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THREE ESSAYS IN HOUSEHOLD FINANCE

Mesquida Yannis

UNIL | Université de Lausanne

FACULTÉ DES HAUTES ÉTUDES COMMERCIALES

DÉPARTEMENT D'ÉCONOMIE

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THÈSE DE DOCTORAT

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pour l'obtention du grade de
Docteur ès Sciences Économiques,
mention « Économie politique »

par

Yannis MESQUIDA

Directeur de thèse
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Jury

Prof. Rafael Lalive, Président
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All revisions that I or committee members
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have been addressed to my entire satisfaction.

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Joint Lifetime Financial, Work and Health Decisions*

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Abstract

Lifetime financial-, work- and health-related decisions made by agents are intertwined with one another, thereby requiring joint modeling. This methodological paper numerically solves, simulates, and structurally estimates a dynamic life cycle model of allocations (consumption/savings, leisure/work and health expenditures), statuses (health, financial and pension wealth) and welfare, allowing for (partially) adjustable exposure to morbidity and mortality risks. Despite its generality, our results show that households' lifetime decisions are challenging to match, even after accounting for the complex interactions between them. Whereas financial savings and pension claims are both well matched, our model overestimates health levels, and consequently life expectancy. Moreover, health is maintained through more spending, and less leisure than currently observed. As a consequence, observed post-retirement income is longer than expected, and explains the divergence in consumption after 65. Relaxing assumptions on full insurance, and pension regimes only partially alleviates these discrepancies.
Keywords: Defined Benefits and Contributions Plans, Consumption, Leisure, Health Expenditures, Mortality and Morbidity Risks. Optimal Savings.

JEL Classification: E21, I12, J26, J32.

1 Introduction

1.1 Motivation and outline

Agents are required to make complex financial, work-, and health-related decisions throughout their lifetime. A major source of difficulty stems from the fact that these decisions are intertwined with one another (Hugonnier et al., 2013). Indeed, given current age, health status, financial wealth and pension entitlement, the agent must decide how much to save, and how much to spend on current non-medical consumption, on health expenditures, and how much leisure activities to undertake. Whereas consumption and leisure yield immediate utility, both the latter and medical expenditures have positive effects on future health which will in turn determine future exposure to sickness and death risks. Moreover, current leisure choices affect expected post-retirement income. These pension claims, combined with exposure to future morbidity and mortality risks, condition the need to set aside precautionary financial reserves against anticipated health expenses and longevity risks. Assuming these effects are fully understood, such lifetime allocations would need to account for the agent's attitudes towards risks (i.e. financial, death and sickness), towards time (i.e. inter-temporal substitution in consumption and/or leisure), as well as towards a-temporal substitution (i.e. between current consumption and leisure to maintain utility, between health expenditures and leisure to maintain health).

These decisions are further complicated by the time variation in investment opportunities. On the one hand, the passage of time worsens the consequences of not investing in one's own health; the aging process further amplifies these consequences. On the other hand, postponing health care can be optimal if one expects to benefit from future medical advances, or if currently uninsured, and covered by Medicare later on (Pelgrin and St-Amour, 2016). Moreover, labor wages follow their own life cycles, peaking around mid-life and falling thereafter. Institutional features of retirement plans also contribute to complexity by imposing pension wealth illiquidity before retirement, and by exogenously setting exposure to financial risks.

Understanding how these lifetime decisions unfold is nonetheless essential if one tries to replicate observed saving patterns in *any* asset. Moreover, allowing some degree of substitution and/or complementarity between human, financial and pension wealth levels and instruments is paramount when jointly modeling financial and health choices. For example, a strategy of living fast (i.e. high current felicity and low future financial and pension wealth) and dying young (low future health and high expected mortality) could be optimally selected and implemented. Complementarity between consumption and leisure would then justify increasing both in order to reduce financial and pension wealth, whereas substitutability between leisure and health expenditures would warrant decreasing the latter so as to reduce future health and expected longevity. The higher exposure to future sickness risks could be justified if contributing to the shortened longevity and/or if Medicare coverage reduces expected marginal illness costs.

Comparatively to the literature and more precisely to Pelgrin and St-Amour (2016), we fully endogenize the social security and private pension plan schemes. Usually, retirement income is simplified as an exogenous process calibrated on data. Whereas public and private pension asset managements remain independent from one another, the computational challenge lies in the fact that both pension payments depend on the life cycle of labor supply decisions made by households. The contribution is also reflected in the consideration of endogenous morbidity and mortality risks on top of the joint life cycle households decisions.

The objective of this methodologically oriented paper is to propose a step in that direction. Towards that aim, we build upon a dynamic model that has all the features previously discussed. More precisely, allowing for (partially) endogenous exposure to morbidity and mortality risks, we study the joint life cycle determination of work, financial and health-related choices, fully accounting for the dynamics in financial, pension, and human health capitals. Importantly, our modeling framework admits a wide range of optimal dynamic policies. For instance, a healthy-and-thrifty policy obtains since the former induces a low discount rate which is conducive to high savings in pension and financial assets, as well as high investing in future health. Conversely, a live-fast and die-young policy is optimal for unhealthy agents facing high mortality risks, and therefore high discount rates, prompting them to favor contemporaneous, over future utility via high current consumption and leisure. Endogenous health ensures that the positioning between these alternatives is determined endogenously.

This model is numerically solved, simulated, and estimated structurally. This allows us to perform a twofold analysis. First, we investigate the effects of current state variables (financial, and pension wealth, as well as health status) on optimal allocations (work/leisure, consumption and health expenditures). Second, we simulate the model to compute the optimal state, and life-cycle allocations.

Our main findings with respect to estimated parameters, marginal effects of state variables, and life cycles may be summarized as follows. Regarding the health production function, our estimated parameters indicate that the null hypotheses of health-independent morbidity and mortality risks, and exogenously set health levels are both rejected, such that agents' decisions can effectively impact how healthy they are and how much they are exposed to sickness and death risks. We also find that the so-called *Long Reach of Childhood* (Smith, 2009) is important; past health levels have strong effects on the productivity of current health investments. Third, we find that aging entails larger costs of inaction; both deterministic and stochastic health depreciation rates increase sharply with age. Fourth, our findings with respect to preferences are consistent with relative complementarity between consumption and leisure, as well as a low degree of inter-temporal substitution. We also identify a utilitarian cost of death that is attenuated by a positive motivation for bequest. The latter justifies keeping high financial wealth balances at old age to be left to heirs in the case of death.[1]

Complementarity entails that consumption, and leisure display similar positive wealth gradients, and negative health gradients. Healthier agents face lower death and sickness risks and save, and work more to accommodate a longer life horizon. Optimal health spending however is not monotonous. Sufficiently healthy agents cut down spending when health and wealth improve, preferring to substitute in favor of more leisure in the latter case. Otherwise, the health and wealth gradients are positive, and unhealthy agents cut down health expenses, and substitute more leisure when health further deteriorates. We also identify substitutability between financial and pension wealth with the latter having minimal independent effect once the former is accounted for.

Despite matching pension and financial wealth very well, our model does not succeed in replicating health levels and thus agents face a shorter horizon than the one estimated (79 vs 84 years). In addition, under full health insurance, and age-increasing wages, health maintenance is achieved by spending more on health investment, and using less leisure than observed levels. A direct consequence of the gap of leisure after mid-life is that elders' observed total (i.e. retirement plus labor) income is smaller than the

[1] See also De Nardi et al. (2015); Love et al. (2009) for discussion and empirical evidence on the role of bequests in explaining insufficient post-retirement dissavings.

estimated one, causing a drop in post-retirement consumption, while the latter increases when estimated. Put differently, observed behavior is only partly recovered, doing well with respect to financial decisions and less so with respect to health-related ones.

We revisit some of the model's key assumption to gauge whether or not they might improve our findings. First, allowing for a defined benefit plan does yield an optimal increase in mid-life leisure, however it also predicts healthier and longer-lived agents, contrary to the data. Second, lowering the return on pension assets forces agents to cut down on leisure, and increase health spending. The fit further deteriorates as more financial wealth is required to offset the fall in pension wealth. Third, removing health insurance for younger agents leads to pre-Medicare health spending cuts, that are only partially offset by more leisure; health status and longevity consequently deteriorate, as required. Unfortunately, so does financial wealth as a shorter life horizon no longer justifies accumulating assets. Finally, we allow for potential myopia of agents by replacing the predicted health-dependent with the observed age-dependent death intensity. Again this modification partially explains the differences (e.g. worse health, higher mortality, lower health investment), yet fails to account for all the gaps between the theory and the data. We conclude that none of these assumptions is single-handedly responsible for the discrepancies.

1.2 Institutional background

Work choices are strongly related to the life cycle variation in health-related risks and decisions. For example, people's probabilities of being sick and dying increase, the result of the aging process which depreciates health capital over time, thereby affecting willingness and capacity to work in old age. Retirement is further associated with a sharp drop in income. Using data from the Bureau of Labor Statistics, we notice that retired households earn on average a third less than working ones. Therefore, retirees dissave by using financial and pension wealth, to optimally adapt to their new conditions. However, nowadays, this process begins later than before, mainly because of the more challenging job market, higher life expectancy and less profitable retirement plans. Put differently, the retirement is postponed.

Since the 2000s, the way employees contribute to their retirement plan also significantly changed. We observe a shift from defined benefits to defined contributions retirement plans. In 1998, 50% of the retirement plan were DC-based, while in 2015, they represented[2] 95%. This trend has some implications for households. First, they are more exposed to market risks, since their retirement funds directly depend on the financial market performance. As an example, during the crisis 2007-2008, the Dow Jones Industrial Average dropped by 53%. Second, pension income are smaller in the DC case. Munnell et al. (2015) showed that the annual rate of return of DC plans was 0.7 point lower than for DB.

In addition to pension capital, financial wealth is the second highest household asset holding, after real estate, with around 20% of US households' wealth being invested in financial securities. The particularity of the US households financial wealth is the fact that the life cycle profile is hump-shaped. Agents accumulate money until the retirement period, and then start to spend it. This pattern is observed in the Survey of Consumer (SCF) 2010, where the average US households financial wealth increases until 60 years old where it tops at around $38'000, and then decreases to around $20'000 at 80 years old.

The background analysis shows that the US economic landscape has changed dramatically in recent years. These changes are all linked and have intertwined consequences, today and in the future. This is where our analysis sheds light on the complexity of this ecosystem.

1.3 Relevant literature

Relatively few researchers study the joint dynamic determination of health, labor and financial decisions. French and Jones (2011) build a dynamic programming model that is also structurally estimated using SME in order to find whether employer-provided health insurance, Medicare, and Social Security have any impact on the retirement decision. Their framework includes a complete model of leisure, wealth, retirement, and bequest motive. However, the pension regime is assumed to be a DB plan for every agent. Importantly, contrary to us, health is modeled as an exogenous stochastic binary variable (bad or good health) and health expenditures are also exogenous.

The paper by French (2005) is also based on a dynamic optimization model that is estimated using SME on life cycle moments. Its aim is to evaluate the role of social

[2] Source: Willis Towers Watson.

security and pension taxation as potential explanation for early retirement observed in the data. As for French and Jones (2011), binary health is exogenous and stochastic. Earnings are also stochastic and social security, pension entitlement and spousal income are taken into account. French (2005) focuses on dynamic decisions regarding consumption, hours of work and social security application. Workers are able to reenter the labor force even if they retired early. However, the DC plan is not investigated and neither are endogenous health investment and out-of-pocket expenditures decisions which we address in our setup.

Fonseca et al. (2013) also estimate a life cycle model with endogenous health, asset accumulation and retirement in order to evaluate why health spending and longevity increased in the US from 1965 to 2005. As in French and Jones (2011), early retirement is possible but is irreversible. Earnings are stochastic and follow an exogenous Gaussian process. The model also incorporates health status, health shocks (sickness and death), health insurance, social security, government transfers, spousal earnings, and pension income modeled as a DB plan, with DC retirement abstracted from. The dynamic decisions concern the choice of consumption and health expenditures but abstracts from labor/leisure choices.

Galama et al. (2013) construct a continuous time and structural model of health, wealth accumulation, and retirement decisions using the human capital framework developed by Grossman (1972), in order to analyze the effect of health on the decision to retire. Interestingly, the retirement decision is completely endogenous. They model DB entitlement, however they do not take into account social security and DC pension.

The focus of Scholz and Seshadri (2013) is similar to French and Jones (2011). The authors investigate the effect of health insurance on retirement decision. However, the model is quite different in that it relies on a health production process with endogenous health expenditures only. Second, they distinguish between working, married, and retired households. Third, they include both mortality and morbidity risks, as well as uncertainty on the earnings process. However, compared to our model, the pension plan is unique and set to DB.

Finally, Samwick and Skinner (2004) rely on an empirical simulation based model with endogenous earnings process and stochastic rate of returns in order to assess whether DC agents are better off than DB ones. They analyze cross sectional data and find that the pension plan type is important in the retirement process. As with us, they argue that it is more important to look at the entire life cycle, and not only the post-retirement period, and claim that any retirement plan difference can be offset by earnings and contribution adjustments throughout the life cycle. However, they do not include labor/leisure choices, and abstract from endogenous health-related risks. The welfare analysis is focused on wealth without evaluating the value function.

The rest of this paper is organized as follows. Section 2 outlines the main features of the theoretical model, with numerical solution methods discussed in Section 3. The main results are outlined in Section 4, with discussion in Section 5.

2 Model

This section outlines the life cycle allocations problem of an agent facing partially diversifiable mortality and morbidity risks. These decisions concern consumption (medical and non-medical) and savings, as well as leisure and work in a setting where health insurance and pension plan characteristics are taken as exogenous. Both health expenditures and leisure improve the depreciable health status which in turn lowers the likelihood of death and sickness. However, leisure entails both present and future costs in foregone current income, and lower future retirement benefits. We first present the dynamics of the two health-related risks. Then, following a discussion of pre- and post-retirement income processes, we describe the budget constraint and agent's preferences.

2.1 Health shocks and status dynamics

In the spirit of Pelgrin and St-Amour (2016), and Hugonnier et al. (2013) let $t = 0, 1, \ldots, T^M \leq T$ denote the age of an agent, where T^M is the age of death, and T is the maximal longevity. We let $\epsilon_t^k \in \{0, 1\}$ denote mortality ($k = m$) and morbidity ($k = s$) shocks following generalized Bernoulli processes with:

$$\Pr[\epsilon_{t+1}^k = 0 \mid H_t] = \exp[-\lambda^k(H_t)] \tag{1}$$

where $\lambda^k : \mathbb{R}_+ \to \mathbb{R}_{++}$ is a decreasing and convex intensity function of the health level H_t. Hence, healthier agents can partially lower their exposure to morbidity and mortality risks subject to diminishing returns, and incompressible lower bounds. The age of death is the first positive occurrence of the death shock:

$$T^M = \min\left\{t : \epsilon_t^m = 1\right\}. \tag{2}$$

Relying on a long tradition in the demand-for-health literature, health is modeled as a depreciable human capital that can be adjusted through health expenditures. We follow recent advances that append healthy leisure, morbidity shocks and time-varying depreciation and productivity to the law of motion:

$$H_{t+1} = \left(1 - \delta_t - \phi_t \epsilon_{t+1}^s\right) H_t + A_t I^g(H_t, I_t, \ell_t). \tag{3}$$

Denoting $\mathbb{I}$ the unit vector, we let $I^g : \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{I} \rightarrow \mathbb{R}_+$, define the increasing and concave gross investment function of health status, expenditures I_t, and leisure ℓ_t. Note that this framework only allows for beneficial effects of leisure on health, i.e. we abstract from detrimental "couch potatoes" habits. We partially account for this limitation through diminishing returns to leisure in the gross investment function $I^g(H, I, \ell)$. The capital depreciates at age-dependent deterministic rate δ_t which is augmented by ϕ_t upon occurrence of sickness. Time-varying depreciation and productivity rates are obtained by letting $\hat{d}_t = g^d \geq 0$ for $d \in \{\delta, \phi, A\}$. This assumption is convenient to ensure that both health maintenance, and sickness become increasingly costly as one ages, although this effect is somewhat mitigated by access to better medical technology in A_t.

2.2 Retirement plans and income processes

2.2.1 Retirement plans

We first define $T^R = 65$ as the age at which both public and private retirement benefits can be drawn (henceforth the retirement age). For tractability, that age is taken as given and cannot be chosen by the agent. In order to account for the growing trend in elders' participation in the labor market, we do not impose complete and irreversible retirement from work activities after T^R, that is we allow for work $(1 - \ell_t) \in \mathbb{I}, \forall t \in [16, T^M]$. It follows that pre-retirement income is composed of labor income only, whereas post-retirement income is the sum of labor income, and retirement benefits.[3]

[3] Note that this formulation does not exclude corner solutions in which the agent optimally selects not to work after retirement age, i.e. $\ell_t = 1, t \geq T^R$.

We consider two private retirement plans, DC and DB, and one public plan (Social Security). Both private plans have in common that the contributions are calculated as shares of the cumulated labor income. For tractability, we assume that these shares are paid into the retirement fund only up to retirement age. In the DB fund, the cost of those contributions are paid entirely by the employer, whereas the cost is shared between employer and employee in the DC case. While the retirement benefit is non-stochastic in the DB case, it depends on the cumulated portfolio return involving risky assets for the DC plan. Since the majority of US workers with pension plans are under defined contributions schemes,[4] DC plans will be our main assumption, although we will evaluate the effect of DB plans in our policy analysis in Section 4.4.1. Finally, Social Security (also known as Primary Insurance Amount, or PIA) is qualitatively similar to the DB plan, with non-stochastic returns, although involving a more complex entitlement formula detailed in Appendix A.

2.2.2 Income process

Let $\mathbb{1}_t^R = \mathbb{1}_{t \geq T^R}$ denote the post-retirement age indicator let $r \in \{DC, DB\}$ denote the private retirement plan, and Y_t, Y_t^r respectively denote the income, and private pension income, with w_t the after-tax wage rate. The income process is characterized by:

$$Y_t = \left[1 - \left(1 - \mathbb{1}_t^R\right) \tau_w^r\right] w_t(1 - \ell_t) + \mathbb{1}_t^R \left(PIA_t + Y_t^r\right) \tag{4}$$

$$Y_t^r = \alpha^r W_t^r \tag{5}$$

$$W_{t+1}^r = \left[W_t^r + \left(1 - \mathbb{1}_t^R\right) X_t^r\right] R_{t+1}^r \tag{6}$$

$$X_t^r = \min\left\{\left(\tau_w^r + \tau_f^r\right) w_t(1 - \ell_t), X_{\max}^r\right\}. \tag{7}$$

The specific values of the plan-specific parameters and variables are outlined in Table 1.

Employees can thus work at all ages in (4), but contribute a share τ_w^r to pension plans costs only up to retirement age, where that contribution is $\tau_w^{DC} > 0$ under DC, and is zero under DB. After retirement, they receive Social Security PIA_t, and the private pension income Y_t^r they are entitled to, in addition to any labor income $w_t(1 - \ell_t)$ they optimally

[4]Pension coverage type has evolved from DB to DC plans (Munnell and Perun, 2006; Broadbent et al., 2006). Indeed, Munnell (2013) reports that over the 1983-2013 period, DB shares fell from 62% to 17% of workers with pension coverage, whereas DC shares increased from 12% to 71% over the same period.

Table 1: Pension plan-specific rules

plan r	DC (benchmark)	DB
τ_w^r	τ_w^{DC}	0
τ_f^r	τ_f^{DC}	τ_f^{DB}
α^r	α^{DC}	1
$X_{\max}^r$	$X_{\max}^{DC}$	∞
R_t^r	$R^f + \omega(R_t^e - R_t^f)$	1

select. The pension income (5) is an annuity α^r applied on cumulated pension wealth W_t^r, where the latter is calculated in (6) as the contributions X_t^r that are cumulated only up to retirement age. The contributions represent the sum of the worker's and employer's shares $\tau_w^r + \tau_f^r$ of labor income in (7), up to maximal amount $X_{\max}^r$, where the latter is bounded under DC and unbounded under DB. Finally, the portfolio return on pension balances R_{t+1}^r is obtained under the DC plan from investing a share $\omega \in (0, 1)$ in the risky asset with return R_{t+1}^e, and the balance in the risk-free asset with return R_{t+1}^f, whereas the DB plan pays no net return.

Regarding public pension, the Primary Insurance Amount PIA_t is the Social Security income computed using the (annualized) $AIME_t$, where the Average Indexed Monthly Earnings defined as:

$$PIA_t = PIA(AIME_t) \tag{8}$$

$$AIME_t(\{\ell_s\}_{s=16}^t) = \frac{1}{t}\sum_{s=16}^{t} w_s(1-\ell_s) \tag{9}$$

where the exact PIA formula follows Social Security rules and is given in (31) in Appendix A.

To our knowledge, no paper models in such a detailed way the life cycle income process through the life cycle. This is what mainly distinguishes it from Pelgrin and St-Amour (2016). However, we are fully aware of the limitation brought by the assumption of exogenous timing to claim for retirement benefits (i.e fixed at $T^R = 65$ years old). Therefore there is still space for improvement of the fit but at the expense of an extensive computational time.

2.3 Budget constraint

Following Pelgrin and St-Amour (2016), agents can insure against health expenditures through a contract defined by (i) a deductible level $D_t > 0$, (ii) a co-payment rate $\psi \in (0, 1)$ applicable on health expenditures $P_t^I I_t$ above deductible, and (iii) an insurance premium Π_t. The latter is equal to the market premium for young insured agents, and to the Medicare-subsidized premium for elders.

Let $\mathbb{1}^D = \mathbb{1}_{P_t^I I_t \geq D_t}$ denote the deductible reached indicator. The out-of-pocket medical expenditures $OOP_t(I_t)$, and health insurance premia are defined as follows:

$$OOP_t(I_t) = \left(1 - \mathbb{1}^D\right) P_t^I I_t + \mathbb{1}^D \left[D_t + \psi \left(P_t^I I_t - D_t\right)\right] \tag{10}$$

$$\Pi_t = (1 - \mathbb{1}_t^R \pi)\Pi \tag{11}$$

where medical prices and deductibles grow at rate $\hat{x}_t = g^x$, for $x = P, D$ to parallel the growth in medical productivity. The insurance contract in (10) is standard in that the insured agent covers all medical expenditures $P^I I$ up to deductible D and pays the latter plus a share ψ on expenses above D once the deductible is reached. The premia (11) has agents cover the market premia Π until 65, and the Medicare-subsidized premia $(1 - \pi)\Pi$ afterwards.

Given these elements, the law of motion for financial wealth W_t is obtained as:

$$W_{t+1} = \left[W_t + Y_t - C_t - OOP_t - \Pi_t\right] R^f \tag{12}$$

where C_t is non-medical consumption, pre- and post-retirement income Y_t is given in (4), out-of-pocket health expenditures OOP_t are in (10), and health insurance premia Π_t is given in (11). The budget constraint is expressed as a standard financial wealth process. At period t, agents hold financial wealth equal to W_t, receive an income Y_t. They make the choice to consume C_t, spend OOP_t as health expenses and pay their health insurance Π_t . The remaining wealth is invested at the risk free rate R^f.

2.4 Preferences

As shown in Pelgrin and St-Amour (2016), and Hugonnier et al. (2013), the agent's dynamic problem with time-separable VNM preferences, stochastic horizon T^M, and constant discounting $\beta \in (0,1)$ can be rewritten as a deterministic horizon program with health-dependent, endogenous discounting:

$$\beta^m(H_t) = \beta \exp[-\lambda^m(H_t)] < \beta. \tag{13}$$

Moreover, let the instantaneous utility be defined as:

$$\begin{aligned} \mathcal{U}_t &= U(C_t, \ell_t) + [\beta - \beta^m(H_t)]U^m(W_t, Y_t^r), \\ &= \mathcal{U}(C_t, \ell_t, W_t, H_t, Y_t^r) \end{aligned} \tag{14}$$

where $U : \mathbb{R}_{++} \times \mathbb{I} \to \mathbb{R}_+$ and $U^m : \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_-$ are monotone increasing, and concave instantaneous, and bequest utility functions that satisfy $\mathcal{U} : \mathbb{R}_{++} \times \mathbb{I} \times \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$. Since $\lambda^m(\cdot)$ is a decreasing function, the healthier agent thus behaves as a more patient individual in (13), and assigns a lower weight on the bequest utility in (14). Observe further that, since U^m is increasing and negative, the marginal utility $\mathcal{U}_x \geq 0, x = W, H, Y^r$, ensuring positive instantaneous value to bequeathed wealth and pension entitlement, as well as to health.

Taking current health H_t, wealth W_t, and pension income Y_t^r as given, the agent's dynamic programming problem is:

$$V_t^r = \max_{C_t, I_t, \ell_t} \mathcal{U}_t + \beta^m(H_t)\mathrm{E}\left[V_{t+1}^r \mid H_t\right] \tag{15}$$

where $V_t^r = V(W_t, H_t, Y_t^r) \geq 0$ is the value function, and the period utility $\mathcal{U}_t$ is given in (14). The optimization (15) is subject to (i) the Bernoulli distribution (1), (ii) the law of motion for health (3), (iii) the retirement income process (6), and (iv) the budget constraint (12).

The model admits a wide range of optimal life cycle strategies depending on the structural preference, technological, and distributional parameters. For instance, a healthy-and-thrifty policy obtains naturally as a high H induces a low discount rate $\lambda^m(H)$, and high patience $\beta^m(H)$ in (13), which is conducive to high savings in pension and financial assets, as well as high investing in future health. Conversely, a live-fast and die-young policy can be warranted for unhealthy agents with very high mortality risks, – and therefore high discount rates – and low $\beta^m(H)$, encouraging them to favor contemporaneous, over future utility via high current consumption and leisure. Importantly, because health is endogenous, the positioning between these various alternatives is determined endogenously. Our empirical strategy is therefore centered on structurally identifying the deep parameters through the data so as to match observed life cycle decisions.

3 Empirical Methods

This section describes the empirical strategy that we use to solve and estimate the model via a Simulated Moments Estimation (SME). Following the discussion about the functional forms, we outline the iterative and simulation procedures, and present the SME estimator. An overview of the data used in the estimation strategy closes the section.

3.1 Functional forms

We draw from Pelgrin and St-Amour (2016) and Hugonnier et al. (2013) in parameterizing the death and sickness intensity functions $\lambda_t^k(H_t)$, gross investment $I^g(H, I, \ell)$, and the instantaneous utility and bequest functions $U(C, \ell), U^m(W, Y^r)$ as follows:

$$\lambda^m(H) = \lambda_0^m + \lambda_1^m H^{-\xi^m}, \tag{16}$$

$$\lambda^s(H) = \lambda_2^s - \frac{\lambda_2^s - \lambda_0^s}{1 + \lambda_1^s H^{-\xi^s}}, \tag{17}$$

$$I^g(H, I, \ell) = I^{\eta_I} \ell^{\eta_\ell} H^{1-\eta_I-\eta_\ell}, \tag{18}$$

$$U(C, \ell) = \frac{1}{1-\varepsilon} \left[\mu_c C^{1-\gamma} + \mu_\ell \ell^{1-\gamma}\right]^{\frac{1-\varepsilon}{1-\gamma}}, \tag{19}$$

$$U^m(W, Y^r) = \frac{\mu_m \left(W + \delta^r Y^r\right)^{1-\gamma_m}}{1-\gamma_m} \tag{20}$$

Consistent with the model, the two intensities in (16), and (17) are decreasing and convex in health, and bounded below by λ_0^k, whereas λ_1^k determines the endogeneity of sickness and health shocks. The Cobb-Douglas specification for gross investment (18) allows for monotone increasing, concave effects of health, expenditures and leisure inputs. The instantaneous utility (19) is specified as a CES to maintain positive utilitarian flows from living. In the spirit of Auerbach and Kotlikoff (1987), we allow for differences in the intra- $(1/\gamma)$ and inter-temporal $(1/\varepsilon)$ elasticities of substitution. The bequest utility function (20) is negative and reflects a cost of dying for $\gamma_m > 1$; that cost is attenuated by leaving bequests equal to financial wealth plus pension income entitlements for surviving heirs. Finally, the gross risky return R_t^e under the DC plan is assumed to be log-normally distributed, with mean μ_e, and variance σ_e^2.

3.2 Iteration and simulation

Let $Z_t = (W_t, H_t, Y_t^r)$ and $Q_t = (C_t, I_t, \ell_t)$ respectively denote the state and control sets at time t, with $Z \in \mathbb{Z}$ representing a given element of the discretized state space. We also let $\epsilon_t = (\epsilon_t^m, \epsilon_t^s, \epsilon_t^e)$ denote the death, sickness and financial shocks. The iterative step consists of solving the program (15) through a backward iteration:

$$V(Z_t) = \max_{Q_t} \mathcal{U}(Q_t, Z_t) + \beta^m(Z_t)\mathrm{E}\left[V(Z_{t+1}) \mid Z_t\right] \tag{21}$$

$$\text{s.t.} \quad Z_{t+1} = Z_{t+1}(Q_t, Z_t, \epsilon_{t+1}), \quad \forall Z_t = Z \in \mathbb{Z}. \tag{22}$$

The output we recover is thus the sequence of age-dependent optimal allocations and value functions on each point in the state space:

$$\{Q_t(Z), V_t(Z)\}_{t=16}^{T}, \quad \forall Z \in \mathbb{Z} \tag{23}$$

Next, we simulate the dynamic optimal paths for agents $i = 1, 2, \ldots, K_I$, and Monte-Carlo replication $n = 1, 2, \ldots, K_N$ as follows:

1. The initial state draws (with replacement) from the observed population wealth, health levels at age 15:[5]

$$Z_{15}^{i,n} \sim \mathbb{Z}_{15}^{POP}. \tag{24}$$

2. For each year $t = 16, 17, \ldots T$,

   (a) A trilinear interpolation of the policy functions (23) is used to evaluate $Q_t^{i,n}, V_t^{i,n}$ at the contemporary state $Z_t^{i,n}$.

[5] The initial pension entitlement Y_{15}^r is set at the minimum point on the discretized state space.

(b) Death and sickness shocks are endogenously drawn from the generalized Bernoulli,

$$\epsilon_{t+1}^{k,i,n} \sim \{0,1\}^2 \mid \lambda^k(Z_t^{i,n}). \tag{25}$$

(c) Financial shocks are drawn from the log-normal distribution:

$$\log(R_{t+1}^e) \sim \text{N.I.D.}(\mu_e, \sigma_e^2) \tag{26}$$

(d) We use the laws of motion (22) to update the state variables:

$$Z_{t+1}^{i,n} = Z_{t+1}\left(Q_t^{i,n}, Z_t^{i,n}, \epsilon_{t+1}^{i,n}\right). \tag{27}$$

3.3 Moments and SME estimation

Given the output sequence $\left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}$, the theoretical life-cycle $\hat{M}_t$ and unconditional moments $\hat{M}^u$ need to be calculated for the population of living agents only. For that purpose, let $\mathbb{1}_t^{i,n} \in \{1, \text{NaN}\}$ be the alive indicator for agent i, in simulation n, at age t. The life-cycle and unconditional moments are given by:[6]

$$\hat{M}_t = \frac{\sum_{i=1}^{K_I}\sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}\left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}}{\sum_{i=1}^{K_I}\sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}, \tag{28}$$

$$\hat{M}^u = \frac{\sum_{t=16}^{T} \hat{M}_t}{T-16}. \tag{29}$$

These life-cycle moments can be contrasted with observed ones to construct a Simulated Moments Estimator (SME, e.g. Duffie and Singleton, 1993; Keane and Wolpin, 1994; French, 2005).

For that purpose, define $\Theta = (\Theta^e, \Theta^c)$ the estimated and calibrated parameter set. Let $\hat{M}(\Theta) = \{\hat{M}_t(\Theta)\} \in \mathbb{R}^{K_M}$ denote the collection of theoretical life cycle moments of interest, and M denote the corresponding observed moments. For a given weighting

[6] In practice we rely on the `nanmean` function in Matlab to avoid factoring in the deaths in computing the moments.

matrix $\Omega \in \mathbb{R}^{K_M \times K_M}$, the SME estimation of the structural parameters Θ^e is:

$$\hat{\Theta}^e = \underset{\Theta^e}{\operatorname{argmin}} \left[\hat{M}(\Theta) - M\right]' \Omega \left[\hat{M}(\Theta) - M\right]. \quad (30)$$

The calibrated and estimated parameters are discussed in further details below. We compute the theoretical life cycle moments for health, wealth, leisure, out-of-pocket expenditures, and the annual mortality rates over 5-year intervals for ages between 20–80. The corresponding observed moments are discussed below and refer to the US population for the years 2010 and 2011. By using 5 life cycle variables times 12 five-year bins, meaning a total of $K_M = 60$ moments, the Simulated Moments Estimation of Θ^e is clearly over-identified since we estimate 23 deep parameters.

The SME methods require observed life cycle moments on wealth, health, leisure, and out-of-pocket health expenditures. Ideally, a single panel database regrouping all these variables would be used. Unfortunately, to the best of our knowledge, such a database does not exist. Another limitation concerns the type of data. Since we are not able to use panel data, the risk is for the model to capture a cohort effect and not a pure life cycle effects. Following literature's best practice (Pelgrin and St-Amour, 2016), we rely on separate well-known panels that are representative of the American population. These sources are presented in Table 4. First, for financial wealth, we rely on the Survey of Consumer Finances (SCF). Our measure for financial wealth includes assets (stocks, bonds, banking accounts, ...). Second, leisure is the share of time spent not working, and is taken from the American Time Use Survey (ATUS). Third, we use the National Health Interview Survey (NHIS) to get a measure of health. Indeed, this survey includes ordered qualitative self-reported health status ranging from very poor to excellent that are converted to numerical measures using a linear scale. Fourth, the total (Consumer Expenditures Survey, CEX) and out-of-pocket medical expenses (Medical Expenditures Survey, MEPS), are the mean expenses per person, conditional upon expenditures.

Finally, the retirement plans also require administrative and statistical information on retirement income in order to parametrize the Social Security, DB, and DC formulas (e.g Average Monthly Index Earnings thresholds, DC annuity factor). To compute social security benefits, we use 2010 and 2011 data from the U.S Social Security Administration. However, we fix the DB contribution rate τ_f^{DB} and the DC annuity factor α^{DC} by averaging different literature sources since no survey exist on these parameters.

4 Results

We first discuss the estimated parameters, followed by a presentation of the output obtained from the iteration and simulation phases. We close this section by discussing the role of alternative key assumptions.

4.1 Parameters

Calibration set The values and sources for the calibrated parameters Θ^c are shown in Table 5.a (values), and .b (sources). These parameter values were selected relying on data, official figures, and literature as much as possible. The remaining free parameters concern the range and dimension of the state, and control spaces, and were calibrated through an extensive trial and error procedure.

Estimation set The estimated parameters Θ^e are reported in Table 6, with standard errors in parentheses. The latter indicate that all the parameters in Θ^e are precisely estimated, and have the correct expected signs. In panel 6.a, the mortality intensity $\lambda^m(H)$ parameters in (16) confirm that the endowed death intensity λ_0^m is low. The weight and curvature parameters with respect to health indicate that death risk is diversifiable ($\lambda_1^m, \xi^m \neq 0$). Next, the sickness intensity process in (17) unsurprisingly reveals a much higher exposure to sickness than to death risk ($\lambda^s(H_t) > \lambda^m(H_t), \forall H_t$). Moreover, the parameters are consistent with endogenous exposure ($\lambda_1^s, \xi^s \neq 0$), as well as with a high endowed intensity, and the absence of bounds on sickness risk exposure ($\lambda_0^s, \lambda_2^s \gg 0$).

In panel 6.b, the deterministic depreciation δ_t is non-trivial, and age-increasing. Conditional upon sickness, the incremental depreciation that is suffered by the agent is found to be consequential ($\phi_t > \delta_t$), and more age-dependent than its deterministic counterpart ($g^\phi > g^\delta$). All in all, this suggests that the health capital falls rapidly in the absence of constant maintenance, that the sickness process we identify is associated with severe, rather than benign illness, and whose consequences are much more detrimental for elders, than for young agents. The gross investment function (18) that we estimate is indicative of medical technological progress ($g^A > 0$), and of positive, diminishing marginal products of investment and leisure in maintaining health ($\eta_I, \eta_\ell \in (0, 1)$). Moreover, the large marginal effect of health in the gross investment ($\eta_H \equiv 1 - \eta_I - \eta_\ell > 0$)

suggests path dependence in the sense that not all contemporary health issues may be solved through high expenditures and healthy leisure only.

Turning to preferences in panel 6.c, the CES utility (19) that we estimate is characterized by low intra-temporal elasticity of substitution between leisure and consumption ($1/\gamma \ll 1$) that is consistent with known estimates of Frisch elasticity, and indicative of relative complementarity between consumption and leisure.[7] Moreover, we observe a strong importance of leisure relative to consumption in the utility function ($\mu_\ell > \mu_C$), as well as a high inter-temporal elasticity of substitution $1/\varepsilon \gg 1$. The estimates of the bequest function (20) suggest a utility cost of death ($\gamma_m > 1$), and realistic relative risk aversion with respect to stochastic financial risk ($\gamma_m = 2.09$). The bequest motive is also found to be non-negligible ($\mu_m > 0$).

Finally, in panel 6.d, the growth in medical productivity that we identify ($g^A > 0$) is paralleled with medical prices inflation ($g^P > 0$), that is accompanied by a corresponding increase in deductibles ($g^D > 0$). Observe that medical prices augment more rapidly than both medical technology and deductibles ($g^P > g^D > g^A$).

4.2 Optimal allocations

Figure 1 in Appendix C.1 plots the mean optimal consumption (panel a), leisure (panel b), health investment (panel c), and welfare (panel d) in function of financial wealth (W), and health (H), where the mean is taken across the age, and retirement wealth dimensions. Figure 2 plots these variables in the retirement wealth, and health space (W^R, H), where the mean is taken across the age, and financial wealth dimensions, whereas Figure 3 plots these variables in the (W^R, W) space, where the mean is taken across the age, and health dimensions.

First, the optimal consumption in Figure 1.a is monotone increasing in wealth, and decreasing in health. Whereas the wealth effects are as expected, the negative health gradient can be explained by the lower discounting for healthier agents who prefer to consume less, and save more at a given wealth level, in order to account for a longer life horizon. Second, the optimal leisure choice in Figure 1.b displays strong similarities with consumption, due to the complementarities that was previously estimated ($1/\gamma \ll 1$). Again, it is unsurprisingly increasing in financial wealth, and decreasing in health, where

[7] See Auerbach and Kotlikoff (1987, pp. 51-52) among others.

the latter obtains because healthy agents face lower death, and sickness risks exposure and can select to work more when health improves. Observe that the sufficiently healthy and rich agents elect not to work, and take full leisure ($\ell = 1$) instead.

Third, the optimal investment in Figure 1.c is non-monotone in both wealth and health. Sufficiently healthy agents tend to substitute away from health spending, and in favor of leisure when wealth increases; otherwise, the wealth gradient of spending is positive for the unhealthy. Moreover, health spending falls in health for sufficiently healthy agents, but increases for unhealthy individuals. Very unhealthy agents, facing a near unit probability of further sickness and death, thus prefer to cut down on spending, and take full leisure instead when health further deteriorates. This choice is sensible as leisure provides instantaneous utility, whereas spending does not. Finally, as expected, the welfare in Figure 1.d is monotone increasing in both financial wealth and health. Note that the strong convexities in the adjustment costs of gross investment $I^g(H, I, \ell)$, and of risk exposure $\lambda^k(H)$ entails that the curvature is more pronounced with respect to H, than W.

Figures 2, and 3 both isolate the effects of retirement wealth on the optimal allocations and on welfare. The retirement wealth gradient is found to be very similar to financial wealth (Fig. 2), yet is moderate once the latter is accounted for (Fig. 3). Indeed, replacing financial, with retirement wealth yields very similar policies in the (W^R, H) space, whereas averaging across health and expressing the policies in (W^R, W) space shows negligible marginal effects of retirement wealth, once financial net worth is accounted for. Again, the substitution away from health spending (panel c) and in favor of leisure (panel b) for wealthier agents is apparent. All in all, this suggests substitutability between financial and retirement wealth, once health status and age are integrated across.

4.3 Optimal life cycles

To isolate the effects of age, the optimal life cycle trajectories are reported in Figure 4 in Appendix C.2. They are computed as the mean of the simulated paths at a given age using (28). We plot the benchmark simulated allocation (red), along with standard errors (dotted red), and the corresponding observed data (black). Overall, these results confirm that our benchmark model performs well in reproducing the shape of the life cycle paths, with some notable exceptions.

Indeed, panel 4.a illustrates that the secular drop in health levels is accurately reproduced. However, the level is not, indicating that agents in the model are healthier compared to the observed ones. Consequently, their exposure to mortality risk (panel b) is smaller, and their life horizon is longer than it should be (79.3 years in the data vs 83.9 years predicted).

Moreover, predicted spending (panel c) is overestimated, and leisure, while exaggerated before mid-life, is insufficient afterwards (panel d). Complete health insurance coverage suggests that agents in the model should also substitute more leisure with less health spending to maintain health and reconcile with observed data.

Third, despite pension income adequacy (panel e), insufficient leisure and excessive work imply the estimated total income to be overestimated after mid-life (panel f). The predicted consumption level is also insufficient before mid-life, and clearly above what is observed after 65 (panel g). Put differently, theoretical prediction of consumption is growing too strongly compared with observed data. Despite insufficient pre-retirement consumption, high predicted health spending and pre-retirement leisure entails that observed and predicted financial wealth paths coincide throughout lifetime (panel h). The old-age increase in estimated consumption is therefore attributable to higher labor income, and not to excessive wealth or pension claims.

4.4 Alternative specifications

We now analyze the effects of relaxing several key assumptions in the theoretical model in order to verify how the empirical performance can be affected. First, we replace our DC assumption with one where individuals are covered by a defined benefit (DB) plan. Second, we allow for potential mis-management of pension funds by altering the risk-return mix on the pension assets' portfolio. Third, we account for the fact that many young agents remain uninsured with respect to health spending. Fourth, we allow for potential myopia with respect to the endogeneity of death risk exposure. Keeping the deep parameters constant, the model is solved and simulated again for each alternative. In Appendix C.3, we plot the observed X_t (black), benchmark $\hat{X}_t$ (red) and alternative $\tilde{X}_t$ (blue) life cycles.

4.4.1 DB pension plans

As discussed earlier, recent trends have witnessed a fall in DB-type pension plans in favor of DC regimes, prompting us to adopt a defined contribution perspective. Still, defined benefits remain important for many workers, and the model is modified accordingly. The effects on predicted life cycles are reported in Figure 5.

DB plans are often considered to be more generous than their DC counterparts, and this is reflected in much higher pension claims (panel e). The latter encourages DB workers to take an early retirement path (panel d) which results in limited post-retirement improvements in health (panel a), and moderately lower mortality (panel b). Moreover, more mid-life leisure entails that health expenditures can be substituted away (panel c), leading to more pre-retirement financial wealth (panel h). Because pension income is higher, consumption at mid-life can be accelerated (panel g), and causes financial wealth to recede more rapidly after retirement.

4.4.2 Lower return on the pension assets

We have imposed a risky portfolio share $\omega = 60\%$ on DC pension assets. Potential mismanagement may result in lower shares which will reduce the rate of return on pension funds, and therefore the post-retirement pension claims. For that purpose, we reduce ω to 30%. The effects on predicted life cycles are reported in Figure 6.

As expected, lower returns on pension assets results in a decline in pension income (panel e), and post-retirement total income (panel f), forcing the agent to cut down on leisure, and increase hours worked (panel d). The drop in leisure is mostly compensated by increased health spending (panel c), such that both health (panel a), and mortality (panel b) remain unaffected. The drop in the value of pension wealth forces the agent to increase financial wealth (panel h), by cutting down consumption (panel g).

4.4.3 Uninsured young agents

Our model assumes full insurance for young and old agents alike. Yet, before PPAC-A becomes fully operational, a sizable share of the US younger population remains uninsured with respect to health risks.[8] To analyze the effects of uninsurance, we modify the

[8]Hence, 32 millions (16.7%) non elderly Americans remained uninsured in 2014 (Henry J. Kaiser Family Foundation, 2015).

model to let young agents face the full price of health expenditures, while allowing for full Medicare coverage for elders. The changes with respect to the initial theoretical predictions are reported in Figure 7.

First, uninsured young agents are unsurprisingly in worse health than insured individuals (panel a), and consequently face a higher mortality risk exposure (panel b). As expected they substitute away from costly health spending (panel c), and in favor of more leisure (panel d) so as to maintain health. As Medicare becomes operational after 65, they reverse these choices by spending more, and cutting down on leisure. The latter is however too late to offset a fall in pension income (panel e), while pre-retirement drop in hours worked results in important cuts in labor revenues (panel f). A shorter expected life span, and higher price of medical expenditures mean that both post-retirement financial wealth (panel h), and consumption (panel g) are reduced.

4.4.4 Myopic health risks

Finally we consider an alternative where agents correctly anticipate the mean death risk at any given age, but are myopic to the possibility of altering these risks through their health decisions. The results in Figure 8 thus replace the theoretical death intensity by $\tilde{\lambda}_t^m$ obtained by projecting the observed death intensities at age t, obtained from the Life Tables on a constant, and on age. Agents are thus myopic in omitting to account for the endogenous dependence of their risk exposure on their own adjustable health, $\lambda_t^m(H_t)$.[9]

As expected, removing the endogeneity of death risk exposure reduces the attractiveness of spending resources to maintain health. Consequently, both investment (panel c), and leisure (panel d, after age 55) fall sharply, inducing a sharp drop in health level (panel a), and an increased mortality (panel b) compared to our benchmark theoretical model. More work for elders translates to higher total income (panel f), despite a drop in pension revenues (panel e). Finally, a shorter expected lifetime reduces the need to maintain financial wealth balances (panel h), which is sufficiently important as to force a cut in post-retirement consumption (panel g).

[9] Qualitatively similar results are obtained by replacing the projected mortality rate by the actual rate.

5 Discussion

This paper's objective is to assess whether observed life cycle choices by agents with respect to health, leisure/work, and consumption/savings can be matched using a dynamic life cycle model that takes into account the interactions between agents' decisions.

Our modeling strategy evolves around a flexible dynamic optimization framework that can accommodate many optimal dynamic policies. In particular, endogenous exposure to future morbidity and mortality risks, as well as future consequences of current leisure choices on future pension entitlement are fully internalized. A key difference with previous studies is that life cycle health-, financial, and work-related choices are thus analyzed *jointly*, rather than separately to assess financial and health adequacy. Moreover, structural estimation of the model ensures a one-to-one mapping between the theory and the empirical assessment.

Based on the previous results, we can hardly conclude that observed choices are fully explained by our model. Whereas financial savings and pension claims do not appear to be inadequate (i.e. agents are thrifty), individuals in the data are less healthy, and consequently face a shorter horizon than agents in our estimations. Moreover, assuming full insurance optimally points to more spending, and less leisure to maintain health than currently observed. As a consequence, post-retirement income is too high, and explains a sharp increase in consumption after 65 that is inconsistent with households' behavior.

In order to assess the general fit of the model, we performed the Sargan-Hansen test (Hansen, 1982), i.e. J-test, to test the over-identifying restrictions. By using the parametric bootstrap method (Hall and Horowitz, 1996), the J-test gives the following conclusion: $J^{hat} = 43.60 < 52.19 = J_{0.95}$ where $J_{0.95}$ is chi-square distributed with 37 degrees of freedom. Therefore the null hypothesis cannot be rejected at the 5% level, i.e. the estimated model of life cycle allocations adequately describes the observed data.

A fair concern is whether our underlying assumptions stand behind the model's inability to fully reproduce the data. To address this question, we relaxed several key hypotheses. First, to account for a sizable (although receding) share of the population covered by defined benefit pension plans, we allowed for DB regimes instead of our assumed defined contribution plan. Relaxing the pension plan hypothesis only partially improves the results. Whereas the model predicts that leisure should increase after mid-life, health spending is lower for DB agents. However, both effects offset one another with respect to health maintenance such that DB agents are similarly healthy, and long-living than their DC counterparts.Moreover, the predicted consumption, and financial wealth life cycles diverge further from the observed values.

Second, to account for potential mismanagement of pension fund leading to lower rates of return on asset holdings, we reduced the portfolio share on risky assets. Since the latter pay a positive risk premia, this results in cutting down the value of pension claims. However, the effects on health levels, mortality are negligible, whereas investment increases, and leisure falls counter-factually. Moreover, the effects on income, consumption, and wealth are weak, leading to no improvement in model performance.

Third, before PPAC-A becomes operational, important shares of young US population remain uninsured for health expenses. Replacing our full insurance hypothesis by a no insurance for younger and Medicare-covered insurance for elders also provides partial improvement, with much more potent effects on health-related variables. First, predicted health falls sharply, and mortality rates increase and become closer to those observed in the data. However, uninsured young agents also substitute away from spending and in favor of more leisure, leading to a deterioration of performance on both fronts. Moreover, post-retirement wealth falls sharply because of the shorter expected lifetime, leading to further inconsistencies.

Fourth, we also considered potential myopia with respect to mortality risks by replacing the death endogenous intensity with an age-increasing, but health-independent version, such that agents correctly expect their death exposure on average, but fail to internalize the positive impacts of healthy choices on longevity. Again this modification holds some promises, yet is insufficient to account for all the differences between predicted, and observed behavior. In particular, as we remove the longevity value of better health, predicted health deteriorates strongly via lower expenses and leisure. Moreover, post-retirement consumption is pro-factually much lower, but results from counter-factual drops in financial wealth for elders.

Finally, different functional forms were tested as robustness checks[10]. For instance, death and sickness risk exposures were tested as functions of age in addition to health. Age-increasing incidence could reduce the attractiveness of investing in one's health and could help reconciling the model with the data. It turns out that results were not improved

[10]Results can be provided upon request.

compared to the ones obtained using the functional forms reported in Section 3. We also tried to incorporate health in the utility function, as in the Grossman model of health demand, i.e. using $U(C, H, \ell)$ instead of $U(C, \ell)$ for the period utility. Intuitively, being healthy (i.e. high health stock) allows agents to spend more time on other activities and it also brings them direct welfare. But again, the fitting was not improved.

Overall, we conclude that the discrepancies between the data and the estimated allocation cannot be solely attributed to excessive assumptions related to pension, or health insurance regime, nor through those regarding the forward-looking aptitudes of agents. Other alternative explanations include real estate which has been omitted from the analysis. Higher post-retirement leisure could be explained by more liquid wealth incorporated in house value, allowing less work for elders. A shorter life horizon induced by unhealthy behavior could also be rationalized by more bequest utility from bequeathed housing wealth. A further alternative could be limitations preventing elders' participation in the labor market. For instance fiscal, means-testing or Social Security penalties on post-retirement labor income, or employers' reluctance to hire elders could explain excessive leisure for elders. In addition, the endogenous decision of retiring would give the real life flexibility to agents, and could help to reconcile with end of life pension and leisure choices. Furthermore, the current estimation is only based on matching the first moment (mean). Adding higher ones such as variance could help to increase the accuracy and could match the most challenging shapes. Finally, relaxing the assumption of a single type of leisure, and allowing for a neutral or even a unhealthy leisure could help at matching the health profile. We leave these and other potential explanations on the research agenda.

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A Social Security

Given the Average Indexed Monthly Earnings $AIME_t$, the Social Security income is obtained as:

$$PIA_t = \min \left\{ \alpha_1^{PIA} \min \left(AIME_t, Cap_1^{AIME} \right) + \alpha_2^{PIA} \max \left[0, \min \left(AIME_t - Cap_1^{AIME}, Cap_2^{AIME} - Cap_1^{AIME} \right) \right] + \alpha_3^{PIA} \max \left(0, AIME_t - Cap_2^{AIME} \right), PIA^{max} \right\} \quad (31)$$

Note that in order to reduce the dimension of the state space, the Social Security income can also be expressed as a function of Y_t^{DB}:

$$AIME_t = \frac{1}{T^E \tau_f^{DB}} Y_t^{DB} \quad (32)$$

such that (31) becomes:

$$PIA_t = \min \left\{ \alpha_1^{PIA} \min \left(\frac{Y_t^{DB}}{t \times \tau_f^{DB}}, Cap_1^{AIME} \right) + \alpha_2^{PIA} \max \left[0, \min \left(\frac{Y_t^{DB}}{t \times \tau_f^{DB}} - Cap_1^{AIME}, Cap_2^{AIME} - Cap_1^{AIME} \right) \right] + \alpha_3^{PIA} \max \left(0, \frac{Y_t^{DB}}{t \times \tau_f^{DB}} - Cap_2^{AIME} \right), PIA^{max} \right\} \quad (33)$$

where we set $T^E = 49$, and $\tau_f^{DB} = 0.014$ in AIME (32).

B Tables

Table 2: Asset Allocation and percentage share invested in equities for DC plans

% of 401(k) in equities	Age 20's	Age 60's	Average
0	0.9	0.16	0.0
(0,20]	0.1	0.8	0.1
(20,40]	0.2	0.14	0.3
(40,60]	0.5	0.26	0.5
(60,80]	0.19	0.16	0.7
(80,100]	0.64	0.20	0.9
Average	0.74	0.48	0.6

Notes: Equities include equity funds, company stock, and the equity portion of balanced fund. Funds include mutual funds, bank collective trusts, life insurance separate accounts, and any pooled investment product invested primarily in the security indicated. Source: Tabulations from EBRI/ICI Participant-Directed Retirement Plan Data Collection Project (ICI, 2013).

Table 3: Joint Survivor Annuity for a $100'000 investment in 2010-2011

100% Joint Survivor Monthly Annuity for $100'000 invested					
Age	01.01.2010	01.07.2010	01.01.2011	01.07.2011	Average
65	494	480	481	465	480
70	538	524	526	508	524
75	596	580	596	566	584.5
80	684	668	675	649	669
50% Joint Survivor Monthly Annuity for $100'000 invested					
Age	01.01.2010	01.07.2010	01.01.2011	01.07.2011	Average
65	575	559	555	538	**556.75**
70	643	627	623	609	625.5
75	734	717	713	699	715.75
80	870	851	846	829	849
$\delta^r = \frac{0.5}{\alpha^a}$ and $\alpha^a = 12 \times \$556.75/\$100'000 = 0.067$					

Notes: Sources: www.immediateannuities.com/annuity-shopper/as-archive.html

Table 4: Data sources

Variables	Data, and explanations
W_t	Survey of Consumer Finance (SCF) data (Summary extract data set, 2010, rscfp2010.dta, corresponding to data used in the Federal Reserve Bulletin). Because the model abstract from durables and housing, wealth is defined as financial wealth (fin).
W_t^{DC}	Survey of Consumer Finance (SCF, 2010). DC account is the sum of any households pension account except IRA/Keogh accounts included in the financial wealth.
H_t	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Health is defined as respondent's self-reported health status (RTHLTH31), and categorized by age. The original polytomous data is converted to numerical values using a linear scale where Poor=0.10, Fair=0.825, Good=1.55, Very good=2.275, Excellent=3.0.
$P_t^I I_t$	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Total health expenditures are defined as total health care (TOTEXP11).
OOP_t	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Out-of-pocket health expenditures are defined as total health care paid by self/family (TOTSLF11).
ℓ_t	American Time Use Survey (ATUS), Bureau of Labor Statistics (2010 Activity file). Leisure is defined as the share of usual hours not worked per week, (1-uhrsworkt/40) where codes 9999 (NIU) and 9995 (variable hours) were set to 1.
C_t	Consumer Expenditures Survey (CEX) data, Bureau of Labor Statistics (2011 interview file). Consumption is defined as adjusted total expenditures last quarter (totex4pq) from which we subtract health care (healthpq) and vehicles (cartknpw+cartupq+othvehpq), with quarterly data in converted to annual values.
Y_t	Current Population Survey (CPS, 2010), Bureau of Labor Statistics. The annual income is the weekly total income times 52 weeks computed using both full and part-time (less than 35h of work per week) households, respectively weighted, for each age group.
w_t	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Wages are hourly wage (HRGW31X), with inapplicable values converted to missing, and converted to an annual basis through a 40-hours per week and 52 weeks conversion.
$\lambda^m(t)$	Probability of dying between age t and $t+1$, National Vital Statistics Reports, Life Table for the Total US population, 2010 (Arias, 2014, Tab. 1).

Table 5: Calibrated parameters values and sources

(a) Values

Param.	Value	Param.	Value	Param.	Value	Param.	Value
T	100.0	κ	−37.0	β	0.9656	P_0^I	1.8522
ψ	0.20	Π	0.0413	Π_M	0.0167	τ	0.0145
R^f	1.0408	R^e	1.0709	σ^e	0.187	ω^e	0.6
τ_f^{DB}	0.014	τ_f^{DC}	0.05	τ_w^{DC}	0.06		
α^a	0.067	δ^r	7.4839	$X_{\max}^{DC}$	0.49		
α_1^{PIA}	0.9	α_2^{PIA}	0.32	α_3^{PIA}	0.35		
Cap_1^{AIME}	0.0755	Cap_2^{AIME}	0.4552	$PIA^{\max}$	0.2356		
$W_{\min}$	0.05	$W_{\max}$	5.0	$H_{\min}$	0.1	$H_{\max}$	3.0
$C_{\min}$	0.05	$C_{\max}$	1.0	$\ell_{\min}$	0.0	$\ell_{\max}$	1.0
$I_{\min}$	0.1	$I_{\max}$	1.0	K_Z	10^3	K_Q	10^3

(b) Sources

Parameters	Sources and explanations
T, κ	Life tables, Arias (2014). Median age, Bureau of Labor Statistics (2011, Tab. 2, p. 4).
β	Various literature
P_0^I	National Center for Health Statistics (2012, Tab. 126), CPI and annual percent change for all items, selected items and medical care components, 2010. The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
ψ, Π, Π_M, τ	Henry J. Kaiser Family Foundation (2011a,b); Medicare.gov (n.d.). The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
R^f, R^e, σ^e	Federal Reserve Bank of St-Louis (n.d.); French (n.d.)
ω^e	Table 2 and ICI (2014, p. 132)
τ_f^{DB}	Various literature, Chen and Hardy (2010), Forman (2000), Fronstin and Helman (2013), Pang and Warshawsky (2013)
τ_f^{DC}, τ_w^{DC}	Deloitte (2014, p. 6), Deloitte (2009, p. 12), and McIsaac (2013, p. 5)
α^a, δ^r	Table 3 and EBSA (2013)
X_{max}^{DC}	IRS (2009, 2010)
$\alpha_1^{PIA}, \alpha_2^{PIA}, \alpha_3^{PIA}, PIA^{max}$	SSA (2010, 2011)
$Cap_1^{AIME}, Cap_2^{AIME}$	SSA (2010, 2011)

Table 6: Estimated parameters values

Param.	Value (std. err)	Param.	Value (std. err)	Param.	Value (std. err)	Param.	Value (std. err)
			a. Sickness and death intensities (16), (17)				
λ_0^m	0.0003	λ_1^m	3.7702			ξ_m	9.3898
	(0.0000)		(0.0087)				(0.0051)
λ_0^s	1.7193	λ_1^s	4.1696	λ_2^s	89.8946	ξ_s	7.0050
	(0.0061)		(0.0115)		(0.0002)		(0.0080)
			b. Health production (3), (18)				
δ_0	0.0267	g^δ	0.0171	ϕ_0	0.0974	g^ϕ	0.0269
	(0.0001)		(0.0001)		(0.0005)		(0.0001)
A_0	2.1727	g^A	0.0039	η_I	0.2732	η_ℓ	0.4666
	(0.0048)		(0.0000)		(0.0080)		(0.0018)
			c. Preferences (19), (20)				
γ	5.1795	μ_c	0.0493	μ_ℓ	0.1979	ε	0.0002
	(0.0167)		(0.0002)		(0.0060)		(0.0000)
γ_m	2.0876	μ_m	0.6518				
	(0.0088)		(0.0024)				
			d. Deductibles and medical prices (10), (11)				
D_0	0.0104	g^D	0.0059	g^P	0.0063		
	(0.0000)		(0.0000)		(0.0000)		

C Figures

C.1 Optimal allocations

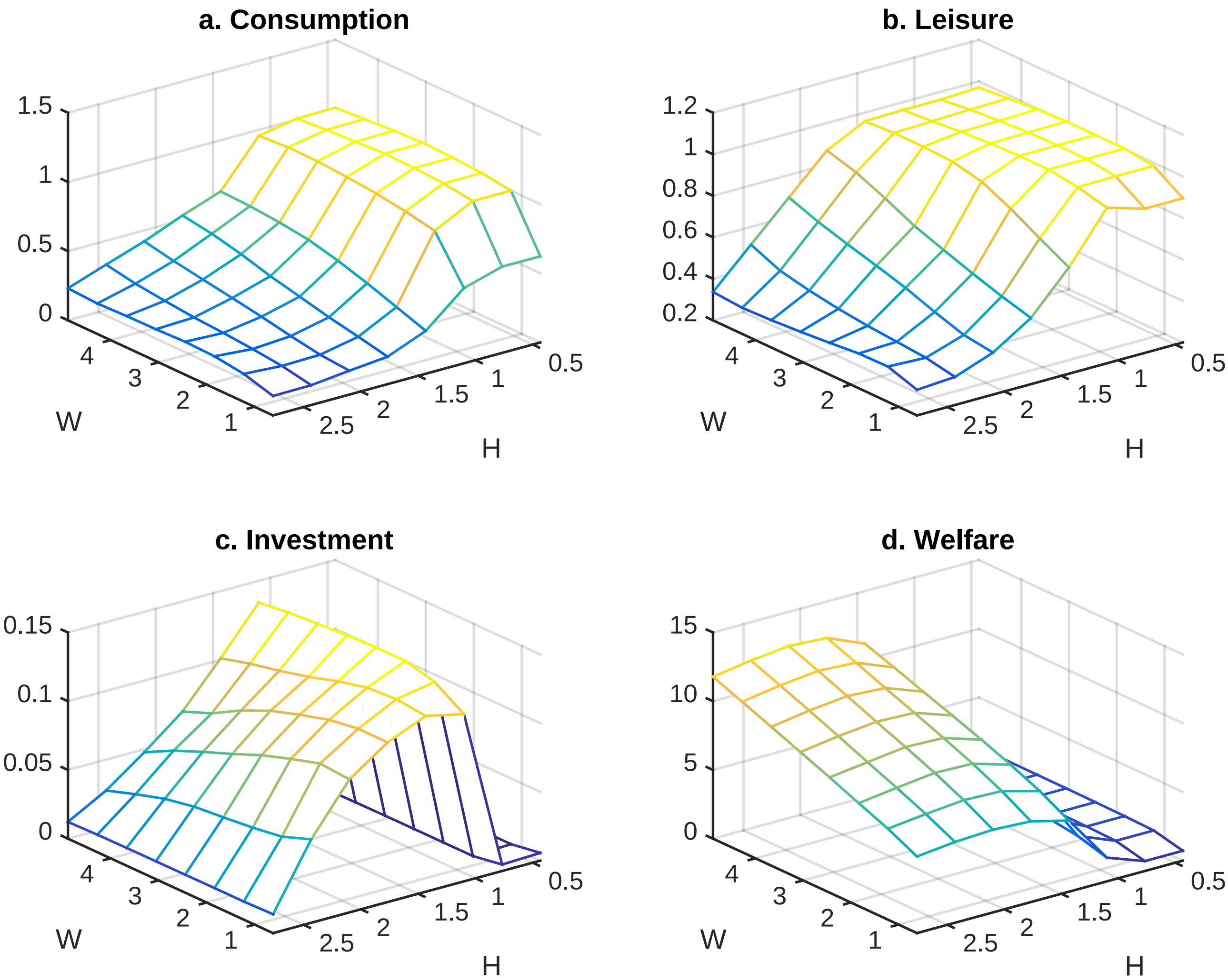

Figure 1: Allocations and welfare in (W, H)

Notes: Mean of optimal allocations and welfare across levels of pension wealth, and between ages 20–80.

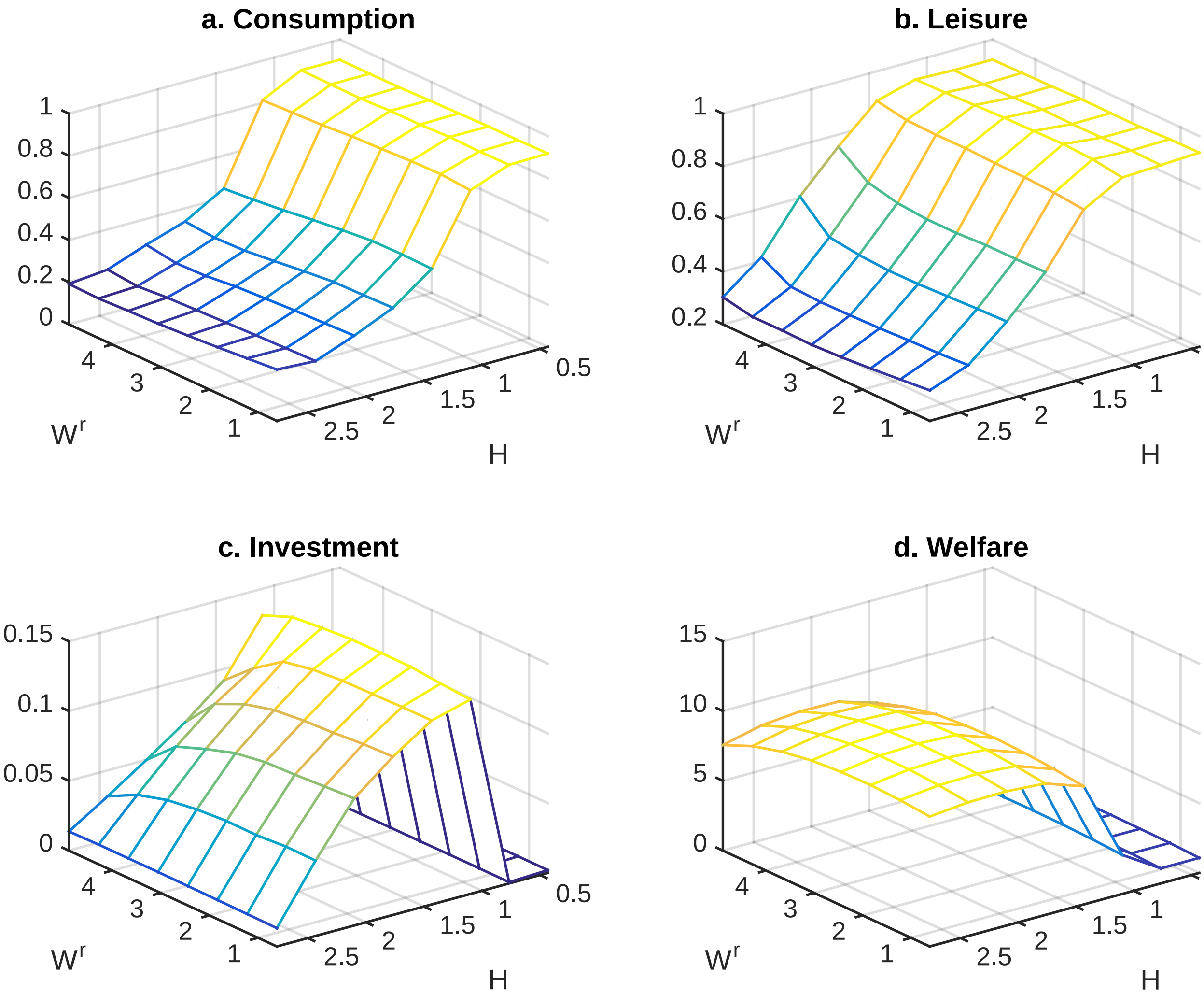

Figure 2: Allocations and welfare in (W^r, H)

Notes: Mean of optimal allocations and welfare across levels of financial wealth, and between ages 20–80.

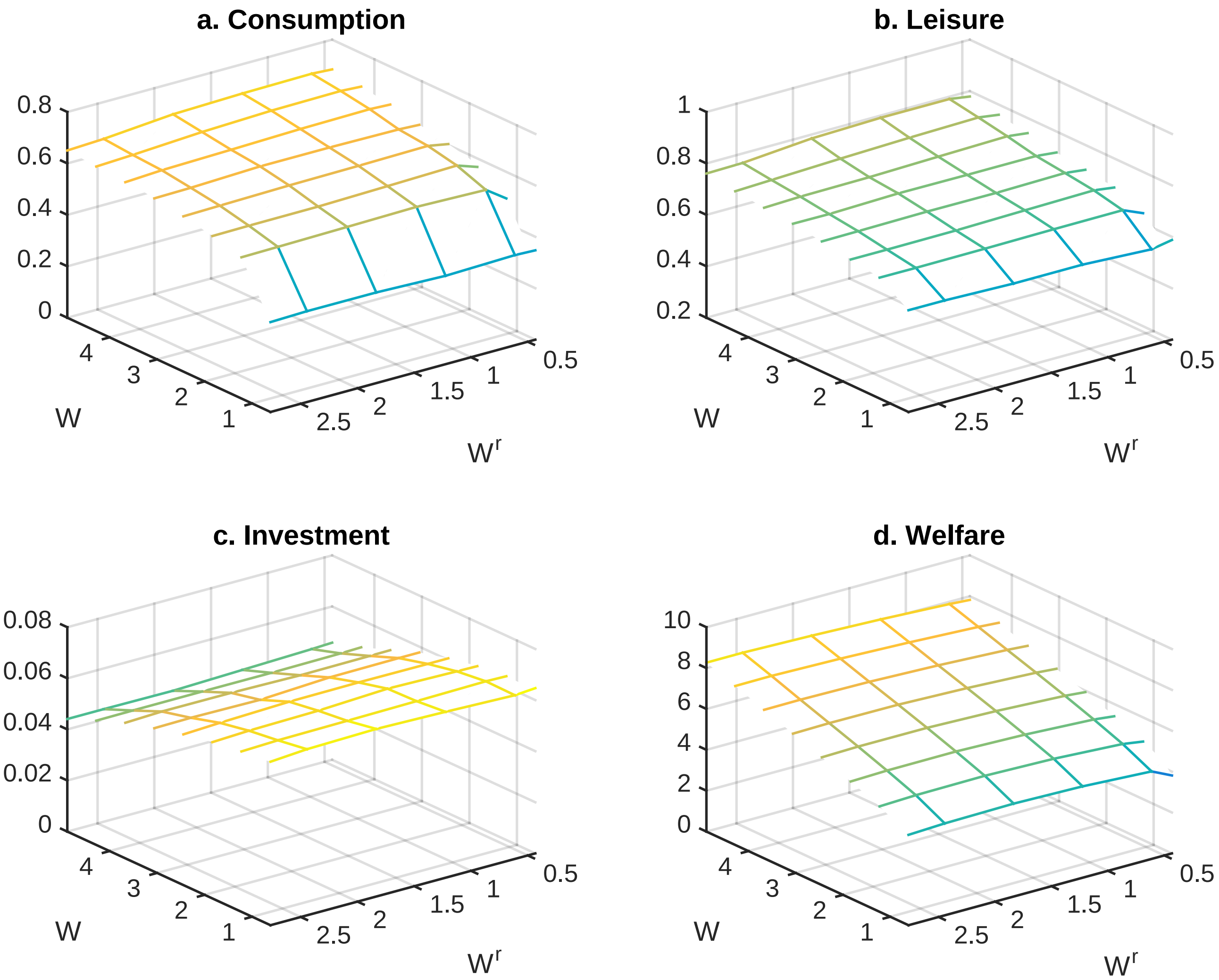

Figure 3: Allocations and welfare in (W, W^r)

Notes: Mean of optimal allocations and welfare across levels of health, and between ages 20–80.

C.2 Optimal life cycles

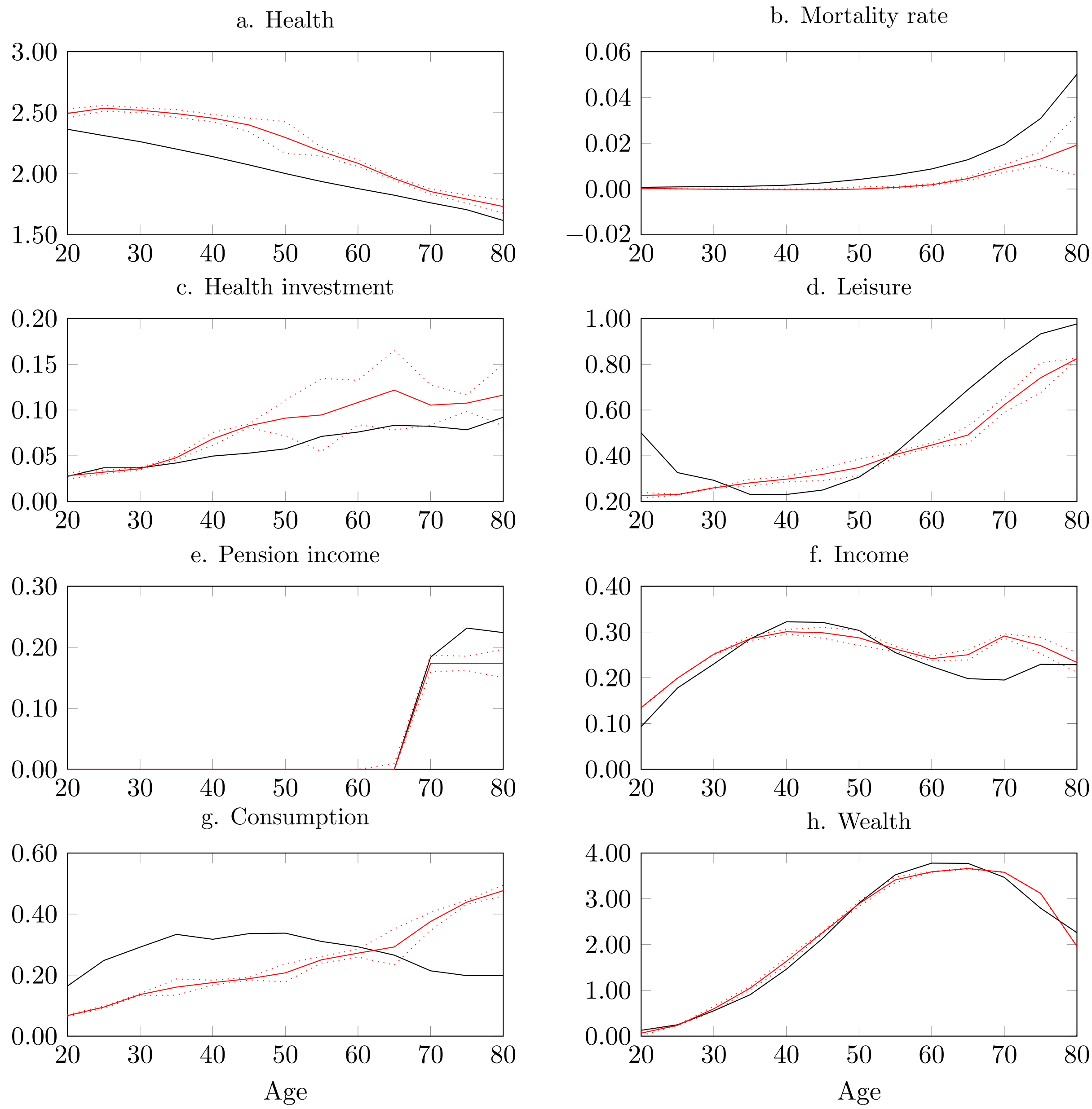

Figure 4: Life cycle allocations

Notes: Data: solid black line (—); benchmark: solid red line (—); 95% confidence intervals: dotted red line. Nominal values in panels d–h are reported in $100,000 units.

C.3 Alternative model assumptions

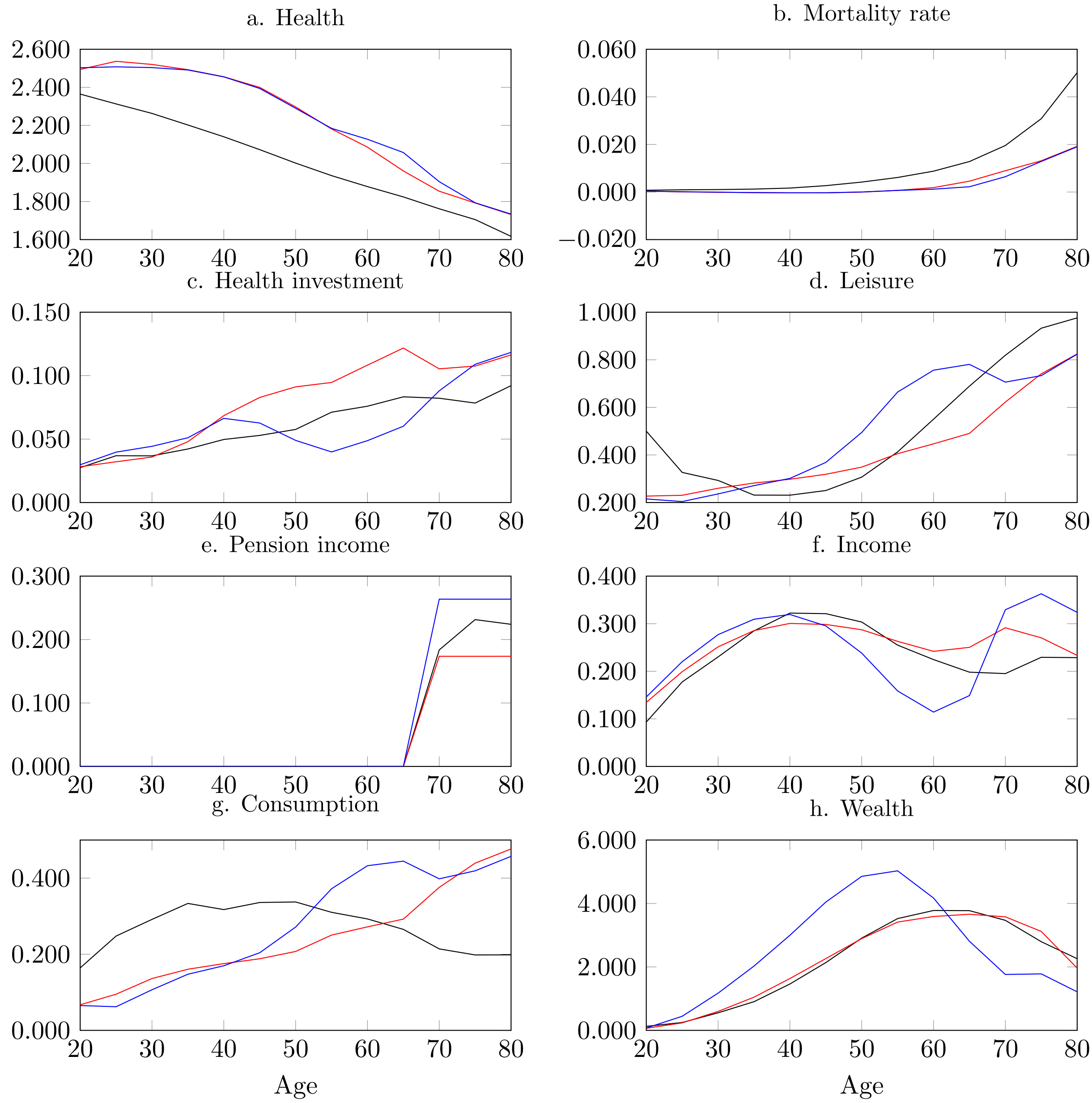

Figure 5: Defined benefit

Notes: The alternative is obtained by using the Defined Benefit plan outlined in Table 1. Data: solid black line (—); benchmark: solid red line (—); alternative: solid blue line (—). Nominal values in panels e–h are reported in $100,000 units.

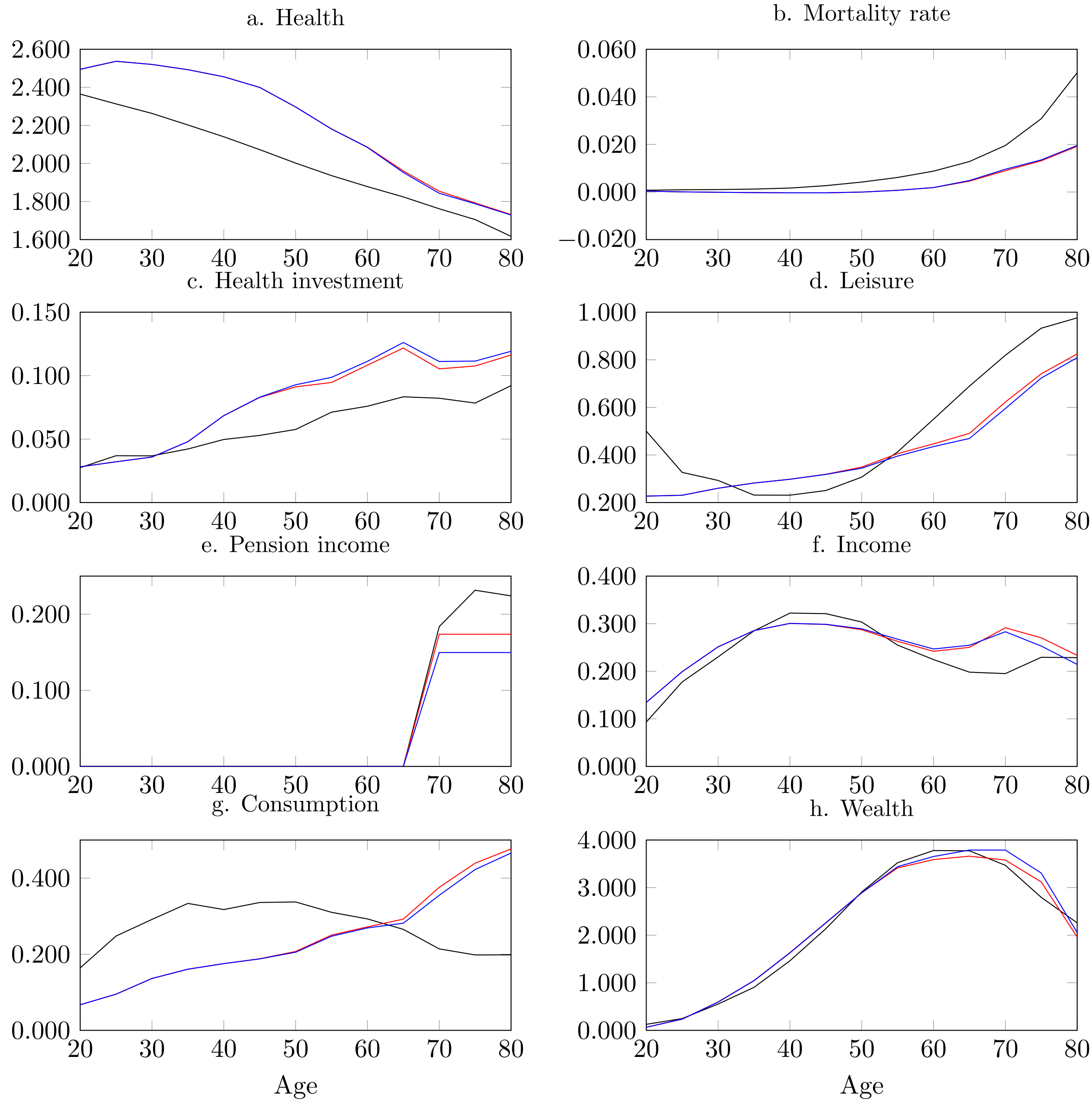

Figure 6: Low risky share

Notes: The alternative is obtained by lowering the risky share of the pension fund portfolio $\tilde{\omega} = 0.5\omega$. Data: solid black line (—); benchmark: solid red line (—); alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.

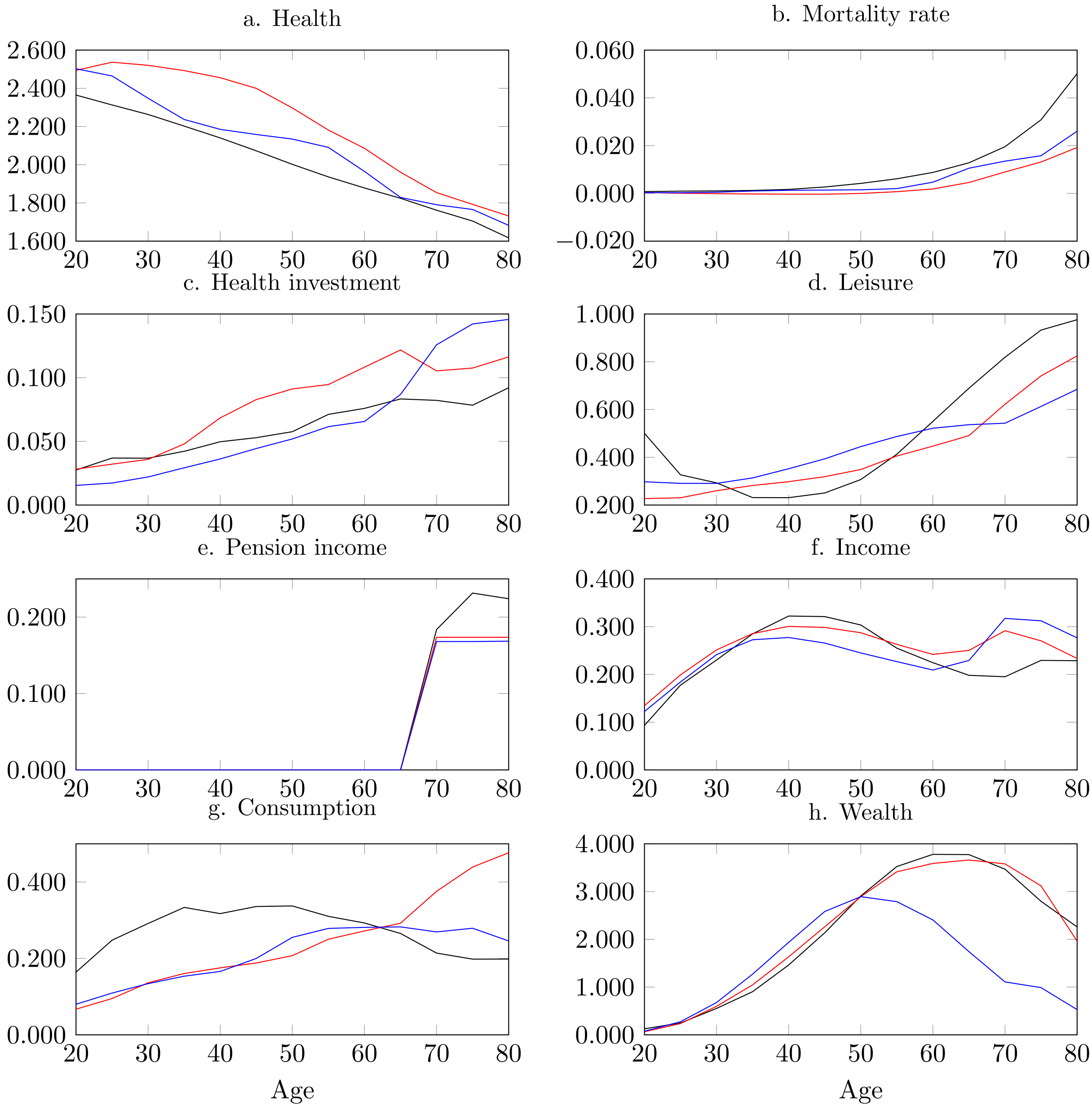

Figure 7: Uninsured young agents

Notes: The alternative is obtained by removing the health insurance for young agents, while retaining Medicare coverage after 65, i.e. $\tilde{OOP}_t(I_t) = (1 - \mathbb{1}_t^R)P_t^I I_t + \mathbb{1}_t^R OOP_t(I_t)$. Data: solid black line (—); benchmark: solid red line (—); alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.

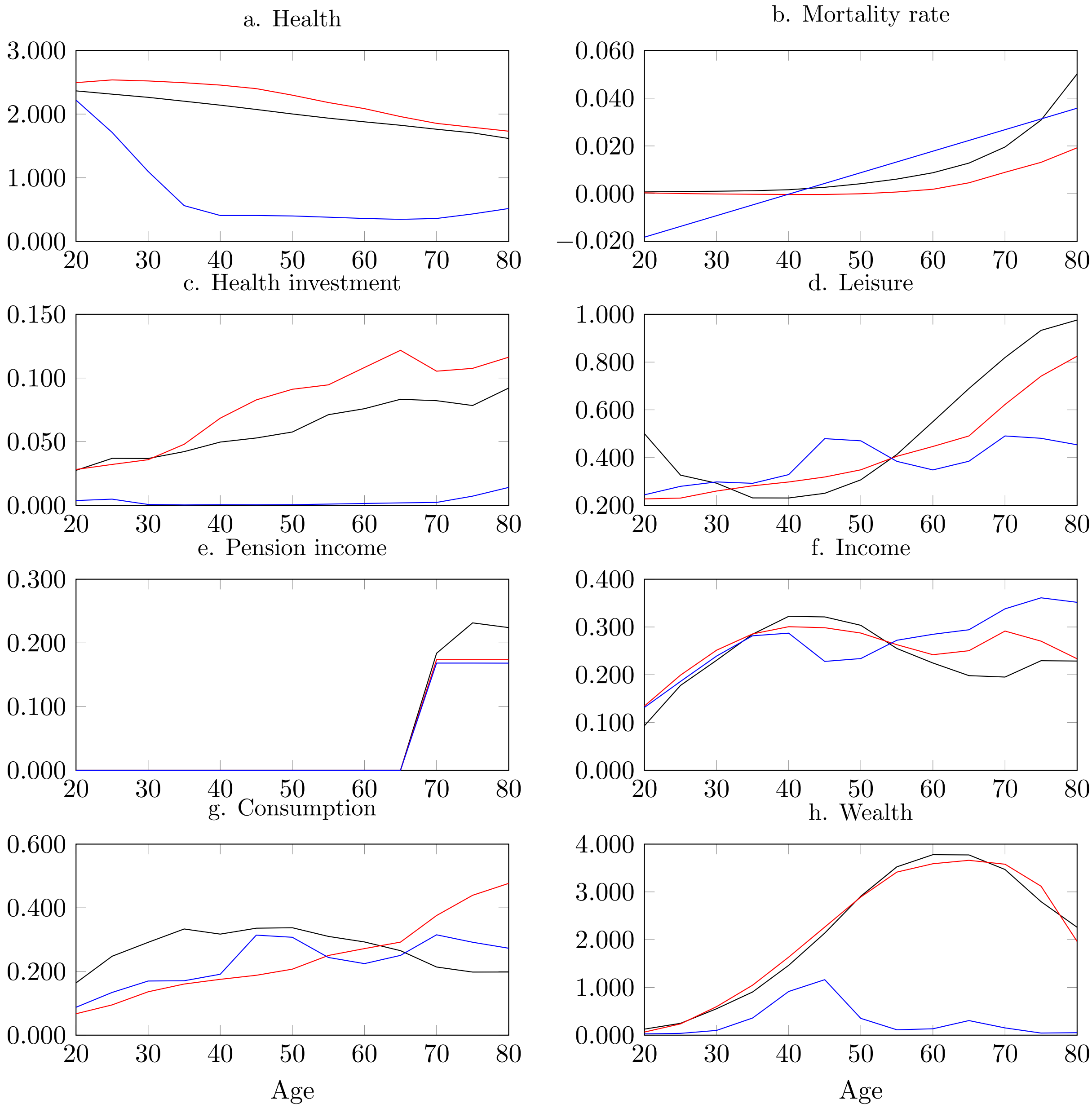

Figure 8: Myopic health risks

Notes: The alternative is obtained by replacing predicted $\hat{\lambda}^m(H_t)$, by the projected, and health-independent death intensity $\tilde{\lambda}^m = \tilde{\lambda}_0^m + \tilde{\lambda}_1^m \times t$, the the projection is based on a OLS estimate using actual death intensities. Data: solid black line (—); benchmark: solid red line (—); alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.

Homeowners' Life Cycle Responses to Financial, Health and Real Estate Shocks*

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Abstract

US households, and more specifically homeowners, are exposed to markets risks and crises through their housing and pension investments. They are also subject to unemployment and health risks as they age, thus creating interactions between health, work and assets holdings decisions over the life cycle. How do financial and other shocks affect agents' optimal responses? To answer, I propose a unique structural life cycle model, *jointly* incorporating assets holdings, time allocation, and financial, health and real estate risks. After successfully matching the US households life cycle data, I distinctly simulate health, financial and real estate shocks to analyze the homeowners' optimal responses. I show that assets rebalancing and time allocation decisions are shock-dependent.

Keywords: Health Shock, Real Estate crisis, Financial Crisis, Assets Holdings, Wealth Shocks, Homeowners, Financial Savings, Pension Assets, Housing Wealth, Time Allocation, Life Cycle Choices, Assets Holdings and Rebalancing.

JEL classification: D14, D91, G11, I12, J22

1 Introduction

U.S. households hold the bulk of their wealth in financial/retirement funds (17%) and housing (64%) according to the Survey of Consumer Finance 2013, making them exposed to financial and stock market fluctuations. During the crisis of 2007–2008, the value of American real estate assets fell by more than 28% (Reinhart and Rogoff, 2013) and that of US private pension assets by about 25% (Whitehouse, 2009). Such strong and unexpected declines in wealth can be challenging for many of the agents' future decisions. Housing accounts for the biggest share of households wealth for two reasons mainly. First, this is the only asset that offers direct utility services when owned. People not only get returns but also a service providing them welfare. Second, government policies in favor of accessing property motivate households to buy real estate assets. These latter being less liquid than financial assets therefore tend to be kept longer. Furthermore, economic and health risks are part of everyday life and depend on many socio-economic factors such as age and socio-professional categories (Seeman et al., 2004). Health shocks affect health-related choices (e.g. medical expenses), and also time allocation (e.g work hours) and assets holdings (e.g. pension) decisions because these latter are intertwined (Hugonnier et al., 2013). Put differently, shocks have different multidimensional repercussions on many entwined households' decisions. Therefore building a framework that accounts for all variables affected by shocks is crucial to rigorously analyze the optimal life cycle responses (e.g. policy purposes).

Through this study, I investigate how US homeowners react to some unpredictable and negative shocks, and the differences in responses according to the types of shocks. Put differently, the analysis focuses on the effects of shocks on households' lifetime optimal decisions. The adjustments made on time allocation and assets holdings are analyzed using an extended model in which health risks are endogenous, incorporating financial, housing and pension assets, and consumption, leisure and health-related activities, and housing time and money investments. One of the limitations is that risky assets do not intervene in the financial wealth process for the model to remain computationally solvable. The model takes into account the complex interactions between health risks, assets holdings and labor using a custom labor constraint. Indeed, the time endowment is divided into four categories, i) work hours affecting both income and pension funds, ii) healthy leisure which increases in welfare and reduces health risks (prevention), iii) time spent on housing allowing for real estate assets accumulation (i.e. maintenance and repairs) and welfare, and iv) healing time when a health shock happens, that reduces the available time devoted to work, leisure and home. The model's deep parameters are estimated using the Simulated Moments Estimation method (Duffie and Singleton, 1993; Keane and Wolpin, 1994). The predicted life cycles are then simulated and subjected to financial, housing and health shocks.

Many structural life cycle papers model wealth as a share of savings invested in a risky asset and the rest in a risk free one (Cocco et al. (2005); Gustman and Steinmeier (2005); Chai et al. (2011b); Haan and Prowse (2014); Pelgrin and St-Amour (2016) for examples). Notice that French (2005) distinguishes pension assets from total wealth. Importantly, modeling wealth as a composite asset, instead of separately abstracting from its different properties (liquidity, direct services, bequeathable components) is too restrictive and hides specific properties. Hence, all the individual wealth components need to be disaggregated but jointly modeled to robustly analyses the life cycles of households' savings and the effects of serious health issues, and real estate and financial markets downturns. Additionally, researchers dealing with housing wealth do not take into account time as an input required for real estate wealth accumulation, but consider money as single input (Yao and Zhang (2005); Cocco (2005); Li and Yao (2007); Iacoviello and Pavan (2013) among others) while agents can accumulate housing wealth by investing time (e.g. self home renovations and repairs) and/or money (e.g. cash, mortgage). Furthermore, because time is a scarce resource, people's time allocation choices strongly influence their resources. However, modeling time use is not straightforward, and most models only treat it as decisions between labor and leisure (Rust and Phelan (1997); Bloom et al. (2003); Scholz and Seshadri (2010); Galama et al. (2013); Pelgrin and St-Amour (2016) among others). Note that French (2005), Halliday et al. (2017), and French and Jones (2011) explore this issue further by taking into account a healing time in their models.

Moreover, households life cycle decisions are fully intertwined with health-related choices (Hugonnier et al., 2013), which makes them essential when analyzing agents' optimal allocations. Finally, few papers study the impact of shocks on household decisions in a complete framework. When they do (Sevak, 2002; Hurd and Rohwedder, 2010; Gustman et al., 2010), the focus is on the effects of bad economic events on retirement. To my knowledge, the only exception is Chai et al. (2011a) who show that the effects of financial shocks depend on the age of individuals. However, they do not consider that crises could affect different variables such as assets classes, and generate tailored households' responses.

The main contribution of the paper is to provide new light on the relation between assets holdings and time allocation decisions, especially the modeling of time spent on housing. The time variation in investment opportunities and the fluctuation and tightening in time endowment through life is of particular interest. As people age, the probability of getting sick increases, time becomes a scarce resource, and therefore housing renovations become harder to handle. Unfortunately, computational issues stemming from the model's complexity made me put aside certain features such as endogenous financial risky assets. The borrowing constraint has also some limitations and only depends on financial wealth, instead of income. The other contributions of this paper are fourfold. First, it completes the life cycle models of saving by jointly and realistically including the three main assets held by US households, i.e. financial, pension and real estate ones. Second, it adds extended time allocation decisions (labor/leisure, health, housing) to the life cycle models of labor supply. Third, it draws from the literature about health risks through the modeling of age-varying diversifiable morbidity shocks which affect time allocation through two channels, prevention (leisure time) and healing (time endowment reduction). Fourth, this paper supplements the literature on the influence of negative and unpredictable events that affect households life cycle decisions by analyzing the houseowners responses to different types of shocks.

The results are summarized as follows. First, the estimated parameters accord with the relevant literature, data and conventional wisdoms. Secondly, I show that the model successfully reproduces the observed data, especially for the real estate portfolio weight, net worth, as well as for health-related activities. The pension assets accumulation is well matched too. Last, the simulation part identifies optimal responses to different negative events. The simulations are based on three shocks, i.e. financial, health and real estate, occurring when people are 45 years old, and lasting for 5 years[1]. I find that all shocks decrease the agents' net worth, especially for the housing shock (-75% at 70 years old). Agents almost recover their net worth levels in the cases of health and financial shocks, mainly by investing in real estate assets. Furthermore, in the three scenarios, we observe part-time work in retirement[2] to compensate for the loss of wealth. Finally, in all the three cases, the share of housing assets in agents' portfolio increase. Houseowners compensate the real estate crisis by strengthening their positions in housing assets (mostly by getting into debt). Note that they still increase pension wealth by working more.

The rest of this paper is structured in the following way. Section 2 gives the institutional background, while Section 3 briefly surveys the literature about housing. Section 4 reports the model specifications. In Section 5, I introduce the numerical methods used to solve the model, preceding the results reported in section 6. Section 7 concludes.

2 Institutional background

The homeownership rate peaked at 69% and the median house price increased by almost 20% from 2005 to 2007, in part fueled by US policies to promote access to homeowning. Unfortunately, at that time, this went hand in hand with an increase in the loan size through the creation of subprime mortgages. These latter allowed households to buy houses with zero down payment and to benefit from a relaxed income constraint. Furthermore, mortgage interest rates were variable and the securitization boomed (+300% from 2002 to 2006 according to Chernenko et al. (2013)).

[1]Empirically, crises (e.g. dot-com bubble, mortgage crisis) last more than a year and less than ten, justifying the model assumption of 5-years duration. In addition, data show that the period of life during which agents are the most affected by negative occurrences is around 45 years old because of the significant amount of assets and liabilities held, and the increasing health and unemployment risks faced.

[2]Gustman et al. (2010); Chai et al. (2011a) also found that retirement is deferred. Here, this translates into a delayed increase in leisure time.

The growth in homeownership was stopped by the Financial Recession of 2007-2008. The latter stands out as the most devastating since World War II. According to the Federal Reserve Bank of St. Louis, the US consumption spending felt by almost 4%, and importantly, investments by more than 40%, work hours by 10% and house prices dropped by almost 30%.

The real estate crisis also affected other sectors. The contagion occurred in 2008 when the mortgage crisis affected the stock market, the latter being the second highest household asset holding (more than 17% of households' wealth is invested in financial securities). Indeed the Dow Jones Industrial Average dropped from a spike around 14'000 in summer 2007 to a trough around 6'500 early 2009 (i.e. 53% decrease).

In addition, the shift of retirement plans, from defined benefits to defined contributions is also part of the story. In 1998, 50% of the retirement plan were DC-based, while in 2015, they represented[3] 95%. The market risks are therefore transfered from employers to employees, the latter being more significantly affected when financial markets are down.

Finally, time allocation and endowment change over generations and over the life cycle. People live longer and adapt their activities according to their personal characteristics and environment. For instance, medical advances and change in policy make people retire later. Also, the transition from manufacturing to services in the 20th century also affected individuals' time endowment, health and schedules. The pace and hardness of work are different, as are the professional opportunities and the risk of unemployment. Through the life course, time allocation evolves for different factors, health being one of them. As people age, their probability of being sick increases and in return less time endowment remains for other activities. However, technology mitigates this effect and changes the opportunity cost in investing money or time in health. Around 60 years old, the retirement decision has an important impact on people's life. Most of the time, households have more time for other-than-work activities but their income decreases and they start a dissaving process, happening more and more late across generation because of life expectancy and the shift of normal retirement age. In the last 20 years, the life

[3] Source: Willis Towers Watson.

expectancy increased by 6 years in the US[4], and the average retirement age by 4 years[5].

3 Housing in the literature

This paper belongs to the very broad literature of household life cycle decisions, portfolio choice, housing, time allocation, health, and effects of shocks. This section mainly summarizes interesting references about housing and macroeconomics, since the goal of this paper is to bring together housing with other asset holdings, as well as time allocation and health.

Illiquidity of real estate assets distinguish them from other assets and play a key role to explain investment patterns. Kaplan and Violante (2014) show that since many households mainly hold illiquid (and costly to sell) assets (e.g. housing, pension), therefore change in non durable consumption will depend on their liquid portion of wealth, and to fiscal stimulus. The literature also gauges how policy affects home-owning decisions (e.g. Maclennan et al. (1998); Jappelli and Pistaferri (2007); Saarimaa (2010)).

Closely related, Berger et al. (2017) show that real estate price movements significantly affect consumption spending because of many factors such as the level of debt, and housing size among others. Li and Yao (2007) also prove that house price changes affect consumption and welfare, especially at young and old ages. Importantly, they find that renters are worse off, while homeowners are better off in terms of net worth and consumption. It also partly relates to papers enlightening the link between real estate prices and consumption (e.g. Gan (2010); Iacoviello (2011); Attanasio et al. (2011)).

Speaking of housing price movements, several papers try to understand their origins (e.g. Kiyotaki et al. (2011); Favilukis et al. (2017)). This literature strand also studies the boom and crises. For instance, Burnside et al. (2016) develop an heterogeneous agent model consistent with observed booms and busts. City-level housing price movements attempt to be understood by Landvoigt et al. (2015) using data from San Diego.

The general equilibrium literature emphasizes the relation between macroeconomics

[4]Source: CDC.
[5]Source: Gallup.

and housing (e.g. Iacoviello (2005); Leamer (2007) among others). For a review of the literature, Leung (2004) and Piazzesi and Schneider (2016) are two key references. The latter survey the whole domain of housing related to macroeconomics. From real estate price evolution, to housing supply and financing, as well as asset holding and hedging. Overall, it summarizes the housing-related hot topics. For example, a theoretical household life cycle framework to properly model housing and its features (e.g. tenure status, collateral constraints, transaction costs) is discussed. They also study housing under an asset pricing perspective to compare housing and financial asset Euler equations. Finally, very related to this paper, they review both housing and savings over the life cycle, as well as housing as an asset class available to household portfolio choice (e.g. Cocco (2005); Chetty et al. (2017) among others).

Many other researchers participate in the growing literature on housing modeled into general equilibrium life cycle models. Nakajima (2005) includes housing to analyze the link between earning inequality, asset holdings and prices. An increase in the volatility of earnings, increases the demand of real estate assets. Again in a general equilibrium setting, Nakajima (2010) uses an overlapping generations model to discuss the impact of housing tax policy on capital income taxation. He finds that the effect is significant, the capital income tax rate narrow the tax wedge between real estate and other asset holdings.

Furthermore, there are also many papers in which partial equilibrium models have been created to construct life cycle optimal household decisions (e.g. Cocco (2005); Yao and Zhang (2005); Campbell and Cocco (2015) among others). For instance, Landvoigt (2017) builds a life cycle model of housing demand to mainly find that price expectations depend on the long-run average and that housing equity requirements are a function of the market, i.e. tighter during bust phases. Li et al. (2016) also employ the same methodology, i.e. a structural model of life cycle optimal choices, to study the households wealth and housing profiles, and the intra-temporal elasticity of substitution between real estate asset holdings and consumption spending.

Finally, an ongoing research area investigates the relation between mortgage, collateral, illiquidity and foreclosure in the housing market (e.g. Chatterjee and Eyigungor (2015); Corbae and Quintin (2015); Hedlund (2016) among others). Note that Gorea and Midrigan (2017) focus on the liquidity constraint in the US housing market. They build a life cycle model in which housing is an illiquid asset but agents can make their home equity liquid through the refinancing of the mortgage.

This overview of the housing literature shows how broad and complex housing topics are. It confirms that not much has been done to jointly model housing, health and time allocation. It also highlights the trade off to make models tractable and solvable. In this paper, the focus is rather on the analysis of the impact of shocks taking into account the joint decisions between assets holding and time allocation, than on as realistic as possible modeling of the life cycle real estate mechanisms which has already been done very accurately by many of the previous cited references (e.g. Li and Yao (2007); Kiyotaki et al. (2011); Attanasio et al. (2012)). In this paper, assumptions on the housing process are made and acknowledged for computational reasons.

4 The Model

This section introduces the life cycle dynamic programming problem. In this setup, individuals face endogenous morbidity, exogenous risks on pension and real estate assets, and have to make decisions about consumption, time and money dedicated to their property, and (healthy) leisure. I begin by presenting the morbidity process. Then, following an outline of the retirement system and income process, I expose the budget constraint and the agents' preferences.

4.1 Morbidity process

Let $t \in (T_{min}, T_{max})$ be the age of an agent, $T_{min} = 0$ and $T_{max} = 100$ is the maximum biological longevity. The length of the life cycle is exogenous and set according to the dataset. I define $\epsilon^s \in \{0, 1\}$ as a generalized Bernoulli morbidity shock, with probability of occurrence conditional upon time spent on healthy leisure given by:

$$Pr\left(\epsilon_{t+1}^{s} = 1 | l_{t}^{s}\right) = 1 - exp\left[-\lambda(t, l_{t}^{s})\right] \tag{1}$$

where $\lambda : \mathbb{R}_{+} \rightarrow \mathbb{R}_{++}$ is a function of age and healthy leisure ($l_{t}^{s} \in \mathbb{I}$). $\mathbb{I}$ denotes the unit vector.

Agents have the possibility to reduce the likelihood of becoming ill by increasing their time spent on healthy activities, expressed differently, they can partially hedge themselves against the morbidity risk. However, death is fixed and assumed to be exogenous because this feature is not crucial in this framework, and for the model to remain estimable without facing the curse of dimensionality.

4.2 Retirement setup

Let T^{r} and $\mathbb{1}_{t}^{r} = \mathbb{1}_{t \geq T^{r}}$ respectively define the Normal Retirement Age (NRA) and the post-retirement age indicator. The NRA represents the age at which agents start to receive a retirement income composed of public (i.e. social Security known as Primary Insurance Amount, or PIA), and private (i.e. defined contribution (DC) pension scheme[6]) benefits. The pension plan contributions stop at the NRA, but people can work until death[7]. Therefore, the pre-retirement income is only made of labor income whereas the post-retirement income is composed of labor income, public benefits, and private retirement income. Furthermore, in a DC plan both the employer and employee contribute. The pension account is invested in risky and risk free assets, which makes the pension income entitlement stochastic, whereas Social Security benefits are not subject to any investment risk.

The Primary Insurance Amount[8], PIA_{t}, is computed using an Annualized Average

[6]The model does not allow for defined benefit (DB) plans which is consistent with the data as a shift from defined benefit to defined contribution plans is observed, mainly due to US government regulations (Rajnes, 2002; Gebhardtsbauer, 2004; Ghilarducci, 2006).

[7]This feature enables to account for the increasing elderly labor trend observed in the data as examined by Lim (2003), Harper and Shoffner (2004), and Schellenberg et al. (2005) among others.

[8]The formula is reported in Appendix A.1.

Indexed Monthly Earnings ($AIME$) given by:

$$AIME_t\left(\{n_s\}_{s=T_{min}+1}^{t}\right) = \frac{1}{t}\sum_{s=T_{min}+1}^{t} w_s n_s$$

where w_s and n_s are respectively wages and working time at age s.

With W^r denoting the pension fund balance and X^r the pension contributions, the private pension income entitlement Y_t^r is defined as:

$$Y_t^r = \mathbb{1}_t^r \alpha^r W_t^r, \tag{2}$$

$$W_{t+1}^r = \left[W_t^r + (1-\mathbb{1}_t^r)X_t^r\right] R_t, \tag{3}$$

$$X_t^r = \min\left\{\left(\tau_t^w + \tau_t^f\right) w_t n_t, X_{max}^r\right\} \tag{4}$$

Y_t^r is defined by (2) as the private pension balance account (3), converted into an annual annuity at age T^r, using the annualized monthly rate α^r. Furthermore, the pension account (3) is the sum of the contributions (4) invested at R_t. The private pension portfolio gross return R_t is made of shares ω and $(1-\omega)$, respectively invested in the risky R_t^e and risk-free R^f assets. Finally, the total contributions are given by the sum of the age-varying employee (τ_t^w) and employer (τ_t^f) contributions, and are bounded above by X_{max}^r.

4.3 Income process

The participation in the labor market is modeled by the labor constraint:

$$n_t = 1 - \phi_t \epsilon_t^s - l_t^h - l_t^s, \quad l_t^s, l_t^h \in \mathbb{I} \tag{5}$$

The function ϕ_t represents the time needed to recover from a disease occurring at age t. Among the remaining share of time, agents can decide to spend time on their housing (l_t^h), and/or healthy leisure (l_t^s). By dedicating time to their home, agents are able to slow down the depreciation of their real estate assets, and by investing time in leisure, they reduce their sickness risks. The rest of their time endowment is spent in work hours

(n_t).

Time in housing is important for two reasons. First, agents face time variation in investment opportunities. They constantly have to adapt according to the variations. For instance, high real estate assets rate of returns could motivate them to increase their share of time spent on housing. And, they also may invest additional cash in housing. Second, time endowment (and income) tightens as people age, mainly because of health (and retirement) issues. Time allocation is therefore more challenging, and complex trade-offs have to be made between investing time and/or money in the house, or even selling it.

The total income process Y_t is given by:

$$Y_t = [1 - (1 - \mathbb{1}_t^r)\tau_t^w]\, w_t n_t + \mathbb{1}_t^r (PIA_t + Y_t^r) \tag{6}$$

The total income (6) is the sum of three stochastic sources of income, i.e. labor, social security and pension. The workers contributions τ_t^w are deducted from their income, and only allowed before the NRA. Agents start to receive the Social Security and private pension benefits from retirement on, but remain free to work without contributing to their pension afterwards. As previously seen, although the NRA is 65, agents can still continue to work afterwards to complement revenues. This assumption is consistent with the data on old-age participation in labor markets (See Pelgrin and St-Amour (2016) for specific references).

4.4 Budget constraint

The net worth W_t is invested at the portfolio gross return R^P_{t+1}. The budget constraint is therefore specified as:

$$W_{t+1} = [W_t + Y_t - C_t]\, R^P_{t+1}, \tag{7}$$

$$R^P_{t+1} = R^{Hnet}_{t+1}\omega^H_t + R^f\omega^b_t, \tag{8}$$

$$R^{Hnet}_{t+1} = \frac{P^h_{t+1}}{P^h_t}(1-\delta^h), \tag{9}$$

$$0 \leq \omega^H_t \leq \frac{1}{1-\alpha^H} \tag{10}$$

where C_t denotes consumption expenditures, ω^H_t is the weight of total wealth invested in real estate assets, and $\omega^b_t = 1-\omega^H_t$ is the one invested in the risk-free asset[9]. In this setup, agents could therefore face negative net housing assets value. This situation happens when the housing value is inferior to the remaining mortgage balance. For instance, a crisis (e.g. mortgage crisis in 2007) could affect the real estate market so hardly that some agents end up with the value of their housing smaller than the mortgage amount to pay back. To get even closer to reality, financial wealth could have been invested into some portfolio (like the pension plan). This means an additional control variable, i.e. portfolio share invested in the risky assets. Unfortunately, in this case, the model would have been too complex to fight the curse of dimensionality. Equation (7) shows that wealth can be invested in risky housing and pension assets, and risk-free financial assets. Borrowing is possible and constrained by equation (10), in which α^H is the loan-to-value (LTV) ratio. Finally, the real estate assets value cannot be negative.

In line with the standard housing literature, real estate is modeled as a depreciable and stochastic asset. Yet, in this framework, the depreciation rate is a function of housing tenure $h = \{own, rent\}$. Real estate is modeled as a portfolio asset class for tractability, which is one of the assumption and limitation of the model. Indeed, in this setup, at each period households can adjust (sell or buy) housing units without any constraints, which means that taxes, fees and lumpiness of housing investments are omitted (Iacoviello et al.,

[9]Notice that $\omega^b_t < 0$ corresponds to borrowing situations.

2007). R_{t+1}^{Hnet}, defined in equation (9), corresponds to the net housing assets return where P_s^h is the rental ($h = rent$) or purchase ($h = own$) housing price at period s, and δ^h is the tenure status-dependent housing depreciation rate. The latter is a function of time spent on housing for owners and corresponds to full depreciation for renters. Renting a home, i.e. paying a rent to get a housing service flow, can be seen as investing money in real estate that completely depreciates from one period to another. Therefore, at each time, households have to invest again to get positive housing services. The above portfolio notation of the budget constraint is equivalent to the standard formulation used in real estate and urban economics (see Appendix A.2).

4.5 Preferences

Let's define $\beta^h \in (0,1)$ the discount factor for estimated tenure status h. The instantaneous utility $\mathcal{U}_t$ with time-separable Von Neumann-Morgenstern preferences is specified as:

$$\mathcal{U}_t = U(W_t^H, C_t, l_t^s) + \beta^h U^m(W_t, W_t^r) \geq 0 \tag{11}$$

where U is positively- and U^m negatively-defined monotone increasing and concave instantaneous utility and bequest functions. The preferences in (11) consider the flow utility (U) from real estate assets as a service ($W_t^H = \omega_t^H W_t$), consuming, and spending time on healthy activities. The welfare also takes into account the amount of bequest left by agents (U^m). The latter is a function of pension funds and of the net worth.

The optimization problem is the following:

$$V_t^h(W_t, W_t^r) = \max_{C_t, l_t^h, l_t^s, \omega_t^H} \mathcal{U}_t + \beta^h E_t \left\{ V_{t+1}^h(W_{t+1}, W_{t+1}^r) \mid W_t, W_t^r \right\} \tag{12}$$

subject to (1), (3) and (7). Importantly, V is separately solved for homeowners and renters, meaning that the tenure status is exogenously set. In this economy, agents are either owners or renters, with no possible transition. The two statuses are assigned respecting the proportions of tenure types in the economy, at each age of the life cycle.

Following standard practices in the literature, agents derive utility from real estate, but not from financial holdings. Note that renters get utility from real estate assets, but they cannot use them to accumulate wealth. At each period, they have to spend money to get some housing services since renting corresponds to the particular case of full depreciation of real estate assets. In fact, renters does not holds real estate assets in contrast to the owners, and they pay a rental price.

5 Estimation

This section outlines the empirical strategy implemented to numerically solve, and structurally estimate the model. First, I describe the functional forms. Then, after presenting the simulated moments procedure, I focus on the Simulated Moments Estimation (SME) method, and conclude with an overview of the data used in the estimation strategy.

5.1 Functional forms

The model specification is based on a convex housing depreciation rate, polynomial morbidity intensity, convex time of recovery, as well as CES and CRRA utility functions:

$$\delta^{own} = \frac{\delta_0}{1+l^h}, \tag{13}$$

$$\lambda(t, l^s) = \lambda_0 + \lambda_1 t + \lambda_2 \left[l^s\right]^{-\xi}, \tag{14}$$

$$\phi(t) = \phi_0 e^{\phi_1 t}, \tag{15}$$

$$U(W^H, C, l^s) = \frac{1}{1-\epsilon}\left[\mu_H {W^H}^{1-\gamma} + \mu_C C^{1-\gamma} + \mu_l {l^s}^{1-\gamma}\right]^{\frac{1-\epsilon}{1-\gamma}}, \tag{16}$$

$$U^m(W, W^r) = \frac{\mu_m}{1-\gamma_m}\left(W + \delta^m W^r\right)^{(1-\gamma_m)} \tag{17}$$

The discount factor is specified as $\beta = e^{-\beta_0}$. The risky asset's log-returns $\ln(R_t^e)$ and real estate rental and purchase log-prices $\ln(P_t^h)$ are normally distributed, respectively with means μ_e and μ_p^h, and standard deviations σ_e and σ_p^h. The depreciation rate is defined in (13) as a negative function of l^h. The rate is adjusted according to the time that households spend maintaining or renovating their property. Because real estate can be maintained either by investing money or time, the more time households invest, the less value their property will loose, everything else being equal. The morbidity risk intensity (14) is a linear function of age, and convex in healthy leisure to account for diminishing returns. The healing function (15) is convex and age-increasing. In addition, preferences (16) are specified as a generalized CES function to allow for different intra- and inter-temporal elasticities of substitution (Auerbach and Kotlikoff, 1987). Finally, the bequest function (17) has the same specifications as in Pelgrin and St-Amour (2016), i.e. negative values for curvature parameter $\gamma_m > 1$ (dying is costly for agents) but keeping a positive marginal value of bequeathed wealth. Notice that a share δ^m of pension assets, as well as any other assets enter in the bequest. As previously explained, the bequest is made of financial assets, i.e. risk-free and a share of pension funds, and of the net value of financial and real estate assets; the latter being sold right after death.

5.2 The simulated moments estimation

With $\Theta^e = (\Theta^{own}, \Theta^{rent})$ defining a set of estimated parameters[10] for homeowners and renters, Θ^c a set of calibrated parameters (Table 5), $\hat{M}^h(\Theta^e, \Theta^c) \in \mathbb{R}^{K_M}$ the vector of theoretical simulated life cycle moments[11] for the set of variables $\left\{l^h, l^s, \omega^H, W\right\}$ and for tenure status h, $M^h \in \mathbb{R}^{K_M}$ the empirical ones, $\Omega \in \mathbb{R}^{\mathbb{K}_\mathbb{M} \times \mathbb{K}_\mathbb{M}}$ the optimal weighting matrix, i.e. the inverse of the moments conditions' covariance matrix, and α_s^h the observed exogenous share of agents aged s with tenure status h in the economy, the SME formula is given by:

$$\hat{\Theta^e} = \underset{\Theta^e}{\operatorname{argmin}} \sum_{h=\{own,rent\}} \alpha_t^h \left[\hat{M}^h\left(\Theta^{own}, \Theta^c\right) - M^h\right]' \Omega \left[\hat{M}^h\left(\Theta^{own}, \Theta^c\right) - M^h\right] \quad (18)$$

The estimation approach comes from the one implemented by Pelgrin and St-Amour (2016) and is fully reported in Appendix B. In this paper, the process is more complex and asks for distinctly solving for the two tenure statuses. Briefly, the estimation is based on

[10] More details can be found in Section 6.1 and Table 6.

[11] They correspond to the 50^{th} percentile from 20 to 80 years old, with a 5 years increment.

two phases. First, a backward iteration step run over the ages for the entire state space, and separately for both tenure statuses. Second, a simulation phase follows from young to old ages, and is based on the optimal path found in the first iterative step.

5.3 Data

Presently, there is no database containing all the information needed to estimate the model. Therefore, based on several reliable U.S. surveys (i.e. ATUS, CE, MEPS and SCF), I construct an aggregate set of variables, for year 2010. Following this best practice methodology, I am aware of the fact that the model potentially replicates a cohort effect, and not a pure life cycle effect. From the American Time Use Survey, I extract and scale the time allocation variables, i.e. time spent on housing, health-related activities, and work. The Survey of Consumer Finances contains data about financial, housing and pension assets. The net worth is taken net of the retirement accounts, and the pension wealth is made of any private retirement funds. The real estate share ω^H is defined as the ratio of housing value to net worth. Finally, the hourly wage rates are obtained from the Medical Expenditure Panel Survey. A complete description is reported in Table 3.

6 Results

This section discusses the estimated parameters, followed by the iterative method results. Then, I present the outcome obtained from the benchmark case. Finally, I introduce the main application of the model, which is the analysis of the effects of health, financial and real estate shocks.

6.1 Parameters

Table 6 summarizes the estimated parameters in Θ^e. The standard errors, reported in parenthesis, confirm that all estimated parameters are significant at the 95% level. First, I focus on the health-related parameters. Second, I analyze the homeowners and renters subsets of parameters.

Health shocks In Table 6.a, $\lambda_0, \lambda_1 > 0$ show that the health-related risks cannot be fully hedged (Pelgrin and St-Amour, 2016), and the risk of falling sick is age-increasing (Fries, 2002). $\lambda_2, \xi > 0$ expresses the endogeneity of the morbidity risk, reduced by increasing the share of time endowment spent on healthy activities[12]. Because the probability of illness is age-increasing, as people age, the positive health effect of leisure turns out to be smaller. The positive parameters ϕ_0 and ϕ_1 show that recovering from a disease is time-consuming and age-increasing. Agents do not instantaneously get healthier after being sick, and the older the more time it takes to recover[13].

Homeowners In addition, in Table 6.b, $\gamma > 1$ is consistent with the literature on intra-temporal elasticity of substitution, and highlights the low substitutability between consumption, housing and leisure. $\epsilon > 0$ confirms the non-separability and willingness to inter-temporally substitute. Furthermore, $\mu_l > \mu_H > \mu_C$ expresses the important role of leisure and real estate assets in agents' welfare. The bequest parameter $\mu_m > 0$ shows that bequest motives are clearly relevant in the decision process, and the curvature parameter $\gamma_m > 1$ affirms that positive bequests are costly for people, but the cost decreases as the bequest value increases, motivating people to rationally leave bequests at death. Finally, the time preference discount parameter $\beta < 1$ and the housing depreciation base rate $\delta_0 > 0$ are in accordance with the literature.

Renters Renters coefficients (Table 6.c) have the same signs as the ones of houseowners, except for γ. Indeed, $\gamma = 0$ makes the function linear in W^H, C, and l^s. Interestingly, $\mu_C^{renter} > \mu_C^{owner}$ saying that renters value more non durable consumption than owners. Furthermore, $\beta^{renter} < \beta^{owner}$ tells us that renters have a bigger preference for consumption today towards the one in the future compared to owners. Finally, $\mu_m^{renter} < \mu_m^{owner}$ is the key to the homeowners' decision to keep their housing and any other assets at old age, and may explain the dissaving puzzle near the end of life (De Nardi et al. (2015)).

[12]See Caldwell (2005), and Mannell (2007) among others.
[13]See Lai and Hung (2001); Messenio et al. (2013), among others.

6.2 Benchmark: all households

Figure 1 reports the benchmark life cycle properties. Data from panels a, b, c, and d are used in the estimation procedure. Panel e is out-of-sample.

Overall, the model fits the U.S. households life cycle data very well. By looking at panel a, we clearly see that the model matches ω_t^H, the housing portfolio weight. Besides, the time spent on real estate (panel b) is underestimated by the model before midlife, but is recovered near the end of life. The simulated and observed time spent in health-related activities are similar (panel c). Importantly, the net total wealth (panel d), with its particular hump-shape, is accurately recovered. Furthermore, the out-of-sample pension wealth process (panel e) fits well the data, except after 60, where the predictions are too high, yet simulated values are close to the observed values. The divergence could be explained by the model's assumptions which abstract from partial pension withdrawal before the NRA, whereas US law authorizes this process under restricted conditions (Purcell, 2008).

Notice that a significant change in the optimal choices is observed around midlife. On the one hand, the young agents optimally accumulate wealth in different forms. On the other hand, as people age, they increase health-related activities and the wealth accumulation slows down, and even stops. Last, the model successfully replicates the puzzling fact that households keep their real estate assets longer than other assets (De Nardi et al., 2015). It also indicates that midlife workers contribute more to their pension funds than younger ones.

6.3 Homeowners' optimal life cycle responses to shocks

This section analyses how householders[14] change their allocations if a shock takes place. Put differently, what is the effects of shocks on households' lifetime optimal decisions. I concentrate on three relevant cases which are the differences in optimal allocations induced by health (i.e. a major illness disabling agents 50% of their time), real estate

[14]The following analysis only considers US homeowners since they are the only ones holding real estate assets.

(i.e. a negative expected return and a higher housing prices volatility) and financial (i.e. a negative expected return and a higher risky asset volatility) shocks. We assume that these shocks occur at 45 years old and last 5 years. The shock duration and severity are both assumed to be completely unanticipated by the agents. After 5 years, the situation is back to normal.

I report the settings in Table 7, and the results are disclosed in Figures 2, 3 and 4.

Health shock In Figure 2 we can see the houseowners' optimal response to a health shock. The optimal response is to increase real estate investments by 22% at midlife (panel a), using leverage through a 38% increase in the proportion of real estate assets in the portfolio(panel b), while reducing time spent on housing by 15% at the same time (panel c). Even though agents spend a lot of time recovering, in the short run they increase their leisure activities by 36% (panel e) to reduce the high morbidity risk exposure at the expense of a diminishing working time. Therefore pension wealth is negatively impacted (-24% in panel f). To compensate, they choose to work part-time after the NRA (panel e). Overall the net worth decreases significantly at midlife (-11.5%) but almost recovers the benchmark level at 80 years old (panel d).

Real estate shock Figure 3 exhibits the optimal response to a housing shock. This type of shocks negatively affects the expected return and volatility of real estate assets. First of all, unsurprisingly the weight of real estate assets in the portfolio (panel a), as well the time spent on housing (panel c) and the net worth (panel d) substantially decrease compared to the benchmark, respectively -70% at 75, -85% at 60 and -75% at 70 years old. However, the housing wealth declines less sharply than the net worth because agents make positive investments in their home (panel b), increasing the proportion of real estate assets held in the portfolio and simultaneously reducing the effect of the shock (especially when the shock is over) by bailing out through debt and cash. Furthermore, the health-related activities (panel e) decrease (-37% at 75 years old), sickness and work hours augment, generating an increase in the pension wealth (+16% at the NRA) and part-time work after the NRA (panel f). Surprisingly, homeowners do not move towards other financial assets, except indirectly via work hours that increase their pension wealth. Instead they try to compensate the bad housing event by making massive real estate investments right after the crisis is over.

Financial shock The financial shock is the unpredictable negative expected return and high volatility of the financial risky asset. Figure 4 highlights that the benchmark results are almost recovered near the end of life (only a 3% difference in net worth at 80 years old). Overall, the housing wealth increases (+40% at 50 in panel a), and the net worth and pension wealth diminish (respectively -22% at 50 in panel d and -17% at 65 years old in panel f). Interestingly, during the first 10 years after the shock occurs, the time spent on housing (panel c) and healthy leisure (panel e) levels are bigger than in the benchmark case, and smaller thereafter, respectively +175% and +42% at 45, and -25% and -18% around the NRA. US homeowners compensate the financial loss by making exceptionally high and leveraged investments in real estate assets (panel b, +75% at midlife). Since the pension assets are partly invested in the risky asset, their performance worsens, therefore the agents decrease work hours and increase health-related activities to reduce their exposure to the financial risk. Finally, they attempt to offset the loss in retirement wealth by working more than in the benchmark case right after the shock is completely over, postponing the age at which they retire.

Discussion Depending on the nature of the shock, the homeowner's response is significantly different. In the case of a real estate assets crash, effects are larger and last longer than in a financial crash or a major illness event. Intuitively, because the share of housing assets held by homeowners is substantial and leveraged, the real estate market downturns have a greater impact on optimal life cycle allocations. These results prove that agents are able to reduce the negative effects of unpredictable bad events by rebalancing their assets and time allocations. In addition, in all cases the shocks generate part-time work in retirement, in agreement with the literature (Gustman et al., 2010; Chai et al., 2011a). I also notice that in all scenarios, the net worth is smaller. However, homeowners almost recover their net worth levels when they face some health or financial shocks. This is done mainly by investing in real estate assets using debt. Finally, in all three cases, agents rebalance their portfolio by putting more weight on real estate assets. Even houseowners compensate the real estate crisis by strengthening their positions in housing assets (mostly by getting into debt) at the expense of financial assets. Notice that they still increase pension contributions through extra working time. Because real estate assets are not only a way to easily transfer wealth in precautionary savings or consumption smoothing purposes, but also a way to increase current welfare since they provide a service (i.e. a home), agents compensate the decrease in welfare by investing in housing services.

7 Conclusion

Putting together assets holdings, time allocation, and specific features such as endogenous health, exogenous financial and housing risks in a single dynamic life cycle framework gives promising results on the joint understanding of wealth life cycles. Foremost, the model matches very well the U.S. households' profiles of the real estate assets holdings, pension wealth and net worth. Indeed, the model successfully replicates the well-known and puzzling fact that people tend to keep their housing longer than other wealth types. At the same time, it also recovers the hump-shaped net worth profile, and the low but age-increasing pension fund accumulation pattern which lasts until the age of retirement.

Most importantly, the model's ability to reproduce life cycle patterns makes it useful for policy purposes. By simulating health, real estate and financial shocks distinctly, the model allows to compute the US homeowners' optimal responses to different unpredictable or unexpected bad events. The simulations highlight that all three shocks have significant effects on the owners' decisions throughout their lives. Unsurprisingly, they decrease the net worth and postpone the full retirement age, but in different magnitudes. Additionally, the life cycle impact is bigger when the real estate market collapses. Indeed, a crisis on housing assets has stronger effects on the US homeowners' net worth, assets rebalancing and optimal time allocation decisions than one affecting financial assets[15] or

[15]The magnitude of the 2007 subprime crisis confirms this outcome.

one hitting health. The consequent impact is to blame for the low homeowners' portfolio diversification around 45 years old. Indeed, houseowners' wealth is mainly composed of real estate assets. Furthermore, comparing health and wealth shocks is very interesting because on one hand, the former constrains time allocation choices by cutting time endowment, but assets holdings have the same characteristics as before the shock. On the other hand, wealth shocks change the characteristics of the assets held, but leave completely unconstrained time allocation decisions.

Overall, the model proves that owners should optimally and rationally adjust their life cycle choices to minimize the negative effects of unexpected declines in health, pension, housing, savings, or other valuable assets. It is also worth to mention that the results presented depend on the assumption that the optimal allocations levels are achievable, which may not always be the case. For instance, in a period of economic crisis, the labor demand is usually low, making the rise of working time difficult for workers. Moreover, paying for end-of-life nursing home and long term care using real estate assets would have been a relevant households' choice to model. When agents sell their private home to finance a nursing home, they do not have to make the tradeoff between investing money or time in their home any more. Their time allocation and asset holdings therefore could improve the fit of the model. Other alternatives such as renting the house, or contracting a reverse mortgage are also possible and interesting, but out of the scope of the paper. Note that the model is tractable in the sense that different shocks can be simulated at the same time. Further analysis could allow for some degree of anticipation, with agents having expectations on the likelihood and amplitude of these shocks. An alternative could also include a coexistence between informed and uninformed agents. Finally, in this framework, I abstracted from medical expenses even though they are crucial for weakly health insured agents. Adding them for further research could complete the study.

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A Model Implementation Formulas

A.1 The Primary Insurance Amount (PIA)

The Social Security formula is defined as:

$$
\begin{aligned}
PIA_t = \min \big\{ & \alpha_1^{PIA} \min \left(AIME_t, Cap_1^{AIME}\right) + \\
& \alpha_2^{PIA} \max \left[0, \min \left(AIME_t - Cap_1^{AIME}, Cap_2^{AIME} - Cap_1^{AIME}\right)\right] + \\
& \qquad \alpha_3^{PIA} \max \left(0, AIME_t - Cap_2^{AIME}\right), PIA^{max} \big\}
\end{aligned}
$$

A.2 The Budget Constraint

The setup presented in this paper remains equivalent to the standard one used in the housing literature. The proof is derived from the standard budget constraint (BC) as follows:

$$
\begin{aligned}
P_t^h H_{t+1} + q_t b_{t+1} + c_t - y_t &\leq (1-\delta^h) P_t^h H_t + b_t \\
&\leq \frac{P_t^h}{P_{t-1}^h}(1-\delta^h) P_{t-1}^h H_t + q_{t-1} b_t \frac{1}{q_{t-1}}
\end{aligned}
$$

$$
V_t + c_t - y_t \leq R_t^{Hnet} P_{t-1}^h H_t + R^f q_{t-1} b_t = W_t = V_{t-1} R_t^P \tag{19}
$$

where P_t^h is housing price for tenure status h at time t, H_t is the number of housing units hold or rent, q_t bond price, b_t bond units held or sold, c_t the consumption, y_t the income, $V_t = W_t^H + W_t^b$ and $R_t^{Hnet} = \frac{P_t^h}{P_{t-1}^h}(1-\delta^h)$.

Then, from (19):

$$
\frac{W_{t+1}}{R_{t+1}^P} + c_t - y_t \leq W_t
$$

Hence, the BC can be written as a law of motion of the net total wealth invested in portfolio P:

$$W_{t+1} \leq [W_t - c_t + y_t] \, R_t^P$$

where $R_{t+1}^P = \frac{W_{t+1}}{V_t} = R_{t+1}^{Hnet} \frac{W_t^H}{V_t} + R^f \frac{W_t^b}{V_t} = R_{t+1}^{Hnet} \omega_t^H + R^f (1 - \omega_t^H)$

B Estimation Methods

B.1 Iterative step

Using the notation of Pelgrin and St-Amour (2016), let $Z = (W, W^r) \in \mathbb{Z}$ specify the discretized state space of dimension K_Z, $\epsilon^s \in \{0, 1\}$ the health shock, and $Q = (C, l^h, l^s, \omega^H) \in \mathbb{Q}$ the discretized control space of dimension K_Q. The dimensions of both spaces, as well as the minimum and maximum values for the state and control variables, are summarized in Table 4.

The iterative step is run separately for the two housing tenure statuses. It consists of numerically solving the model (12) by backward induction, via a Value Function Iteration (VFI) approach from age T_{max} to T_{min}:

$$
\begin{aligned}
V_t^h(Z_t) &= \max_{\{Q_t^h \in \mathbb{Q}\}} \mathcal{U}(Q_t, Z_t) + \beta E_t \left\{ V_{t+1}^h(Z_{t+1}) \mid Z_t \right\} \\
s.t.\ \ Z_{t+1} &= Z_{t+1}(Q_t, Z_t, \epsilon_{t+1}^s, R_{t+1}^e, R_{t+1}^P), \quad \forall\ Z_t = Z \in \mathbb{Z}
\end{aligned}
\tag{20}
$$

For all state space points and for $h = \{own, rent\}$, the optimal controls and welfare are computed, and later used in the simulation phase. The optimal solution set can be expressed as:

$$
\{Q_t^h(Z), V_t^h(Z)\}_{t=T_{min}}^{T_{max}}, \quad \forall Z \in \mathbb{Z}, \quad h \in \{own, rent\} \tag{21}
$$

B.2 Simulation step

To find the optimal life cycle path, I simulate K_I agents for each of the two tenure statuses and run K_N Monte-Carlo replications using together the optimal allocations (21), the health shock process (1), and the laws of motion (3) and (7). The simulation is performed for individuals aged T_{min} and over as follows:

1. The first state, for agent i of type h in simulation n, is initialized by randomly drawing from the observed population financial wealth level at age T_{min}, and by

setting pension wealth to its minimum value:

$$W_{T_{min}}^{h,i,n} \sim W^{DATA}, \;\; W_{T_{min}}^{r} = W_{min}^{r}$$

2. Then, from $t > T_{min}$ to $t = T_{max}$:

   - The optimal rules $Q_t^{h,i,n}$ and value function $V_t^{h,i,n}$ are evaluated at the state $Z_t^{h,i,n}$ by running a spline interpolation of the policy functions (21), previously linearly interpolated in the iterative process.

   - The morbidity shock is endogenously drawn from the generalized Bernoulli distribution:

   $$\epsilon_{t+1}^{s,h,i,n} \sim \{0,1\}|\lambda(Q_t^{h,i,n})$$

   - The risky asset returns and housing prices processes are generated by log-normal-distributed random variables as follows:

   $$R_{t+1}^{e,n} \sim Log - \mathcal{N}(\mu_e, \sigma_e), \;\; P_{t+1}^{n} \sim Log - \mathcal{N}(\mu_p, \sigma_p)$$

   - The state variables are updated:

   $$Z_{t+1}^{h,i,n} = Z_{t+1}(Q_t^{h,i,n}, Z_t^{h,i,n}, \epsilon_{t+1}^{s,i,n}, R_{t+1}^{e,n}, P_{t+1}^{n})$$

C Tables

Table 1: Asset Allocation and percentage share invested in equities for DC plans

Equity % in 401(k)	Age 20's	Age 60's	Average
0	0.09	0.16	
(0,20]	0.01	0.08	
(20,40]	0.02	0.14	
(40,60]	0.05	0.26	
(60,80]	0.19	0.16	
(80,100]	0.64	0.20	
Average	0.74	0.48	$\omega = 0.6$

Notes: Equities include equity funds, company stock, and the equity portion of balanced fund. Funds include mutual funds, bank collective trusts, life insurance separate accounts, and any pooled investment product invested primarily in the security indicated. Source: Tabulations from EBRI/ICI Participant-Directed Retirement Plan Data Collection Project. See ICI Research Perspective, "401(k) Plan Asset Allocation, Account Balances, and Loan Activity in 2012".

Table 2: Joint Survivor Annuity for a \$100'000 investment in 2010-2011

100% Joint Survivor Monthly Annuity for \$100'000 invested					
Age	01.01.2010	01.07.2010	01.01.2011	01.07.2011	Average
65	494	480	481	465	480
70	538	524	526	508	524
75	596	580	596	566	584.5
80	684	668	675	649	669
50% Joint Survivor Monthly Annuity for \$100'000 invested					
Age	01.01.2010	01.07.2010	01.01.2011	01.07.2011	Average
65	575	559	555	538	556.75
70	643	627	623	609	625.5
75	734	717	713	699	715.75
80	870	851	846	829	849
$\delta^m = 0.5$ and $\alpha^r = \frac{556.75 \times 12}{100000} = 0.06681$					

Notes: Source: www.immediateannuities.com/annuity-shopper/as-archive.html

Table 3: Data sources

Variable	Database (2010)	Description
W_t^H	SCF (file: rscfp2010.dta, var: houses)	Housing wealth is defined as the market value of the primary residence.
W_t	SCF (file: rscfp2010.dta, var: networth-retqliq)	Net worthcorresponds to the net total wealth, assets minus debt, except the one concerning retirement.
α_t^{own}	SCF (file: rscfp2010.dta, var: hhouses)	It is equal to the share of homeowners in the economy at age t.
W_t^r	SCF (file: rscfp2010.dta, var: retqliq)	Pension wealth is equal to the funds accumulated for retirement purpose.
l_t^h	ATUS (file: atussum_2010.dat, var: t02xxxx+t09xxxx)	Time spent on housing is defined as the share of time (in hours) when agents undertake interior/exterior cleaning, arrangement, decoration, building and repairing. Then, scaled in a way that the total time spent on housing, health, recovery and work is equal to 1.
l_t^s	ATUS (file: atussum_2010.dat, var: t01xxxx+t08xxxx +t12xxxx + t13xxxx)	Time spent on healthy leisure activities and illness recovery is defined as the scaled time when people practice mental or physical activities considered as good for health (e.g. sleeping, relaxing, listening to music, biking, running...), or when they receive healthcare services (e.g. going to the doctor, to hospital...).
w_t	MEPS (file: h142.dat, var: hrlywage)	Wages are hourly wages converted to an annual basis through a 40-hours per week and 52 weeks conversion.

Table 4: State and control spaces settings

Parameter	Value	Parameter	Value
W_{min}	0.001	W_{max}	2.5
W^r_{min}	0.00	W^r_{max}	0.45
C_{min}	0.00	C_{max}	0.45
l^h_{min}	0.00	l^h_{max}	0.17
l^s_{min}	0.40	l^s_{max}	1.00
ω^H_{min}	0.00	ω^H_{max}	4.5
K_Z	15^2	K_Q	15^4

Table 5: Calibrated parameters values, descriptions and sources

Parameter	Description	Value	Source
T_{min}	Minimum age	15.000	Data surveys.
T_{max}	Maximum biological age	100.00	Life tables, (Arias, 2014).
T^r	Normal retirement age (NRA)	65.000	U.S Social Security Admin.
R^f	Risky free asset gross return	1.0408	Federal Reserve Bank of St-Louis.
μ_e	Risky asset log-return mean	0.0790	S&P500 return 2010-2014.
σ_e	Risky asset log-return volatility	0.1870	S&P500, volatility 2010-2014.
ω	Risky asset share	0.6000	Table 1 and ICI (2014).
μ_p^{own}	Purchase log-return mean	0.0493	St.Louis FED, House Price Index for the United States.
σ_p^{own}	Purchase log-returns volatility	0.059	St.Louis FED, House Price Index for the United States.
μ_p^{rent}	Rent log-return mean	0.0302	St.Louis FED, Rent of primary residence 2010-2014.
σ_p^{own}	Rent log-returns volatility	0.0156	St.Louis FED, Rent of primary residence 2010-2014.
τ_t^w	Employee contribution rate	$0.05e^{0.02t-1}$	Literature on DC/401(k) contribution rates.
τ_t^f	Employer match rate	τ_t^w	Rule of dollar-for-dollar.
δ^m	% of the joint annuity bequest	0.5000	Table 2, EBSA (2013) and Hersh (2010).
X_{max}^r	Max. DC/401(k) contribution	0.1650	IRS (2009, 2010).
α_1^{PIA}	PIA formula's parameter 1	0.9000	SSA (2010, 2011).
α_2^{PIA}	PIA formula's parameter 2	0.3200	SSA (2010, 2011).
α_3^{PIA}	PIA formula's parameter 3	0.1500	SSA (2010, 2011).
Cap_1^{AIME}	Annualized AIME Cap 1	0.0900	SSA (2010, 2011).
Cap_2^{AIME}	Annualized AIME Cap 2	0.5462	SSA (2010, 2011).
PIA^{max}	Max. Social Security benefits	0.2827	SSA (2010, 2011).
α^r	Annualized annuity rate	0.0668	Table 2.
δ^{rent}	Renter depreciation rate	1	Assumption of the model.
α^H	Loan-to-value ratio	0.8	Literature on mortgages.

Table 6: Estimated parameters values and standard errors

Parameter	Value (Std. err.)	Parameter	Value (Std. err.)
	a. Health shocks		
λ_0	1.3003 (0.0503)	λ_1	0.1019 (0.0021)
λ_2	0.9003 (0.0546)	ξ	1.4004 (0.0408)
ϕ_0	0.0500 (0.0009)	ϕ_1	0.0058 (0.0004)
	b. Homeowner		
γ	3.0056 (0.0778)	ϵ	0.5289 (0.0101)
γ_m	3.2197 (0.0848)	μ_m	9.4466 (0.1963)
μ_H	1.1003 (0.0523)	μ_C	0.0801 (0.0007)
μ_l	1.5206 (0.0466)	β_0	0.0645 (0.0016)
δ_0	0.0248 (0.0009)		
	c. Renter		
γ	0.0000 (0.0001)	ϵ	0.5289 (0.0101)
γ_m	3.6750 (0.0879)	μ_m	0.0005 (0.0000)
μ_H	1.3300 (0.0381)	μ_C	0.2025 (0.0092)
μ_l	1.3002 (0.0315)	β_0	0.1501 (0.0033)

Table 7: Shocks parameters

Parameter	Value	Parameter	Value
		a. Health	
ϕ_0	0.3894		
		b. Housing	
μ_p	-0.0702	σ_p	0.2398
		c. Financial	
μ_e	-0.079	σ_e	0.374

Notes: For initial parameters values, see Table 5 and 6.

D Figures

D.1 Benchmark

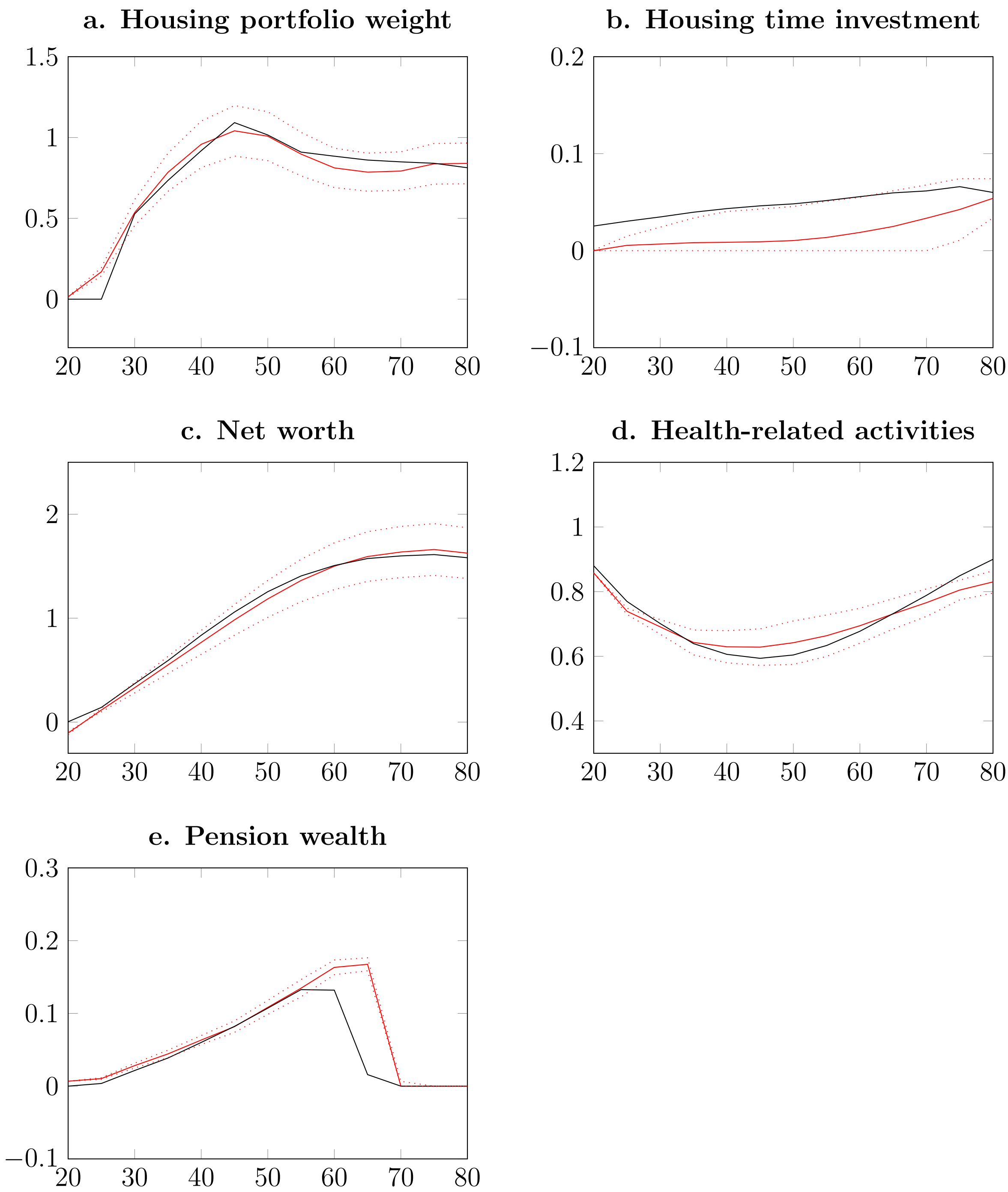

Figure 1: Life cycle simulated and observed allocations and statuses

Notes: Data: solid black line (—); benchmark: solid red line (—); 95% confidence interval: dotted red lines (·····).

D.2 Life Cycle Effects of Shocks

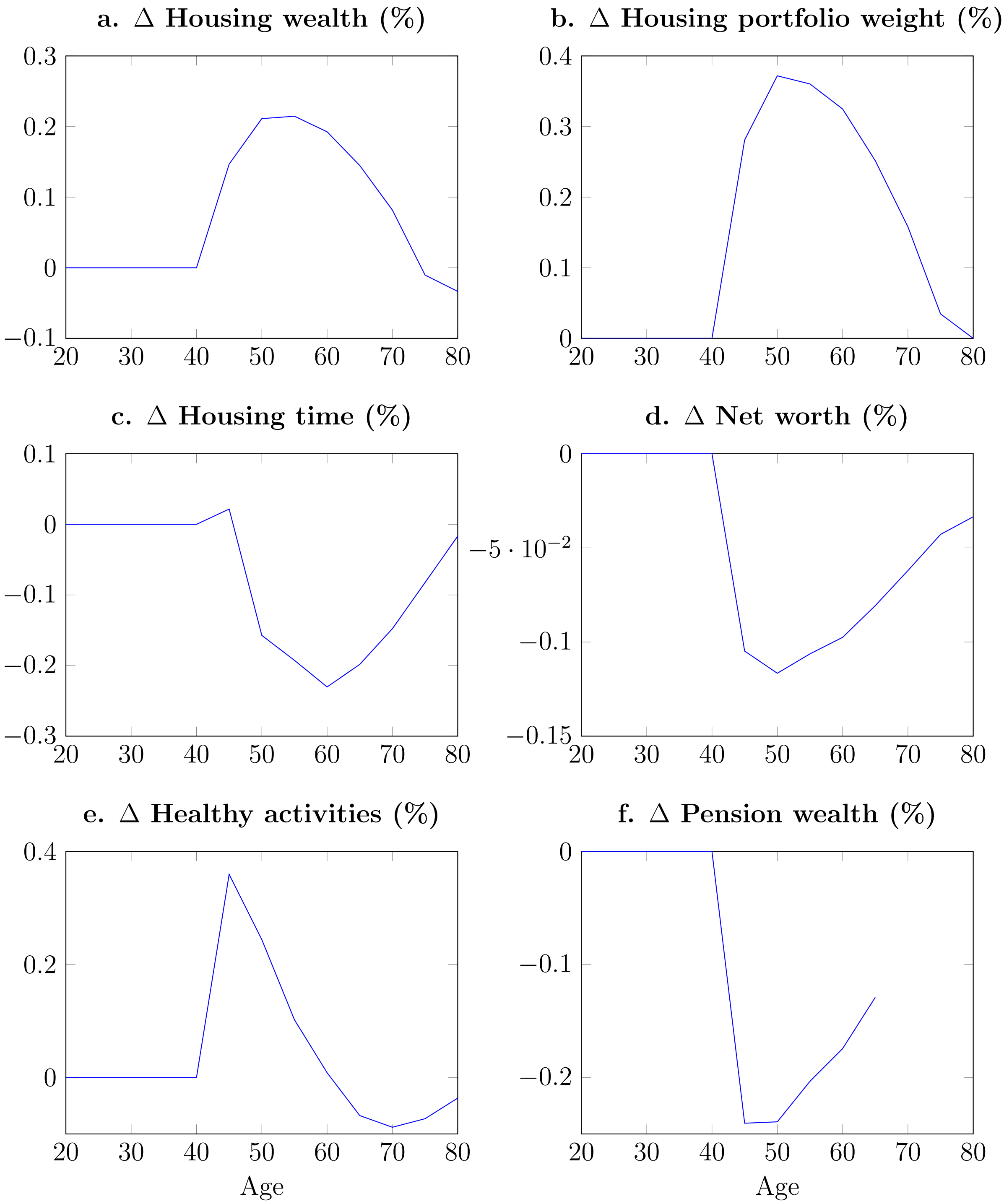

Figure 2: Effects of health shocks on the homeowners' life cycle allocations

Notes: Life cycle (LC) percent variations implied by a 5-years health (He) shock happening at 45 years old ($\frac{LC^{He-shock}-LC^{bench}}{LC^{bench}}$).

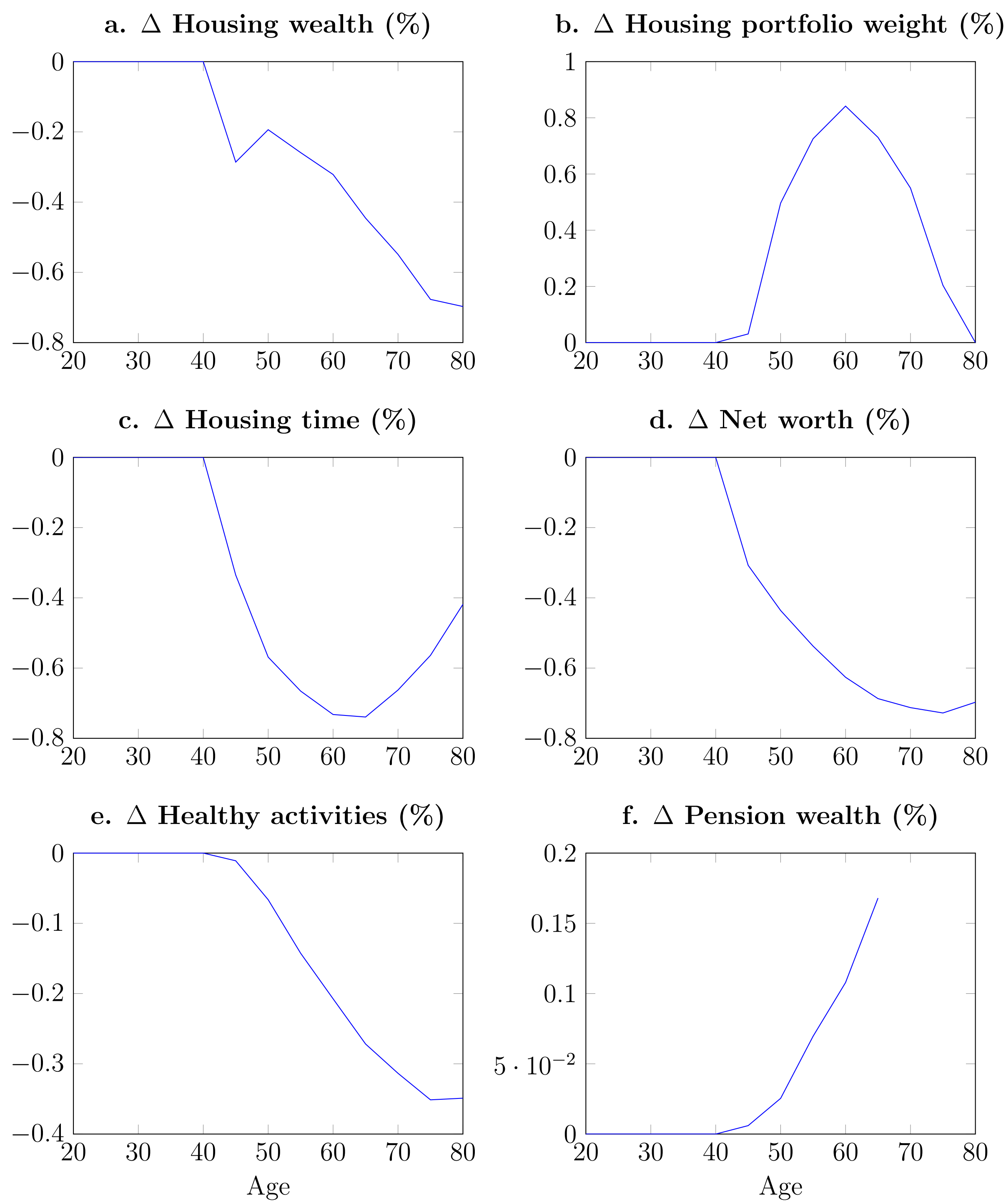

Figure 3: Effects of housing shocks on the homeowners' life cycle allocations

Notes: Life cycle (LC) percent variations implied by a 5-years housing (Ho) shock happening at 45 years old ($\frac{LC^{Ho-shock} - LC^{bench}}{LC^{bench}}$).

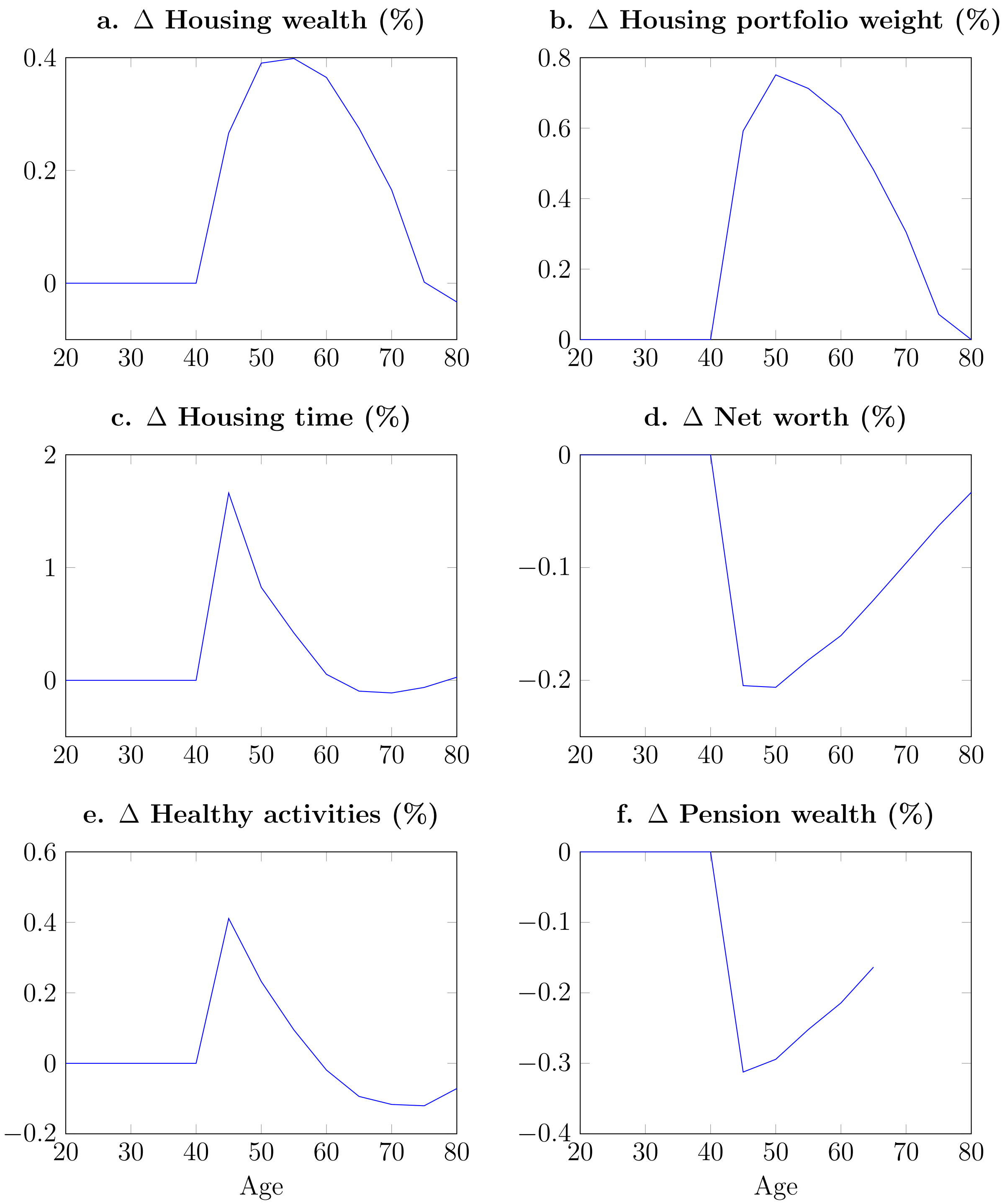

Figure 4: Effects of financial shocks on the homeowners' life cycle allocations

Notes: Life cycle (LC) percent variations implied by a 5-years financial (F) shock happening at 45 years old ($\frac{LC^{F-shock}-LC^{bench}}{LC^{bench}}$).

Effects of Financial Literacy on Financial Inclusion: Evidence from Pakistan*

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Abstract

Literature has shown that financial inclusion is beneficial for welfare. Despite the attempts to develop the formal financial sector, Pakistan still faces a high formal financial exclusion (Global Findex - World Bank). This paper examines the impacts of conventional (i.e. man-made law) and Islamic (i.e. Sharia rules) financial literacies on the Pakistani households participation in the formal and informal financial sectors. It uses a non recursive simultaneous equations probit model based on the 2015 Access to Finance - Pakistan survey (Horus – Gallup Pakistan). Overall, I find that the conventional financial literacy positively and strongly affects the use of formal financial services, while the Islamic financial literacy has a weaker positive impact. Moreover, both types of financial knowledge decrease the participation in the informal market, especially when it comes to the Islamic financial proficiency. I conclude that financial literacy programs such as the Nationwide Financial Literacy Program (NFLP) could be relevant to reduce financial exclusion.

Keywords: Financial Inclusion, Conventional and Islamic Financial Literacy, Formal and Informal Financial Services, Feedback Effects, Non Recursive Simultaneous Equations Probit Model.

JEL classification: C39, D14, G21, G23, G28 I28

1 Introduction

The effects of financial development on economic growth has been widely studied in literature (Patrick (1966); Demetriades and Hussein (1996); Hassan et al. (2011) among others). Access to formal finance[1], and more precisely financial inclusion (i.e. access to and use of formal financial services), has been proven beneficial for households welfare (Burgess and Pande (2005); Tita and Aziakpono (2017)) and firms growth (Rahaman (2011); Adomako et al. (2016) among others). Indeed, Demirgüç-Kunt and Singer (2017) state that financial inclusion affects intra- and inter-temporal spending and financial choices, and therefore makes it easier for agents to transfer resources through time, to smooth-out consumption levels, hedge against financial, income, or health shocks, and increases the likelihood of investing in education and business. Households also benefit from being formally financially included because formal products have a higher efficiency (smaller cost and higher speed), a better safety (lower risk of theft and default) and more transparency (existence of official records) relative to informal services.

These benefits justify the intervention of the World Bank and Consultative Group to Assist the Poor (CGAP) to improve the welfare of agents by promoting formal financial inclusion in developing countries. To provide measurement, they develop financial inclusion indicators (Access, 2009; Demirgüç-Kunt and Klapper, 2012). Other international organizations such as the International Monetary Fund (IMF) and the United Nations (UN) also fight against financial exclusion[2]. They develop different solutions to promote and improve the use of financial services such as advising financial services providers and policy makers.

The level of financial literacy is closely linked to financial inclusion and welfare. According to Mandell (2006), financial literacy is defined as "what people must know in order to make important financial decisions in their own best interest". Agents with

[1] Ledgerwood (1998) defines formal financial institutions as organisms that "are chartered by the government and are subject to banking regulations and supervision.".

[2] According to Sinclair (2001), financial exclusion is "the inability to access necessary financial services in an appropriate form. Exclusion can come about as a result of problems with access, conditions, prices, marketing or self-exclusion in response to negative experiences or perceptions.". See also (Claessens et al., 2009).

poor financial knowledge are less likely to make optimal financial choices (Hilgert et al., 2003; Lusardi, 2008) because of poor money management skills, and might even achieve overwhelming debt situations that increase their likelihood of being financially excluded in future decisions.

Despite remaining a poor and rural country, Pakistan has progressed with respect to financial inclusion. For instance, in the 1960s as in India, many banking branches were opened, to reach more than 3000 branches in the 1970s, period in which banks became national, leading to very inefficient services in the next years. At this time, the informal finance strengthened because it was the only one serving rural area and non wealthy households. Banks were privatized in the 1990s, contrary to India for instance, and the State Bank of Pakistan (SBP) was seen as the only banking regulator. However, as of today, banks still face high rates of non performing assets. Recently, the US embassy assessed the Pakistani banking system and concluded that a major transition is happening, with new formal market players, and a financial development occurring at the household level. Branchless banking, ATM and mobile money are at the center of the SBP's policy. As reference, Ahmad et al. (2010) detailedly reviewed the historical background of the banking/financial sector in Pakistan, from independence to nowadays.

The context of Pakistan is particular because it is a Muslim country, in which religion potentially affects agents' financial decisions (Demirgüç-Kunt et al., 2014). While the supplies of traditional, micro and mobile[3] financial services have been developing in the past years, the rate of financial exclusion remains high. With only 14% of Pakistani households using formal financial services[4], and with an index of financial inclusion (IFI[5]) equal to 0.109 in 2010, Pakistan belongs to the lowest formally financially-included countries in the world. Various reasons are mentioned by Pakistanis for the opening of bank accounts. Above all, they open accounts to receive money from employers or from personal businesses (61.44%) and to save money (33.73%). However, bottlenecks are numerous and mainly indicative of self-exclusion reasons. First, 44% of households declare

[3]Financial services that are provided through mobile phones.

[4]Source: 2015 Pakistan Access to Finance survey.

[5]See Sarma et al. (2008).

a lack of knowledge about banks and 35% about bank accounts. In addition, about 25% say that an account would not bring them any advantages and 17.7% think that they do not have enough money to open one. Other possible reasons are the eligibility criteria such as providing necessary papers to open an account or the collateral constraint to get a loan.

Unsurprisingly, theses rates of low financial literacy and high financial exclusion go hand in hand with an informal financial sector[6] coexisting with the formal one. The data show that a high proportion of households (around 58%) use informal services in the economy. These transactions are hardly monitored since there are no official records. Because of this coexistence, the study is challenging if both types are to be jointly modeled. One of the main interactions highlighted by literature is the crowding out effect (McKernan et al., 2005). The latter occurs when an increase in the access to formal (informal) finance decreases the use of informal (formal) financial services. Therefore, in such a context, a household-level survey on the joint demand for both formal and informal financial services is essential to assess consumer financing choices.

Moreover, conventional and Islamic banking are two very different financial systems. While the former is man-based law and profit-oriented, the latter is based on the Islamic law (Shariah). Since the 1950s, the Islamic religion has rules to regulate finance (Ala Maudoodi, 1979), stating that any financial transaction has to be Shariah compliant, i.e. in accordance with the Islamic law. This means respecting some rules such as the prohibition of paying/receiving interest, the control of the industry in which the investment is made (e.g. alcohol businesses are forbidden), and finally the split of profits and losses between lenders (i.e. stakeholders) and borrowers (i.e. clients). Among the mechanisms used, there are mainly i) Mousharaka, ii) Mourabaha, iii) Ijara, iv) Sukuk and v) Istisna. They are respectively equivalent to a situation in which i) the money lender is a shareholder, ii) the financial institution buys the goods and directly sells it to the client with a premium, iii) the good is rented, iv) a bond with fixed and risk-free interest, and v) a customer signs a construction contract for a pre-determined amount

[6]In Pakistan, available financial services can be either formal (e.g. checking account, (micro-) credit) or informal (e.g. cash stored at home, cash advances from retailers).

of money. However, some researchers and philosophers complain about these products by stating that they are just disguised conventional finance instruments. On the other hand, under the conventional finance legislation, money is a product that gives interest and there is limited risk sharing between banks stock and deposit holders. Their ways of working and being used involve different knowledge and beliefs. Distinguishing the two is important, especially in a strong Muslim context such as Pakistan.

My objective is to evaluate the effects of conventional and Islamic financial literacies on the use of both formal and informal financial instruments. I achieve this by building a non-recursive simultaneous equations model with endogenous dummy variables. It includes all participation in the formal and informal financial services (e.g. checking/savings accounts, micro-credit, Islamic finance products, cash held at home, cash advances from retailers, family/friends loans and others) merged in two distinct groups, i.e formal and informal. I estimate it using the method of Full-Information Maximum Likelihood (FIML). The model relies on unique data from the 2015 Access to Finance - Pakistan survey. This survey is composed of data on access to finance for Pakistani households, especially their use of financial services. It was conducted in early 2015 on more than ten thousand households across the four provinces of Pakistan (Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh). Hence, it gives a unique opportunity to analyze the relation between different categories of financial literacies (conventional and Islamic) and different types of financial inclusion (formal and informal).

This study relates to two axes of literature. First, it contributes to the identification of the effects of financial literacy on households financial behaviors by distinguishing conventional from Islamic financial knowledge, and by endogenizing financial decisions. Second, it assesses the effects of literacies not only on the formal financial inclusion but also on the informal financial sector participation through feedback effects modeling. Hence, the framework avoids potential simultaneity biases, permits indirect effects and common shocks, and questions the relevance of financial literacy programs.

The main results are the following. First of all, the model validates the hypothesis that levels of financial literacy positively impact the formal financial inclusion of Pakistani households, although the Islamic financial literacy has a weaker effect than the conventional one[7]. Furthermore, Islamic financial literacy negatively affects the likelihood of Pakistani households to use informal financial products. The effect is particularly strong, implying that Islamic banking may be a good substitute for the informal financial sector, in particular if Pakistanis share the belief that the informal sector does not respect Islamic finance principles. Finally, these results tend to confirm that financial literacy programs such as the one run by the State Bank of Pakistan (NFLP) are relevant in a formal financial inclusion policy trying to intervene on the demand side of financial markets.

The rest of the paper is organized as follows. Sections 2 and 3 respectively provide a literature review and an overview of the data used in the analysis. Section 4 presents the model specification and the estimation method. The empirical findings are reported in section 5. Finally, Section 6 concludes.

2 Literature review

The effects of accessing finance on income and the importance of formal financial inclusion for growth and households welfare[8] have been widely studied. Improving access usually reduces income inequality, and poverty in general (King and Levine (1993); Giné and Townsend (2004); Beck et al. (2007); Beck and Demirgüç-Kunt (2008); Bauer et al. (2016); Demirgüç-Kunt and Singer (2017) among others). In addition to income, some studies focus on consumer spending. For instance, Seck et al. (2017) highlight that access to finance participates in the increase in Nigerian households' consumption. Conversely, accessing credit does not improve households consumption smoothing in Ghana (Annim et al., 2011). Interestingly, Cole et al. (2011) show that bank accounts and formal credits are used more often when households consumption levels are higher, both in India and Indonesia. Allen et al. (2016) emphasize that financial inclusion reduces banking costs

[7] The exogeneity assumption of financial literacy unfortunately limitates the strength of the model because of the lack of good enough instruments to run an IV estimation. Therefore talking about causality is delicate. This is further discussed in Section 4 and 6

[8] To obtain policy-oriented details, you can refer to the review on access to finance written by Claessens (2006).

and makes the political environment more stable, among other findings. However, none takes into account that financial services and consumption might have some feedback effects mitigating a strong unilateral causality relation, and causing endogeneity through a simultaneity bias.

It is not only traditional banking that improves people's well-being, microfinance and mobile money accounts have also strongly helped in the last two decades, especially in developing countries. It has also been shown that microcredit contributes to poverty reduction (Khandker, 2005). Yet, researchers debate about its effects on consumption and welfare. While Mahjabeen (2008) finds that microfinance institutions increase income and consumption levels, Morduch et al. (1998) show that households eligible to borrow through a microfinance program do not consume more than others. Actually, the main criticism is about the targeted population and eligibility of microcredit programs. Scully (2004) and Simanowitz (2002) depict how extremely underprivileged poor people are left aside from the programs. As in traditional finance, Ciravegna (2005) highlights self-exclusion issues. It is also worth to mention that microfinance can play an insurance role by mitigating the negative effect of health shocks on consumption and income (Islam and Maitra, 2012). For more details, Brau and Woller (2004) and Hermes and Lensink (2011) review articles about microfinance. Moreover, Donovan (2012) analyses the benefits of deploying mobile money solutions, and Must and Ludewig (2010) show how mobile money can reduce poverty. In many countries this technology has grown, notably in Kenya (Jack and Suri, 2011). The advantages of mobile bank accounts over traditional ones are mainly the reduction of infrastructure costs, ease of implementation (wired vs. antenna), access and only owning a mobile phone as eligibility criteria.

The literature on the supply side of financial services is well developed and found several key variables that drive supply (Levine, 2005). However, on the demand side determinants are not well understood, making it an active research area. Economists have proved that many individual characteristics affect household financial behaviors (Honohan and King (2012); Demirgüç-Kunt and Klapper (2013); Fungáčová and Weill (2015) among others). These individual characteristics condition agents' eligibility (e.g. collateral constraint) and self-exclusion (e.g. beliefs). More precisely, Cámara and Tuesta (2015) use a quantitative approach on Peruvian data to show that individual characteristics such as gender, age or types of human settlement matter for financial inclusion. Wachira and Kihiu (2012) exhibit that Kenyan households' access to finance is a function of age, education, income, gender, distance from banks, marital status and other personal attributes. Some studies focus on the credit instruments (Diagne, 1999; Barslund and Tarp, 2008) and remittances. Ambrosius and Cuecuecha (2016) find positive effects of remittances on different formal savings and borrowing using household-level data from Mexico. As for Demirgüç-Kunt et al. (2014), they demonstrate that Muslims are less likely to own a formal account than non-Muslims, although this conclusion does not hold with respect to formal or informal borrowing. Although these are useful contributions for policy purposes, the simultaneity biases could arise from joint spending and use of financial instruments decisions, or between formal, informal or both types of financial services. An attempt was made by Bendig et al. (2009) who estimate a multivariate probit model with three formal services on household survey data from Ghana. They reveal that wealth positively determines the households likelihood of using formal financial services and that the participation depends not only on socio-economic characteristics but also on household's potential risks and exposure to past shocks. However, they do not include spending and informal financial decisions in the estimation procedure.

Financial literacy has extensively been studied, especially its effects on households financial behaviors. Lusardi and Mitchell (2014) review theoretical works which include financial literacy as a certain type of human capital investment, and empirical studies assessing the effects of financial literacy on consumer behaviors. This literature shows that financial knowledge has a positive effect on households' participation in financial markets (e.g. Cole and Shastry (2008); Van Rooij et al. (2011)), diversification (Gaudecker, 2015), individual saving and borrowing (e.g. Lusardi (2008); Jonubi and Abad (2013); Doi et al. (2014); Jamison et al. (2014); Brockman and Michayluk (2015)), retirement planning (Lusardi and Mitchell, 2007b, 2009, 2011). Furthermore, Klapper et al. (2013) prove that households financial market participation increases with financial literacy. On the other hand, some papers argue that financial literacy is not a strong determinant of financial inclusion (Wachira and Kihiu, 2012; Lyons et al., 2017). Finally, very few papers examine financial literacy in Pakistan. As example, Ghaffar and Sharif (2016) highlight that Pakistani households with financial knowledge tend to save more money than the financially illiterate ones.

A non negligible literature strand concentrates on formal and informal financial services. Klapper et al. (2013) emphasize that financial knowledge decreases the use of informal financial services. A major effort has been made to understand the mechanisms linking formal and informal financial services, more particularly on the understanding of the crowding out effect (Morduch (1999); McKernan et al. (2005) among others). In addition, Carpenter and Jensen (2002) investigate the use of formal and informal saving instruments in Pakistan to find that even poor and rural households use conventional banking to some extent, and that policies should focus on literacy and numeracy programs. Guirkinger (2008) and Madestam (2014) study the coexistence of formal and informal credits. They respectively find that the informal sector is used by any type of household, and that the degree of substitution between formal and informal loans depends on the bargaining power of banks. However, they abstract from non-credit financial services, such as checking/savings accounts[9].

3 Data

In this section, I describe the data source and show some descriptive statistics. Then, I provide more details about the relevant variables used to estimate the model.

3.1 The survey

The data come from the unique survey named Access to Finance Study Pakistan - Questionnaire. This survey was conducted in early 2015 jointly by Horus Consulting and

[9]Note that Collins (2005); Ellis et al. (2011); Demirgüç-Kunt and Klapper (2012) document the use of any formal/financial instruments, respectively in South Africa, Kenya and in 148 countries. However, these papers are limited to descriptive analyses.

Gallup Pakistan for the State Bank of Pakistan, and is based on more than ten thousand households interviewed across the four provinces of Pakistan (Baluchistan, Sindh, Punjab, and Khyber Pakhtunkhwa). One objective is to provide information to Pakistani banks about Pakistani households' use and satisfaction with financial services. Because more than 30% of the Pakistani households are totally financially excluded, and only around 15% use any formal financial services, the State Bank has two goals. First it seeks to gauge the evolution of the access to finance during the last years, and second to achieve a deeper understanding of the factors explaining the low demand for financial services, especially when other countries nearby have substantially higher demand for formal services[10]. The survey description tells us that the aim is to improve financial inclusion to boost economic growth and households' income. The survey mainly contains information about households' financial literacy, bank and mobile account owners and non-owners, expenses, borrowings and savings, remittances and income. The methodology of the sample design is well established and the sample is representative with an error margin of 1% at the 95% confidence interval level. The sample quality is ensured by the use of standard survey statistical procedures, interviewer trainings, and control of data collection and entry.

3.2 General descriptive statistics

The questionnaire has the conventional socio-economic and demographic descriptions about the respondents and households characteristics such as age, gender, type of living area, province, marital status, education, occupation, and living conditions. Table 10 reports the main statistics. The average respondent age is 36 years old, the female-male ratio equals 0.7241, 67.07% live in rural areas, 85.9% are married. While 95.97% have an easy access to drinking water infrastructure, 61.02% own a refrigerator, 65.70% a mobile phone, 72.89% a motorized vehicle and 88% a TV. Notice that about 30% of households are composed of large family units, with more than 9 individuals. In addition, we learn that less than 7% of respondents have a high level of education (i.e. at least

[10]For instance, according to Gallup, by 2008, only 1% of Pakistanis use micro credit, while 35% of the population use it in Bangladesh and 25% in India.

graduated from college). Only about 1% hold an insurance contract, while 37.94% report being exposed to job/business, 26.12% health, 23.81% thief and 14.08% destruction risks. Furthermore, 4.83% already faced a food shock in the last 12 months, and 5.35% about utility bills. Remittances rates are equal to 4.25% for sending and 3.1% for receiving money.

Figure 1 exhibits the access to finance by occupation. Housewives, unskilled workers and students are the least formally included and the most financially excluded overall, whereas high skilled workers, farmers and retired people are the most formally financially included. Shop and business owners with unskilled workers as well, belong to the least financially excluded categories, and are the most informally financially included.

Finally, Figure 3 provides information on the categories of expenditures. More than 94% of the respondents declare daily life spending, 50.51% for education and 18.17% for health expenditures. 96.64% had at least one of the three types of expenses in the last 12 months, and 66.16% had either education, health or both. Besides, 27.32% of households acknowledge to have both daily life and health expenses, 17.62% when it comes to education and daily life, and less than 4% when it is about incurring education and health.

3.3 Key Variables

The survey highlights that cash payments are prevalent in Pakistan, the main savings method is by keeping cash at home, borrowing is not widespread, and that the retailers are the main credit providers. Importantly, Figure 2 shows that about 15% of individuals are formally financially included (variable I^F), 58% are informally included (variable I^I), and 33% are totally excluded from the use of financial services. The types of financial services are constructed using the survey questions reported in Tables 5, 7 and 8. The households possession of any accounts, savings and borrowing are categorized to get the formal (e.g. bank accounts, bank loans) and informal (e.g. family and friends loans, cash advances from shopkeepers) financial types (Appendix A). Furthermore, formal financial services are used sparingly. According to the questionnaire, about 88% of households do not have any traditional checking or saving bank accounts, and about 96% do not have any formal borrowings. Only 3.69% of households hold formal loans, while 14.84% have informal ones. Importantly, half of the respondents use informal ways to save money.

Another important section of the survey is the one about financial literacy, from which is learnt that while 23% of Pakistani households have both low financial and Islamic finance literacy, only 2.28% have high ones. Table 2 shows variables $FINLIT$ and ISL_FINLIT, standing respectively for conventional and Islamic financial literacies. Most of the respondents have a medium conventional financial knowledge (more than 71%) whereas less than 5% have a high one. 68.7% do not have awareness of Islamic finance and 7.8% know a lot about it. The two variables are constructed using a specific question (Table 9) about the knowledge of conventional (e.g. ATM, credit card) and Islamic (e.g. Takaful, Mudaraba) financial-related words. The measures are proxies for financial literacies, with scores based on the subjective answers of households (Appendix A). Conventional financial literacy is low for score above 28, medium if the score is between 12 and 27 and high if below 13. Islamic financial literacy is constructed in the same way but with different thresholds (respectively 9, 6 and 10, and 7). Notice that even if this survey is unique, some questions unfortunately remain too basic to obtain the highest robustness. For instance, literacies are based on personal opinion and not on an objective examination. Therefore, an over confidence problem affecting households' answers may exist.

Table 3 gives a correlation matrix between the two types of literacies and the two categories of financial services. The literacies and services are positively correlated, especially with formal financial inclusion (0.1953 and 0.1715 respectively for financial and Islamic financial knowledge). The correlation coefficients of the informal sector are close to zero. Finally, a crowding out effect is apparent between formal and informal services since their correlation coefficient is negative (-0.1427).

This descriptive analysis confirms the Pakistani households' financial exclusion, especially from the formal services, and motivates to question the impact of financial literacy on households participation in financial markets, i.e. financial inclusion, while caring about the feedback effects between the types of financial services. Indeed, non null correlation coefficients from Table 3 encourage to formally test the relation between financial literacies and services. To provide a further analysis, I use statistical inference methods presented in the next section.

Additional information about the data construction can be found in Appendix A and Tables 5 to 9.

4 Empirical modelling framework

This section discusses the econometric model specification, identification and estimation procedure. I construct a simultaneous multivariate probit[11], composed of the two categories of financial services (i.e. formal and informal). The framework is based on the general model of Nelson and Olson (1978). It allows for non recursion between multiple structural equations and respects the logical consistency condition without requiring constraints on coefficients of the endogenous variables[12]. Only exclusion restrictions characterizing SEM-type models are imposed and reported in Appendix B. The estimation procedure is based on the standard Full-Information Maximum Likelihood (FIML) method.

4.1 The model

4.1.1 Structural form

Let's define $Y_l = \{I^F, I^I\}$ observed dependent dichotomous variables and Y_l^* the corresponding latent variables with I^F, I^I being formal and informal financial services. Let also μ be a zero vector of dimension $L \times 1$, and Σ a $L \times L$ covariance matrix of variance 1 and covariance terms ρ_{jk}. The simultaneous L-equations probit model can be written

[11] See Heckman (1978), Nelson and Olson (1978) and Amemiya (1978) among others.

[12] Nelson and Olson (1978) proved that by using the latent form of the endogenous variables in the right-hand side, no constraints are required on endogenous variables coefficients.

as:

$$Y_{nl}^{*} = X_n B_l + \sum_{\substack{i=1 \\ i \neq l}}^{L} Y_{ni}^{*} \alpha_{il} + FINLIT_n \times \beta_l^{FIN} + ISL\_FINLIT_n \times \beta_l^{ISL} + \varepsilon_{nl} \quad (1)$$

$$Y_{nl} = \begin{cases} 1, & \text{if } Y_{nl}^{*} > 0 \\ 0, & \text{otherwise.} \end{cases} \quad (2)$$

where $n = \{1, ..., N\}$, $l = \{1, ..., L\}$, $\varepsilon = (\varepsilon_1, ..., \varepsilon_L) \mid X \sim \mathcal{N}(\mu, \Sigma)$ is a random multivariate Gaussian process of mean μ and covariance Σ, X_n is the 1 by K vector of exogenous variables, $FINLIT_n$ and ISL_FINLIT_n are exogenous conventional and Islamic financial literacies with associated coefficients β_l^{FIN} and β_l^{ISL}. The exogeneity assumption could be problematic. For instance, households may have access to banking learning programs after opening a bank account. Therefore being financially included may increase the probability of being financially educated. Indeed, one of the limitations of the model is that we unfortunately do not have access to good instruments to run robust IV estimations. This would have helped to solve the potential reverse causality. Many papers also struggle with the potential endogeneity of financial literacy and try to use some instruments (e.g. Lusardi and Mitchell (2007a); Fornero and Monticone (2011)). The instruments they refer to are unfortunately not available or good enough for this paper[13]. Also notice that they all are analyzing developed countries, while the story could be different in Pakistan, a developing Muslim country. To address the endogeneity of literacy, a Durbin-Wu-Hausman's test was performed and did not reject the null hypothesis of exogeneity of both conventional and Islamic financial literacies. Finally, B_l and α_{il} are respectively a K-vector and a scalar of unknown parameters associated to equation l.

Interestingly, in (1), the endogenous dependent variables also appear in the right-hand side, corresponding to the non recursion feature of the model and allowing to avoid the simultaneity bias. Because a crowding out effect might occur between the two finan-

[13]For instance, education level, distance to bank, use of computers have been tried without success.

cial sectors, their relations must be modeled by taking into account the two-way causal relationship to prevent the potential endogeneity induced by simultaneity biases. The coefficients α_{il} inform about the crowding out effects between the types of financial services I^F and I^I.

In addition, the model permits autocorrelation between error terms, i.e. non-zero error covariances. Empirically, this feature is reflected in common causes of the residual terms. Correlated errors between formal and informal financial services could be a liquidity crisis or the result of an interest rates policy. The ones between the types of consumption may depict a global rationing on goods and services.

4.1.2 Restricted reduced form

The restricted reduced form corresponding to the econometric model (1) can be written in the following matrix notation:

$$Y^* = XBA^{-1} + FINLIT \times \beta^{FIN} A^{-1} + ISL\_FINLIT \times \beta^{ISL} A^{-1} + \varepsilon A^{-1} \qquad (3)$$

where Y^* is a $N \times L$ matrix, X a $N \times K$ matrix of observed exogenous variables, A and B respectively $L \times L$ non singular and $K \times L$ matrices of unknown parameters. $FINLIT$ and ISL_FINLIT are two $N \times 1$ matrices associated to the two $1 \times L$ vectors of parameters β^{FIN} and β^{ISL} to estimate.

4.2 Estimation

The non recursive system of probit equations is estimated using the Full-Information Maximum Likelihood method (Davidson and MacKinnon, 1995). This estimation is challenging because all the observed endogenous variables are categorical. The system is therefore multivariate probit and does not have an analytical solution. In addition, it accounts for the simultaneity between the latent variables, and the correlation between error terms across equations, making the system non recursive.

The log-likelihood to maximize is therefore given by:

$$\ln \mathcal{L}\left(\Gamma, \tilde{\Sigma}; Y \mid \tilde{X}\right) = \sum_{n=1}^{N} \omega_n \ln \Phi_L \left[q_n \circ \tilde{X}_n \Gamma; \tilde{\Sigma}\right] \tag{4}$$

where Φ_L is the L-dimensional multivariate normal distribution with mean μ and covariance matrix $\tilde{\Sigma} = A'^{-1}\Sigma A^{-1}$, $\tilde{X} = [X \quad FINLIT \quad ISL\_FINLIT]$ is a $N \times (K+2)$ matrix, ω_n is an exogenous observation weight, $\Gamma = \tilde{B}A^{-1}$ the matrix of unknown coefficients in the reduced form model where $\tilde{B} = \left[B' \quad \beta^{FIN'} \quad \beta^{ISL'}\right]'$ is a $(K+2) \times L$ matrix, and $q_n = 2Y_n - 1$ a $1 \times L$ vector.

During the estimation process, I experimented with various optimization algorithm and also controlled for many variables (e.g. age, education gender, income, remittances) to make the results as accurate as possible, while ensuring that order, and necessary and sufficient rank conditions specific to SEM models are met. A complete description of the control variables is given in Appendix C.

5 Empirical results

I report the estimated marginal effects and robust standard errors in Section 5. Table 11 reports the independent probit in Column (1) and the SEM probit allowing feedback effects between financial sectors in Column (2). I firstly analyze the effects of the conventional financial literacy on financial inclusion. Then, I focus on the impacts of the Islamic financial literacy on households participation into financial markets.

5.1 Marginal effect of conventional financial knowledge on financial inclusion

In this section, I investigate how the conventional financial literacy, i.e. the degree of knowledge of formal financial services, affects the probability that Pakistani households use formal and/or informal financial services after controlling for many other variables. Two different approaches are used and presented below, with the second one correcting major flaws of the first model.

By looking at specification (1) in Table 11, we observe that higher levels of conventional financial literacy significantly increases the probability that Pakistani households use formal financial services at the 0.001 significance level. From low to medium literacy, the probability of using formal instruments increases by 9.8%, and from low to high knowledge the increase equals 16.64%. However, the effect is not significant with respect to informal services. These first observations suggest that by investing in conventional financial literacy programs, households' likelihood to use formal services will increase. However, this specification might have three weaknesses. First, there are no feedback effects between the formal and informal use of financial services, meaning that the potential crowding out effect between the two financial sectors is not modeled and might lead to biased estimates. Second, households spending is treated as exogenous variables whereas there could exists two-way relations between the spending and financial decisions. Third, the disturbance terms are not correlated. This is a strong and potentially unrealistic assumption since the two financial sectors might be affected by common shocks.

The SEM specification (2) is the most complete and preferred model. It improves the independent probit model by taking into account the feedback effects between formal and informal financial services, and by adding correlation between the error terms. This model also rejects the null hypothesis that the conventional financial literacy does not influence the households participation in the formal sector at the 0.001 level. It reveals that households with an average financial literacy have 10% more chance to use the formal financial services compared with low financially literate ones. This probability increases to 16.66% when we look at the high financial literacy agents. Again, the effects of financial literacy on the use of informal tools are not significant. Yet, the estimated coefficients (for medium and high literacy) are both negative.

Hence, improving the conventional financial understanding of Pakistani households makes them more likely to use the formal financial services and barely to give up the informal sector, even after controlling for the feedback effects between the two financial sectors.

5.2 Marginal impacts of Islamic financial literacy on Pakistani households participation in financial sectors

In this section, I concentrate on the effects of Islamic financial literacy on the likelihood that households use formal and informal financial products.

From Column (1) in Table 11, we see that the effects of being averagely and highly Islamic financially literate on the probability of using formal instruments are both positive and significant, respectively 1.88% at the 1% level and 9.25% at the 0.1% level. However, the change in likelihood for the informal products is not rejected only for the higher level of Islamic financial literacy. Indeed, households with a high Islamic financial literacy are 15.31% less likely to use the informal sector, in contrast to low level agents.

In the second model reported in Table 11, Column (2), the null hypotheses that the medium and high Islamic financial knowledge do not influence the use of formal financial services are rejected, respectively at 5% and 0.1%. The probability of participating to the formal sector increases by 1.85% for households with a medium literacy and by 11.43% for those with a high knowledge compared with low Islamic financially literate households. As for the null hypotheses regarding the informal services, they are not rejected. Yet, the marginal effect coefficient associated to the high Islamic financial literacy is negative.

5.3 Robustness checks

As robustness check, I tested a specification where an interaction term between the two types of literacies is added to model (1) and (3). This term captures the potential interaction between conventional and Islamic knowledge.The effects of conventional financial knowledge have the same sign and significance level on the use of formal (0.1018^{***} vs. 0.0994^{***} and 0.1702^{***} vs. 0.1612^{***}) and informal financial tools (-0.0423^{**} vs. -0.0726^{*} and -0.0268 vs -0.1188). If we look at the effect of being Islamic financially educated on formal financial inclusion, again coefficients are close and mostly remain in the same significance thresholds to the ones previously found (0.0174^{*} vs. 0.0139 and 0.1116^{***} vs. 0.1013^{**}). The story is similar when we analyze the effect on the informal inclusion

(0.0123 vs. -0.0477 and -0.1782*** vs. -0.2996***). Note that the effect of Islamic finance proficiency on households' use of informal financial instruments is substantially bigger when interactions between literacies are taken into account. To sum up, incorporating the interaction term strengthens and does not contradicts the initial results.

In addition, as second robustness check, endogenous consumer spending have been added to the SEM specification. The methodology and estimation results are reported in Appendix F. This check is based on the theory predicting that households do not just make choices on the use of financial services, but they also jointly decide the types and quantities of goods and services that they consume (e.g. from consumption to education, and going through health expenses) (Morduch, 1995; Menon, 2004). Interestingly, these choices intertwine, and consumption-smoothing across time, states and types of goods is made possible through optimal choices of financial instruments in a complete-market setting. Access to finance may limit consumption levels and consumer spending determines the demand for financial services and vice versa. To take into account the bilateral effects between spending and financial decisions may produce more robust and unbiased analyses. This theory is reinforced by the correlation matrix between financial services (i.e. formal and informal), and consumer spending (i.e. daily life and education-health) reported in Table 4. Daily life expenses are positively correlated with both types of financial services, and financial services are negatively correlated between each other. The correlation between informal services and education-health expenses is also positive, while the one with formal services is negative but close to zero. Therefore it seems that financial inclusion and consumer spending have a positive linear relationship, especially for the informal inclusion. The SEM specification reported in Table 12 incorporates feedback effects between the two types of financial services, considers correlation between errors and endogenizes households spending with the use of financial services, making them simultaneous choices. Overall, even after controlling for many micro determinants and simultaneity biases, the model confirms that the conventional financial literacy still positively affects the households likelihood to use formal financial services in Pakistan. Having a medium conventional financial knowledge increases by 10.18% the probability that households use instruments from the formal financial sector, and by 17.02% when they have high literacy compared to low literate agents at the 0.1% level. Interestingly, the hypothesis that having an average knowledge about conventional finance does not have any impact on the use of informal financial services is rejected at the 1% level. Indeed, having a medium literacy decreases the probability that households employ informal financial instruments by 4.23%. Furthermore, it confirms and concludes that increasing the proficiency of households in Islamic finance positively impacts their likelihood to use the formal financial services, and negatively the informal ones. For instance, highly Islamic financially literate households are 11.16% more likely to use the formal financial sector, and 17.82% less likely to use the informal sector in comparison to low Islamic financially literate agents. At the average level of Islamic financial knowledge, effects are weaker, and even insignificant for the one related to the informal sector.

Assuming that households with a high conventional financial knowledge naturally use the formal conventional services, and the one with a high Islamic financial literacy use the formal Islamic tools, we can suppose that the formal conventional finance is not related to the informal sector, and that the formal Islamic finance may be a substitute to the informal financial services. Alternatively, we can argue that the Pakistani informal financial sector offers products that are not Sharia-compliant, and are not targeting highly Islamic financial literate households, but rather those who are more literate in conventional finance.

6 Conclusion

This paper studies the mechanisms affecting the formal financial exclusion observed in Pakistan. Despite the fact that the supply side is well developed, the demand from Pakistani households for the formal financial sector is very low. The case is particular because a strong informal financial market coexists with the formal sector and many agents self-exclude for various reasons. Because financial literacy levels are direct variables that the Pakistani Government could use to improve financial inclusion, it is therefore interesting and challenging to assess whether or not the financial literacy of households influences their financial inclusion, after controlling for all other potential micro determinants.

This paper has presented a non recursive simultaneous equations model with binary endogenous variables. It contributes to literature in two ways. First, by taking into account of feedback effects between the formal and informal financial services, and by allowing for correlated errors, the model produces more accurate results than standard independent probit models. Second, the analysis distinguishes the effects of conventional financial literacy from the Islamic one. This is important since Pakistan is a Muslim country and people's financial decisions can be influenced by religion (Demirgüç-Kunt et al., 2014).

The findings can be summarized in three main points. First, I show that both types of financial literacy positively affect the formal financial inclusion, the latter being beneficial to households' welfare (e.g. Burgess and Pande (2005); Tita and Aziakpono (2017)). Second, I highlight that the conventional financial literacy has stronger effects on the use of financial instruments than the Islamic financial knowledge. Third, the Islamic financial literacy decreases the likelihood to use the informal financial services more than the conventional one. These results could mean that Islamic banking is a substitute for the informal financial sector, whereas conventional banking seems unrelated. Alternatively, it could mean that because informal products are not based on the Islamic law (e.g. no interest rates paid or received, sustainable activities funding, material finality behind transactions), highly Islamic finance-skilled households, being aware of it, switch to the formal Shariah-compliant services.

On the policy side, this study confirms that financial literacy programs could enhance households participation in the formal financial sector. Depending on the desired outcome, these programs could either strengthen the formal financial inclusion, or strengthen it while reducing the use of informal services. They should be conventional or Islamic finance-oriented.

However, despite the complexity of the model, which takes into account several feedback effects, conventional and Islamic financial literacies are assumed to be exogenous.

It is therefore difficult to talk about causality between financial literacy and financial inclusion since the estimation could potentially be plagued by endogeneity. Talking about correlations is more conservative but would be more reasonable in this analysis.

Furthermore, it is worth to mention that the model is based on endogenous categorical variables. One built on continuous data would have been preferable. Unfortunately, the data are not available to run such a study on Pakistan. Nonetheless, this paper can be seen as a good starting point for further analyses. Note that because the model is computationally demanding, a trade-off has to be made between the convergence speed and the number of endogenous variables. Indeed, the more types of spending and financial services are added, the harder the convergence becomes. Getting multi-country data could be an axis of future research, like comparing the magnitudes of impact in developed and developing countries for instance.

Last, another promising line of research is the study of the impact of mobile money literacy on Pakistani households financial inclusion. Indeed, in the next years, more data will be available on the use of this technology, currently seen as a very good and effective solution to formal financial exclusion in developing countries like for instance in Kenya. A longitudinal study on the evaluation of long-term effects of mobile money on financial inclusion and welfare would be promising.

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A Endogenous variables and literacies construction

Observed endogenous variables defining the use of financial services are constructed using variables from the questionnaire. The questions asked are therefore about having any formal accounts, savings methods and forms of borrowing (see Tables 5, 7 and 8). Here is how I recoded the information:

- $I^F = 1$ (formal services), if $q301\_X = \{1, ...12\}$ or $q701\_X = \{1, ...23\}$, zero otherwise; where $q701\_X = 1$
- $I^I = 1$ (informal services), if $q601\_X = 18$ or $q701\_X = \{24, ...36\}$, zero otherwise;

Finally, conventional and Islamic financial literacies variables (see Table 9) are constructed in the following way:

- $FINLIT$ equals 1 if the financial literacy score is above 28 (low literacy), 2 if above 12 and below 29 (medium literacy), 3 if below 13 (high literacy). The financial literacy score being the sum of the binary variables q202_{a,b,c,e,f,g,i,j,m,n,o,p} which represent whether or not respondents never heard about (+3), heard but do not understand (+2), or heard and understand (+1) bank, interest, fixed term deposit, loan, savings, debit card, ATM, bank fees,credit card, cheque, exchange rate and mortgage.
- ISL_FINLIT equals 1 if the Islamic financial literacy score is above 9 (low literacy), 2 if above 6 and below 10 (medium literacy), 3 if below 7 (high literacy). The financial literacy score is the sum of the dichotomous variables q202_{d,h,l,q}, respectively for the knowledge of Islamic banking, Takaful, Mudaraba, Musharakah. Variables are coded 3 if respondents never heard about, 2 if heard about but do not understand, or 1 if heard about and understand.

B Coherency and identification

As proved in Nelson and Olson (1978), because the endogenous variables only appear in their latent form in the right-hand side of the structural equation (1), no constraints on endogenous variable parameters are required. This model specification naturally implies logical consistency, i.e. coherency, with A being invertible and defined as:

$$A = \begin{pmatrix} 1 & \gamma_{12} \\ \gamma_{21} & 1 \end{pmatrix}$$

However, the standard problem of identification associated to any simultaneous equation model needs to be solved. According to the theory (e.g. Davidson and MacKinnon (1995), Gujarati (2009)), the L-simultaneous equations are identified if the order and rank conditions are met. B ensures identification using exclusion restrictions[14] and is specified as the following constrained matrix:

$$B' = \begin{pmatrix} b_{11} & b_{12} & 0 & 0 & b_{15} & b_{16} & b_{17} & b_{18} & b_{19} & b_{110} & b_{111} & b_{112} & b_{113} & b_{114} & b_{115} & b_{116} & b_{117} & b_{118} & b_{119} & b_{120} & b_{121} \\ b_{21} & b_{22} & b_{23} & 0 & b_{25} & b_{26} & b_{27} & b_{28} & b_{29} & b_{210} & b_{211} & 0 & b_{213} & b_{214} & b_{215} & 0 & b_{217} & b_{218} & b_{219} & b_{220} & b_{221} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} & b_{36} & b_{37} & b_{38} & b_{39} & b_{310} & b_{311} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & 0 & b_{44} & b_{45} & b_{46} & b_{47} & b_{48} & b_{49} & b_{410} & b_{411} & b_{412} & b_{413} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

where b_{lk} corresponds to the unknown parameter associated to the observed exogenous variable k in equation l. Appendix C reports details about observed exogenous regressors and their correspondence to the b_{lk} coefficients.

[14]The restrictions are in line with economic theory.

C Control variables

Table 1: Control variables description

Variable	Description (survey-related variable)
age ($b_{\cdot 1}$)	Age of the respondent (q1302).
gender ($b_{\cdot 2}$)	Sex of the respondent, 1 if female, zero otherwise (q1301).
popbyareaproj ($b_{\cdot 3}$)	It refers to the projected population by tehsils, for year 2015 (it is based on Pakistan 1998 (last) Census and annualized population growth rates (by tehsils) from 1951 to 1998)
children ($b_{\cdot 4}$)	Number of children younger than 13 years old in the household (q1310).
income ($b_{\cdot 5}$)	It defines the income of the respondent, equals low if below 10000, medium if between 10000 and 21000, high if bigger (q1005).
married ($b_{\cdot 6}$)	Marital status of the respondent, equals 1 if married, 0 otherwise (q1303).
moneysent ($b_{\cdot 7}$)	They are dichotomous variables: 1 if the respondent sent money in Pakistan/abroad, at least once, in the last 12 months, zero otherwise (q801s).
moneyreceived ($b_{\cdot 8}$)	They are also dichotomous variables: 1 if the respondent received money from Pakistan/abroad, at least once, in the last 12 months, zero otherwise (q801r).

education ($b_{.9}$)	It equals low if the respondent does not have formal education (cannot read), or if no formal education (can read) or primary education (not complete (NC)); medium if primary education (complete(C)) or matriculation (NC), or if matriculation (C) or intermediate (NC) , or if intermediate (C) or some diploma; high if diploma (C) or some college/uni, or if university degree (C) or post-grad (q1304).
province ($b_{.10}$)	It refers to the living province of the respondent: 1 for Punjab, 2 for sindh, 3 for Khyber Pakhtunkhwa, 4 for Balochistan (aa1).
work_sector ($b_{.11}$)	It corresponds to the working sector of the respondent and equals 1 if "farmer", 2 if unskilled sector ("public or health service worker", or "farm worker", or "cleaner/house help", or "watchman", or "driver"), 3 if low skills sector ("messenger", or "conductor", or "salesperson in a store", or "manual labor, unspecified profession", or "factory employee", or "waiter/cook"), 4 if high skills sector ("professional, i.e., doctor, teacher...", or "manager", or "clerk", or "secretary", or "policeman"), 5 if craftperson sector ("carpenter/mason", or "mechanic", or "electrician", or "tailor", or "salonist"), 6 if "shop owner", or "business owner", or "money lender", 7 if "street vendor/hawker", 8 if others such as "retired", "student", "housewife", "landlord/landlady" or anything else (q1305).
urban ($b_{.12}$)	Households type of living area, equals 1 if urban, zero otherwise (aa6).
hhsize ($b_{.13}$)	Number of persons in the household, small if below 5, medium if between 5 and 9, high if above (q1309).
shocks ($b_{.14}$)	In the last 12 month, did you have a situation where you had not enough money to buy/pay? 1 for food, 2 for bills (q403).

risks ($b_{\cdot 14}$)	Which dramatic events do you think are the most likely to happen to people around you? 1 for thief, 2 for health, 3 for destruction, 4 for job/business failure (q410).
relocate ($b_{\cdot 16}$)	It equals 1 if the household moved at least once in the past 12 months, zero otherwise (q1306).
banksbyheadproj ($b_{\cdot 17}$)	Number of banks per individual (using population projections and data from bank websites).
banksdensity ($b_{\cdot 18}$)	Density of bank by tehsil (using data from bank websites) .
motor ($b_{\cdot 19}$)	Does the household own a motorized vehicle? 1 if yes, zero otherwise (q1318).
phone ($b_{\cdot 20}$)	Does the respondent own a mobile phone? 1 if yes, zero otherwise (q1319).
tv ($b_{\cdot 21}$)	Does the household own a TV? 1 if yes, zero otherwise (q1317).

D Figures

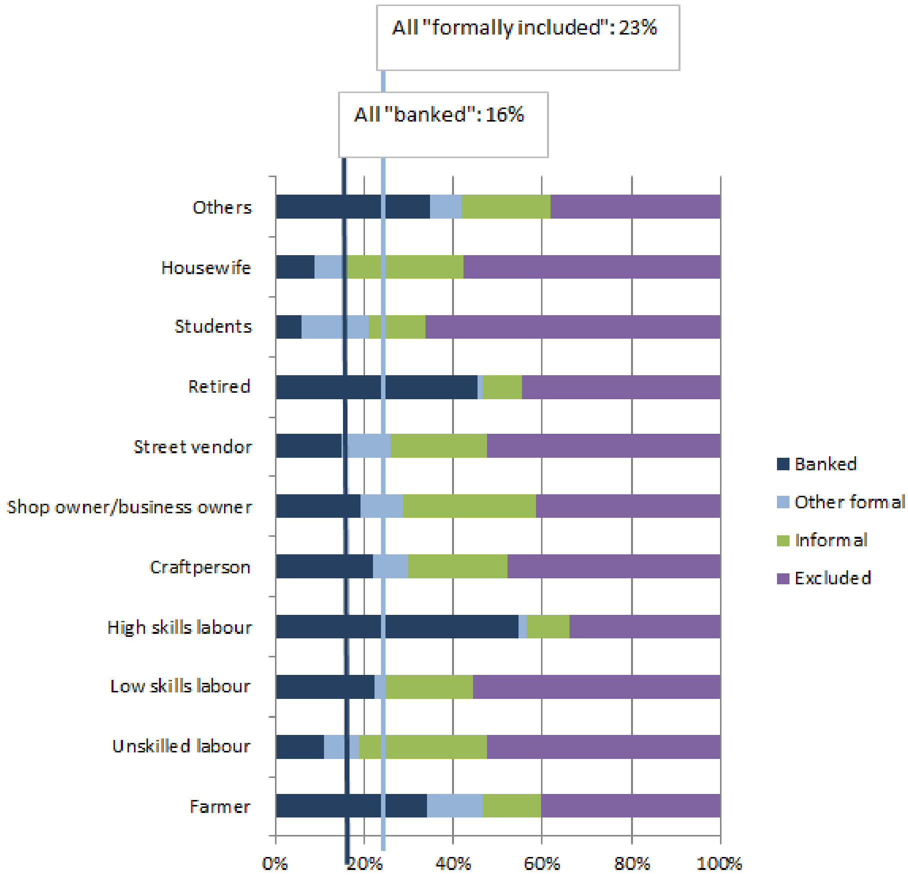

Figure 1: Formal and informal financial inclusion rates by respondents' occupation
Source: http://www.a2f2015.com

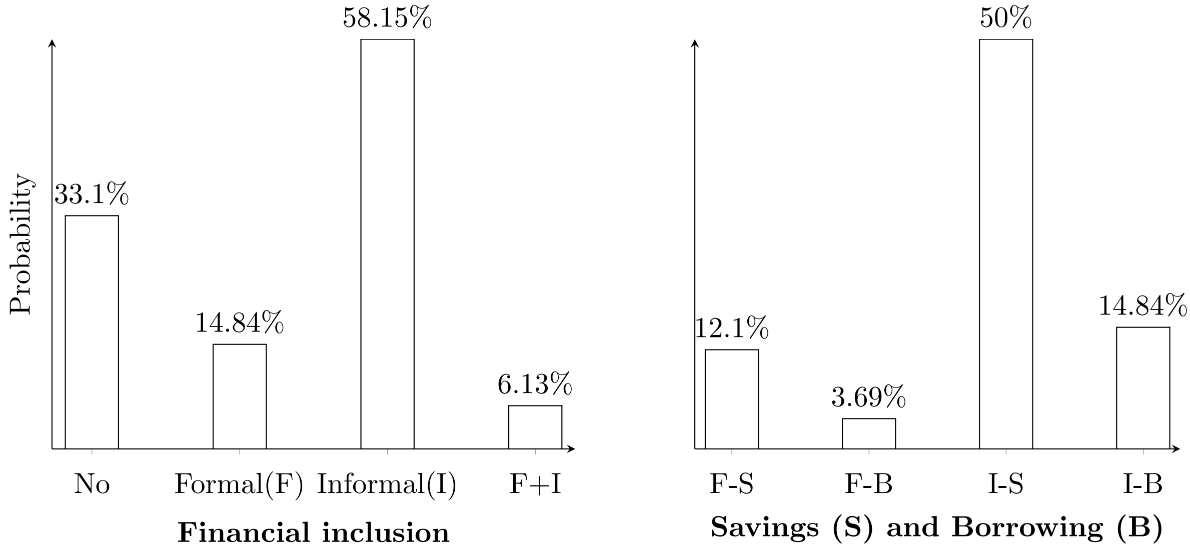

Figure 2: Histograms of Pakistani households' financial inclusion, savings and borrowing by formal and informal types

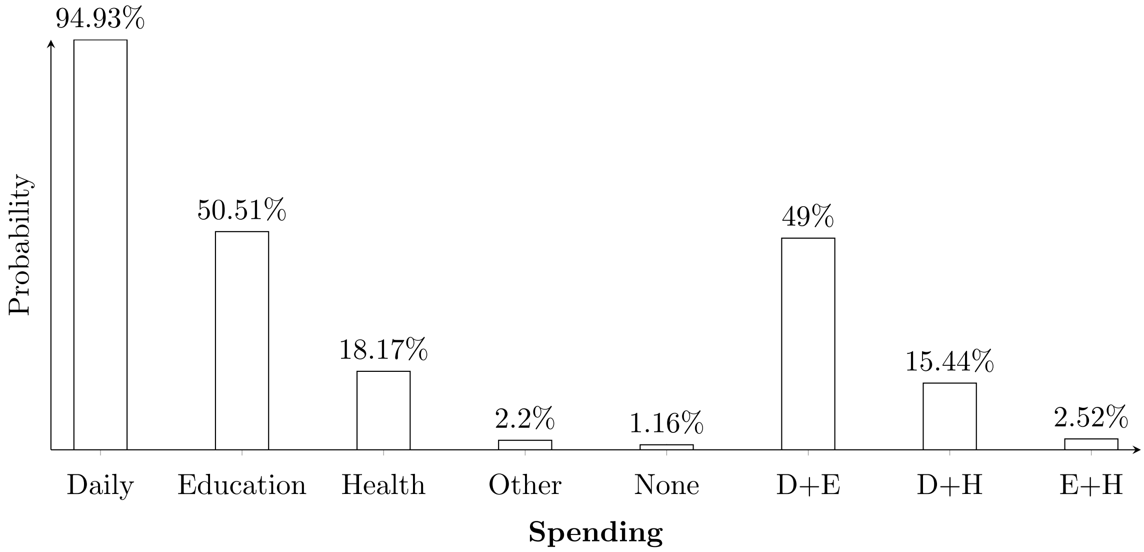

Figure 3: Histogram of Pakistani households' spending by categories

E Tables

$FINLIT$ / ISL_FINLIT	Low	Medium	High	Total
Low	23%	0.59%	0.01%	23.60%
Medium	44.18%	21.90%	5.51%	71.59%
High	1.52%	1.01%	2.28%	4.81%
Total	68.7%	23.5%	7.8%	100%

Table 2: Sample distribution by conventional and Islamic finance literacy

	$FINLIT$	ISL_FINLIT	I^F	I^I
$FINLIT$	1			
ISL_FINLIT	0.3927	1		
I^F	0.1953	0.1715	1	
I^I	0.0220	0.0127	-0.1427	1

Table 3: Correlation table between literacies and financial services

	C^D	C^E	I^F	I^I
C^D	1			
C^E	0.1585	1		
I^F	0.0457	-0.0017	1	
I^I	0.0753	0.0874	-0.1427	1

Table 4: Correlation table between financial services and consumer spending

Question	Answer	Code
$q301$: Do you have any of the following accounts in your own names?	Current account/checking account	1
	Savings account / PLS Savings Account	2
	Basic Banking Account	3
	Foreign Currency account	4
	National Savings Centre Account	5
	Post Office Savings Account	6
	Islamic Current Account	7
	Islamic Foreign Currency Account	8
	Islamic Saving Account / PLS Savings Account	9
	Islamic Term Deposit Account	10
	Fixed term deposit account	11
	Account used to get assistance money from the Gov.	12
	No, I do not have an account in my own names	99

Table 5: Survey question about households' accounts (2015 Access to Finance survey)

Question	Answer	Code
$q1012$: Can you please tell me, which were the three items for which you spent the largest part of your household money during the past 12 months, from in this list below?	Education	1
	Food	2
	Rent	3
	Transport	4
	Clothing	5
	Mobile phone	6
	Other communications	7
	Utility bill	8
	Taxes	9
	Health	10
	Ceremonies	11
	Donations	12
	Leisure	13
	Unexpected, exceptional event	14

Table 6: Household spending survey question (2015 Access to Finance survey)

Question	Answer	Code
	Banks	1
	Islamic bank	2
	Microfinance bank	3
	Pakistan Postal Savings Bank	4
	Money on a Mobile account	5
	Money on a National Savings Account	6
$q601$: As we said before, there are many different ways to put something aside for future expenses. Now, I would like you to tell me which of the following forms of savings you have at the moment when we speak.	Money in Government savings certificates	7
	Money in a Mudaraba certificate	8
	Money in a Government's pension scheme	9
	Money on a Pensioners' Benefit Account	10
	Money in a Provident Fund	11
	Money in bonds/shares traded in the stock market	12
	Money in a Life Insurance	13
	Money in an endowment/Investment saving plan	14
	Money in an Education Plan	15
	Prize Bonds	16
	I contribute to a Committee	17
	Money put aside at home	18
	Silver/gold/jewels	19
	Foodstuff	20
	Animals	21
	Stocks of agriculture products	22
	Stocks of agriculture inputs	23
	Land/property	24
	Animals belonging to the landlord	25
	Money entrusted to friends/relatives	26
	Money entrusted to business partners	27
	I expect to get help from friends in case of emergency	28
	I have no savings at the present moment	98

Table 7: Survey question related to households' savings (2015 Access to Finance survey)

Question	Answer	Code
*q*701: I am now going to read a list of possible forms of borrowing. First borrowing money to purchase things for yourself or for your household or for your business or for the activity with which you earn money; then borrowing by receiving goods that you did not have to pay for immediately. Please, tell me which of these you have currently. I mean any borrowing you made and that you still have to pay back or are in the process of paying back at this moment when we speak.	Credit ceiling granted by your bank to be used with your credit card	1
	Overdraft facility granted by your bank	2
	Advance against salary from a bank	3
	Facility granted by a bank for Hajj/Umrah expenses	4
	Short term personal loan from a bank or other organization	5
	Personal loan from a bank to finance household equipment	6
	Islamic loan	7
	Household appliance lease from a bank, a leasing companies or a retailer	8
	Microlease from a leasing company or a microfinance	9
	Loan or lease to finance vehicles	10
	Loan to finance property/housing	11
	Microloan from a microfinance bank or an NGO or another organization	12
	Group loan	13
	Loan to start a business	14
	Business loan to finance working capital	15
	Business loan to finance equipment	16
	Business vehicle lease	17
	Business equipment / plant / machinery lease	18
	Microloan for business	19
	Microlease for business	20
	Agriculture loan from a bank	21
	Education loan	22
	Advance received from employer against salary	23
	Loan received from employer	24
	Money borrowed from a money lender	25
	Cash advance from a shopkeeper	26
	Credit received from the landlord	27
	Peshgi	28
	Money from friends or relatives (payback)	29
	Money from friends or relatives (no payback)	30
	Borrowing from a committee in which you are a member	31
	Borrowing from an association in which you are a member	32
	Cash advance from retailers or wholesalers	33
	Cash advance from business partners or landlord	34
	Goods received on credit from shopkeeper or retailers	37
	Goods received from an association or another organization	38
	Goods received from relatives or friends	39
	Goods received from the landlord	40
	Goods or material received on credit from retailers or wholesalers	41
	Chit or parchi system	42
	Agricultural inputs (seeds, fertilizer, etc.)	43
	No current loan or credit facility	98

Table 8: Households borrowing question (2015 Access to Finance survey)

Question	Answer
$q202$: I am going to read out some words, please tell me whether: you have heard of the word and understand its meaning (1); you have heard the word but do not understand what it means (2); or you have never heard of the word (3).	Bank
	Interest
	Fixed term deposit
	Islamic banking
	Loan
	Savings
	Debit card
	Takaful
	ATM
	Bank services fees
	Insurance
	Mudaraba
	Credit card
	Cheque
	Exchange rate
	Mortgage
	Musharakah
	Mobile money

Table 9: Question about households' financial knowledge (2015 Access to Finance survey)

	Mean	Standard Deviation
Demographics		
Age	36	(10.78)
Female/male ratio	72.41%	(0.4938)
Married	85.9%	(0.3480)
Children	85.19%	(0.3552)
Living in Urban	32.93%	(0.4700)
Relocation	2.26%	(0.1485)
Household size		
$5 >$	11.60%	(0.3203)
$10 > \cdot > 4$	58.21%	(0.4932)
> 9	30.19%	(0.4590)
Education		
Low	38.97%	(0.4877)
Middle	54.27%	(0.4982)
High	6.76%	(0.2511)
Income		
Low	24.56%	(0.2135)
Middle	40.73%	(0.4913)
High	34.71%	(0.4761)
Province		
Balochistan	16%	(0.3593)
Khyber Pakhtunkhwa	28%	(0.4521)
Punjab	37%	(0.4814)
Sindh	19%	(0.3928)
Living conditions		
Easy water access	95.97%	(0.1967)
Fridge	61.02%	(0.4877)
Phone	65.70%	(0.4747)
Motor	72.89%	(0.4445)
TV	88%	(0.3250)
Remittances and insurance		
Remittances sent	4.25%	(0.2017)
Remit. received	3.1%	(0.1735)
Insurance	0.99%	(0.0991)
Risks		
Thief	23.81%	(0.4260)
Health	26.12%	(0.4393)
Destruction	14.08%	(0.3478)
Job/Business	37.94%	(0.4853)
Shocks		
Food	4.83%	(0.2143)
Utility	5.35%	(0.2251)

Table 10: Households summary statistics

Table 11: Estimated marginal effects and robust standard errors of the independent probit (1) and non recursive multivariate probit models (2).

	(1)		(2)	
	I^F	I^I	I^F	I^I
FINLIT				
Mid	0.0980***	-0.0181	0.1000***	-0.0194
	(0.0073)	(0.0133)	(0.0104)	(0.0345)
High	0.1664***	0.0187	0.1666***	-0.0103
	(0.0191)	(0.0265)	(0.0203)	(0.0212)
ISLFINLIT				
Mid	0.0188**	0.0130	0.0185*	0.0038
	(0.0073)	(0.0119)	(0.0073)	(0.0089)
High	0.0925***	-0.1531***	0.1143***	-0.0821
	(0.0145)	(0.0206)	(0.0156)	(0.1456)
Feedback I^F-I^I	No		Yes	
Correlated errors	No		Yes	
Endo. consumpt.	No		No	
Control variables	Yes		Yes	
Observations	10590	10590	10590	
R^2	0.33195	0.0907	0.1669	
Log-likelihood	2971.33	6545.60	9614.27	

The baseline corresponds to low conventional and Islamic financial literacies.
Results associated to the control variables are available upon request.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ - Robust standard errors are in parentheses.

F SEM with endogenous consumption

The spending categories, $C^{(s)}$, are based on non-exclusive categorical variables. The interviewers asked the biggest three expenditures the respondents had during the past 12 months (see Table 6). The construction of variables is as follows:

- $C^D = 1$ (daily life: food, rent, utilities) if $q1012\_X = \{2, 4, 5, 8\}$, zero otherwise.
- $C^E = 1$ (education: school/university + health: doctor, hospital) if $q1012\_X = \{1, 10\}$, zero otherwise;

The estimation is based on the model presented in Section 4, except that here $Y_l = \{I^F, I^I, C^D, C^E\}$

In the simultaneous L-equation probit model, the coefficients α_{il} inform about the crowding out effects between the types of financial services I^F and I^I, the nature of goods (i.e. complements or substitutes) for spending categories C^D and C^E, and the intra-temporal relation between consumption and financial decisions.

Note that the corresponding latent variables C^* may be negative. Indeed, C^* should be interpreted as excess demand over and above home production; a negative C^* would then indicate surplus of production over needs (e.g. for agricultural products). Similarly, households with a certain education level or with some health services skills (e.g. baba, pir, sufi) may provide services to other households. In these cases, households consume their own consumption goods or services, and do not need to buy from external sources.

Correlated errors between financial services and consumption might represent an institution that does not accept to finance some consumption categories.

In the reduced form, the invertible matrix A is defined as $A = \begin{pmatrix} 1 & \gamma_{12} & \gamma_{13} & \gamma_{14} \\ \gamma_{21} & 1 & \gamma_{23} & \gamma_{24} \\ \gamma_{31} & \gamma_{32} & 1 & \gamma_{34} \\ \gamma_{41} & \gamma_{42} & \gamma_{43} & 1 \end{pmatrix}$

Table 12: Estimated marginal effects and robust standard errors of the non recursive multivariate probit model with endogenous consumption.

	I^F	I^I
$FINLIT$		
Mid	0.1018***	-0.0423**
	(0.0081)	(0.0142)
High	0.1702***	-0.0268
	(0.0195)	(0.0280)
$ISLFINLIT$		
Mid	0.0174*	0.0123
	(0.0074)	(0.0122)
High	0.1116***	-0.1782***
	(0.0159)	(0.0223)
Feedback I^F-I^I	Yes	
Correlated errors	Yes	
Endo. consumpt.	Yes	
Control variables	Yes	
Observations	10590	
R^2	0.1209	
Log-likelihood	17796.59	

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