence of non-linear labor income taxes, by changing the ranking of utilitarian social welfare weights along the income distribution.

To overcome the limitations of the utilitarian approach to social welfare in a context of multidimensional preference heterogeneity, the analysis is generalized to a more flexible social welfare criterion that allows the government to redistribute on the basis of society's fairness concerns rather than on people's different preferences for effort versus leisure and consumption enjoyment. This framework bridges the gap between optimal taxation results and actual tax practice and shows that the model can rationalize the tax systems implemented in reality under high degrees of government inequality aversion. Quantitative simulations also suggest that differentiated consumption taxes - with substantially higher rates on durables - can play a crucial role as redistributive tools jointly with progressive labor income taxes.

The debate on how the government should tax different consumption goods and labor income over the life cycle is far from resolved. The analysis conducted in this paper has highlighted the importance of several elements including preference heterogeneity and durable goods. However, other dimensions are left unexplored and represent promising avenues for future research. My dynamic model could be extended to allow for a home production function that implies full non separability in preferences between consumption and labor, as proposed by Kleven (2004) in a static setting. Modelling the complementarity/substitutability between multiple consumption categories and family labor supply in a context of preference heterogeneity might lead to different results on the optimal taxation of different commodities and labor income.

Another promising direction consists in investigating how optimal direct and indirect taxes are affected by capital income taxes. Building on my framework, I could develop a life cycle model featuring three kinds of assets characterized by different degrees of liquidity: completely liquid risk free government bonds, partially illiquid consumer durables, housing stock implying high fixed costs of adjustment. Studying how taxes on these different categories of assets interact with taxes on different consumption goods and labor income - and how households' respond to them - would deepen our understanding of the current tax systems and inform the policy debate.

Moreover, the rich structure of the estimated model described in Chapter 2 lends itself to other broader applications in Household Finance. Expanding on Kaplan (2012), the model could be exploited to investigate consumption inequality over the life-cycle in a realistic setting in which households can allocate their expenditure among different categories of consumption goods and can self insure against shocks not only through the standard mechanism of saving in liquid assets, but also by relying on their durable stock and by adjusting the labor supply decision of the second earner.

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Appendix A

Almost Ideal Demand System

A.1 Theory

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:

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

Provided that $\sum_i \alpha_i = 0$ and $\sum_j \gamma^*_{k,j} = \sum_k \gamma^*_{k,j} = \sum_j \beta_j = 0$, equation (A.1) 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:

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

A.2 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 A.1: 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

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix 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 size of the panel component has increased gradually over time and is now roughly 57% of the overall sample.

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 drop out 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.

Table B.1 shows in some more detail the structure and size 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 B.1 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 B.2 shows that panel and non panel households are similar in terms of demographic and socio-economic characteristics, thus suggesting that non-random attrition is not a major problem in the SHIW data.

Table B.1: 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 B.2: 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.1.1 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 homeowners 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 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.1.2 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 B.3: 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

$N = 19,957$

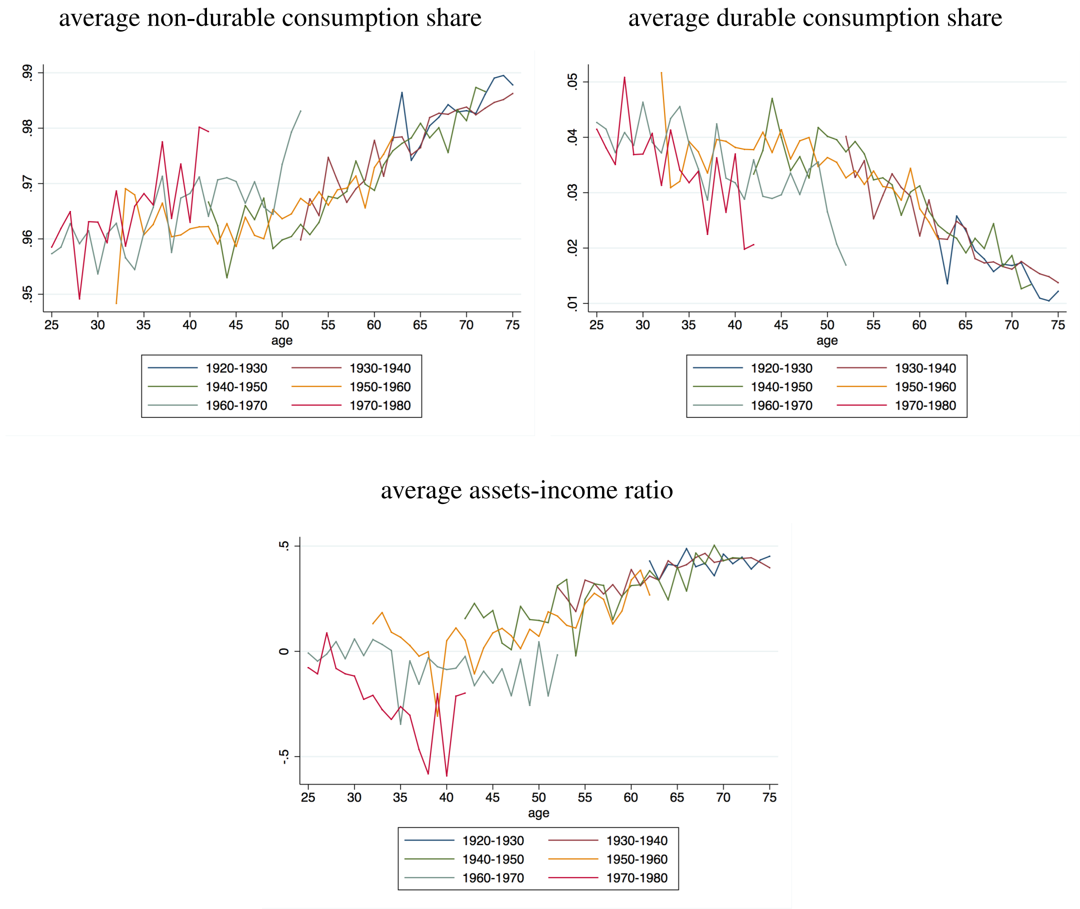
Table B.4: Net sellers

	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

$N = 462$

B.1.3 Check for cohort effects

Figure B.1: Cohort analysis in SHIW (1987-2014)



B.2 HBS dataset

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 Equivalence scale

I use the non-durable consumption equivalence scale provided by ISTAT.

Table B.5: non-durable consumption equivalence scale, ISTAT

members in hh	1	2	3	4	5	6	7 or more
coefficient	0.60	1	1.33	1.63	1.90	2.16	2.40

Appendix C

Computational details

Solution. The household maximisation problem described in Section 2.3 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[1].

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.

[1] The solution is computed in Fortran90 using parallelization on multiple nodes.

Appendix D

Identification

D.1 Identification of 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[1]

$$var(\tilde{y}_{i,t}) = var(z_{i,t}) + var(\varepsilon_{i,t}) = \rho^{2t}\sigma^2_{z0} + (1-\rho^{2t})\frac{\sigma^2_u}{1-\rho^2} + \sigma^2_\varepsilon \tag{D.1}$$

$$cov(\tilde{y}_{i,t}, \tilde{y}_{i,t-j}) = cov(z_{i,t}, z_{i,t-j}) = \rho^j var(z_{i,t-j}) \qquad if \qquad j > 0 \tag{D.2}$$

The predicted residuals from the estimation of the deterministic 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:

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

[1]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.

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

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

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

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

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

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

Full identification is achieved with two lags of the current age $(t, t-2, t-4)$, therefore the same household must be interviewed for at least three subsequent waves of SHIW in order to be 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 $\psi = \{\rho, \sigma_u^2, \sigma_\varepsilon^2, \sigma_{z_0}^2\}$ 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:

$$\hat{\psi} = \arg\min_{\psi}[\mathbf{m} - \mathbf{f}(\psi)]'\mathbf{W}[\mathbf{m} - \mathbf{f}(\psi)] \tag{D.3}$$

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.

D.2 Identification of durables dynamics parameters

Starting from durables law of motion: $d_t = (1-\delta)d_{t-1} + x_t$.

- 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 sub sample 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:

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

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

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

once δ has been identified, also π is identified in the sub sample 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 sub samples of net sellers (N_s) and net buyers (N_b)

Appendix E

Estimation

E.1 Estimates and elasticities for restricted version of the model

Table E.1: Estimated preference parameters

	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)		
	Sec	HS	College	
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 E.2: 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 durables
	(.0043)	

Table E.3: 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

Appendix F

Model Fit

F.1 Additional model fit

Table F.1: 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

F.2 Additional validation checks

As an additional validation check, Figure F.1 compares the life cycle profiles of the empirical and simulated standard deviations of net earnings for men and women of different education levels. The model performs well in fitting these moments.

F.3 Homogeneous versus heterogeneous consumption preferences

Figure F.2 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 F.1: Std. dev. of net wages by education, data vs model

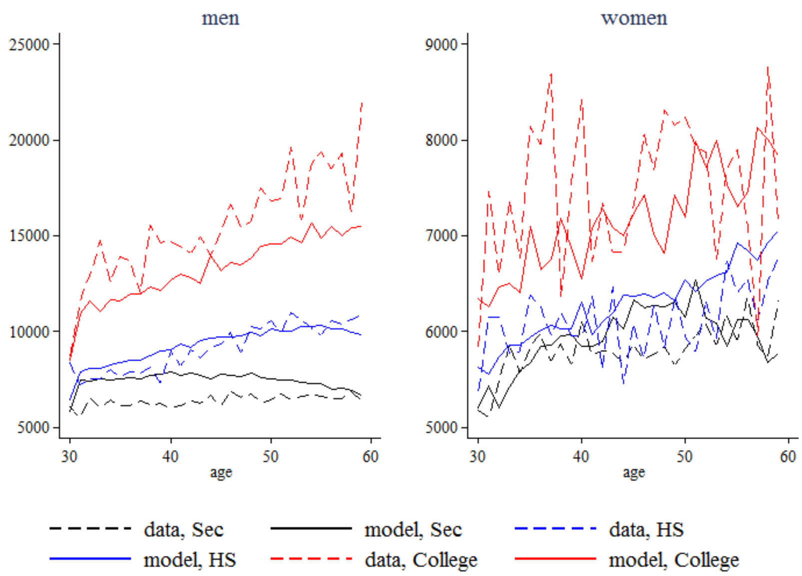


Figure F.2: Mean life cycle profiles of assets, data vs model