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Retirement Behaviours, Housing Demand, and Housing Markets: a Dynamic Analysis

SETTORE SCIENTIFICO DISCIPLINARE DI AFFERENZA: SECS-P/01
Tesi di Dottorato di Bertrand Achou, matricola 956144

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Estratto per riassunto della tesi di dottorato

L'estratto (max. 1000 battute) deve essere redatto sia in lingua italiana che in lingua inglese e nella lingua straniera eventualmente indicata dal Collegio dei docenti.

L'estratto va firmato e rilegato come ultimo foglio della tesi.

Studente: Bertrand Achou ______________________________ matricola: 956144 ____________

Dottorato: Ricerca in Economia ______________________________

Ciclo: 28°__________

Titolo della tesi[1] : Retirement Behaviours, Housing Demand, and Housing Markets: a Dynamic Analysis______________________________

Abstract:

Questa tesi applica strumenti dall'analisi dinamica per rispondere a domande relative ai comportamenti di pensionamento e / o ai mercati immobiliari. Nel primo capitolo intitolato "Long-Term Care Insurance, Housing Demand, and Decumulation", studio l'influenza delle abitazioni sulla domanda di assicurazione di cura a lungo termine. Per fare questo, confronto un modello strutturale con dati dagli Stati Uniti. Nel secondo ("Disability in Retirement, Home Production, and Informal Insurance Between Spouses"), studio di come l'assicurazione informale tra coniugi influenza i comportamenti di risparmio. Il terzo intitolato "Sectoral Productivity, Collateral Constraints, and Housing Markets" è un lavoro congiunto con Hippolyte d'Albis e Eleni Iliopulos. Studiamo l'influsso di introdurre un mercato degli affitti in un modello altrimenti standard del mercato immobiliare con vincoli di garanzia.

This thesis applies tools from dynamic analysis to answer questions related to retirement behaviours and/or housing markets. In the first chapter entitled "Long-Term Care Insurance, Housing Demand, and Decumulation", I study the influence of housing on the demand for long-term care insurance comparing a structural model with US data from the Health and Retirement Study (HRS). In the second one ("Disability in Retirement, Home Production, and Informal Insurance Between Spouses"), I study how the informal insurance from a spouse affects dissavings behaviours. The model reproduces some key patterns observed in the HRS and a companion survey the Consumption and Activities Mail Survey (CAMS). The third one entitled "Sectoral Productivity, Collateral Constraints, and Housing Markets" is a joint work with Hippolyte d'Albis and Eleni Iliopulos. We study the influence of introducing a rental market in an otherwise standard model of the housing market with collateral constraints.

Firma dello studente

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1 Il titolo deve essere quello definitivo, uguale a quello che risulta stampato sulla copertina dell'elaborato consegnato.

Università Ca' Foscari - Dipartimento di Economia

PhD Thesis

Retirement Behaviours, Housing Demand and Housing Markets: a Dynamic Analysis

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Advisors:
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A thesis may look like an individual effort, and in many ways it is. However, its outcome does depend (sometimes greatly) on the contributions of many other people than its author. In my case, there were many, and I hope I do not forget any. If I do, please forgive my failing memory.

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À ces trois années et à toutes celles et ceux rencontrés en chemin…

Chapter 1

General Introduction

This thesis applies tools from dynamic analysis to tackle issues related to two major elements impacting modern economies: ageing (and more specifically retirement behaviours) and the dynamics of housing markets.

1.1 Ageing

Ageing is a global process impacting modern economies. To see this, notice that the dependency ratio, i.e. the ratio of those older than 65 over those between 15 and 64, is expected to rise substantially in the next 40 years in most developed economies as is shown in table 2.1. At the extreme, this ratio is expected to go as high as 71.8% in 2050 for Japan, while it is of about 36% today. Other developed economies are no exception. For instance, Italy and Germany, both having a low natality rate and facing an increase in longevity, are expected to have dependency ratios around 60% in 2050, while their dependency ratios in 2010 were around 30%. Even in some developing economies we observe such a rise. For instance, in China, partly due to the one-child policy, the dependency ratio is expected to be multiplied by roughly 3.5.

This phenomenon raises some key challenges. First of all, the rise in the dependency ratio is going to impact the sustainability of public finances, in countries using pay-as-you-go system, as a smaller share of workers is going to finance a greater share of retirees. It is not only the consequence of an increasing longevity but also reflects the inheritance of the baby boom, often followed by the baby bust. Indeed, the different sizes of successive cohorts, the older the bigger, tend to increase the difficulty for modern economies to deal with the many challenges raised by an increasing longevity.

TABLE 1.1: The evolution of the dependency ratio in different countries

Country	Dependency Ratio (2010)	Dependency Ratio (2050)
China	11.4	39.0
France	25.9	44.2
Germany	31.6	59.9
Italy	30.9	62.3
Japan	36.0	71.8
United States	19.5	35.5

[1] The data come from the UN. The data for 2050 are taken from the median scenario computed by the UN.
[2] All figures are in percentage.

Even in countries in which retirement is financed by capitalization, privately or through the government, the same types of issues are raised[1]. In a closed economy, at constant productivity per worker, if the share of workers in the overall population decreases, GDP per capita will fall as well. Thus, the issue on how to maintain a satisfactory standard of living of retirees without lowering the one of workers remains.

A set of solutions are of course available to alleviate this issue: investing abroad (i.e. financing retirees by the young elsewhere), favouring migration of the young (i.e. more or less the same), increasing the retirement age (to lower directly the ratio of retirees over workers), to put in place measures to favour a rise in productivity (to increase overall output per hours worked, though this type of policy might be quite uncertain)... All these solutions, as is often the case in economics, raise different additional questions.

To tackle these issues, it is however essential to understand well individual behaviours. For instance, in the design of public policy or insurance schemes (both public and private), it is fundamental to grasp the extent of the risks and needs which are specific to retirees. This has been the objective of the first two chapters of this thesis which, I hope, contribute in a meaningful way to our general knowledge on the subject.

First of all, I would like to highlight the fact that retirees have different needs than the rest of the population. In particular, retirees have a higher probability to be in bad health condition or to be disabled. As a consequence, to allow for the best possible level of welfare for them, it is not sufficient to allow them to consume throughout retirement the same goods they were consuming while working. Disability in particular requires

[1]Though different types system can have different impact on capital accumulation and growth. See for instance, the analysis in De la Croix and Michel [2002]

some services which can be very expensive and are uncertain. For the US case, which is the one I focused on along my research, these costs can be very high late in life as demonstrated in French and Jones [2004] and De Nardi et al. [2010], and tail risk can be important (French and Jones, 2004). This makes retirement planning in many ways more complicated than, for instance, in the seminal work of Yaari [1965], which showed that life annuities[2] should be widespread in a world in which the only uncertainty stems from longevity[3]. Indeed, the risk that retirees face is not only about how long they are going to live, but if, when and how much they might face medical expenditures and disability. In terms of the optimal allocation of savings across retirement, of the value of informal insurance mechanisms and of the insurance products which would be valuable for retirees, this has very important consequences.

Second, the issues faced by retirees are in many ways dynamic in nature. Typically, the question on how much to dissave (or save) each year is a dynamic question. And to this question is linked the one of the benefits of financial or insurance products available to retirees. Thus, a constant of my work on the subject has been to use the life-cycle model. This model has a long history which dates back at least to the works of Franco Modigliani. Despite its age, this field experienced several interesting developments in the last 30 years and is still very active today. In particular, the introduction of risk within this framework has helped to reconcile several observed patterns in the data. For instance, Zeldes [1989] has shown that the introduction of labour income risk implied that the consumption function was very different from the certainty equivalence solution. It helped him to reconcile the life-cycle model with two facts: the excess sensitivity of consumption to transitory income and the high growth of consumption in the presence of low interest rates. Moreover, he already pointed out at the time that medical expense risk could explain the low dissavings of the elderly, a point studied afterwards in more detail by Palumbo [1999] and De Nardi et al. [2010]. Several other works also pointed to the importance of risk to explain life-cycle behaviours as Carroll [1997] or Gourinchas and Parker [2002]. This latter work also started to use the method of simulated moments to estimate life-cycle models, a technique which has been applied in several other works afterwards (De Nardi et al., 2010 or Lockwood, 2013 are noticeable examples). Other works also attempted to understand the effect of public programs on life-cycle behaviours as Hubbard et al. [1995] or De Nardi et al. [2014]. Moreover, it has been shown, as for instance in Attanasio and Weber [1995], that controlling for labour supply and demographics was important to assess the relevance of the life-cycle model.

[2]A life annuity is an insurance product protecting against longevity risk. In its more standard form, it is a product providing a constant annuity while a person is alive and zero return in the case this person is dead. In equilibrium, such a product serves to pool longevity risk.

[3]This result has been extended in a more general setting in Davidoff et al. [2005]

The question of the life-cycle behaviours of retirees has itself experienced very interesting developments in recent years. Palumbo [1999] and De Nardi et al. [2010] have shown that a model with medical expense risk can rationalize the low dissavings rate of retirees observed in the data. This shows once more that the modelling of risk is an important element to understand life-cycle behaviours. These models have however some difficulty to rationalize the low demand for insurance products such as long-term care insurance (LTCI) as argued in Lockwood [2013]. This latter attributes the low demand for LTCI to the presence of large bequests towards which individuals have little risk aversion. In the first chapter, I study the demand for LTCI and look more closely at the influence of housing on its demand as in Davidoff (2009, 2010).

While, I have concentrated my work on life-cycle behaviours starting at retirement age, there is an obvious interaction between the needs to save for retirement and the life-cycle behaviours prior to retirement. In particular, French [2005] and French and Jones [2011] introduced life-cycle models with endogenous labour supply in which the risks experienced during retirement affect the decision to retire. For instance, the latter find that Medicare is important to understand retirement behaviours as it affects medical risk during retirement. Despite its large interest, more work is obviously needed to integrate both the risk prior and after retirement in life-cycle models.

A second concern about the current literature is that it has so far mainly dealt with single individuals (see for instance De Nardi et al., 2010). In my second chapter, I have tried to deal with this issue by modelling couples explicitly. My idea is that couples might differ from singles in the sense that, in a couple, a healthy spouse can take care of a disabled one, providing thus some type of insurance. Though this idea is not new, it has so far not been included in a life-cycle model and thus its importance on life-cycle behaviours could not be assessed. A key innovation of my work has been to study more closely home production patterns that are observed during retirement. In particular, as I argue in more details in the paper a key advantage of home production to study this insurance channel is that it allows for intertemporal comparisons. I thus introduced the home production dimension as in Becker [1965] into a collective model[4] as introduced by Chiappori [1988] and Apps and Rees [1988]. I show that this model can reproduce most of the patterns observed in the data, and thus can allow to study the importance of this insurance channel.

My belief is thus that there are three major roads for future research which can (and ultimately need to) be combined. The first is to understand better the interaction between working life and retirement. The second is to understand better how couples differ from singles, for which this thesis provides, I think, an innovative and relevant

[4]Though, I focus more on the special unitary case of the collective framework.

answer. A related concern is that we need to understand better the extent of informal insurance within the family[5]. Finally, most of the results in these works have still not been applied to general equilibrium settings. The interactions between the dimensions stressed in those works and the dynamics of capital accumulation and innovation should definitely be put on the agenda.

I now describe in more details the work and results of the first two chapters of this thesis and how they relate to some of these literatures and questions.

1.1.1 First Chapter: "Long-Term Care Insurance, Housing Demand, and Decumulation"

In the first chapter, I focus on the welfare gains that retirees might derive from the purchase of long-term care insurance (LTCI). This question has been addressed in many other research paper, and a very instructive review of the evidence can be found in Brown and Finkelstein [2009]. In particular, a constant question which has concerned economists is: why people do not buy more LTCI? Indeed, despite the fact that the risk of long-term care (LTC) is large (at least for the US case) and that retirees (in particular at higher wealth levels) do not decumulate wealth substantially, the demand for private LTCI remains low, despite sometimes very favourable pricing in particular for women (see Brown and Finkelstein, 2008). In a standard life-cycle model, in which individuals care only about themselves and in which their savings behaviours are driven by precautionary motives, a low dissavings rate should be the sign of high gains from insuring risk. As a matter of consequence, this low demand for LTCI is puzzling and has given rise to the so-called "LTCI puzzle".

Brown and Finkelstein [2008] have shown that the presence of Medicaid might explain the low demand for LTCI for individuals at the lower part of the distribution of wealth. Typically, Medicaid pays for a nursing home when retirees become destitute, however this facility might not be of the same quality as the one that would be afforded with more resources. In particular, Ameriks et al. [2011] have shown that retirees display public care aversion, meaning that they are unwilling to rely on Medicaid if they need to go to a nursing home facility. Hence, it remains that, for wealthy retirees, the low demand for LTCI remains in many ways puzzling.

In two related articles Davidoff (2009, 2010) argued that the presence of housing might explain the low demand for LTCI. In particular, he argues that "home equity is a particularly plausible substitute for LTCI among wealthier households, who typically have home equity holdings that are large relative to most of the distribution of long-term care

[5]See for instance Barczyk and Kredler [2014] and Dobrescu [2015] for interesting works on this subject.

costs" (Davidoff, 2010, p.45). His reasoning is the following. As shown in Venti and Wise [2004], retirees rarely move out of their homes, and mainly do so if they become widowed or if they move to LTC. Hence, if retirees have a strong preference for not moving and do not have a reverse mortgage, they would decumulate housing equities mainly when moving to LTC. As a consequence, housing provides money in times of LTC as does a LTCI, which suggests that housing might be a substitute for LTCI.

In his papers, he argues that the higher the ratio of housing wealth over total wealth, the higher the crowding-out effect of housing on LTCI if retirees have a strong preference for staying in their homes. He concludes saying that a more active reverse mortgage market might be a prerequisite for the development of the LTCI market.

In this chapter, I argue that a way to assess the relevance of Davidoff's argument is to use information on wealth decumulation and in particular on the speed at which retired homeowners decumulate financial wealth. To understand this, notice that in a standard life-cycle model *without housing* and *without bequest motives*, the speed at which individuals decumulate their wealth indicate the extent of their precautionary motives and, in the end, the gains they would derive from being insured.

With this type of model in mind a researcher, to find the level of risk aversion of retirees, would look at the way they decumulate total wealth. In theory you can observe roughly two types of behaviours pictured in figure 1.1 where total wealth is represented as a function age. I assume that the figure starts at the time of retirement so I am abstracting from the potential endogeneity of retirement age and initial wealth at retirement. The first type of behaviour is represented by the black downward sloping curve. The second is represented by the grey hump-shaped curve. Typically, the second type of behaviour would be considered as more precautious than the first. And thus, an agent with such type of behaviour would gain more from being offered to buy an insurance than an agent displaying the first type of behaviour.

Now, how does it differ when housing is introduced into the picture and when individuals have no access to a reverse mortgage market and have preferences over housing similar to those argued in Davidoff (2009, 2010)? That is, when individuals are unwilling to move out of their homes if not going to LTC. Housing, in the case an individual would not move to LTC is represented by the dotted curve parallel to the x-axis. In this setting, an agent would still be able to adjust financial wealth, i.e. the difference between total wealth and housing wealth. Hence, we still can infer how precautious an individual is by looking at how much he is willing to decumulate financial wealth. The first type of agent would be in some sense *over-insured* by housing at point B, meaning he would have more wealth at the age corresponding to point B that what he would have kept for precautionary motives. In such a case, the crowding-out effect of housing on LTCI would

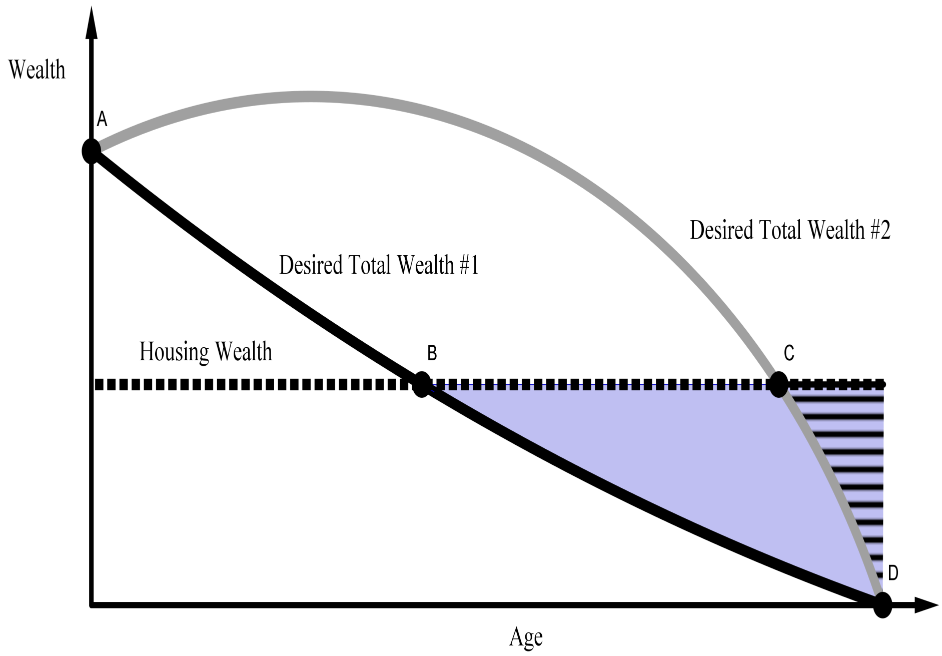


FIGURE 1.1: Wealth Decumulation and the Importance of Housing

be large. However, if an individual is of the second type, he would be only over-insured by housing very late in the life cycle. In this case, the crowding-out effect would be much lower as there would be substantial gains from being able to consume more earlier through the purchase of an insurance that would reduce the need to keep large savings until late in life.

Finally, we see that not only the ratio of housing wealth over total wealth matters but also the pace at which financial wealth is decumulated. Hence, to be able to understand how relevant Davidoff's point is, it is necessary to take into account this dynamic feature. The main contribution of this chapter is to take into account this aspect and to use it to evaluate the crowding-out effect of housing on the demand for LTCI.

In order, to do so we need to be able to observe how retired homeowners decumulate their wealth. As a consequence, I use the Health and Retirement Study (HRS) which is certainly the most famous database on ageing relative to the US. One of its many advantages is its long panel dimension. Hence, I can track individuals over time and analyse their dissavings behaviours. In particular, I can track the behaviours of those who remain homeowners as they age.

I can then calibrate life-cycle models taking into account the presence of housing in order to match the observed behaviours in the data. This calibration is essential as it is aimed at reproducing the features observed in the data and thus allows for a credible counterfactual analysis.

I find, using a Davidoff-type model calibrated to the data and featuring realistic LTC risk, that, for single retirees, the low demand for LTCI can be rationalized by the presence of housing in the first three quartiles of the wealth distribution at age 70-80. Hence, housing can help to explain a large share of the low demand for LTCI. However, it has difficulty to explain the low demand for LTCI at higher wealth levels. Indeed, I find that many individuals in the fourth wealth quartile would benefit greatly from purchasing a LTCI. The reason behind it is that these individuals keep large amounts of financial assets until late in life, which suggests that their precautionary motives are very strong. As a matter of consequence, housing might reduce the level of coverage for these individuals but would not explain why only 15% of them buy a LTCI.

Moreover, the assumptions of Davidoff might be considered as quite strong. His assumption of a very strong preference for staying in a given home generates a very strong and almost exogenous asset commitment to housing. I show that a rich model with endogenous housing demand, an imperfect rental market, and transaction costs in housing[6] can, in presence of LTC risk, generate patterns of late homeownership in which homeowners decumulate housing only after having exhausted all their financial assets. In this model, I do not assume any preference relative to staying in a given home. In this case, I show that the demand for LTCI would even be greater. The reason is that, as people purchase LTCI, the asset commitment to housing is reduced which reduces the crowding-out effect of housing on LTCI demand. Hence, this confirms that a realistically calibrated model cannot explain the low demand for LTCI of wealthy retirees.

Hence, other explanations are needed. One of them has recently been put forward by Lockwood [2013]. In his paper, he argues that large bequests motives towards which individuals are relatively unaverse can explain the low demand for LTCI. It would also help to explain why individuals do not also purchase life annuities as shown in Lockwood [2012] and why the market for reverse mortgages is particularly thin as well[7]. In the context of his argument, housing would then be more or less a sideshow as late homeownership would mainly be explained by the presence of bequest motives that would make LTCI unattractive. This would reinforce the point that housing cannot explain the low demand for LTCI among richer individuals.

However, there is still no general agreement among economists that bequest motives would explain the low demand for all these products. In particular, as LTCI (as well as

[6]The basic structure of this model is taken from Yao and Zhang [2005].

[7]Though it has been growing recently, see Nakajima and Telyukova [2014b] for evidences on the subject.

annuities and reverse mortgages) is a long-term contract it can be subject to different issues linked to enforcement which might reduce the trust consumers place in it. As I argue in the paper, if this is the case then tackling simultaneously the inefficiencies in the market for LTCI and in the one for reverse mortgages might be a prerequisite for their developments. Indeed, while Davidoff (2009, 2010) argued that the absence of reverse mortgages would reduce the demand for LTCI, I point out that, absent a LTCI, wealthier households would also find reverse mortgages unattractive as they would wish to keep assets worth more than the value of their homes. Hence, there seems to be a potential double complementarity between the two products. The conclusion of it is that policymakers which would like to see one market or the other grow might actually need to tackle inefficiencies in both markets simultaneously.

1.1.2 Second Chapter: "Disability in Retirement, Home Production, and Informal Insurance between Spouses"

In this chapter, I analyse an issue which I think is quite new. The large majority of the existing life-cycle models in retirement either study single individuals as in De Nardi et al. [2010], or study the case of couples in a simple manner, for instance through the assumption of economies of scale as in Nakajima and Telyukova [2014b]. In this paper, I try to understand how couples differ from singles by studying a particular channel: the informal insurance brought out by a healthy spouse to a disabled one. The general question of this paper is: does this type of insurance significantly impact life-cycle savings?

In order to do so, I build a model in which couples are modelled explicitly and in which consumption is a mixture of time spent on home production and expenditures as introduced by Becker [1965]. While several authors, and in particular Aguiar and Hurst (2005, 2007) have studied the patterns of home production during the transition from working life to retirement, I am not aware of any study trying to understand how home production patterns in retirement may influence life-cycle decisions. However, there is a lot of interesting variations that are observed in the data[8] which can inform us on the role of spousal insurance.

First of all, home production, as I argue in detail in 4.1.1, is helpful to understand the influence of disability on consumption. This stems from the fact that home production activities are done in a more or less similar way along the life cycle. Thus, time spent

[8] Once again the data are for the US. In particular, I use data from the Consumption and Activities Mail Survey (CAMS) which is asked to a subset of HRS respondents. This survey asks questions on the time spent on home production.

on these activities can be used for intertemporal comparisons. This is a great advantage compared to many other measures related to care.

A second interesting feature of home production is that it experiences very large variations during retirement. For instance, a woman aged 70 without disability issues would spend roughly 1,200 hours annually on home production which is about 65% of the average time spent working by a US worker. A highly disabled woman in her 90s would spend however less than 200 hours on home production.

Finally, we observe insurance-like mechanisms. In particular, I find that when a woman in a couple becomes disabled the time spent on home production by her husband increases substantially. In my preferred estimate, a healthy man, if his wife gets to the highest level of disability, would increase time spent on home production by about 75%. A woman, if she does not receive help from her family and if the household does not have a LTCI, is also expected to increase hours of home production substantially when her husband gets disabled.

However, the influence of this insurance on life-cycle behaviours can only be understood if we take into account the uncertainties surrounding the life course of retired individuals. In particular, as members of a couple age at the same time and may face disability simultaneously, it is important to model realistically the risk that they face to evaluate how this insurance affects savings.

As a consequence, I extend my model to a life-cycle setting. I then can estimate the risk of death, disability and medical expenditures directly on the data. Feeding this risk into the model, I can adjust its different parameters to match some key moments of the data[9].

First of all, I show that this model can reproduce most of the observed patterns in the data. In particular, as can be seen in figure 4.5, it reproduces well the patterns of home production in parallel with those of wealth for households in the second to the fourth income quartiles. More precisely, the model reproduces declines in time spent on home production as a function of age and disability which are in line with the data. Moreover, it reproduces well the fact that a husband increases hours of home production when his wife is disabled. It also reproduces well the fact that women in a couple spend more time on home production than single women, while the reverse is true for men. Finally, it manages to reproduce quite well wealth patterns as a function of age and disability for households in the second to the fourth income quartiles.

[9]This method is known as the method of simulated moments and consists in (i) simulating a model with a given vector of parameters, (ii) measuring the distance between the moments of the model and those in the data and (iii) repeating (i) and (ii) until the distance is minimized.

A key advantage of building a structural model is that it allows for rich fined-tuned experiments. For instance, using the model we can assess the effect of disability on life-cycle behaviours by simply shutting down the increase in the disutility from doing home production when disabled. We can also ask questions such as: what would be the consequences if men faced longevity risk similar to the one of women? Finally, for my purpose a great advantage is that I can shut down the insurance channel brought out by the presence of a spouse and see its influence on life-cycle behaviours.

First of all, I show that the negative effects that disability and age have on home production affect greatly savings behaviours in the model. Typically, if we shut down the effect of disability on home production, we find that households would dissave much more rapidly. This suggests that the welfare costs of disability are high and that a large amount of precautionary savings are needed to deal with it.

Second, I study the welfare gains that stem from the insurance brought out by a spouse. In particular, I show that if a man is not able to increase hours of home production when his wife is highly disabled, this results in a substantial loss in a one-period setting or intratemporally. Thus, it appears that this insurance channel is valuable for a household in which one of the two members is disabled.

However, I find that intertemporally this insurance has little influence. I perform a similar exercise to the one just described above and then see how this would affect savings behaviours. I find that it has little influence. Typically, simulating the model with or without this insurance leads to dissavings behaviours which are very close. This stems from the fact that disability risk is correlated between spouses and that a woman faces a large risk of being widowed when she is disabled. Hence, the provision of the insurance described previously is very uncertain.

A second channel through which a spouse insures another spouse also stems simply from the fact that they might not be disabled at the same time. To evaluate how this affects savings, I look at how savings behave when the man faces similar shocks to his disutility to do home production than his wife. In this case, I find that there is less dissavings but the quantitative impact is not very large either. Hence, the insurance channel brought out by a spouse, though present and valuable intratemporally, has a relatively minor effect on savings behaviours.

Finally, I try to assess what would be the implications if men had a longevity similar to the one of women. I find that the savings behaviours of couples would be greatly change in this case. Couple households would dissave much less rapidly as can be seen in figure 4.12. Hence, contrary to the argument in Lakdawalla and Philipson [2002] which say that a reduction of the gap in longevity between men and women would reduce long-term care needs by increasing the amount of informal care, I find that, would men and women have similar longevity, the needs for savings for precautionary motives would increase. Of course, one could assume that men could experience an increase in longevity with less disability than women, but this is not evident.

All in all, the results suggest that the informal insurance brought out by a spouse is highly limited by the fact that risk is correlated between spouses and that disability often occurs when one is single. Hence, policymakers if thinking about making entitlement reforms should not overvalue such type of insurance. Moreover, an increase of the longevity of men for instance would have high chances of increasing the needs for savings rather than decreasing them. Indeed, the results of this chapter suggest that the increase in needs for old age is way higher than the reduction in needs brought out by the potential provision of informal insurance by a spouse.

1.2 Housing Markets

Housing markets experienced very large fluctuations in recent years. The early 2000s saw increases of house prices in real terms of more than 50% in countries like Britain, France, Ireland, Spain or the United States. Usually, these large variations in house prices have also been characterized by debt crisis such as in the US (the so-called *subprime crisis*), Ireland or Spain with usually large consequences on financial stability and public debt. As a matter of fact, the research on the subject has been growing as it became evident that understanding better housing markets is essential for policymaking as fluctuations in those markets appear to have large spillovers.

The history of the study of debt dynamics is not new. Irving Fisher [1933], following the great depression, developed a theory of debt-deflation which, according to him, would have explained the severity of the depression which followed the crash of 1929. More recently, Kiyotaki and Moore [1997] have developed a framework in which agent have heterogeneous discounting and in which debt is linked to the value of a collateral. The reason behind the existence of such a collateral lies in the fact that debt repayment cannot be enforced. They have shown that such collateral constraints can amplify small and temporary shocks to technology or income. This is because the presence of collateral constraints generates both a static and a dynamic multiplier. Typically, a negative shock to the value of collateral affects negatively the amount of debt agents can borrow, which reduces economic activity and affects even more negatively asset prices. As investment falls, it also impacts output in future periods and the price of collateral. This latter effect generates a dynamic multiplier.

The purchase of a home is very often associated with borrowing from a mortgage which features the home as a collateral. The framework in Kiyotaki and Moore [1997] has thus been applied to the housing market starting mainly with Iacoviello [2005]. Since then, it has been used extensively to study the parallel dynamics in the housing and debt markets. Without being exhaustive the list of papers using this framework includes: Campbell and Hercowitz [2006], Iacoviello and Neri [2010], Liu et al. [2013], Justiniano et al. [2014], Ferrero [2015] or Guerrieri and Iacoviello [2015]. Hence, this framework can now be considered as a benchmark in the literature.

However, one element that these models do not usually take into account is the presence of a rental market for housing. In the US, for instance, the share of renters is about a third of the population. Moreover, the rent price ratio experienced sizeable fluctuations in recent years. Both its size and its potential interactions with the market for housing purchases imply that this is an important market to study. Moreover, D'Albis and Iliopulos [2013] have shown that, when introducing this *missing* market in the benchmark model with collateral constraints, impatient agents do not borrow and purchase houses in steady state as in Kiyotaki and Moore [1997], but rent houses from the patient agent. As a consequence, introducing this market implies that debt does not play any role in local dynamics as there will be no indebted homeowners. Given that we observe a rental market in real life, this result suggests that there is an important flaw in the theory.

In the third chapter of this thesis, which is a joint work with Hippolyte d'Albis and Eleni Iliopulos, we show that it is actually possible to modify the setting à la Kiyotaki and Moore [1997] to allow for a rental market and, at the same time, have indebted homeowners. This is done by introducing a simple parameter (ϕ in our model) which, in our opinion, reflects the fact that the rental market for houses is imperfect. There are several reasons to think that this is the case. For instance, there are evident moral hazard concerns in this market as has been emphasized in Henderson and Ioannides [1983]. Moreover, certain modifications of the home by the renter are usually prevented. In our model, it is possible to have in the end three types of agents: a homeowner lending funds and housing services to others, an indebted homeowner, and a renter.

To understand this result, it is key to grasp the reasons behind the one in D'Albis and Iliopulos [2013]. In a model à la Kiyotaki and Moore [1997] where there is no rental market, impatient agents would borrow from patient agents up to the limit imposed by the collateral constraint. This is due to the fact that the interest rate will effectively be set by the patient agents and will thus be too low for the impatient agents to save. As, in general, they can borrow only a share $m < 1$ of the value of their homes, the collateral constraint effectively forces them to save at an interest rate considered too low.

If you now introduce a perfect rental market you are effectively removing an inefficiency. Impatient agents would not have to save at an interest rate considered too low and thus will decide to be renters rather than homeowners. As a consequence, there will be no indebted homeowners in steady state and debt will play no role in local dynamics. However, if we think that the rental market for housing is not perfect, then we see that the result in D'Albis and Iliopulos [2013] might be extended to allow for such a possibility.

This is what is done in the third chapter of this thesis. In our model very impatient agents will decide to rent despite the inefficiency in the rental market. This is because they care very little about the future and thus will have a large "aversion" to save. Moderately impatient agents will however become indebted homeowners as they care more about the future and are thus more inclined to save rather than rent and face the inefficiency in this latter market. We are thus able to replicate the observed feature in the data of the existence of indebted homeowners and of renters, within the framework of Kiyotaki and Moore [1997].

An advantage of our framework is that it can easily be extended to a real business cycle (RBC) setting which can be solved with usual perturbation methods. While some works have included a rental market as Kiyotaki et al. [2011] and Sommer et al. [2013], they had to have additional demographic elements which prevented them to introduce aggregate risk. Thus, their studies were limited to study the transition from one deterministic steady state to another. Iacoviello and Pavan [2013] introduced a rental market in a setting with aggregate risk but their model did not feature endogenous house prices. On the contrary, our small deviation from the framework that can be found, for instance, in Iacoviello and Neri [2010] allows us to study the dynamics of debt and house prices in a model with a rental market and aggregate risk.

We thus apply our model to a real business cycle setting and calibrate it to match several key elements of the data. In particular, we match a realistic proportion of homeowners and renters, while previous models had difficulties along this line as they did not feature a third of the population (the renters). Moreover, we match the debt to GDP ratio which allows us to study the fluctuations of mortgage debt.

We then study how our model reacts under technological shocks in the housing and construction sectors. We show that these shocks can help to reproduce most of the volatilities and correlations that are observed in the data. In particular, they can explain about 60% of the volatility of house prices at business cycle frequencies and can explain about all the volatility of debt. Moreover, we reproduce quite well most of the correlations in the data and, in particular, the correlation between debt and house prices. The model is less successful in reproducing the positive correlation between residential investment and house prices, which is a usual result for a model with only technological shocks as is the case in Davis and Heathcote [2005]. We also have some difficulty to reproduce the negative correlation between the rent price ratio and house prices as the one our model reproduces is less negative than the one in the data. But overall, our model is successful in many dimensions as it can replicate most of the empirical patterns in a model with a rental market for houses and with debt. Moreover, this model could be easily extended to allow for other interesting features.

Finally, we study how relaxing the borrowing constraint affects the dynamics of our model. We find that, by itself, the relaxation of borrowing constraints has only a minor effect on house prices. This seems to confirm the results in Kiyotaki et al. [2011] and Sommer et al. [2013] which found, in models with rental markets and debt very different from ours, that relaxing collateral constraints had very little influence on house prices.

Chapter 2

Introduction Générale

Cette thèse applique certains des outils de l'analyse dynamique pour aborder plusieurs questions liées à deux éléments majeurs ayant un impact les économies modernes : le vieillissement (et plus particulièrement les comportements durant la retraite) et la dynamique des marchés immobilier.

2.1 La question du vieillissement

Le vieillissement est un processus global ayant un influence importante sur les économies modernes. Pour le voir notons que le taux de dépendance, à savoir le rapport de la population âgée de plus de soixante-cinq ans sur la population âgée de quinze à soixante-quatre ans, devrait augmenter sensiblement dans les quarante prochaines années, et ce dans la plupart des économies developpées comme indiqué dans le tableau 2.1. En ce qui concerne les pays pour lesquels cette évolution devrait être la plus forte, notons par exemple la cas du Japon qui, d'ici 2050, devrait voir ce taux passer à 71,8% alors qu'il est d'environ 36% aujourd'hui. Bien que l'évolution japonaise soit des plus extrêmes, notons que les autres économies dévelopées ne font pas exception. Par exemple, l'Italie et l'Allemagne - deux pays ayant un taux de natalité bas et faisant face à l'augmentation de la longévité - devraient avoir des taux de dépendance aux alentours 60% en 2050, tandis que ceux-ci étaient d'à peu près 30% en 2010. Même dans certaines économies en développement, nous pouvons observer des hausses comparables. Par exemple, en Chine, en partie en raison de la politique de l'enfant unique, le taux de dépendance devrait être multiplié par environ 3,5 d'ici 2050.

Ce phénomène soulève des défis clés. Tout d'abord, l'augmentation du taux de dépendance exerce un pression mécanique sur la viabilité des finances publiques au sein des pays utilisant des systèmes par répartition. En effet, une moindre proportion de travailleurs va

TABLE 2.1: L'évolution du taux de dépendance dans plusieurs pays

Pays	Taux de dépendance (2010)	Taux de dépendance (2050)
Chine	11.4	39.0
France	25.9	44.2
Allemagne	31.6	59.9
Italie	30.9	62.3
Japon	36.0	71.8
États-Unis	19.5	35.5

[1] Les données proviennent des nations unies. Les données pour 2050 représentent le scénario médian calculé par les nations unies.
[2] Tous les chiffres sont en pourcentage.

financer une proportion toujours plus importante des retraités. Ceci est non seulement la conséquence naturelle d'une augmentation de la longévité, mais reflète également l'héritage du baby-boom, qui a souvent été suivi par un effondrement de la natalité. Ainsi, le fait que les cohortes partant à la retraite sont d'une taille importante par rapport à celles plus récentes accentue la difficulté pour les économies modernes de faire face aux nombreux défis posés par une longévité croissante.

Même au sein des pays où la retraite est financée par capitalisation, via un système privé ou bien organisé par l'État, les mêmes types de problèmes se posent[1]. Dans une économie fermée, à productivité par travailleur constante, si la part des travailleurs dans la population totale diminue, le PIB par habitant diminuera mécaniquement. Ainsi, la question portant sur la manière de maintenir un niveau de vie des retraités satisfaisant sans baisser celui des travailleurs reste posée.

Bien évidemment, de nombreuses solutions pouvant atténuer ce problème existent : investir à l'étranger (c'est-à-dire financer les retraites à l'aide du travail des étrangers), favoriser la migration des jeunes (ce qui revient plus ou moins au même), augmenter l'âge de départ en retraite (afin d'abaisser mécaniquement le rapport nombre de retraités sur nombre de travailleurs), mettre en place des mesures favorables à une hausse de la productivité (afin d'augmenter la production globale par heures travaillées, bien que ce type de politique puisse avoir des résultats incertains)... Toutes ces solutions, comme cela est souvent le cas en économie, soulèvent d'autres questions.

[1] Bien que diffŕents types de système peuvent avoir des conséquences différentes sur l'accumulation du capital et la croissance. Voir, par exemple, l'analyse dans De la Croix and Michel [2002]

Pour aborder ces questions, il est cependant essentiel d'avoir une compréhension approfondie des comportements individuels. Par exemple, pour la mise en place de politiques publiques ou des systèmes d'assurance (à la fois publics et privés), il est fondamental de comprendre l'étendue des risques et des besoins qui sont spécifiques aux retraités. Cela a été l'objectif des deux premiers chapitres de cette thèse qui, je l'espère, contribuent de manière significative à notre connaissance générale sur le sujet.

Tout d'abord, je tiens à souligner le fait que les retraités ont des besoins différents de ceux du reste de la population. En particulier, les retraités ont une plus forte probabilité d'être en mauvais santé et de faire face à des situations de dépendance. En conséquence, afin de leur permettre le meilleur niveau possible de bien-être, il est important de prendre en compte ces facteurs qui affectent les besoins de consommation. La dépendeance nécessite en particulier certains services qui peuvent être très coûteux et sont incertains. En ce qui concerne les États-Unis, sur lesquels j'ai concentré mes recherches, ces coûts peuvent être très élevés notamment en fin de vie comme démontré dans French and Jones [2004] et De Nardi et al. [2010], avec des risques de dépenses extrêmement larges non négligeables (French and Jones, 2004).

Cela rend la planification de la retraite à bien des égards plus complexe que celle que l'on trouve, par exemple, dans le travail fondateur de Yaari [1965], qui a démontré que les rentes viagères [2] devraient être préférées aux simples obligations dans un environnement où la seule incertitude découle de la longévité [3]. En effet, le risque auquel les retraités font face ne comprend pas seulement leur durée de vie, mais également leur état de santé futur et les dépenses qui pourraient en résulter. Pour ce qui concerne l'allocation optimale de l'épargne au cours de la retraite, de la valeur des mécanismes informels d'assurance et des produits d'assurance qui peuvent être intéressants pour les retraités, ceci a bien évidemment des conséquences très importantes.

Deuxièmement, les problèmes rencontrés par les retraités sont à bien des égards de nature dynamique. Typiquement, la question de la désaccumulation de la richesse au cours de la retraite est une question dynamique. Et reliée à cette dernière est celle des avantages des produits financiers ou d'assurance disponibles pour les retraités. Ainsi, une constante de mon travail sur le sujet a été d'utiliser le modèle de cycle de vie. Ce modèle a une longue histoire qui remonte au moins aux travaux de Franco Modigliani. En dépit de sa longue histoire, ce domaine a connu plusieurs évolutions majeures ces trente dernières années et est encore extrêmement actif aujourd'hui. En particulier, l'introduction du risque dans ce cadre a permis de rćoncilier avec la théorie plusieurs faits observées dans les données.

[2]Une rente viagère est un produit d'assurance contre le risque de longévité. Dans sa forme la plus standard, il offre une annuité constante tant qu'une personne est vivante et zéro annuité dans le cas où cette personne est morte. À l'équilibre, un tel produit sert à mutualiser le risque de longévité.

[3]Ce résultat a été redémontré dans un cadre plus général par Davidoff et al. [2005]

Par exemple, Zeldes [1989] a montré que l'introduction du risque lié aux revenus du travail génère une fonction de consommation très différente de son équivalent certain. Cela permet en outre d'expliquer deux phénomènes empiriques: la forte sensibilité de la consommation aux revenus transitoires et la forte croissance de la consommation en présence de taux d'intérêt faibles. En outre, il soulignait déjà à l'époque que le risque de frais médicaux pourrait expliquer la faible désépargne des personnes âgées, un point étudié ensuite plus en détail par Palumbo [1999] et De Nardi et al. [2010]. Plusieurs autres travaux ont également souligné l'importance du risque pour expliquer les comportements au cours du cycle de vie comme Carroll [1997] ou bien Gourinchas and Parker [2002]. Ces derniers ont également introduit la méthode des moments simulés pour l'estimation des modèles de cycle de vie, une technique qui a été appliquée dans de nombreux autres travaux par la suite (De Nardi et al., 2010 ou Lockwood, 2013 sont des exemples notables). D'autres travaux ont également tenté de comprendre l'effet des programmes publics sur les comportements au cours cycle de vie comme Hubbard et al. [1995] ou De Nardi et al. [2014]. Par ailleurs, il a été démontré, comme par exemple dans Attanasio and Weber [1995], que contrôler pour l'offre de travail et la démographie est essentiel pour évaluer la pertinence du modèle de cycle de vie.

La question des comportements de cycle de vie au cours de la retraite a elle-même connu des évolutions très intéressantes au cours des dernières années. Palumbo [1999] et De Nardi et al. [2010] ont montré qu'un modèle de cycle de vie avec risque de dépenses de santé pouvait rationaliser le faible taux de désépargne des retraités observé dans les données américaines. Cela montre une fois de plus que la modélisation du risque est un élément essentiel pour la compréhension des comportements de cycle de vie. Ces modèles ont toutefois quelques difficultés à rationaliser la faible demande pour certains produits d'assurance comme l'assurance dépendance (AD) comme démontré par Lockwood [2013]. Ce dernier attribue la faible demande d'AD à la présence de motifs de legs importants chez le retraités qu'ils ont peu de désir d'assurer. Dans le premier chapitre de cette thèse, j'étudie la demande d'AD et regarde de plus près l'influence de l'immobilier sur celle-ci, un point précédemment abordé par Davidoff (2009, 2010).

Alors que je me suis concentré lors de mon travail sur les comportements de cycle de vie à partir de l'âge de la retraite, il existe bien évidemment une interaction entre les besoins d'épargner pour la retraite et les comportements du cycle de vie avant la retraite. En particulier, French [2005] et French and Jones [2011] ont introduit des modèles de cycle de vie avec offre de travail endogène dans lesquels les risques rencontrés au cours de la retraite influent sur les décisions de départ à la retraite. Par exemple, ces derniers montrent que Medicare a un impact important sur les décisions de retraite des Américains car ce programme diminue le risque médical pendant la retraite. Malgré le grand intérêt pour ce type de travaux, ceux-ci sont encore peu nombreux. Par conséquent, une recherche plus approfondie est nécessaire afin d'intégrer à la fois le risque avant et après la retraite dans les modèles de cycle de vie.

Une deuxième limite de la littérature actuelle est que, jusqu'à présent, celle-ci s'est souvent intéressée aux retraités célibataires par simplicité comme par exemple dans De Nardi et al. [2010]. Dans mon deuxième chapitre, j'ai essayé de répondre à cette limite en modélisant explicitement les couples. Mon idée est que les couples pourraient différer de célibataires dans le sens où, dans un couple, un conjoint en bonne santé peut prendre soin d'un conjoint en moins bonne santé, fournissant ainsi un certain type d'assurance. Bien que cette idée n'a rien de nouveau, elle n'a jusqu'à présent pas été incluse dans un modèle de cycle de vie et donc son importance sur les comportements de cycle de vie ne pouvait pas être évaluée. Une innovation clé de mon travail a été d'étudier de plus près les comportements liés à la production domestique qui sont observés pendant la retraite. En particulier, comme je le montre en détail dans cet article un avantage clé de la production domestique pour étudier ce type d'assurance informelle est qu'il permet des comparaisons inter-temporelles. J'ai par conséquent introduit cette dimension production domestique, comme dans Becker [1965], dans le modèle collectif de ménage introduit par Chiappori [1988] et Apps and Rees [1988]. [4] Je montre que ce modèle peut reproduire la plupart des dynamiques observées dans les données, et peut donc permettre d'étudier l'importance de ce canal d'assurance.

Pour ma part, je crois qu'il existe actuellement trois voix que la recherche future devrait explorer plus en avant, celles-ci pouvant être également combinées entre elles. La première est qu'il est nécessaire d'améliorer notre compréhension des interactions entre vie active et retraite. La seconde est qu'il est nécessaire de mieux comprendre en quoi les couples peuvent être différents des célibataires. Sur ce point, je pense que cette thèse apporte une contribution originale et pertinente. Un point qui est lié à cette dimension de couple est qu'il est nécessaire de mieux comprendre l'assurance informelle qui peut provenir de la famille[5]. Troisièmement, la plupart des résultats de la littérature actuelle n'ont pas été appliqués à des cadres d'équilibre général. Or comprendre comment ces mécanismes peuvent affecter l'accumulation du capital, l'innovation, et en fin de compte la croissance, semble fondamental.

Je décris à présent en détail les travaux et résultats des deux premiers chapitres de cette thèse et les relis à la littérature existante.

[4] En fait, je me concentre essentiellement sur le cas spécial unitaire du modèle collectif.

[5] Barczyk and Kredler [2014] et Dobrescu [2015] sont des contributions importantes dans ce domaine.

2.1.1 Premier Chapitre: "Long-Term Care Insurance, Housing Demand, and Decumulation"

Dans le premier chapitre, je m'intéresse aux gains que les retraités pourraient retirer de l'assurance dépendance (AD). Cette question a été étudiée dans divers autre travaux et Brown and Finkelstein [2009] fournissent une revue de littérature détaillée sur le sujet. En particulier, une question constante des économistes est: pourquoi les retraités n'achètent-ils pas plus d'AD ? En effet, en dépit du fait que le risque de dépendance est très coûteux, au moins aux États-Unis, que les retraités - en particulier les plus riches - désépargnent relativement peu, et que le prix de l'AD est relativement juste en particulier pour les femmes (voir Brown and Finkelstein, 2008), la demande d'AD privée reste faible. Dans un modèle de cycle de vie classique, dans lequel les individus n'ont pas de motifs de legs, un taux de désépargne faible devrait être le signe de gains importants à s'assurer. Par conséquent la faible demande d'AD constitue un puzzle qui est connue sous le nom de "long-term care insurance puzzle".

Brown and Finkelstein [2008] ont montré que la présence du programme Medicaid pouvait expliquer la faible demande pour ce produit pour les ménages avec relativement peu de richesse. En effet, Medicaid paie pour les soins de dépendance, et en particulier pour l'institutionnalisation, quand les ménages sont dans le dénuement. Cependant, le type d'institutions pour lequel Medicaid paie n'est pas forcément de très bonne qualité et on observe un certaine aversion des personnes âgées pour ce type d'aide comme démontré dans Ameriks et al. [2011]. Par conséquent, il reste difficile à comprendre pourquoi la demande pour ce produit reste faible pour les ménages ayant une richesse importante.

Dans deux articles liés l'un à l'autre, Davidoff (2009, 2010) a démontré que l'immobilier pouvait réduire les gains liés à l'AD. En particulier, il dit que la richesse immobilière est un substitut crédible à l'assurance dépendance chez les ménages les plus riches qui ont généralement une richesse immobilière qui est importante par rapport à une grande partie de la distribution des coûts de dépendance. Pour comprendre son raisonnement il faut remonter aux travaux de Venti and Wise [2004] qui ont montré que les retraités désaccumulent leur richesse immobilière principalement en cas de veuvage ou de départ en maison de retraite. Par conséquent, si les individus ont une forte préférence pour rester dans leur maison tout le long de la retraite et n'ont pas accès à des produits de type "reverse mortgage"[6], ils devraient désaccumuler leur richesse immobilière principalement au moment du départ en maison de retraite. Ainsi, l'immobilier fournit des fonds en

[6] Un reverse mortgage est un emprunt hypothécaire à l'envers où les ménages peuvent emprunter sur la valeur de leur bien immobilier et dont le remboursement s'effectue en général à la mort du contractant ou lorsque celui-ci revend le bien immobilier. En français, le terme reverse mortgage se traduit par prêt hypothécaire inversé.

période de dépendance, de même que l'AD. Ceci suggère que l'immobilier pourrait jouer un rôle de substitut à l'AD.

Dans ces travaux, il soutient que plus le ratio de la richesse immobilière sur la richesse totale est élevée, plus l'effet d'éviction de l'immobilier sur l'AD est fort si les retraités ont une forte aversion à la mobilité et n'ont pas accès à des "reverse mortgages" attractifs. Il conclut en disant que le développement du marché des prêts hypothécaires inversés pourrait être un pré-requis au développement de l'AD.

Dans ce chapitre, je soutiens qu'un moyen d'évaluer la pertinence de l'argument de Davidoff est d'utiliser les informations disponibles sur la désacccumulation de la richesse et, en particulier, sur la vitesse à laquelle les retraités désépargnent leur richesse financière. Pour comprendre ceci, remarquons tout d'abord que dans un modèle de cycle de vie standard sans immobiler et sans motif de legs, la vitesse à laquelle les individus désépargnent est un indicateur de l'étendue de leurs motifs de précaution. L'évaluation de ces derniers est essentiel pour comprendre l'étendue des gains à s'assurer.

Avec ce type de modèle en tête un chercheur, pour comprendre l'étendue de l'aversion au risque des retraités, s'intéressera tout d'abord à la manière dont ils désépargnent leur richesse totale. En théorie on peut observer deux types de comportements. Ces derniers sont illustrés sur la figure 1.1 où la richesse totale est représentée comme une fonction de l'âge. Je fais l'hypothèse que le graphique commence à l'âge du départ en retraite et, par conséquent, je fais abstraction de l'endogénéité de celui-ci et de la richesse au début de la retraite. Le premier type de comportement est représenté par la courbe noire décroissante. Le second type de comportement est représenté par la courbe grise en forme de bosse. Visiblement, le second type de comportement sera considéré comme faisant état d'un motif de précaution plus fort que le premier. Ainsi, un agent présentant le second type de comportement aura des gains à s'assurer plus forts qu'un agent du premier type.

A présent posons nous la question de savoir en quoi cela diffère si l'immobilier est introduit dans le modèle. Nous supposerons comme Davidoff (2009, 2010) que les retraités ont une forte aversion à la mobilité résidentielle, excepté s'ils sont contraints d'aller en maison de retraite, et n'ont pas accès à un marché de prêts hypothécaires inversés. L'immobilier dans ce cas de figure est représenté par la courbe en pointillés parallèle à l'axe des abscisses. La différence entre la courbe de richesse totale et cette courbe représente la richesse financière désirée pour satisfaire les motifs de précaution. Le premier type d'agent serait "sur-assuré" par l'immobilier au niveau du point B, c'est-à-dire relativement tôt. En effet, s'il est encore en bonne santé et n'a pas accès à un prêt hypothécaire inversé, la valeur de sa richesse immobilière sera plus importante que la richesse qu'il aurait désiré conserver pour des motifs de précaution. Dans ce cas, l'effet

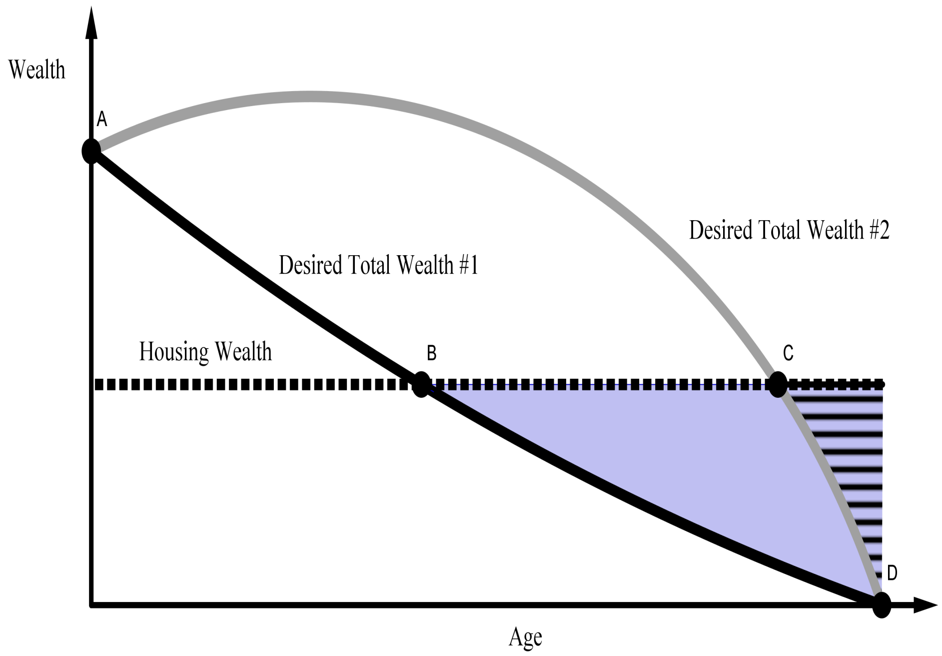


FIGURE 2.1: Désaccumulation de la richesse et importance de l'immobilier

d'éviction de l'immobilier sur l'AD sera fort. En revanche, un agent du second type ne sera sur-assuré par l'immobilier que relativement tard. L'effet d'éviction dans ce cas-ci sera plus faible. En effet, l'agent aurait encore des gains substantiels à s'assurer car cela lui permettrait de désaccumuler sa richesse financière plus tôt et donc de consommer plus plus tôt sans risquer de ne jamais consommer une grande partie de son épargne.

On voit, par ailleurs, que non seulement le ratio de la richesse immobilière sur la richesse totale est important pour déterminer la force de cet effet d'éviction, mais également la rapidité avec laquelle cette richesse est désépargnée. Par conséquent, pour évaluer la pertinence de l'argument de Davidoff, il est essentiel de prendre en compte cet aspect dynamique. La principale contribution de ce chapitre est d'utiliser les informations sur cette désépargne afin d'évaluer l'effet d'éviction de l'immobilier sur l'AD.

Afin d'effectuer cette analyse, il est important d'observer le comportement des retraités par rapport à leur richesse au cours du temps. Par conséquent, j'ai décidé d'utiliser la base de donnée HRS[7] qui est, sans aucun doute, la base de données américaine la plus connue sur les retraités. Un de ses nombreux avantages est que la dimension de panel de cette base est très importante. On peut donc suivre les comportements des agents sur de longues périodes. En particulier, je peux observer les comportements de ceux

[7] Pour Health and Retirement Study.

qui restent propriétaires et voir à quelle vitesse ils réduisent le montant de leur épargne financière.

Cela me permet de calibrer de manière réaliste des modèles de cycle de vie avec immobilier, afin qu'ils reproduisent les comportements observés dans les données. Cette étape est essentielle car elle permet de mettre en place des analyses contre-factuelles crédibles qui permettent d'évaluer les gains liés à l'AD en présence d'immobilier.

Je trouve en utilisant un modèle similaire à celui de Davidoff, mais calibré de manière à reproduire les dynamiques de la richesse observées empiriquement, qu'un modèle avec immobilier peut expliquer pourquoi les célibataires retraités dans les trois premiers quartiles de la richesse entre 70 et 80 ans n'achètent pas d'AD. Par conséquent, l'immobilier pourrait expliquer une part significative de la faible demande d'AD observée. Cependant, le modèle a plus de difficulté à expliquer pourquoi la demande d'AD reste faible dans le quatrième quartile. En effet, dans les données seulement 15% des retraités ont une AD alors que le modèle génère des gains élevés à acquérir une AD pour cette frange de la population. Ce résultat provient du fait que ces individus gardent une richesse financière élevée même à des âges avancés, ce qui est cohérent avec un fort motif de précaution.

De plus les hypothèses mises en avant par Davidoff peuvent être considérées comme relativement fortes. En particulier, son hypothèse que les retraités ne veulent absolument pas bouger s'ils ne doivent pas aller en maison de retraite génère une très forte volonté (presque exogène) de ne pas vouloir se départir de sa richesse immobilière. Je démontre que dans un modèle (basé sur celui de Yao and Zhang [2005]) avec demande d'immobilier endogène, un marché locatif imparfait, et des coûts de transaction, nous pouvons reproduire le fait que les retraités ont tendance à conserver leur bien immobilier jusqu'à très tard et que celui-ci est vendu principalement quand les individus font face aux dépenses liées à la dépendance. Dans ce modèle, la volonté de rester propriétaire provient de l'imperfection du marché locatif, des coûts de transaction et du fait que les individus souhaitent garder une richesse immobilière importante pour faire face au risque de dépendance. Dans ce modèle, le fait que les individus restent propriétaires jusqu'à très tard est lié au risque de dépendance. Ainsi, si un individu achète une AD il aura tendance à rester propriétaire moins longtemps et l'effet d'éviction de l'immobilier sur l'AD sera donc plus faible. Je démontre que, dans ce modèle, une proportion plus importante de la population pourrait bénéficier de l'AD. Ceci confirme le fait qu'il est difficile de rationaliser la faible demande d'AD chez les ménages les plus riches par la présence de l'immobilier.

Par conséquent, d'autres explications sont nécessaires. Une d'entre elles, mise en avant par Lockwood [2013], serait que les retraités auraient des motifs de legs importants qu'ils auraient peu de volonté d'assurer. Ceci permettrait d'expliquer la faible demande d'AD, mais également de rentes viagères comme démontré dans Lockwood [2012] et de prêts hypothécaires inversés. Dans le contexte de son argument, l'immobilier ne jouerait qu'un rôle mineur sur la demande d'AD, car le désir de rester propriétaire jusqu'à tard serait expliquer par les motifs de legs, ces derniers expliquant par eux-mêmes le faible intérêt pour l'AD. Dans tous les cas, cela renforcerait le fait que l'immobilier ne peut pas expliquer la faible demande d'AD chez les ménages les plus riches.

Cependant, il n'existe pas à présent de consensus sur cette question des motifs de legs. En particulier, l'AD étant un contrat de long-terme, plusieurs problèmes de confiance sont exacerbés. Si ceux-ci sont prépondérants pour expliquer la faible demande d'AD, alors résoudre ce type de problèmes en parallèle pour le marché de l'AD et des prêts hypothécaires inversés paraît essentiel pour développer ces deux marchés. En effet, alors que Davidoff (2009, 2010) a mis en avant le fait que l'absence de prêts hypothécaires inversés pouvait réduire la demande d'AD, je montre que les ménages les plus riches auraient très peu d'intérêt à contracter un prêt hypothécaire inversé en l'absence d'AD. Ainsi existe-t-il une double complémentarité entre ces produits. Une politique visant à développer un de ces deux marchés aurait ainsi tout intérêt à aussi développer l'autre pour être véritablement efficace.

2.1.2 Deuxième chapitre: "Disability in Retirement, Home Production, and Informal Insurance between Spouses"

Dans ce chapitre, j'analyse une problématique relativement nouvelle. La grande majorité des travaux existants sur les modèles de cycle de vie à la retraite s'intéresse soit aux célibataires comme dans De Nardi et al. [2010], soit représente le couple sous une forme très simple, via par exemple l'existence d'économie d'échelles comme dans Nakajima and Telyukova [2014b]. Dans cet article, j'essaie de comprendre comment les couples diffèrent des célibataires en intégrant un mécanisme particulier : l'assurance informelle qu'un conjoint en bonne santé peut apporter à un autre en mauvaise santé. La question principale posée par ce chapitre est: est-ce que ce type d'assurance affecte de manière significative les dynamiques de la richesse ?

Afin de répondre à cette question, je construit un modèle dans lequel les couples sont modélisés explicitement et dans lequel la consommation est une combinaison de temps passé sur la production domestique et de dépenses comme introduit par Becker [1965]. Alors que plusieurs auteurs, et en particulier Aguiar and Hurst (2005, 2007), ont étudié les phénomènes liés à la production domestique lors de la transition entre vie active et retraite, je n'ai pas connaissance d'études économiques essayant de comprendre en détail l'influence des variations de la production domestique observées durant la retraite. Cependant, on observe de nombreux phénomènes intéressants. En particulier, j'utilise les données américaines CAMS[8] et je montre qu'on observe des mécanismes d'assurance entre époux en ce que qui concerne la production domestique.

Tout d'abord, la production domestique, comme je le soutiens en détail dans 4.1.1, est utile pour comprendre les effets des problèmes d'invalidité sur la consommation. Cela provient du fait que la production domestique est effectuée de manière relativement similaire au cours du temps et que, donc, cela permet des comparaisons inter-temporelles.

Ensuite, la production domestique offre un sujet d'étude intéressant car elle connaît des variations très importantes au cours de la retraite. Par exemple, une femme âgée de soixante-dix ans sans problème d'invalidité effectue environ 1200 heures de production domestique par an. Ce chiffre représente environ 65% du temps moyen travaillé par un travailleur américain. Une femme âgée fortement invalide et ayant plus de quatre-vingt dix ans passe moins de 200 heures par an à faire de la production domestique. Ces variations sont, on le voit, extrêmement larges.

Enfin, nous observons des mécanismes d'assurance informels. En particulier, quand une femme en couple fait face à une situation d'invalidité, le temps passé sur les tâches de production domestique par le mari augmente de manière substantielle. Dans mon estimation préférée, un homme en bonne santé augmente de 75% le temps passé à effectuer de la production domestique si sa femme fait face à une situation d'invalidité relativement importante. Une femme augmente également le temps passé sur la production domestique si son mari est en mauvaise santé, si elle n'a pas accès à de l'aide extérieure (famille ou amis) et si elle n'a pas d'AD.

Cependant, l'influence de ce type d'assurance sur les dynamiques de cycle de vie peut seulement être comprise si l'on prend en compte l'ensemble des risques et incertitudes auxquels font face les retraités. En particulier, les membres d'un couple vieillissent de manière parallèle et leur risque d'invalidité est corrélé. Par conséquent, il est important de modéliser correctement ces risques afin d'évaluer l'importance de ce mécanisme d'assurance.

Par conséquent, j'étends le modèle à un cadre de cycle de vie. Je peux alors estimer les risques de mortalité, d'invalidité et de dépenses médicales en utilisant les données à ma disposition. En incluant, ces risques dans le modèle, je peux ajuster les paramètres de celui-ci afin de reproduire certains moments des données. Cette méthode est connue sous le nom de méthode des moments simulés.

[8]Pour Consumption and Activities Mail Survey

Tout d'abord, je montre que ce modèle peut reproduire la plupart des dynamiques que nous observons dans les données. En particulier, comme on peut le voir sur le graphique 4.5, il reproduit de manière fidèle les dynamiques de la production domestique et celles de la richesse (tout du moins pour les ménages allant du deuxième au quatrième quartile de la distribution des revenus). Plus précisément, le modèle reproduit quantitativement et qualitativement le fait que la production domestique diminue avec l'âge et le niveau d'invalidité. Il arrive également à imiter le fait que la production domestique des femmes mariées est plus importante que celle des femmes célibataires ou veuves, alors que le contraire est observé pour les hommes. Enfin, le modèle reproduit bien l'évolution de la richesse en fonction de l'âge et du niveau d'invalidité pour les ménages allant du deuxième au quatrième quartile de la distribution des revenus.

Un avantage fondamental de construire un modèle structurel est que ceux-ci permettent d'effectuer de riches analyses contre-factuelles. Par exemple, en utilisant ce modèle nous pouvons évaluer de manière précise les effets de l'âge et de l'invalidité sur les dynamiques de cycle de vie. Il suffit pour cela de simplement supprimer ces effets et de voir en quoi la dynamique de la richesse en serait modifiée. Nous pouvons également poser des questions du type : que se passerait-il si les hommes avaient un risque de longévité et d'invalidité similaire à celui des femmes ? Enfin, pour le but de cette recherche, nous pouvons évaluer l'importance de l'assurance potentielle fournie par un époux sur les dynamiques de cycle de vie en supprimant cette dernière.

Tout d'abord, je démontre que les effets négatifs de l'invalidité et de l'âge sur la production domestique affectent de manière importante l'évolution de la richesse au cours de la retraite. En particulier, si l'on supprime ces effets, on trouve que les ménages désépargnent leur richesse de manière bien plus forte que ce que l'on observe dans les données. Cela suggère que l'invalidité et l'âge ont de fort effets négatifs sur le bien-être qui nécessitent un épargne de précaution importante.

Ensuite, j'étudie les gains en bien-être qui proviennent du fait qu'un des époux puisse augmenter le temps passer sur la production domestique lorsque l'autre est en mauvaise santé. En particulier, je remarque que si un homme n'est pas en mesure d'augmenter le temps passé à effectuer des tâches de production domestique lorsque sa femme fait face à une situation d'invalidité, la perte en bien-être pour le couple dans un cadre intra-temporel est importante. Il apparaît ainsi que cette assurance représente un certaine valeur pour les ménages.

Cependant, d'un point de vue inter-temporel cette assurance a relativement peu d'effet. Pour démontrer cela, j'effectue un exercice similaire et je regarde qu'elle en serait l'impact sur les dynamiques de la richesse. Je trouve que l'influence sur ces dernières est mineure. Cela provient du fait que le risque entre les époux est corrélé et qu'une femme fait face à un risque important d'être veuve si elle se retrouve dans une situation d'invalidité. Ceci rend cette assurance très incertaine d'où son effet limité sur les dynamiques de la richesse.

Un autre canal via lequel un époux peut en assurer un autre provient simplement du fait qu'ils puissent ne pas faire face à des situations de handicap en même temps. Afin d'évaluer l'importance de ce canal, j'étudie la façon dont la richesse évolue si les maris font face aux mêmes chocs d'invalidité que leurs épouses. Dans ce cas, je trouve que les ménages désépargnent moins, ce qui traduit un augmentation du risque. Cependant, l'effet quantitatif est relativement faible également. On peut en conclure que les mécanismes d'assurance informels entre époux à la retraite ont certes une valeur d'un point de vue intra-temporel mais affectent peu les décisions d'épargne.

Enfin, j'étudie quelles seraient les implications si les hommes faisaient face aux mêmes risques de longévité et d'incapacité que leur épouses. Dans ce cas, je montre que la désépargne de la richesse des couples serait beaucoup plus faible. Cela va en quelque sorte à l'opposé du résultat de Lakdawalla and Philipson [2002]. Ces derniers mettaient en avant le fait que l'augmentation de la longévité des hommes par rapport à celle des femmes pourrait réduire les besoins liés à la dépendance du fait de la probabilité plus forte de pouvoir compter sur les mécanismes d'assurance informels entre époux. En effet, mes résultats suggèrent que ces mécanismes ont relativement peu d'importance comparés à une augmentation des besoins d'épargne liés à une augmentation de la longévité.

Pour conclure, ces résultats suggèrent que l'assurance informel provenant d'un époux est fortement limitée par la corrélation des risques et par le fait que l'invalidité advient souvent à des âges avancés où les personnes se retrouvent très souvent veufs ou veuves. Par conséquent, les responsables politiques ne devraient pas sur-évaluer ce type de mécanismes d'assurance dans leur évaluation du financement de la retraite. De plus, un accroissement de la longévité a plus de chances d'augmenter les besoins de financement, que de les réduire via la plus grande probabilité de pouvoir bénéficier d'une assurance informelle de la part d'un mari ou d'une femme.

2.2 Les marchés immobiliers

Les marchés immobiliers ont connu de très importantes fluctuations durant la période récente. Le début des années 2000 a connu des augmentations des prix immobiliers en termes réels de plus de 50% dans des pays tels que la Grande-Bretagne, la France, l'Irlande, l'Espagne ou les États-Unis. De plus, ces variations ont souvent été accompagnées, par la suite, de crises de dette comme aux États-Unis (la crise dite des *subprime*), en Irlande ou en Espagne avec parfois des conséquences très importantes sur la stabilité financière et l'état des finances publiques. Par conséquent, la recherche sur ce sujet est particulièrement active vu qu'il est devenu évident que l'impact des marchés immobiliers devait être mieux compris, au vu des conséquences plus larges qu'ils ont sur le reste de l'économie.

L'étude des dynamiques liées à la dette n'est pas nouvelles. Irving Fisher [1933], au vu de la grande dépression, a développé une théorie de la déflation par la dette qui, selon lui, pouvait expliquer la sévérité de la dépression qui a suivi le krach de 1929. Plus récemment, Kiyotaki and Moore [1997] ont développé un cadre d'analyse dans lequel les agents ont des taux d'escompte hétérogènes et où le niveau maximal de dette est défini par une contrainte de nantissement. La raison derrière l'existence d'une telle contrainte est que le paiement de la dette ne peut pas être forcé. Ils ont démontré qu'une telle contrainte de nantissement pouvait amplifier de petits chocs temporaires sur la technologie et les revenus. En effet, celles-ci génèrent à la fois un multiplicateur statique et un multiplicateur dynamique.

Étant donné que l'achat d'un bien immobilier est très souvent lié à l'obtention d'un crédit immobilier dans lequel le bien acheté sert de collatéral, le modèle de Kiyotaki and Moore [1997] a été appliqué à l'étude des marchés immobiliers. La première application notable de ce cadre pour l'étude des dynamiques immobilières a été effectuée par Iacoviello [2005]. Depuis, ce cadre d'analyse a été réutilisé dans de nombreux travaux essayant de comprendre les dynamiques parallèles de la dette et des marchés immobiliers. Sans être exhaustif, la liste des travaux sur le sujet utilisant ce cadre d'analyse comprend: Campbell and Hercowitz [2006], Iacoviello and Neri [2010], Liu et al. [2013], Justiniano et al. [2014], Ferrero [2015] ou Guerrieri and Iacoviello [2015]. Par conséquent, on peut désormais dire que celui-ci est devenu une référence dans le domaine.

Cependant, il est un élément que ces modèles ne prennent en général pas en compte : la présence d'un marché locatif de l'immobilier. Aux États-Unis, par exemple, la part des locataires dans la population totale est d'environ un tiers. De plus, le ratio loyer sur prix a connu des fluctuations importantes ces dernières années. À la fois par sa taille et par son interaction avec le marché de l'achat immobilier, le marché locatif représente un sujet d'étude important. De plus, comme démontré par D'Albis and Iliopulos [2013], lorsque l'on introduit ce marché manquant les agents impatients n'empruntent pas pour acquérir de l'immobilier à l'état stationnaire comme dans Kiyotaki and Moore [1997], mais préfèrent louer auprès de l'agent le plus patient. Par conséquent, l'introduction de ce marché implique que les dynamiques de la dette ne jouent aucun rôle dans les dynamiques locales comme, à l'équilibre, il n'y a pas de propriétaires-emprunteurs. Étant donné qu'en réalité on observe un marché locatif, cela représente apparemment un défaut important de la théorie.

Dans le troisième chapitre de cette thèse, en collaboration avec Hippolyte d'Albis et Eleni Iliopulos, nous démontrons qu'il est possible d'introduire un marché locatif dans le cadre de Kiyotaki and Moore [1997] tout en ayant à l'équilibre des propriétaires-emprunteurs. Ceci est possible via l'introduction d'un simple paramètre (ϕ dans notre modèle) que nous interprétons comme une imperfection sur le marché locatif. Il existe de nombreuses raisons de penser que le marché locatif est en effet imparfait. Par exemple, il existe des problèmes d'aléa moral évidents comme défendu dans Henderson and Ioannides [1983]. Par ailleurs, un locataire peut être limité dans certains usages qu'il souhaiterait faire du bien immobilier. Dans notre modèle, l'introduction de cette imperfection permet d'obtenir trois types d'agents différents : un propriétaire prêtant des fonds aux autres agents et louant des biens immobiliers, un propriétaire-emprunteur et un locataire.

Afin de comprendre ce résultat, il est important de revenir sur les raisons du résultat dans D'Albis and Iliopulos [2013]. Dans un modèle à la Kiyotaki and Moore [1997], où il n'y a pas de marché locatif, les agents impatients empruntent auprès de l'agent le plus patient jusqu'à la limite imposée par la contrainte de nantissement. Ceci est dû au fait que l'agent patient est celui qui fixe le taux d'intérêt à l'équilibre. À ce taux d'intérêt, les autres agents, moins patients, préfèreraient emprunter plutôt qu'épargner. Comme en général, ils peuvent seulement emprunter une part $m < 1$ de la valeur de leur bien immobilier, la contrainte de nantissement les force en quelque sorte à épargner à ce taux d'intérêt considéré comme trop bas.

Si désormais on introduit un marché locatif parfait, on supprime une inefficacité du modèle. Les agents impatients ne seraient ainsi pas contraints d'épargner à un taux d'intérêt trop bas et pourraient louer plutôt que devenir propriétaires. Par conséquent, il n'y aura pas de propriétaires-emprunteurs à l'état stationnaire. Cependant, si l'on pense que le marché locatif est imparfait, on voit alors que l'on peut modifier le cadre dans D'Albis and Iliopulos [2013] pour permettre une telle imperfection.

C'est ce que nous faisons dans le troisième chapitre de cette thèse. Dans notre modèle, les agents les plus impatients décident à l'équilibre de ne pas s'endetter pour acheter de l'immobilier et préfèrent louer, malgré l'existence de l'imperfection sur le marché locatif. Ceci est dû au fait qu'ils ont un intérêt faible pour le futur et que, par conséquent, ils ont une forte "aversion" à épargner. Les agents modérément impatients décident, en revanche, de devenir propriétaires-emprunteurs. En effet, ils sont plus enclins à épargner et donc préfèrent éviter l'inefficacité du marché locatif. Par conséquent, nous sommes en mesure de reproduire le fait qu'il existe à la fois des propriétaires-emprunteurs et des locataires dans le cadre de Kiyotaki and Moore [1997].

Un avantage de notre modèle est qu'il peut facilement être étendu à un cadre de cycles réels pouvant être résolu avec les techniques classiques de perturbation. Alors que d'autres travaux ont introduit des marchés locatifs comme Kiyotaki et al. [2011] ou Sommer et al. [2013], ils devaient ajouter d'autres éléments qui les empêchaient d'introduire du risque agrégé dans leurs modèles. Par conséquent, leurs travaux se limitaient à l'étude de la transition d'un état stationnaire déterministe à un autre. Iacoviello and Pavan [2013] ont introduit un marché locatif avec risque agrégé mais dans leur modèle les prix immobiliers ne sont pas endogènes. Au contraire, notre cadre qui dévie légèrement ce celui que l'on trouve, par exemple, dans Iacoviello and Neri [2010] permet d'étudier à la fois la dynamique de la dette et des prix immobiliers dans un modèle avec risque agrégé et marchés locatifs explicites.

Par conséquent, nous intégrons notre cadre d'analyse dans un modèle de cycles réels calibré pour reproduire certains éléments clés des données américaines. En particulier, nous calibrons le modèle de manière à avoir une proportion réaliste des différents types d'agent, ce que les modèles précédents avaient des difficultés à faire vu qu'ils ne considéraient pas un tiers de la population (les locataires). De plus, le modèle est calibré afin d'avoir un ratio dette sur PIB cohérent avec celui des données.

Nous étudions alors comment notre modèle réagit quand il est soumis à des chocs technologiques, à la fois dans le secteur de la consommation et dans le secteur immobilier. Nous montrons que ces chocs permettent de reproduire la plupart des volatilités et corrélations des données. En particulier, ils permettent d'expliquer 60% des fluctuations des prix immobiliers et à peu près l'ensemble des fluctuations de la dette. De plus, nous arrivons à reproduire la majorité des corrélations observées dans les données. En particulier, la corrélation entre dette et prix immobiliers est très bien reproduite. Le modèle est moins à même de reproduire la corrélation positive entre prix et investissement immobiliers. Ceci est un problème général des modèles avec seulement des chocs technologiques comme par exemple dans Davis and Heathcote [2005]. Nous avons aussi quelques difficultés à reproduire la corrélation négative entre le ratio loyer sur prix et les prix immobiliers qui est très fortement négative dans les données et est négative, mais dans une moindre mesure, dans notre modèle. Cependant, notre modèle est capable de reproduire de nombreux faits stylisés des données tout en introduisant un marché locatif et de la dette. De plus, ce modèle peut facilement être étendu pour intégrer d'autres dimensions intéressantes.

Enfin, nous étudions l'effet de la relaxation des contraintes de nantissement dans le cadre de notre modèle. Par elle-même, celle-ci a un impact faible sur les prix immobiliers. Cela semble confirmer les résultats de Kiyotaki et al. [2011] et Sommer et al. [2013] qui, dans des modèles pourtant très différents du notre, trouvent que le relâchement des contraintes de collatéral a peu d'effet sur les prix immobiliers.

Chapter 3

Long-Term Care Insurance, Housing Demand, and Decumulation

Abstract

A minority of retirees are covered by a long-term care insurance (LTCI), even at high levels of wealth, while many of them keep large amounts of housing wealth until late in life. This suggests that housing might be a substitute for LTCI. To study the relevance of this argument, I construct life-cycle models with housing which reproduce patterns of wealth decumulation similar to those observed in the Health and Retirement Study. Even under strong asset commitment linked to housing, I find that an important fraction of wealthy retirees would still find optimal to purchase LTCI under realistic pricing. This casts doubt on the idea that housing may be the reason behind their lack of demand for LTCI. I also highlight that higher demand for LTCI might increase the attractiveness of reverse mortgages.

Introduction

In recent years, the US market for long-term care insurance (LTCI) has remained small. For instance, Brown and Finkelstein [2009] report that only 4 percent of long-term care expenditures were paid by private insurance policies while one third were paid out-of-pocket. Data from the Health and Retirement Study (HRS) point in the same direction.

For instance, De Nardi et al. [2010] estimate large out-of-pocket medical expenses late in life for the richest individuals, most of which are from nursing home stays.

The reason why people insure so little of this risk has gathered a lot of attention among economists[1]. This "LTCI puzzle" has been addressed in several ways: from behavioural biases to failures on the supply side. In particular, a strand of the literature has attempted to reconcile this puzzle within the rational framework by looking at potential limiting factors on the demand side. The present paper is most related to the latter category.

While, for individuals at lower wealth levels, Medicaid seems to be a powerful candidate to explain the puzzle (Brown and Finkelstein, 2008), it is still hard to understand the lack of insurance coverage among wealthier households. Indeed, they tend to have large asset holdings and, at the same time, face the largest risk of high medical expenditures. Moreover, there exist evidences of public care aversion (Ameriks et al., 2011). One justification for the lack of LTCI demand brought out by Davidoff (2009, 2010) is that housing may crowd out LTCI demand. The reason is that home equity is usually a large part of retirees' portfolios and is mainly cashed out when moving to nursing homes (Venti and Wise, 2004). To quote him: "home equity is a particularly plausible substitute for LTCI among wealthier households, who typically have home equity holdings which are large relative to most of the distribution of long-term care costs".

The objective of the present paper is to assess how powerful housing may be to explain the LTCI puzzle. While Davidoff showed theoretically that housing may crowd-out LTCI demand, he used for his simulation exercise (in his 2009 paper) rather ad-hoc parametrizations of his model. However, finding which parametrizations are realistic is essential to assess empirically the relevance of his argument. The key contribution of this paper, with respect to his work, is to use information on wealth decumulation and pre-existing pensions to assess which parametrizations are in line with the data, and to use those parametrizations to assess whether or not housing may explain the lack of demand for LTCI. The general procedure works as follow. I define different categories of households along their asset holdings (including housing). I then analyse at which pace they decumulate wealth using the panel dimension of the HRS. This informs me on which parametrizations of the model are consistent with the data. I then study what is the optimal demand for LTCI in the presence of housing for these realistic parametrizations. This procedure thus informs us on the households for which the absence of LTCI purchase can be rationalized by a model with housing.

As a baseline, I consider a modified version of the model in Davidoff [2009]. In this framework, agents do not move out of their homes except when moving to long-term

[1] See Brown and Finkelstein [2009] for a detailed review on the subject.

care (LTC). This strong preference to stay in a given home generates, absent reverse mortgages, a strong asset commitment which reduces the attractiveness of LTCI. Using such a model, I find that, absent bequest motives, single individuals in the three first quartiles of the wealth distribution at age 70-80 would find optimal not to purchase LTCI at the beginning of retirement. In the fourth wealth quartile, the low purchase of LTCI is harder to rationalize. In this case, even highly loaded policies would lead many individuals to purchase quite comprehensive LTCI with large welfare gains. I still find that housing has a strong negative effect on the amount of coverage chosen and on welfare gains. However, for a large share of individuals in this quartile, it is not enough to explain why the percentage of individuals covered by some LTCI does not exceed 20%.

As an alternative to the benchmark model, I also study a model in which the asset commitment is not linked to preferences but to the combination of imperfections in the rental market, transaction costs and LTC risk. This model is an extension of one introduced by Yao and Zhang [2005]. In this framework, I find that a higher proportion of the population would benefit from purchasing LTCI. This is because late homeownership is partly due to the presence of the risk of LTC. Hence, purchasing a LTCI reduces the asset commitment, which dampens the crowding-out effect of housing on LTCI.

All in all, both models cast some doubt on the ability for housing to explain the lack of demand for LTCI in the upper quartile of the wealth distribution at age 70-80. While both models are designed for singles, wealth decumulation patterns of couples suggest that housing may not be able to explain the low demand for LTCI for the majority of couples above the median of the wealth distribution at age 70-80. Alternative explanations, possibly in combination with housing, may thus play an important role. As this type of insurance is by nature a long-term contract, there exist several issues linked to contract enforcements that might increase mistrust in it[2]. If such mistrust is widespread, improving the institutional framework to reduce it might lead to an increase in LTCI demand, despite the presence of housing. Moreover, my results suggest that this would also enhance the demand for reverse mortgages which is likely to remain low given the presence of LTC risk. Indeed, a high risk of LTC generates precautionary behaviours which lead to a lack of wealth decumulation. This complementarity between LTCI and reverse mortgages goes in the other direction than the one argued in Davidoff (2009, 2010). Hence, tackling simultaneously the imperfections in both markets might be crucial for their future developments.

[2]In particular, as the policy holder is likely to have a short life once entering LTC, the probability for the insurance company to be sued if it is does not act fairly might be low.

The present work is mainly related to two branches of literature. The first one studies household portfolio choices in the presence of housing such as Campbell and Cocco [2003], Cocco [2005] or Yao and Zhang [2005]. In particular, the latter authors build a rich model of housing demand with transaction costs and a rental market, which is the basis of the second model presented here. Some recent papers have also studied housing investment decisions over the life-cycle in a general equilibrium setting. In particular, Yang [2009] shows that a model with housing and transaction costs is successful in replicating the patterns for housing consumption and non-housing consumption. However, the absence of medical expense risk (or bequest motives) in her model generates too much wealth decumulation at older ages, a feature which is important for the present paper's argument. The second branch of literature this paper is related to studies decision planning in retirement. In particular, in the life-cycle literature, Palumbo [1999] and De Nardi et al. [2010] showed that slow wealth decumulation among retirees could be the result of health risk. Concerning the demand for LTCI, one can refer to Brown and Finkelstein [2009] for a literature review. Recently, Lockwood [2013] argued that bequest motives may explain the lack of demand for both annuities and LTCI. As my results show that housing alone has difficulty explaining the low demand for LTCI at higher wealth levels, this might constitute some further evidence in favour of his argument, though some alternative explanations may still be considered. I relate these two strands as has been the focus of few recent studies on the theoretical side. Noticeable examples are the works of Nakajima and Telyukova (2012, 2014a, 2014b) which use a model somehow comparable to the modified version of Yao and Zhang [2005] presented here. They manage to reproduce the main patterns of wealth decumulation and home-ownership in the data but do not study the demand for private LTCI in this context. Three other noticeable examples are the previously cited works of Davidoff (2009, 2010), as well as Yogo [2009] who studies a model with endogenous health and housing.

The paper is divided into four parts. The first provides an intuitive theoretical justification for using wealth profiles. The second presents the empirical analysis. The third presents two life-cycle models with housing which can reproduce comparable patterns to the one in the data absent LTCI. Using these models I analyse optimal LTCI demand and the resulting welfare gains. The fourth section briefly concludes.

3.1 Theoretical Justification for Using Wealth Profiles

Housing is a particular object for economic analysis. As a durable it can serve at least two purposes: consumption and savings. Moreover, for many households, housing is a large component of their wealth These two elements (nature and size of housing) suggest a particular analysis.

Based on the observation of Venti and Wise [2004] that few retirees decumulate housing except when facing LTC, Davidoff (2009, 2010) studied the potential effect of housing (absent reverse mortgages) on the demand for LTCI[3]. In particular, he showed that, in a model where reverse mortgages are not available and where individuals are unwilling to sell except in the event of LTC, housing could crowd out LTCI demand. Indeed, this unwillingness to sell, absent reverse mortgages, leads to two commitments: a consumption commitment (the "inability" to adjust housing consumption) and an asset commitment (the "inability" to adjust housing equities downward). This latter implies that housing equities are only cashed-out when moving to LTC, thus serving a role similar to the one of an insurance. The former has a more ambiguous, and arguably smaller, effect so that I almost exclusively focus on the asset commitment side.

I argue that the extent of the crowding-out effect of housing on LTCI (absent bequest motives) in a Davidoff-type setting is ultimately linked to the dissavings rate of financial assets of retirees. Davidoff (2009, 2010) showed that the relative size of housing in total wealth mattered. Here, I highlight the fact that the dissavings rate of financial assets is also key to assess empirically whether individuals would benefit from purchasing a LTCI policy.

I illustrate the fact that the dissavings rate of financial assets matters in a Davidoff-type model in figure 3.1. First of all, consider a standard life-cycle model where agents have *no* bequest motive and in which there is *no* housing. The only asset available is a standard risk-free bond. As as been shown in previous works (in particular De Nardi et al., 2010), observed wealth decumulation patterns can be rationalized in this setting if the high level of potential medical expenditures in the data is introduced. As a matter of consequence, assume that individuals mainly keep savings for the risk of future LTC expenditures, LTC being the main component of the rise in medical expenditures late in life.

First of all, let's compare the savings behaviours of two retirees which remain in good health until late in life. In this case, their dissavings behaviours are the reflections of their precautionary behaviours relative to the expectation of potential future LTC expenses. The total amount of wealth of the first agent as a function of age is represented by the black downward-sloping curve starting from point A. The second agent holds savings represented by the grey curve starting also from point A. Obviously, the second agent is more risk-averse than the first and would benefit more from being offered the possibility to purchase a LTCI.

[3] In his 2009 paper, he also looks at annuity demand in this framework, a case I will not study here.

Now, let's introduce housing into the picture. As Davidoff (2009, 2010), I assume that agents are not willing to move except when moving to LTC and have no access to a reverse mortgage. Housing wealth is initially given and is represented by the dotted-line which is parallel to the x-axis. Total wealth is given initially by the coordinate of A on the y-axis. So that financial wealth is initially the difference between total wealth and housing wealth. For agent 1, we can see that relatively early in retirement, would he be able to adjust housing equities downward, he would take on a reverse mortgage. This would occur at the age corresponding to point B. Absent this possibility, this agent will be "over-insured" by housing at point B, in the sense that housing is then more that what he would have optimally saved in a setting in which he can adjust his wealth freely. For him, the marginal utility out of wealth in LTC will be low so that gains from LTCI should highly be reduced by the presence of housing if reverse mortgages are not available.

For the second agent, the gains from buying a LTCI will be reduced as well but to a much smaller extent. Indeed, for him, housing over-insurance occurs much later in life so that there might still be substantial gains from purchasing a LTCI. In particular, this would allow him to consume more earlier in retirement by reducing the marginal utility of keeping substantial amounts of wealth until late in life. Moreover, for this agent the gains from having access to a reverse mortgage market would likely be small if no LTCI is available. So that the complementarity between LTCI and reverse mortgages plays both ways.

In the data, agent 1 is an individual dissavings financial wealth rapidly so that this latter will be small quite early in retirement. On the contrary, agent 2 is an individual keeping a large amount of financial wealth until late in life despite the presence of housing.

These simple intuitions are the main elements driving the results presented below. The key idea is to see which parametrizations of a life-cycle model are consistent with the empirical observations for financial wealth for different categories of homeowners. Given these realistic parametrizations, it is then possible to compute the optimal LTCI coverage and the corresponding welfare gains.

A first concern regarding this approach is the fact that individuals might have bequest motives. For instance, Lockwood [2013] argues that bequest motives might explain the lack of demand for LTCI. His argument is that people might have large bequest motives and be relatively unaverse to it. I take this possibility seriously. For this, I use the estimates for bequest motives estimated in De Nardi et al. [2010] and Lockwood [2013], and plug them in the model. I describe the patterns of wealth decumulation implied by these parametrizations as well and study the corresponding welfare gains.

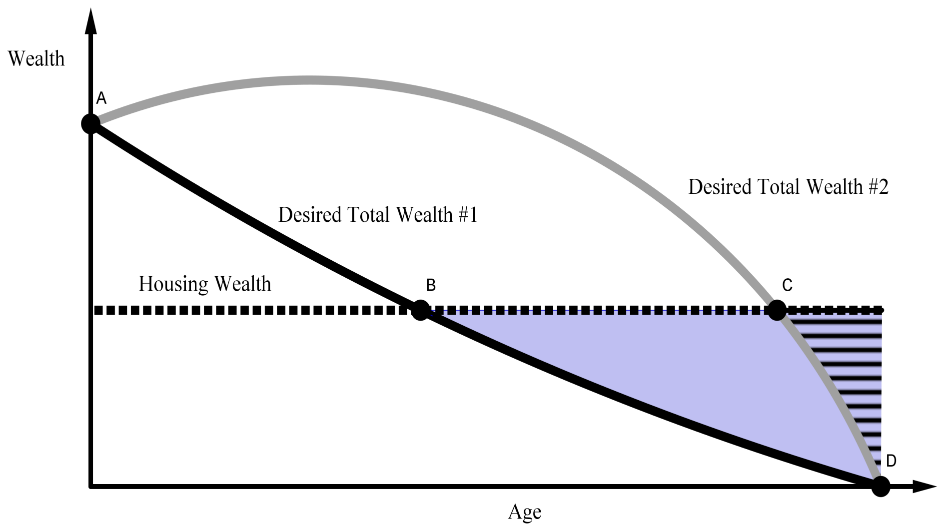


FIGURE 3.1: Wealth Decumulation and the Importance of Housing

A second concern is that the assumptions above might be too strong. In Davidoff's setting the mobility into LTC is somehow purely exogenous. However, it is possible that the asset and consumption commitments to housing are endogenous. I emphasize this point in a modified version of a model introduced by Yao and Zhang [2005]. In this setting, the decision to remain a homeowner until late in life is due to the presence of an imperfect rental market, a transaction cost proportional to the whole value of the home and the presence of LTC risk. In such a setting, the crowding-out effect of housing on LTCI tends to be weaker as the asset commitment is reduced when LTCI is purchased.

3.2 Empirical Analysis

3.2.1 Empirical Strategy

The key idea of this empirical analysis is to follow specific types of individuals across time to understand their savings behaviours. It informs us on the parametrizations of the models below which are realistic. In this work, I use the RAND release of the Health and Retirement Study (HRS). The HRS is a representative survey of elderly households in the United States. I use seven waves from the HRS: 1998, 2000, 2002, 2004, 2006, 2008 and 2010. This provides the time dimension needed for this work. The HRS contains data on wealth. In particular, I consider two distinct measures of wealth. The first one is the value of the primary residence which I will call *housing wealth*. The second one is the value of all wealth minus all debt minus the value of the primary residence. I will call this latter *financial wealth*. These measures are converted in 1998 dollars using the consumer price index for personal expenditures from the Bureau of Economic Analysis.

In this section, I consider only retired individuals which are single across all waves. This is because the simulated model is designed for singles. I discuss briefly empirical patterns for couples in section 4. I take individuals born between 1918 and 1928 which are thus aged between 70 and 80 in 1998[4].

I separate the sample in four wealth quartiles according to their total amounts of wealth in 1998. I then consider only homeowners (people declaring a positive value for primary residence) and separate this group in two subgroups. The first contains *continued homeowners* which are individuals declaring a positive value for primary residence in all of the seven waves. The second contains individuals which declare at some point no positive value of primary residence. I call this latter group *movers*. For the top wealth quartile, the first sample is made of 117 individuals while the second is made of 282 individuals. A majority of the latter group actually dies before 2010 (208 individuals). Both groups, not surprisingly, consist in a majority of women (100 vs 17 for continued homeowners and 204 vs 78 for movers). The idea to separate the sample in these two subgroups is simple. If continued homeowners are those likely not to have faced LTC shocks yet, then their savings behaviours should be informative on how much they tend to save for possible future LTC shocks. This constitutes a sort of control group. A concern is that this group might be fundamentally different from the group of movers. However, as I show this concern is in large part mitigated by the fact that dissavings behaviours of both groups are very similar in the first waves (when most of the movers are still alive).

In the next subsection, I analyse median profiles of financial wealth and housing wealth of the above groups. This serves as a basis for the calibrations of the theoretical models presented in section 3.

3.2.2 An Analysis of Wealth Profiles

3.2.2.1 Wealth Profiles of Wealthy Individuals

For individuals in the fourth quartile of the wealth distribution, we can see that median financial wealth is sizeable and remains large until advanced ages for continued homeowners. We can observe this from panel a) of figure 3.2. This latter shows median profiles of financial wealth for the sample of continued homeowners[5]. The first element to notice is that these medians are usually between $150,000 and $200,000, a rather

[4]The main patterns are not much modified considering individuals born between 1928 and 1936 for instance.

[5]I display only the waves 1998, 2002, 2006 and 2010 on the figures for clarity.

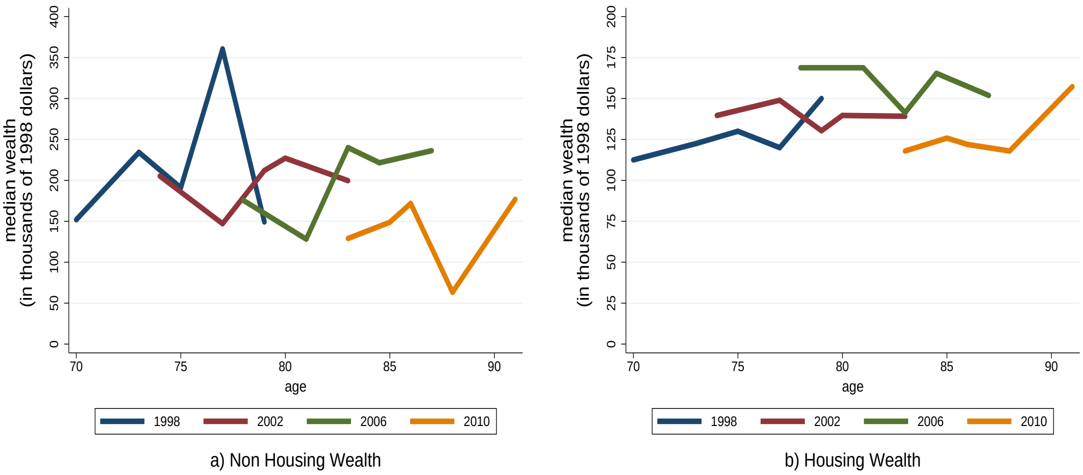


Figure 3.2: Median of Non Housing and Housing Wealth of Continued Homeowners, Fourth Wealth Quartile, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. Continued homeowners are individuals declaring a positive value for primary residence from wave 1998 to wave 2010.

large amount. This appears somehow larger than housing wealth for which the median is initially at around \$125,000. This can be seen from figure 3.2b which is similar to figure 3.2a but for housing wealth. The increase in housing wealth at a median between \$140,000 and \$160,000 in 2006 likely reflects the housing boom.

Overall, median financial wealth does not show any clear decline before age 85 and remains substantial. If any decline occurs it is around age 90. This partly reflects a rise in median out-of-pocket medical expenditures in this group (see figure 3.6a discussed later). But, even in this case, median financial wealth remains usually higher than \$100,000 and always higher than \$50,000. Thus wealthier individuals do behave in way that could appear precautious, keeping large amounts of financial wealth until advanced ages even though they remain homeowners.

I also split this fourth wealth quartile in half according to their total wealth in 1998. Looking at the less well-off of the upper wealth quartile, I find patterns which are somehow comparable but the decline in wealth is somehow stronger and the ratio of housing wealth over total wealth tends to be higher. This can be seen from figure 3.3 which is the equivalent of figure 3.2 but for this group. Financial wealth is between \$75,000 and \$125,000 in early waves and declines to levels between \$25,000 and \$75,000 around age 90.

A concern is that the sample of continued homeowners is smaller than the one of movers.

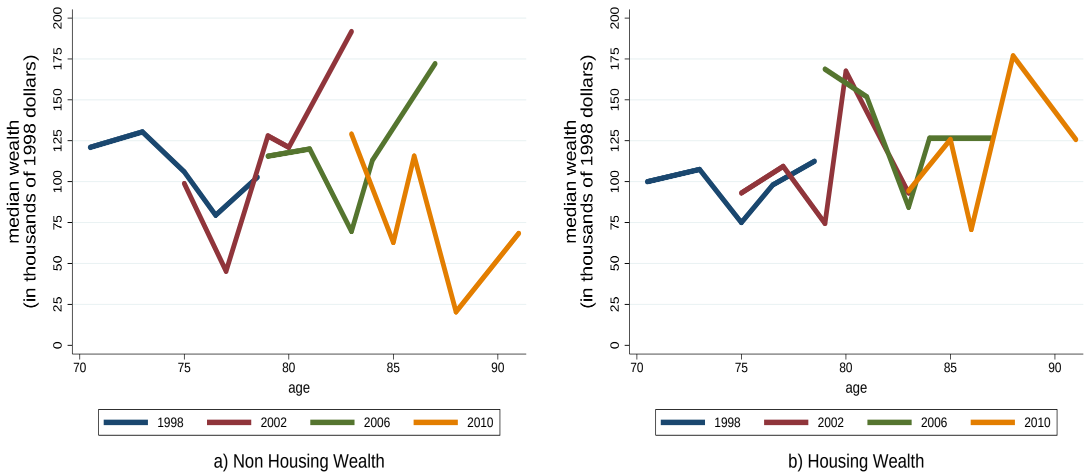


FIGURE 3.3: Median of Non Housing and Housing Wealth of Continued Homeowners, Fourth Wealth Quartile Bottom Half, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. Continued homeowners are individuals declaring a positive value for primary residence from wave 1998 to wave 2010. Here the medians are computed for those belonging to the fourth wealth quartile and which are in the bottom half of the wealth distribution for this group.

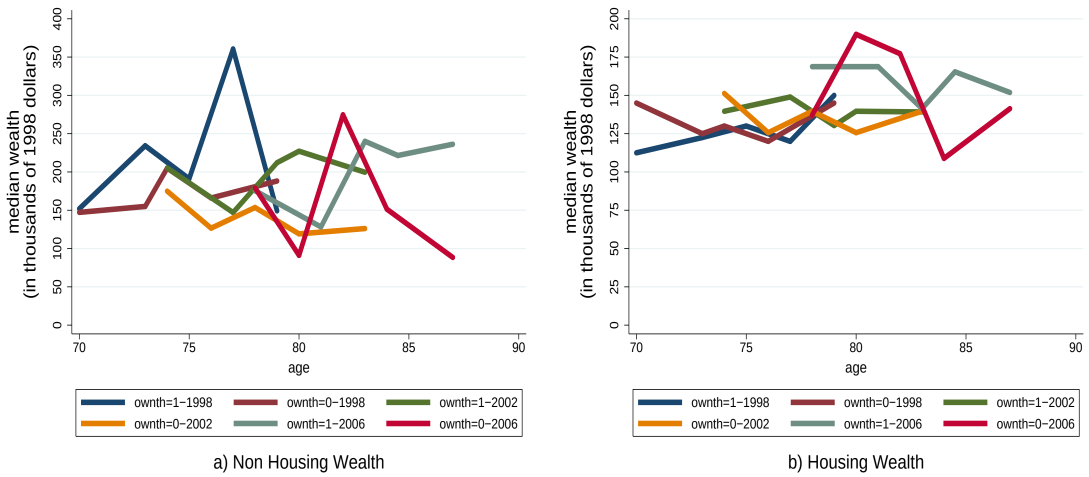


FIGURE 3.4: Median of Non Housing and Housing Wealth of Continued Homeowners and Movers, Fourth Wealth Quartile, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. Continued homeowners (those indicated in the legend by ownth =1) are individuals declaring a positive value for primary residence from wave 1998 to wave 2010. Movers (those indicated in the legend by ownth =0) are those declaring a positive house value in 1998 but which do not report a positive house value in all subsequent waves.

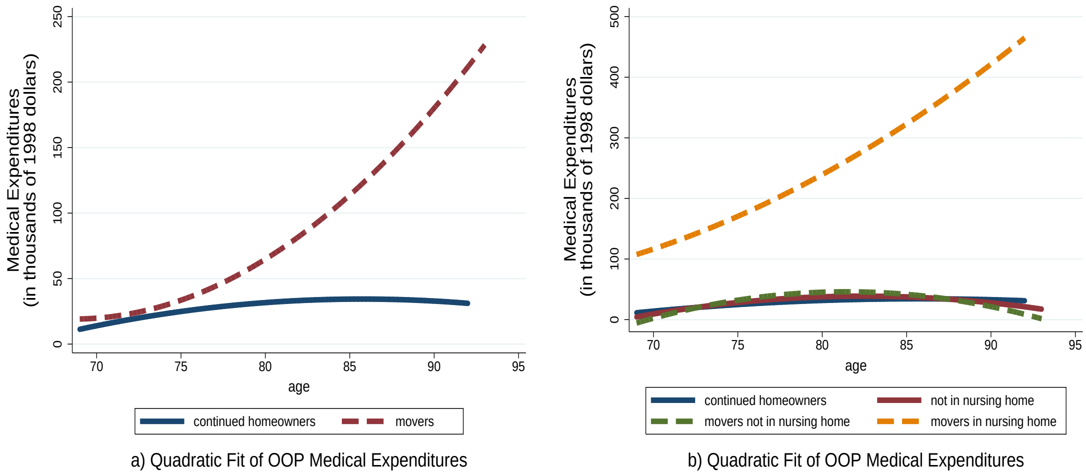


FIGURE 3.5: Out-of-pocket Medical Expenditures in the Past Two Years, Fourth Wealth Quartile, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. They are quadratic fit. Continued homeowners are individuals declaring a positive value for primary residence from wave 1998 to wave 2010. Movers are those declaring a positive house value in 1998 but which do not report a positive house value in all subsequent waves. "In nursing home" (resp. "Not in nursing home") indicates that the person has spent at least one (resp. has not spent any) night in a nursing home in the past two years.

Indeed, this suggests that continued homeowners might be unrepresentative of the owners in the top wealth quartile. However, figure 3.4 shows that, for early waves, the behaviours of the two groups are very similar and that there is no sizeable difference. Interestingly, figures 3.5a and 3.6a show respectively that mean and median out-of-pocket medical expenditures are higher for movers. The mean, in particular, shows a dramatic difference between the two groups. These differences actually appear to be driven almost exclusively by those who moved to nursing homes. This can be seen from figures 3.5b and 3.6b. Continued homeowners and movers who have not moved to a nursing home have comparable medical expenditures. Movers who moved to a nursing home are those for which medical expenditures are particularly high. These elements confirm that movers and continued homeowners are not a priori different and that LTC is the main event leading to high out-of-pocket medical expenditures.

In figure 3.7, I regroup continued homeowners and movers but consider only those who have no LTCI. Wealth profiles for these agents are similar to those presented in figure 3.2. This is not particularly surprising if one plots the proportion of agents in this group which have a LTCI. This can be seen in figure 3.8a. More than 80% in this group do not own any LTCI. If one considers those in this group with more than \$15,000 in pension income, the proportion of those without a LTCI is still 75%. The simulations presented

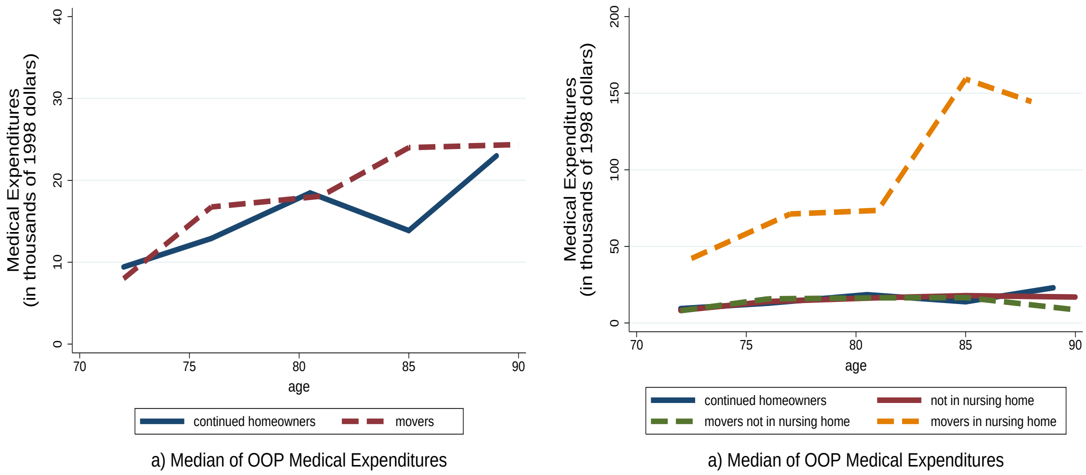


FIGURE 3.6: Out-of-pocket Medical Expenditures in the Past Two Years, Fourth Wealth Quartile, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. They are medians. Continued homeowners are individuals declaring a positive value for primary residence from wave 1998 to wave 2010. Movers are those declaring a positive house value in 1998 but which do not report a positive house value in all subsequent waves. "In nursing home" (resp. "Not in nursing home") indicates that the person has spent at least one (resp. has not spent any) night in a nursing home in the past two years.

afterwards will attempt to understand to which extent a model with housing can explain this lack of demand given the wealth patterns that have been presented above.

3.2.2.2 Wealth Profiles in other Wealth Quartiles

Total wealth in the first wealth quartile is usually very small and the sample of continued homeowners is small as well. This group is thus not of much interest for the present analysis and is, in any case, likely to rely mainly on Medicaid when it comes to LTC. The second quartile has some wealth but almost all the wealth of these individuals is in housing. In the third wealth quartile, one can see from figure 3.9 that the amount of financial assets is quite low at no more than $40,000 and showing a quite clear decline. In this case, financial assets are likely to be a buffer and demand for LTCI under the assumptions of Davidoff (2009, 2010) is likely to be zero. This is confirmed by the simulated model presented in the next section.

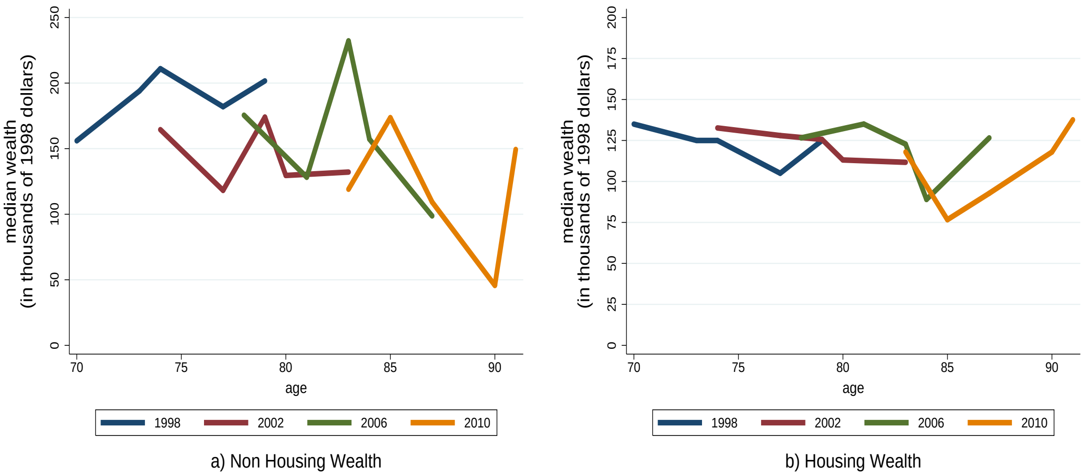


FIGURE 3.7: Median of Non Housing and Housing Wealth, All without LTCI in Fourth Wealth Quartile, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. These profiles are computed for all individuals in the fourth wealth quartile who declare not having a LTCI.

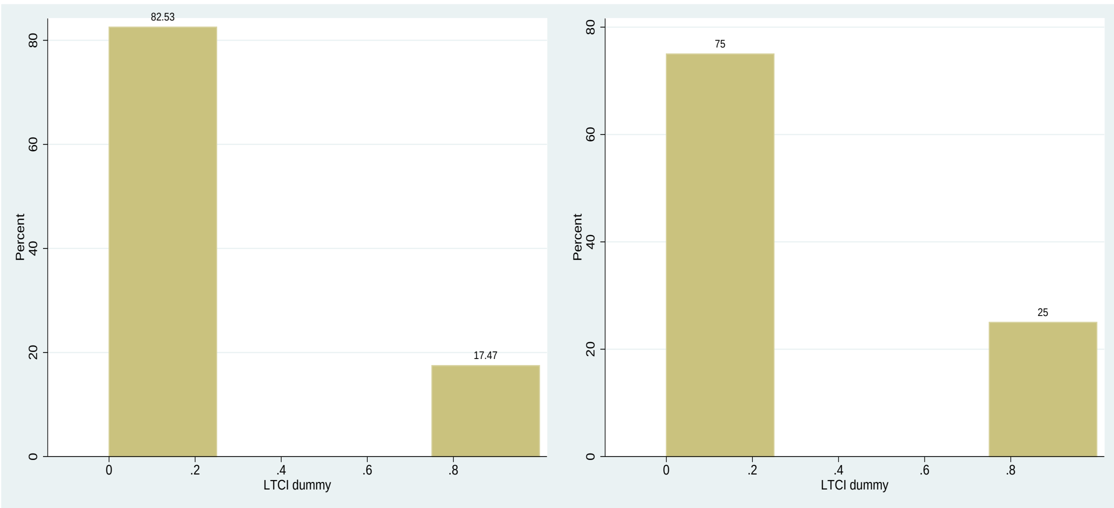


FIGURE 3.8: LTCI coverage ,Fourth Wealth Quartile, Singles

Notes: These histograms are computed for singles using data from the RAND version of the HRS. The LTCI dummy is equal to 1 (resp. 0) if the individual has some LTCI (resp. no LTCI). The left panel considers all those in the fourth wealth quartile in the 1998 wave. In the right panel, I consider only those in the upper half of the wealth distribution in the fourth wealth quartile and which declare at least $15,000 of pension income.

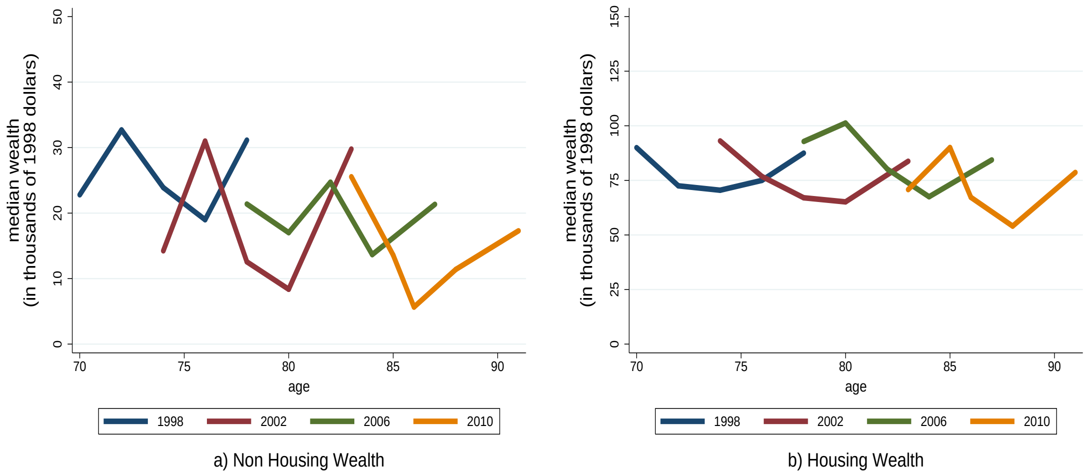


Figure 3.9: Median of Non Housing and Housing Wealth of Continued Homeowners, Third Wealth Quartile, Singles

Notes: These profiles are computed for singles using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. Continued homeowners are individuals declaring a positive value for primary residence from wave 1998 to wave 2010.

3.3 Life Cycle Models with Housing and Gains from LTCI

In this section, I display the results from two life-cycle models with housing. The first is similar in spirit to the one present in Davidoff [2009]. The second is a richer model with endogenous housing demand based on the model of Yao and Zhang [2005]. This later features an imperfect rental market and transaction costs on the whole value of the home. It does not assume any exogenous preference to stay in a given home but is able to endogenously explain late homeownership.

3.3.1 A "Davidoff-type" model

3.3.1.1 Model's Settings

In this model, an individual is initially endowed with a home of value h which, for simplicity, is assumed constant over time. He is also endowed with bonds (or financial wealth) b_{t-1} which offer a gross return R and receives a pension income y. In each period, he decides his level of consumption c_t. However, he never faces any decision regarding the sale of the home. This latter occurs (exogenously from the point of view of the model) only in the case the individual moves to LTC. This implies that the sale of the home is perfectly correlated with the entry into LTC. The underlying assumption is that the individual has very strong preferences for staying in his home[6].

I follow Davidoff [2009] and assume that the agent is initially aged $t = 62$ and can live up to age $T = 120$. In each period, he can be in one of four states s: healthy (0), moderately-ill (1), severely-ill (2) and dead (3). The latter state is, of course, an absorbing state. The agent is assumed to be healthy initially (i.e. in health state 0). State 2 will also be called LTC. The transition between each state is governed by a transition matrix taken from Ameriks et al. [2011]. As Davidoff [2009], I consider parameters for males as a baseline. Results with the transition matrix for women are usually displayed in appendix but are also discussed in the core of the paper. The agent faces medical costs $x(s)$ if in state 1 or 2 which will be respectively \$10,000 and \$50,000.

The agent is assumed to maximize[7]:

$$\sum_{t=62}^{T}\sum_{s=0}^{2} p(s,t)\,\beta^t \frac{c_t^{1-\gamma}}{1-\gamma}$$

where $p(s,t)$ is the probability to be in state s at age t. β is the usual time preference parameter and γ is the coefficient of relative risk aversion. The agent faces the constraints:

$$Rb_{t-1} + y - x(s) = c_t + b_t \text{ if } (s = 0 \text{ or } 1) \text{ or } (h = 0 \text{ and } s = 2) \tag{3.1}$$

$$Rb_{t-1} + y + h - x(s) = c_t + b_t \text{ if } (h > 0 \text{ and } s = 2) \tag{3.2}$$

The first constraint applies to an individual in state 0 or 1 assumed not to sell his home even if he is still a homeowner. If the individual has already sold his home because he moved to state 2 in a previous period, he cannot sell his home a second time. He is thus subject to (3.1) as well. An individual which moves for the first time to LTC is assumed to sell his home and so is subject to (3.2). This latter constraint shows that housing can *a priori* substitute for a LTCI. Indeed, would the individual have no more financial wealth, housing would release cash in the case of LTC. If the left-hand side of both equations falls below a threshold y_{min}, then the agent is endowed with y_{min} to finance consumption and potential future savings. Moreover, the implicit assumption

[6] Davidoff [2009] assumes that the disutility from leaving the home also vanishes when the individual is moderately-ill. I assume here that, when the agent is moderately-ill, he will not move.

[7] I assume no bequest here but will come back to it afterwards. This is done for exposition clarity.

behind (3.1) implies that the agent has limited benefits from wealth decumulation when purchasing a LTCI as he cannot decumulate housing wealth.

Notice that I do not introduce housing as a consumption good in the above model. Davidoff [2010] shows that the consumption commitment of housing can also affect the demand for LTCI, though the effect is ambiguous and arguably much weaker than the effect stemming from the asset commitment. The above model allows only for the asset commitment to play a role, thus keeping the non-ambiguous channel. The pension income y can be interpreted as the pension income net of maintenance cost (for owners) and rent (for those who have moved) in a model in which utility from consumption and housing is additive. The implicit assumption is that the maintenance cost and the rent are of comparable size [8].

3.3.1.2 Parametrization

I consider health expenses of \$0, \$10,000 and \$50,000 for state 0, 1 and 2 respectively as in Davidoff (2009). I take y_{min} the minimum insured consumption to be \$7,000 as can be found in Peijnenburg et al. [2010][9]. R is set at 1.03 as in Davidoff [2009]. β is set at 0.97.

The LTCI considered in this paper is of the same form as the one considered in Davidoff [2009]. I first compute the expected present value of LTC expenses covered. I then compute the present value of a life annuity paying one dollar as long as the individual is alive. Dividing the first amount by the second gives the fair annuity that one has to pay if he were to contract an insurance policy covering a given percentage of LTC expenses. In the case in which I consider a percentage load L (for instance $L = 50\%$), I multiply the annuity by $1 + L$.

I present results for different parametrizations of the model showing the paths for bond-holdings that they generate. I compare them to the patterns presented in the previous section to assess which ones are consistent with the data. For each parametrization, I find the optimal LTCI coverage[10] and compute the resulting welfare gains. These welfare gains represent how much bonds one would be ready to give up initially to go from a world without LTCI to a world where he buys his favoured LTCI coverage.

I sometimes consider versions of the model where the agent has a bequest of the form:

[8] Moreover the additional cost that might stem from renting is mostly included in the cost of LTC. In the Yao and Zhang type model, the dimension rent versus maintenance cost is modelled explicitly.

[9] This amount is close from what is assumed in Brown and Finkelstein [2008].

[10] I considered policies covering 0%, 10%, ..., 90%, 100% of the costs.

$$\varphi\frac{(\zeta+g)^{1-\gamma}}{1-\gamma}$$

This functional form is standard. Generally speaking, φ drives the strength of the bequest motive, while ζ drives the extent to which bequests are luxury goods. g is the amount of wealth left at the time of death.

3.3.1.3 Results

I consider first the case without bequest motives using the transition matrix for men. I show results for three different levels of pension income and two levels of relative risk aversion. The different parametrizations can be found in table 3.1. In figure 3.10, I plot decumulation patterns for financial wealth of an individual who does not face health expenses (i.e. who is always in state 0) under these different parametrizations. The initial value for housing is set at \$125,000 in each case. This is line with what is observed in the fourth wealth quartile for singles. I adjust the initial level of financial wealth under the different parametrizations so that its level at age 70 in figure 3.10 is close to \$150,000. A level which is in line with the median in the data for the fourth income quartile.

In figure 3.2, we can see that the median level of financial assets is way larger than \$100,000 around age 80 and closer to \$150,000. Also the median in 2010 is above \$100,000.[11] In the end a realistic parametrization should lead to financial assets which are above \$100,000 at age 80 and, at least, close to \$100,000 around age 85-90.

Given that the individual in figure 3.2 does not face large medical expenditure, the parametrizations in line with these median levels should lead to financial asset holdings of, at least, similar size. From figure 3.10, we can see that only version 1 and version 2 are somehow in line with these empirical patterns. In both cases, the optimal coverage with no load is 80% with respective welfare gains which are large at \$61,431 and \$34,221. Even introducing a 50% load (in line with Brown and Finkelstein [2008] for men) does not modify the results. Though coverage is lower in this case, welfare gains are still substantial. I also experimented over initial financial wealth and the risk aversion parameter in order to have an amount of financial wealth of around \$200,000 at age 70 and around \$100,000 at age 90. In these cases, welfare gains and optimal coverage are large.

[11] This can be seen from plotting a figure similar to figure 3.2 but with only two bands. This figure is not displayed but is available upon request.

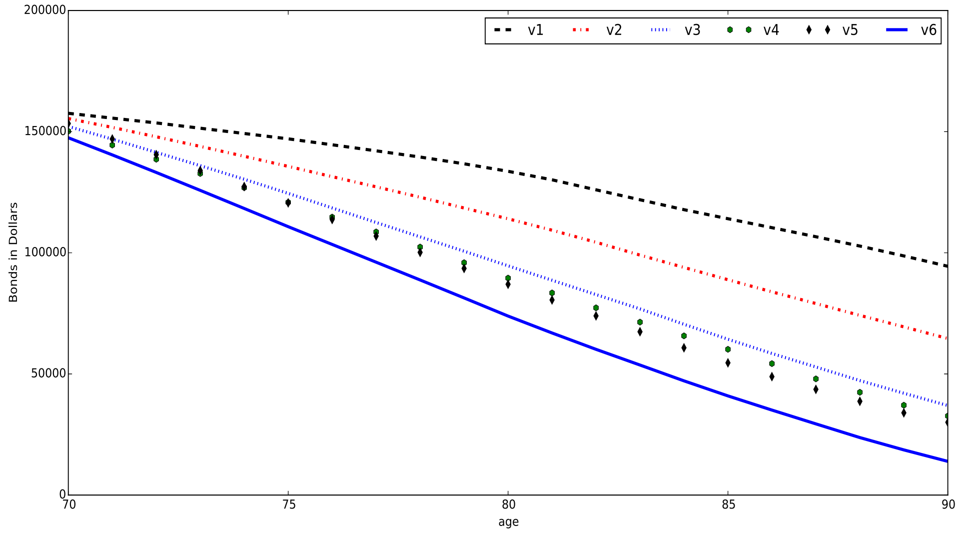


FIGURE 3.10: Financial Wealth for Healthy Individuals without LTCI, Davidoff-Type Model - Men No Bequest

Notes: In this figure are plotted the bond paths as a function of age for individuals facing no negative heath shocks (i.e. which remain in state 0 from age 62 to age 90). The model used is the Davidoff-type model. The parametrizations v1 (for version 1) up to v6 (for version 6) correspond to the parametrizations displaid in table 3.1.

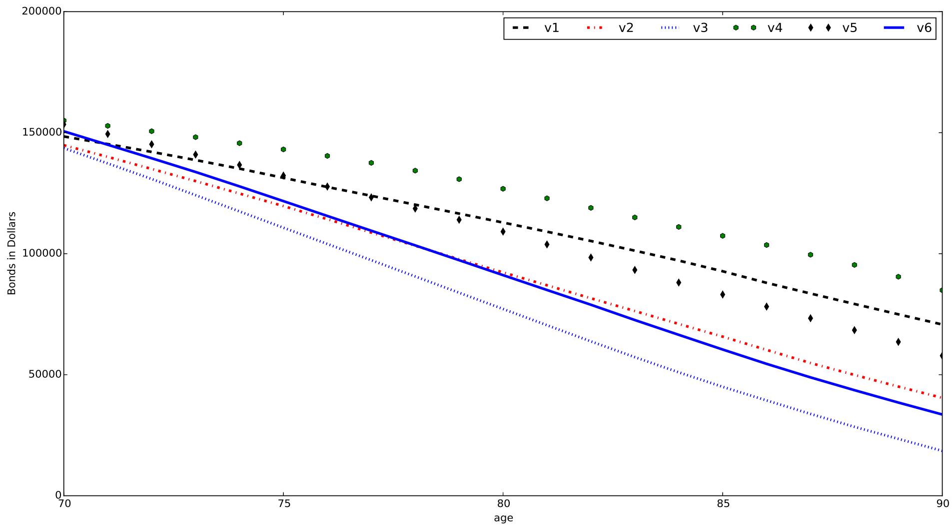


FIGURE 3.11: Financial Wealth for Healthy Individuals without LTCI, Davidoff-Type Model - Men Bequest

Notes: In this figure are plotted the bond paths as a function of age for individuals facing no negative heath shocks (i.e. which remain in state 0 from age 62 to age 90). The model used is the Davidoff-type model. The parametrizations v1 (for version 1) up to v6 (for version 6) correspond to the parametrizations displaid in table 3.2.

TABLE 3.1: Optimal LTCI, "Davidoff-Type" Model - Men No Bequest

Parameters	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
β	0.97	0.97	0.97	0.97	0.97	0.97
γ	4	4	4	3	3	3
R	1.03	1.03	1.03	1.03	1.03	1.03
y	$20,000	$15,000	$10,000	$20,000	$15,000	$10,000
h	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000
b_{61}	$170,000	$180,000	$190,000	$190,000	$200,000	$200,000
y_{min}	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000
No load						
Optimal LTCI Coverage	80%	80%	50%	80%	80%	0%
Welfare Gains	$61,431	$34,221	$3,786	$30,977	13,002$	$0
50%load						
Optimal LTCI Coverage	70%	60%	0%	60%	0%	0%
Welfare Gains	$37,808	$13,544	$0	$7,845	$0	$0
No load, no housing						
Optimal LTCI Coverage	100%	100%	100%	100%	100%	100%
Welfare Gains	$109,026	$77,432	$30,817	$72,007	$48,119	$8,260
50% load, no housing						
Optimal LTCI Coverage	100%	100%	80%	100%	100%	0%
Welfare Gains	$76,685	$44,330	$495	$39,642	$14,865	$0

Even though welfare gains are large, housing decreases welfare gains and coverage. In the two bottom panels of table 3.1, I consider the case in which the individual has no housing. In this case, I set initial financial assets to their levels with housing to which I add half of the value of the home. I do not add the whole value of the home to take into account the fact that housing had no return. Despite this, I find that the individual would benefit more from a LTCI. Thus housing does indeed play a role. It is however not enough to explain jointly median asset holdings in the fourth wealth quartile and the low LTCI demand.

As the results also show, pre-existing annuitized wealth is important to assess the welfare gains from LTCI. Indeed, lower pensions usually result in higher asset decumulation and make the payment of the LTCI policy more costly given the existence of a consumption

Table 3.2: Optimal LTCI, "Davidoff-Type" Model - Men Bequests

Parameters	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
β	0.97	0.97	0.97	0.97	0.97	0.97
γ	3	3	3	3.84	3.84	3.84
φ	1,521	1,521	1,521	2,360	2,360	2,360
ζ	234,600	234,600	234,600	273,000	273,000	273,000
R	1.03	1.03	1.03	1.03	1.03	1.03
y	\$20,000	\$15,000	\$10,000	\$20,000	\$15,000	\$10,000
h	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000
b_{61}	\$170,000	\$180,000	\$190,000	\$170,000	\$180,000	\$190,000
y_{min}	\$7,000	\$7,000	\$7,000	\$7,000	\$7,000	\$7,000
No load						
Optimal LTCI Coverage	80%	80%	0%	80%	80%	50%
Welfare Gains	\$30,339	\$14,699	\$0	\$55,065	\$29,856	\$1,697
50%load						
Optimal LTCI Coverage	60%	0%	0%	70%	60%	0%
Welfare Gains	\$9,489	\$0	\$0	\$31,744	\$9,563	\$0
No load, no housing						
Optimal LTCI Coverage	100%	100%	100%	100%	100%	100%
Welfare Gains	\$47,859	\$36,685	\$9,335	\$98,656	\$70,694	\$26,473
50% load, no housing						
Optimal LTCI Coverage	90%	100%	0%	100%	100%	0%
Welfare Gains	\$22,098	\$7,705	\$0	\$66,899	\$37,972	\$0

floor. However, matching median wealth levels, decreasing pension income requires an increase in γ which has a tendency to increase gains from LTCI[12].

The case for women is similar (see table A.1 and figure A.1). Parametrizations which lead to financial wealth close to \$100,000 around age 90 lead to large welfare gains and quite comprehensive coverage. The 20% load considered is likely higher than reality as Brown and Finkelstein [2007] showed that women face pricing of LTCI which is more than fair. Once again pre-existing annuitized wealth affects welfare gains from LTCI.

In table 3.2 and figure 3.11 (similar to table 3.1 and figure 3.10), I consider the case for bequests. For parametrizations 1 to 3, I use the bequest motive estimated in Lockwood

[12] An alternative is to reduce the consumption floor with an effect which is mostly similar.

[2013]. For version 4 to 6, I use the bequest in De Nardi et al. [2010]. In the case of Lockwood, one can see that only version 1 leads to more than \$100,000 of assets at age 80 and to more than \$50,000 at age 90. In this case, one still finds welfare gains which are quite large even with 50% loads. The bequest in De Nardi et al. [2010] which produces decumulation patterns quite similar to those in the data point, also, to large welfare gains.

Using bequest estimates from models which differ from the one above is somehow problematic. I use those estimates to illustrate that the conclusions in this paper can be robust to the type of bequests found in the literature. However, it would still be possible to get no gains from LTCI by imposing, for instance, linear bequests with a steep slope. Without assuming such an extreme having a low enough risk aversion over bequests which are luxury goods would, in principle, be enough to get no gains from LTCI. Whether the lack of purchase of LTCI represents evidence of such type of bequests as in Lockwood [2013] might still be subject to debate, though it has the merit to potentially explain the lack of purchase of LTCI, annuities and reverse mortgages. Notice that under the argument of Lockwood [2013], the effect of housing on LTCI is likely to be small as in the end late homeownership and the lack of demand for reverse mortgages, LTCI and annuities would stem from the same element: bequest motives.

All in all, the conclusions are the following. First, housing alone cannot explain the lack of LTCI demand for those at the median in the fourth wealth quartile. Models without bequests featuring financial wealth decumulation patterns similar to those in the data point to large gains from quite comprehensive optimal coverages. This is true even if one introduces substantial loads. Second, even introducing realistic bequests may not change the previous conclusions, though this might be subject to debate.

I also conducted some experiments (results not displayed) to assess if those at the bottom of the fourth wealth quartile would benefit from purchasing a LTCI in the case in which there is no bequest motive. For instance, I set initial financial wealth to \$125,000 and initial housing wealth at \$100,000. These levels are comparable to those in figure 3.3. For men, setting γ to 4 and y to \$15,000 we obtain decumulation patterns close to those in figure 3.3. In this case, optimal coverage with a 50% load is 50% and the corresponding welfare gains are \$2,229. In the case where there is no load coverage is 80% and welfare gains are \$21,894. Similarly, for women but setting γ to 3.5, the model reproduces patterns for financial wealth similar to what is found in figure 3.3. In this case, optimal coverage under a fair LTCI is 80%. The corresponding welfare gains are \$10,388. However, under a 20% load any welfare gains are wiped-out. Assuming γ equal to 3 which produces patterns quite similar to those in the data imply no gains from LTCI even at fair prices. This shows that at such wealth levels, welfare gains from LTCI become quite sensitive. It implies that, for such wealth levels, housing may well help explain the absence of LTCI demand under the assumptions made by Davidoff (2009, 2010).

Finally, for women, setting γ to 3.5 and y to \$15,000 and assuming that initial financial wealth is \$30,000 and initial housing wealth is \$75,000 (similar to what is seen from figure 3.9), I find no gains from LTCI even at fair prices. This confirms that housing may explain the lack of LTCI for a large share of the population under realistic parametrizations. Though, it has more difficulty in explaining the lack of demand among at least half of the population in the fourth wealth quartile.

Though the model is not well-suited to study the behaviour of couples, the above results suggest that the difficulty for housing to explain the lack of LTCI among richer households is more prevalent for couples. This can be seen from figure A.3 and A.4 which plot wealth patterns for couples in the fourth and third wealth quartile respectively[13]. In this case, asset holdings in the third wealth quartile are very similar to those observed in the fourth wealth quartile for singles. Moreover, a substantial share of households have no LTCI (figure A.5).

3.3.2 Yao and Zhang Modified Model

3.3.2.1 Model's Settings

The previous model was highly stylized and made somehow strong assumptions over the reasons for late homeownership. I thus consider here a richer model based on Yao and Zhang [2005] where housing demand is endogenous. The risks that the individual faces are the same than the one presented in the previous section. The instantaneous utility that he gets here is a mixture of a Cobb-Douglas and CRRA, a form often used in the housing literature. In its recursive form, the problem an agent faces is:

$$v_t\left(d_{t-1}^o, h_{t-1}, b_{t-1}, s\right) = \max_{\{h_t, b_t, d_t^o, d_t^s,\}} \frac{\left(h_t^{\omega} c_t^{1-\omega}\right)^{1-\gamma}}{1-\gamma} + \beta \sum_{s'=0}^{2} \lambda\left(t, s, s'\right) v_{t+1}\left(d_t^o, h_t, b_t, s'\right) \tag{3.3}$$

β is the usual time preference parameter, ω is the relative weight of housing relative to the non-durable good and γ is a curvature parameter. $v_t\left(\right)$ is the value function associated with a given level of state variables at the beginning of time t.

Its arguments respectively refer to: ownership status at then end of previous period d_{t-1}^o, previous housing consumption h_{t-1} (which determines housing wealth for homeowners

[13]This wealth quartiles are computed for couples only.

at the beginning of t), bondholdings b_{t-1} and health state s. $\lambda(t, s, s')$ is the probability that a household who is in state s in t falls in state s' in $t+1$.

As in Yao and Zhang [2005], I assume that an individual can buy or rent housing services. This status is formalized by a dummy variable d_t^o equal to 1 if he is an owner-occupier in t and to 0 if he is a renter. Moreover, if he was an owner in the previous period he can decide to sell his house in t or to stay in it. The decision to sell is denoted by a dummy variable d_t^s equal to 1 if he decides to sell his former house and to 0 if he stays in it.

At each period t where the agent is alive, he receives an exogenous pension income y and has to pay an amount of health expenses, represented as out-of-pocket costs, $x(s)$ which depends on his health state[14]. If he had bought some financial assets b_{t-1} in the previous period, he receives Rb_{t-1} in t. Finally, if he was a homeowner in the previous period ($d_{t-1}^o = 1$), he can decide to sell his house ($d_t^s = 1$). In this case, he receives $p_t^h(1-\phi)h_{t-1}$ where p_t^h is the price of one unit of housing services and where ϕ is a transaction cost proportional to the value of the house. As a consequence, if one denotes $\mathcal{A}_t$ the available resources of the household net of health expenses, one has:

$$\mathcal{A}_t = y - x(s) + Rb_{t-1} + d_{t-1}^o d_t^s \left(p_t^h h_{t-1} (1-\phi) \right) \tag{3.4}$$

The agent uses these available resources[15] in part for non durable consumption which costs him c_t and to buy financial assets b_t. If he decides to rent housing services he pays $r_t^h h_t$ for housing consumption. If he was an owner and stays in his previous house he pays a maintenance cost proportional to the value of the house $\psi p_t^h h_t$ where $h_t = h_{t-1}$. If he decides to be the owner of a new house, then he pays the price of the house plus the corresponding maintenance cost. That is, he pays $(1+\psi) p_t^h h_t$. Denoting by $\mathcal{E}_t$, the sum of savings and expenses for consumptions, one has:

$$\begin{aligned} \mathcal{E}_t &= c_t + b_t \\ &+ \left(1 - d_{t-1}^o\right) \left(\left(1 - d_t^o\right) r_t^h h_t + d_t^o (1+\psi) p_t^h h_t \right) \\ &+ d_{t-1}^o d_t^s \left(\left(1 - d_t^o\right) r_t^h h_t + d_t^o (1+\psi) p_t^h h_t \right) \\ &+ d_{t-1}^o \left(1 - d_t^s\right) \psi p_t^h h_{t-1} \end{aligned} \tag{3.5}$$

In this model, I assume that housing decumulation can only be achieved by selling the house. Formally, this implies that $b_t \geq 0$ for all t. That is I study the effect of LTCI

[14]The amount for health expenses are the same as in the previous model.
[15]Which are endogenously affected by the decision to sell or not.

absent reverse mortgages or any other kind of mortgages, which was the main focus of Davidoff.

When health expenses are large it is possible to have $\mathcal{A}_t$ becoming low or negative. In the case where $\mathcal{A}_t < y_{min}$ (with $y_{min} > 0$) and $d_t^s = 1$, I assume that the individual is endowed with y_{min} which he can allocate freely for consumption and savings purposes. More formally, in this case I assume that the relevant budget constraint is $\mathcal{E}_t = y_{min}$ with $d_t^s = 1$[16]. I make the simplifying assumption that all prices and, in particular, house prices are constant[17].

In this model, two important elements affect the results apart from the presence of health risk. First, the desire for homeownership stems from the assumption that the rent r^h is large enough relative the maintenance cost ψp^h. This is similar to saying that the rental market for housing services has to be inefficient enough. This inefficiency might stem from different sources: moral hazard as in Henderson and Ioannides [1983], limited ability to modify the house or differences in tax treatments. Second, the transaction cost $\phi p^h h$ which applies to the whole value of the house sold limits the willingness of homeowners to move.

Before moving to the simulations, let's understand the different trade-offs that the agent faces. This is essential to understand why the asset and consumption commitments are affected by the purchase of LTCI. First of all, would the rental market be perfect, the agent would spend a constant share of his income on housing with the quantity of housing being determined by its rental cost. This is the direct consequence of the Cobb-Douglas specification. Given that the rental market is imperfect, a way to increase housing consumption for a given level of expenditures is to purchase a home. This entails some costs such as the one of not being able to adjust housing consumption every period (given the transaction cost) or the opportunity cost of not investing in bonds.

Another cost is that this lower price of housing consumption is only accessible if one keeps enough assets due to the no-borrowing constraint. An agent with low wealth would not be able to buy as it would require setting aside resources which he does not have. If a renter consumes h unit of housing, he pays each period $r^h h$. The value of the corresponding home is $p^h h$. This implies that this agent, in order to buy this house, would need to have a level of wealth corresponding to p^h/r^h times his annual housing consumption. In the realistic calibration below p^h/r^h is 16.7 years. As a consequence, an agent only buys if he has enough assets. This depends on his initial wealth and,

[16]I assume away any special treatment of the house here.

[17]Note that, even though house prices are constant here, housing provides a return by lowering the cost of housing consumption as the maintenance cost is lower than the rent. Given that bonds have a positive return, this assumption implies that the agent will have a tendency to diversify his portfolio. This appears to be the case for the top wealth quartile.

importantly, on the marginal utility out of future wealth. Would this latter be low an agent would decrease assets rapidly and thus would leave homeownership rapidly. Agents with a high marginal utility out of future wealth, essential to explain the lack of decumulation, tend to remain homeowners as will be clear from the simulations. However, purchasing a LTCI will reduce their marginal utility out of wealth and thus their tendency to remain homeowners. Hence, the idea that LTCI may weaken the asset commitment.

Finally, notice that, at first sight, it might appear highly valuable to introduce a reverse mortgage. The agent would benefit from the lower price for housing and would not need to keep large asset holdings. However, this is not that clear. Indeed, if the high rental cost is due to moral hazard as in Henderson and Ioannides [1983], then purchasing a reverse mortgage would bring back the problem. This would be priced in equilibrium and would increase the cost of reverse mortgages. This is particularly relevant as Campbell et al. [2011] find evidence in favour of the fact that death-related discounts on house sales would be due to poor maintenance. In any case, coming back to the previous discussion, a reverse mortgage can only be attractive if the marginal utility out of future wealth is not too high. In this sense, the development of a LTCI might be a pre-requisite for some households to be willing to take on a reverse mortgage.

3.3.2.2 Parametrization and Simulations

In table 3.3, I display the value of parameters used and the welfare gains from LTCI for men and women under different loads. I set γ to 3, β to 0.97 and R to 1.03. I assume that $p^h = p^c = \$1$. ω is set to 0.2 as in Yao and Zhang [2005]. From their paper I also take the remaining parameters. The rent-price ratio is set equal to 6% which implies, as housing prices are assumed constant at unity, that $r_t^h = r^h = \$0.06$. ψ is assumed to be 2% which is in the middle of the two values they consider. I take the transaction cost ϕ to be 6% of the value of the house. Pension income is set to \$15,000. y_{min} is set to \$7,000.

I consider that, at the beginning of retirement, the agent has only financial assets. Given this amount of financial wealth, he chooses the optimal share of his wealth he wishes to put in housing. Thus, the experiment applies directly to those moving at retirement. However, it should apply more broadly to those holding an amount of housing close to this optimal level. This should generally be the case, from a life-cycle perspective, as individuals should smooth the marginal utility of overall consumption across time. Any strong deviation from this optimal level would lead to large losses in welfare. Hence,

Table 3.3: Optimal LTCI, "Yao and Zhang-Type" Model

Parameters	Meaning	Values
ω	housing share	0.2
β	time preference	0.97
γ	curvature of utility	3
R	gross interest rate	1.03
y	pension income	$15,000
y_{min}	minimal income (net of medical expenses)	$7,000
p^h	housing price	$1
r^h	rental cost of housing	$0.06
ψ	maintenance cost	2%
ϕ	transaction cost	6%
Men no load		
Optimal LTCI Coverage		100%
Welfare Gains		$52,082
Men 50% load		
Optimal LTCI Coverage		100%
Welfare Gains		$17,996
Women no load		
Optimal LTCI Coverage		100%
Welfare Gains		$56,456
Women 20% load		
Optimal LTCI Coverage		100%
Welfare Gains		$37,980

those not deciding to move at retirement should have housing holdings close to those implied by the exercise here. If not they would decide to move.

In the case of a single man with $300,000 in bonds, the implied ratio of housing wealth to financial wealth is close to what can be observed for the median in the fourth wealth quartile for singles. This is what can be seen from figure 3.12. All the dollar amounts are scaled by $300,000 so that, for instance, housing holdings worth $150,000 will be 0.5 in the figure. This allows to have the ownership dummy on a similar graph.

As previously, I show life-cycle patterns for an agent in state 0. Figure 12 is quite close to figure 3.2 with possibly a bit too much decumulation around age 90. As explained above, the agent decides to own to avoid the imperfections on the rental market. Given that housing is costly to adjust, the part of his wealth that he adjusts is financial wealth. Here, the agent still owns at age 90 because his precautionary motive is rather strong and his optimal amount of wealth is higher than the value of his home.

The gains from purchasing a LTCI for this agent are large as can be seen from table 3.3. This is true even if one considers loads as high as 50%. In figure 3.13, I show his life-cycle patterns when he decides to purchase a full LTCI with a 50% load. The picture with no load looks very similar.

The agent still decides to purchase a home initially in order to avoid the inefficiency in the rental market. Given the fact that he is insured, he decumulates wealth much faster and thus at age 86, he has no more financial wealth and he decides to move and to become a renter at age 87. In this case a reverse mortgage might become attractive at age 87, while in figure 3.12 there did not seem to be much room for a reverse mortgage. As can be seen, here the asset commitment is in some way reduced by the purchase of a LTCI.

The wealth decumulation patterns for women (figure 3.14) in the absence of LTCI is also close to what can be found from figure 3.2 with financial wealth at age 90 around \$100,000. In this case as well welfare gains from LTCI are large and the purchase of this latter accelerates financial wealth and housing decumulation (figure not shown).

Finally for agents with about \$225,000 in total wealth, which corresponds to the bottom half of the fourth wealth quartile (see figure 3.3), I find patterns very close to those in the data. For instance, financial wealth at age 90 for a healthy man is about \$22,000. I still find welfare gains for a LTCI with 50% load and a fair LTCI is highly valuable with welfare gains of \$35,539 and a 100% coverage.

For a woman with the same amount of initial wealth, financial wealth at age 90 is \$67,690 which is in line with figure 3.3. The welfare gains from purchasing a full LTCI are still \$16,876 with a 20% load. These results show that it is hard to rationalize the low take-up rate of LTCI in the fourth wealth quartile in this setting. Moreover, here, most of the low demand from LTCI arguably stems from the presence of a consumption floor.

3.4 Concluding Remarks

In this paper, I showed that a model with a strong asset commitment to housing as in Davidoff (2009, 2010), calibrated to reproduce the wealth patterns in the data, generates no demand for LTCI for agents up to the third quartile of the wealth distribution for singles. However, I still find that many agents in the fourth wealth quartile would

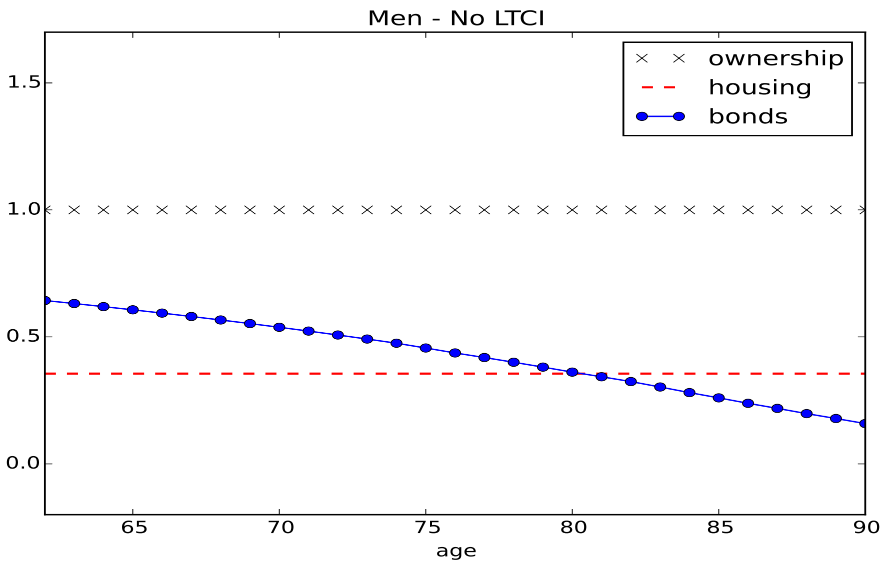


FIGURE 3.12: Financial Wealth, Housing Wealth and Ownership Status for Healthy Men without LTCI, Yao-and-Zhang-Type Model

Notes: The figure plots the evolution of the different state variables for an individual facing no negative health shocks (i.e. who is always in state 0). The model used is the modified version of the one of Yao and Zhang (2005). In this case the agent has no LTCI. The ownership variable is equal to 1 if the individual is an owner and to 0 if he is a renter.

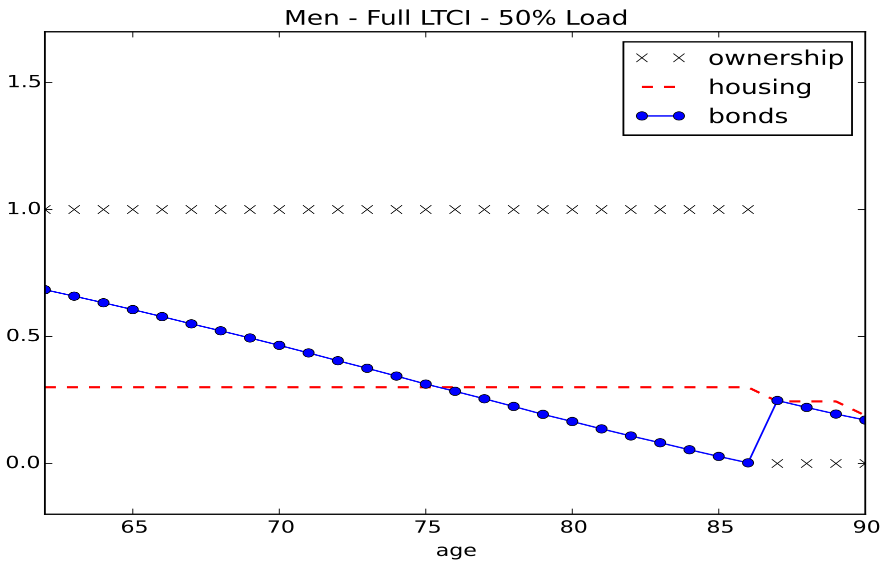


FIGURE 3.13: Financial Wealth, Housing Wealth and Ownership Status for Healthy Men with a Full LTCI with 50% Load, Yao-and-Zhang-Type Model

Notes: The figure plots the evolution of the different state variables for an individual facing no negative health shocks (i.e. who is always in state 0). The model used is the modified version of the one of Yao and Zhang (2005). In this case the agent has purchased a full LTCI with a 50% load. The ownership variable is equal to 1 if the individual is an owner and to 0 if he is a renter.

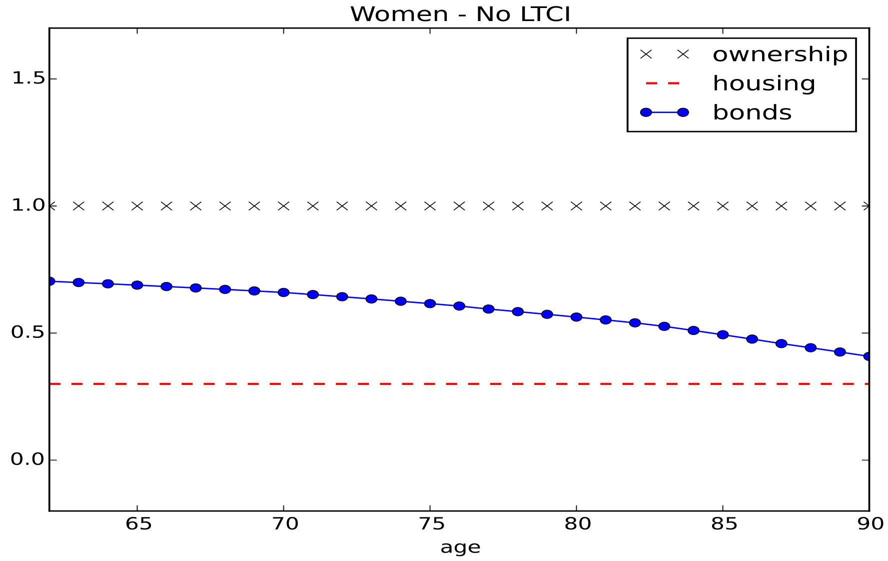


FIGURE 3.14: Financial Wealth, Housing Wealth and Ownership Status for Healthy Women without LTCI, Yao-and-Zhang-Type Model

Notes: The figure plots the evolution of the different state variables for an individual facing no negative health shocks (i.e. who is always in state 0). The model used is the modified version of the one of Yao and Zhang (2005). In this case the agent has no LTCI. The ownership variable is equal to 1 if the individual is an owner and to 0 if he is a renter.

still benefit from purchasing a LTCI, casting some doubt on the fact that housing may explain the low demand for LTCI for richer households. Though the model is designed for singles, the wealth patterns for couple households suggest that the low demand for LTCI in this group is even harder to rationalize by the presence of housing.

These results are confirmed using a model where the asset commitment does not stem from preferences but from the interactions of transaction costs, an imperfect rental market and the risk of LTC. In this case, the purchase of LTCI reduces the asset commitment to housing which dampens the crowding-out effect of housing on LTCI. Hence, in this case, the proportion of agents benefiting from the purchase of LTCI tends to be higher.

The fact that financial wealth decumulation for richer households is low suggests that the purchase of LTCI would increase the demand for reverse mortgages. This complementarity goes in the opposite way than the one in Davidoff (2009, 2010) who argued that reverse mortgages would make LTCI more attractive. It is in line with the results in Nakajima and Telyukova [2014b] who find relatively low gains from the introduction of reverse mortgages for richer households in a model where there is no insurance for medical expense risk. As both complementarities might be relevant empirically, growth in the LTCI and reverse mortgage markets might require that the inefficiencies in both markets be tackled simultaneously. I believe that future research on these complementarities in an equilibrium setting might prove to be of much interest.

Chapter 4

Disability in Retirement, Home Production, and Informal Insurance Between Spouses

Abstract

This paper constructs a life-cycle model of retired households with home production in which couples are modelled explicitly. Disability affects the disutility of doing home production. Inside couples, a healthy spouse can increase time spent on home production when the other spouse becomes disabled, thus providing some sort of insurance. This latter feature is observed in the Consumption and Activity Mail Survey (CAMS). The model reproduces well the main features in the data and is used to assess the effects of disability and age on wealth decumulation patterns, as well as the influence of this informal insurance mechanism on dissavings patterns. I find that disability and age have a large impact on dissavings through their effects on home production. Informal insurance between spouses offers sizeable gains intratemporally but has a minor effect on decumulation.

Introduction

Retired individuals face a significant risk of becoming disabled as they age. This usually translates in higher spending on home care or nursing homes. For couples, an alternative for higher spending exists if one of the member becomes disabled. Indeed, a healthy spouse can, in principle, take care of a sick spouse. While such an insurance mechanism

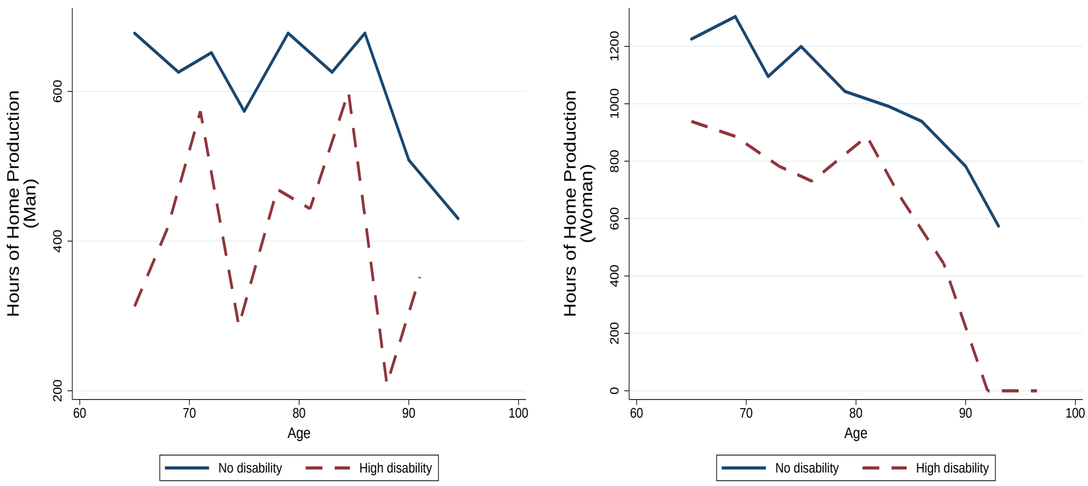


FIGURE 4.1: Hours of home production as a function of age and disability

has been well documented in different fields, quite little is known on its impact on savings behaviours. This is, however, crucial to assess some of the trade-offs linked to entitlements reforms. The present paper tries to fill this gap.

To measure this insurance channel, I use data on time spent on home production. Those data are for the US and come from a survey linked to the health and retirement study (HRS): the consumption and activities mail survey (CAMS). Time spent on home production is particularly relevant as (i) doing home production becomes more difficult when in worse health and as (ii) we observe insurance-like mechanisms regarding home production.

(i) is confirmed when plotting hours of home production as a function of age and disability for women and men (see figure 4.1). Healthy retired women up to 80 years-old spend about 1,100 hours annually (at the median) on home production. This number falls to less than 200 for highly disabled women around 90 years-old. For men, data are a bit more noisy but we also observe a dramatic fall of time spent on home production as they get disabled. The magnitudes of these variations are substantial

(ii) can be seen from figure 4.2 which plots home production hours done by men and women in couples not having some long-term care insurance and not receiving help from the family or friends. They are plotted as a function of the level of disability of the other spouse. We clearly see that men increase their hours of home production as their wives get disabled. A similar pattern is observed for women. Once again, the magnitude of these variations is large with men increasing hours of home production by about 250 hours or about 45%.

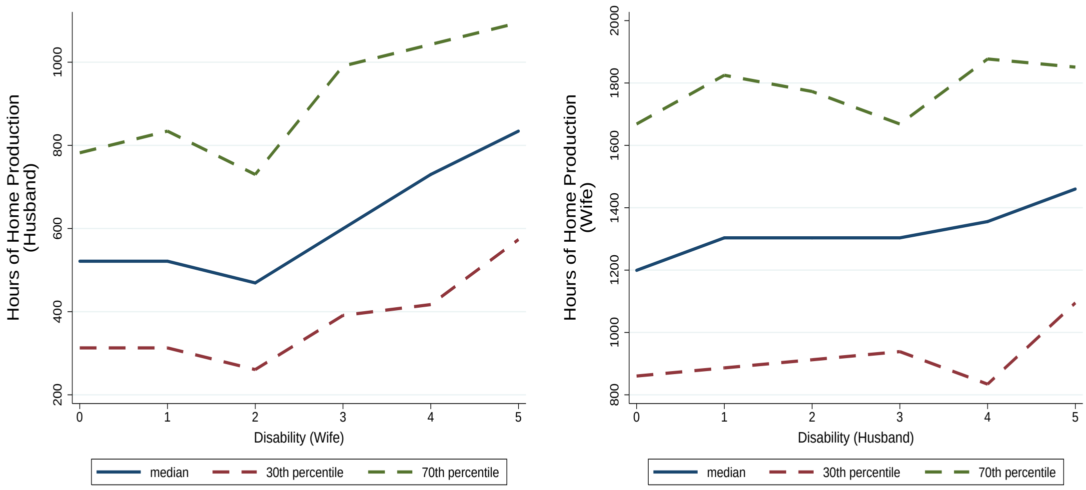


Figure 4.2: Hours of home production as a function of disability of the spouse

To evaluate the effects of these variations, and in particular of the insurance-like mechanism that we observe, on savings, I construct a life-cycle model with home production where retired couples are modelled explicitly. In the model, individuals face a risk of disability which increases the disutility they experience when doing home production. On top of this, they face realistic mortality and out-of-pocket medical expense risks. I show that the predictions of this model are in line with the data and that it reproduces well the qualitative and quantitative patterns that are observed. To fix the values of the different parameters, I use a method of simulated moments.

This model can then be used to perform a set of fined-tuned counterfactual experiments. First, I find that the effects of disability and age on home production affect savings behaviours substantially. Second, I try assess the effect of the insurance-like mechanism described above (which I call *spousal insurance*). I find however that the effect of this insurance on dissavings behaviours is relatively minor despite sizeable intratemporal welfare gains stemming from it. This is due to the fact that health is correlated between spouses, that disability is uncertain, and that there is a high probability to be widowed when disabled. This result suggests that the potential provision of care from a spouse to another spouse should not be over-evaluated when designing policy reforms linked to entitlements for the elderly.

The interest for this research relative to the existing literature lies primarily in the fact that the life-cycle behaviour of couples has so far been understudied For instance, De Nardi et al. [2010] do not study the behaviour of couples. While some papers do, they usually model the couple in a very simple manner, for instance through the presence of economies of scale as in Nakajima and Telyukova [2014b]. Second, while informal insurance might stem from children as in Barczyk and Kredler [2014] or Dobrescu [2015], the variations regarding home production in the data are substantial and thus are interesting to study on their own. In particular, we clearly observe insurance-like mechanisms within retired couples whose influence on life-cycle savings has, to my knowledge, not been studied yet.

The paper is divided in seven sections. First, I discuss the choice of home production and why it is adapted for the purpose of this paper. In the same section, I also discuss the existing literature. As the paper is at the crossroads of many different fields, it is not meant to be exhaustive. It should however give the interesting reader a view of some of the main developments which occurred in the related fields. In a second section, I present the intratemporal part of the model. It encompasses some of the main intuitions of the paper. It is a collective model[1] with home production in which the ability to do home production is affected by health condition and age. The third part discusses the database and documents the main empirical patterns regarding home production, linking them to the theoretical model. The fourth section presents the intertemporal part of the model in which households make optimal decisions regarding expenditures and savings, taking into account different sources of risk. The fifth section discusses the estimation. The sixth part presents the outcome of the model and the results from the counterfactual experiments. The last part concludes.

4.1 Preliminary Discussion

4.1.1 Why home production

The focus of this work could be summarized in two questions. *May disability, through its effect on home production, explain savings behaviours of retirees? May the potential insurance brought out by a spouse affect those behaviours?*

An issue which needs to be discussed concerns the activities which must be included in home production for the present analysis. Indeed, time spent on home production activities (TSHPA, thereafter) will serve as a measure of the effect of disability and of the extent of spousal insurance. Given the life-cycle dimension of the problem under hand, the chosen time measure needs to allow for *intertemporal* comparisons. First of all, I discuss the activities included in home production in this paper and show that they arguably allow for these types of comparisons. I then discuss other activities for which time is not well adapted for such comparisons.

[1] Though, for the estimation of the structural model, I consider the special unitary case of the collective framework.

As the main measure of TSHPA, I use the sum of time spent on: (i) house cleaning, (ii) washing, ironing, or mending clothes, (iii) yard work or gardening, (iv) shopping or running errands and (v) preparing meals and cleaning-up afterwards. First, let's start by the way the questions are asked in the CAMS. They are all asked in a similar way. For activity (v) it is: "How many hours did you spend last week preparing meals and cleaning up afterwards?".

Consider the case of a single individual healthy in t and disabled in $t+1$ and the activity cooking. The hours h_t done cooking in t are *a priori* comparable to the hours h_{t+1} done cooking in $t + 1$. Indeed, cooking done in t is done in a similar manner than cooking done in $t + 1$. Cooking a steak when disabled or healthy has no reason to be much different. Thus, intertemporal comparisons do seem possible using this measure. For a couple, the reasoning is similar with an additional requirement: time declared by a given spouse for an activity must reflect her or his effort on this activity. Even, if spouses do cook together, usually each one does a specific task. For instance, the wife might take care of cooking the vegetables, while the husband might cook the meat, or the reverse. If the wife is now disabled and the husband needs to do both activities, we can clearly state that the effort done by the husband on cooking is now higher if his health has not changed. Hence, for the husband, we can compare his effort cooking in t to his effort cooking in $t+1$. Moreover, for the wife, we can link the reduction of the time she spends cooking to a higher effort for a given amount of time spent on this activity (due to the occurrence of disability). Such a logic can easily be applied to activities (i) to (v) as well.

Now let's consider a set of activities which are not considered but which might be associated to the insurance channel studied here: personal grooming and hygiene, such as bathing and dressing. In this case, the CAMS question is similar to the one above: "How many hours did you spend last week [on] personal grooming and hygiene, such as bathing and dressing?". An issue with those activities is that the body of the person helped is an input in the production function. Hence, if the person is helped, even though she or he reduces his or her input in the production function, she or he might not reduce the time spent doing this activity. So, time is not well suited for intertemporal comparisons here, as it does not measure the effort done by a specific person. Hence, the choice not to consider those activities. The above concern is confirmed by regression analysis. Indeed, if we regress time spent on personal grooming on disability, we do not find any evidence of a reduction in time as the level of disability increases.

It should also be noticed that the activities I consider represent a substantial amount of time. In my sample, women spend on average 1,120 hours on home production annually. The median is a bit lower at 991 hours annually. As a matter of comparison, the average of the hours actually worked by a US worker was of 1,799 in 2005 according to the OECD. For men, the figures for home production are lower with a median of 574 hours and a mean of 729 hours. Hence, for men the median represents about 32% of the average time spent working by a US worker. For women, this figure is 55%. I also computed the ratio of time spent on home production over the sum of time spent on home production and time spent on personal grooming and hygiene. For women, the mean of this ratio is 69%, the median is 75% and the 25th percentile is 64%. For men, these numbers are respectively 63%, 69% and 54%. So, for a large majority of retirees, time spent on home production is higher than time spent on personal grooming.

Finally, home production is interesting to study as it is usually not covered by Medicare and thus not well insured by public programs. Indeed, according to the brochure entitled "Medicare and Home Health Care", it is said that Medicare usually covers only skilled nursing care. It is defined as follow: "Any service that could be done safely without a non-medical person (or by yourself) without the supervision of a nurse, isn't skilled nursing care". Moreover, it is explicitly written that 24-hour-a-day care at home, meals delivered at home, homemaker services (shopping, cleaning...) and personal care (dressing or bathing) are usually not covered.

Overall, the fact that the chosen measure of home production allows for intertemporal comparisons of the efforts of individuals and represents a high share of time makes it a good candidate for tackling the questions of interest here. Moreover, as has been illustrated in the introduction and will be emphasized later, we observe strong variations in home production and apparent insurance-like mechanisms inside couples.

In the next subsection, I summarize the related literature.

4.1.2 Literature Review

The present paper is at the crossroads of several and mostly separate literatures. First of all, several studies have shown that home production, as introduced by Becker [1965], is an important part of consumption. For instance, home production seems to have resolved the so-called retirement consumption puzzle. In particular, Aguiar and Hurst [2005] have shown that the decline in food expenditures upon retirement was met by an increase in time spent cooking. Moreover, they have shown, using detailed food diaries, that actual food consumption did not show any decline despite the fall in spending on this category. Hurd and Rohwedder [2008] reached similar conclusions using the same data I use. Aguiar and Hurst [2007] also showed that data on shopping time and prices imply that the log difference between the opportunity cost of time of a household aged 65-74 and one aged 40-44 is of around -0.25. Moreover, using these results and data on time spent on home production they find an elasticity of substitution between home production and expenditures of 1.8. Stancanelli and Soest [2012] showed also that home production was increasing at retirement for both men and women using French data. Their paper concentrates mostly on couples and they show that retirement of the wife tends also to decrease hours of home production done by the man. Bonsang and van Soest [2014] find comparable results using German panel data. Finally, in the tradition of the large literature trying to explain life-cycle patterns of expenditures, Aguiar and Hurst [2013] show that most of the differences in expenditure patterns as a function of age are due to categories which are input to market work or amenable to home production. They also show that including home production in a life-cycle model leads to a level of uninsurable permanent income risk which is line with the data, a feature that previous models had difficulty to match. To my knowledge, no recent work in the economics literature has attempted to understand the consequences of the dramatic fall in home production hours shown in the introduction in parallel with the dynamics that are observed inside couples.

The second literature this paper is related to is the extremely large literature on the provision of informal care and its complementarity or substitutability with formal care. Most of this literature has focused on the provision of care from adult children to their elderly parents. Bonsang [2009] - using data from the Survey of Health, Ageing and Retirement in Europe (SHARE) - finds that informal care from children tends to substitute for formal care at relatively low levels of disability but that this substitutability tends to vanish as disability increases. Bolin et al. [2008] find somehow comparable results. They find that formal and informal care are substitutes while informal care is complement to doctor and hospital visits. Van Houtven and Norton [2004] using data from the HRS and AHEAD find that informal care by adult children reduces home health care use and delays nursing home entry. Lo Sasso and Johnson [2002] using AHEAD data find that help from children reduces the probability of nursing home use. Johnson and Lo Sasso [2006] found that women who spent time helping their parents cut back their paid work hours by about 367 hours annually which lead on average to foregone wages of $7,000 per year in 1998 dollars. Pezzin et al. [1996] found limited substitutability between formal and informal care. Overall, some of these papers seem to indicate a certain degree of substitutability between formal and informal care, with substitutability tending to be more limited at higher levels of disability. The results in the present paper are globally in line with those results.

The provision of care can also stem from other relatives (other than children) like friends or neighbours as show in Kalwij et al. [2012]. Also, a strand of the literature has attempted to understand the reason behind time and money transfers between children and parents. Contrary to the idea that care stems from altruism (as in Becker, 1974), several studies point to exchange motives behind such transfers (see Bernheim et al., 1985 and Cox, 1987). A detailed review of the literature on the subject can be found in Alessie et al. [2014] which show results in line with the exchange motive. Thus, this strand of the literature suggests that informal care from children might not be free of costs for the elderly parents.

To my knowledge, only two recent papers about retirement have attempted to introduce informal types of arrangement within dynamic life-cycle models. Barczyk and Kredler [2014] build a dynamic framework where the provision of care from children to their elderly parent is the result of complex dynamics which can stem from altruistic reasons or exchange motives. This setting allows to study long-term care policy taking into account the endogenous reaction of care. In particular, they find that formal-care subsidy can be financed at almost zero cost to taxpayers, mainly because there is an effect on the labour force which increases tax revenues. My work differs from theirs in three ways. First, I focus on spousal insurance. Second, the framework I use is collaborative in the sense that households make Pareto efficient choices. Third, I do not consider the help stemming from children. The second difference is linked to the fact that the Pareto efficient setting is more plausible in an intrahousehold setting than it is in their framework where informal mechanisms are between different households. The third difference is mainly done for simplicity and in the paper I try as much as possible to consider households which do not benefit from the help of their children. I believe, however, that considering both intrahousehold and interhousehold mechanisms of informal care might be a fruitful extension of the existing research. Dobrescu [2015] also allows for informal insurance within a dynamic life-cycle model. In her framework, households can self-insure or use insurance contracts. There are two types of insurance contracts: formal and informal. The latter depend on social ties and bequeathable wealth. In particular, she is able to allow for differing social ties using the cross-country differences from SHARE.

The present paper is also related to the work by Kotlikoff and Spivak [1981] in which they show that the family by pooling income and mortality risk can substitute for annuities. The key difference between my paper and theirs is that I am interested in the insurance role of spouses regarding disability. This interest stems from the fact that previous works such as Palumbo [1999] and De Nardi et al. [2010] have highlighted that medical risk, and mostly long-term care risk, is one of the main, if not the main, reasons behind savings behaviours in old age. Given that the presence of a spouse might substitute partly for long-term care expenditures, it is arguably of interest to study such spousal insurance and its influence of savings behaviours. Moreover, the insurance channel described here is different and stems from a channel of labour supply[2]. Lakdawalla and Philipson [2002]

[2]In the sense that individuals can adjust the time they spend on home production, which is a type of labour.

are in many ways related to the paper here. In particular, they argue that the reduction of the gap between the longevity of men and women may reduce the needs for long-term care. The model here is, in a way, richer and its quantitative component can assess the importance of spousal insurance on savings behaviours. Finally, Goda et al. [2013] show that out-of-pocket medical spending, mainly from nursing home stays, are increasing upon widowhood.

On top of the works by Palumbo [1999] and De Nardi et al. [2010], the life-cycle literature in retirement has experienced several interesting developments. For instance, Nakajima and Telyukova (2012, 2014b) study the importance of housing in explaining observed savings behaviours. Ameriks et al. [2011] and Lockwood [2013] look more closely at the importance of bequest motives. Early attempts to empirically assess the importance of bequest motives can be found in Hurd (1987, 1989). His results are in contrast to some more recent work such as the one in Kopczuk and Lupton [2007]. A key innovation in Ameriks et al. [2011] is to use survey data to discriminate between bequest motives and public care aversion. They find that the latter decreases substantially the demand for life annuities. Lockwood [2013] argues that the low dissavings rate of households in combination with the low demand for long-term care insurance constitutes evidences of large bequest motives over which individuals are not very risk-averse. In Lockwood [2012], he also argues that bequest motives may explain why so little retirees own annuities. Hubbard et al. [1995] find that means-tested insurance programs can crowd-out savings. Similarly, Brown and Finkelstein [2008] show that Medicaid can crowd-out LTCI demand for an important share of the elderly population. De Nardi et al. [2014] extend their 2010 work and study more in-depth the effect of Medicaid on savings behaviours and show that high lifetime income households often value Medicaid the most. Scholz et al. [2006] using a model featuring realistic earnings and medical risk argue that most Americans do save enough for retirement.

This paper is also related to the literature on collective models of households as introduced by Chiappori (1988, 1992) and Apps and Rees [1988]. This literature is very active and some noticeable recent examples of applications of this approach include Browning and Gø rtz [2012], Browning et al. [2013] or Cherchye et al. [2012]. Mazzocco [2007] is one application of such a framework to the study of life-cycle behaviours. His key contribution is to allow for the absence of commitment in such a framework. This implies that Pareto weights are endogenous and, in particular, depend on the outside option (for instance divorce). His estimation procedure is an extension of the approach trying to estimate Euler equations. In this work, I assume that Pareto weights are not changing overtime as is done in Hong and Ríos-Rull (2007, 2012) which estimate a dynamic household model using data on life-insurance holdings.

4.2 The intratemporal problem

Consider a household aged t, where t is the age of the husband and Δt is the age of the husband minus the age of his wife, which has a utility function of the form:

$$u^{hh}\left(c_{f,t}, c_{m,t}, h_{f,t}, h_{m,t} | \mathbf{s}_t = \left(\mathbf{s}_{f,t}, \mathbf{s}_{m,t}\right), t\right) = \phi\left(\frac{c_{f,t}^{1-\gamma}}{1-\gamma} - A_f\left(\mathbf{s}_{f,t}, t-\Delta t\right)\frac{h_{f,t}^{1+\eta}}{1+\eta}\right)$$
$$+ (1-\phi)\left(\frac{c_{m,t}^{1-\gamma}}{1-\gamma} - A_m\left(\mathbf{s}_{m,t}, t\right)\frac{h_{m,t}^{1+\eta}}{1+\eta}\right)$$

The first term in bracket is the utility of the wife in the couple. While the second term is the utility of the husband. The utility of the wife is weighted by ϕ, while the one of the husband is weighted by $1-\phi$. I thus assume that the allocation inside the household is Pareto efficient. If ϕ depends on relative pensions, relative education, price variations, we are in the case of the collaborative model. If ϕ is independent of such factors, the model is the special unitary case of the collective framework. In the intertemporal model the weights will be constant over time. This is similar to what is done in Hong and Ríos-Rull (2007, 2012). While, it might be interesting to have a model without commitment in which Pareto weights are endogenous as in Mazzocco [2007], this would raise several issues. Most of these issues are exposed in Hong and Ríos-Rull (2012, p. 3703) and I will repeat or add a few ones. First of all, adding participation constraints would make the problem computationally intensive and would require to make assumptions about any additive term that would stem from becoming single, in the case of the standard assumption that the outside option is the utility from divorce. Second, divorce rates among retirees are lower than in the rest of the population. Despite a rise from 1.79% in 1990 to 4.84% in 2010 for the 65+, it is still much lower than the divorce rate of the 50-64 which was at 13.05% in 2010 (Brown and Lin, 2012). The divorce rate among individuals younger than 44 is even higher, above 20% (Brown et al., 2014). Hence, it appears that divorce, usually considered as the outside option, is not that often exercised among retirees. This suggests a higher cost of divorce for retirees than for the rest of the population. So, the fact that I do not consider changing Pareto weights might have minor costs. Moreover, in the regression analysis I control for different factors which might affect Pareto weights and I find that the main patterns regarding home production are not changed once adding those controls.

$c_{f,t}$ ($c_{m,t}$) is the amount of good c_t allocated to the wife (husband). $h_{f,t}$ ($h_{m,t}$) is the time spent by the wife (husband) on home production activities (HPA). An increase in $h_{f,t}$ ($h_{m,t}$) typically reduces her (his) utility. $A_f\left(\mathbf{s}_{f,t}, t-\Delta t\right)$ ($A_m\left(\mathbf{s}_{m,t}, t\right)$) is a number which drives her (his) disutility relative to TSHPA. It depends on her (his) age $t-\Delta t$ (t) and on a vector of observables describing health condition $\mathbf{s}_{f,t}$ ($\mathbf{s}_{m,t}$). In the application, it will be a vector of dummies indicating her (his) level of disability. Notice that $A_f\left(\mathbf{s}_{f,t}, t-\Delta t\right)$ and $A_m\left(\mathbf{s}_{m,t}, t\right)$ are the only elements differing in the respective utility functions of the wife and the husband. γ and η are standard parameters.

$c_t = c_{f,t} + c_{m,t}$ is a good which is produced by mixing time and expenditures. I assume that it is the only good available. The model can easily be modified to include the possibility of a non home produced-good. However, my interest here focuses on the overall relationship between savings and time spent on home production rather than on the reallocation of expenditures. I thus opted for this simpler structure which also avoids the problem of the classification of expenditures which can always be subject to debate. Denoting by $h_t = h_{f,t} + h_{m,t}$ the overall time spent on home production by the household, the production technology is assumed to have a constant elasticity of substitution (CES) with an elasticity of substitution ϵ. It is of the same form as in Aguiar and Hurst [2007]:

$$c_t = \left(h_t^{\rho} + \psi q_t^{\rho}\right)^{1/\rho}$$

where $\rho = 1-\frac{1}{\epsilon}$ and $q_t = \chi x_t$. ψ measures the weight of q_t relative to h_t in the production of the good c_t. x_t measures the amount of expenditures spent by the household at time t and $\chi \geq 1$ is a parameter which affects the extent of the economies of scale of a couple relative to a single household. x_t is an exogenous variable from the intratemporal problem point of view. Hence, the intratemporal problem consists in finding the optimal amounts for the other variables conditional on the level of x_t. The intertemporal problem will consist in the allocation of x_t across time.

To summarize the problem is to maximize utility under the above constraints. So the problem that the household faces at age t is:

$$\max_{\left\{c_t, c_{f,t}, c_{m,t}, h_t, h_{f,t}, h_{m,t}, q_t\right\}} u^{hh}\left(c_{f,t}, c_{m,t}, h_{f,t}, h_{m,t} | \mathbf{s}_t = \left(\mathbf{s}_{f,t}, \mathbf{s}_{m,t}\right), t\right)$$

subject to:

$$h_t = h_{f,t} + h_{m,t}$$

$$c_t = \left(h_t^{\rho} + \psi q_t^{\rho}\right)^{1/\rho}$$

$$c_t = c_{f,t} + c_{m,t}$$

$$q_t = \chi x_t$$

To simplify notations, I put $A_f \equiv A_f(\mathbf{s}_{f,t}, t - \Delta t)$ and $A_m \equiv A_m(\mathbf{s}_{m,t}, t)$.

From the above optimization problem we obtain the following relation:

$$h_t^{\rho-\eta-1}\left(h_t^\rho + \psi q_t^\rho\right)^{(1-\gamma-\rho)/\rho} = \left((\phi A_f)^{-1/\eta} + ((1-\phi) A_m)^{-1/\eta}\right)^{-\eta} \Phi^{-1} \tag{4.1}$$

where $\Phi = \phi\left(1 + \left(\frac{1-\phi}{\phi}\right)^{1/\gamma}\right)^{\gamma-1} + (1-\phi)\left(1 + \left(\frac{\phi}{1-\phi}\right)^{1/\gamma}\right)^{\gamma-1}$.

This relation implies that a sufficient and necessary condition for time spent on home production and expenditures to be substitute is:

$$\frac{1}{\gamma+\rho-1}\left(-(\eta+\gamma) h_t^\rho + (\rho-\eta-1)\psi q_t^\rho\right) < 0$$

The second term in brackets is negative as long as:

$$\rho - \eta - 1 < 0 \Leftrightarrow -\frac{1}{\epsilon} - \eta < 0$$

which is always true. So a sufficient condition is:

$$\gamma + \rho - 1 > 0 \Leftrightarrow \gamma > \frac{1}{\epsilon}$$

As a consequence, time spent on home production and expenditures are substitute if the curvature of the utility function and the elasticity of substitution between time and expenditures are high enough. I assume in the rest of the exposition that this condition is always satisfied. Assuming that $dq = 0$, it is interesting to see how variations in A (the parameter driving the disutility of performing HPA) affect differently TSHPA for couples and for singles. For couples, we have:

$$\begin{aligned}\left((\rho-\eta-1) + (1-\gamma-\rho)\frac{h_t^\rho}{h_t^\rho + \psi q_t^\rho}\right)\frac{dh_t}{h_t} = \\ \frac{(\phi A_f)^{-1/\eta}}{(\phi A_f)^{-1/\eta} + ((1-\phi) A_m)^{-1/\eta}}\frac{dA_f}{A_f} + \frac{((1-\phi) A_m)^{-1/\eta}}{(\phi A_f)^{-1/\eta} + ((1-\phi) A_m)^{-1/\eta}}\frac{dA_m}{A_m}\end{aligned} \tag{4.2}$$

For a single agent, the relation is[3]:

$$\left((\rho - \eta - 1) + (1 - \gamma - \rho) \frac{h_t^\rho}{h_t^\rho + \psi q_t^\rho} \right) \frac{dh_t}{h_t} = \frac{dA}{A} \tag{4.3}$$

As $\frac{(\phi A_f)^{-1/\eta}}{(\phi A_f)^{-1/\eta} + ((1-\phi)A_m)^{-1/\eta}} < 1$ and $\frac{((1-\phi)A_m)^{-1/\eta}}{(\phi A_f)^{-1/\eta} + ((1-\phi)A_m)^{-1/\eta}} < 1$, a percentage increase in A will lead to a lower percentage fall of h_t in the case of a couple than in the case of a single household if one starts at a similar ratio h_t/q_t. This comes from the fact that A_f and A_m may not be perfectly correlated. If $\frac{dA_f}{A_f} = \frac{dA_m}{A_m}$, then equation (4.2) becomes similar to equation (4.3). This result conveys the idea that informal insurance between spouses stems from the fact that health shocks may not be perfectly correlated among them. However, the likely correlation between A_m and A_f makes this an imperfect insurance mechanism.

One interesting question is whether or not h_m increases following a rise in A_f if A_m and q_t are constant. That is, does a husband increases the time he spends on home production if his wife gets in worse health and if effective expenditures remain constant? h_m is determined by the following optimality condition:

$$h_{m,t}^\eta = \frac{\Phi}{(1 - \phi) A_m} h_t^{\rho - 1} \left(h_t^\rho + \psi q_t^\rho \right)^{(1-\gamma-\rho)/\rho} \tag{4.4}$$

If q_t stays constant a fall in h_t leads to a rise in $h_{m,t}$ through the term $h_t^{\rho-1}$ as long as the elasticity of substitution ϵ is greater than 1. The term $(h_t^\rho + \psi q_t^\rho)^{(1-\gamma-\rho)/\rho}$ increases as well following a fall in h_t under the condition $\gamma > 1/\epsilon$. Thus $h_{m,t}$ tends to rise following a rise in A_f. The reason for this is intuitive. If q_t stays constant, the fall in h_t driven by the fact that the wife is in worse health leads to a reduction in c_t, the quantity of the home-produced good. This reduction in c_t increases the marginal utility of consuming this good. Thus the husband, who does not experience any change in A_m, optimally responds by increasing the marginal disutility of time spent on HPA as, roughly, it should equalize the marginal utility of consumption c_t. This is done by increasing $h_{m,t}$.

An alternative for the household would be, of course, to increase q_t. However, if it is unable to increase it enough so as to maintain c_t at a high enough level, then the occurrence of disability of one member will tend to increase the time spent on home production of the other member. This feature is of course absent in a model with only one agent. Thus, the above model produces some sort of intrahousehold insurance, a mechanism of adjustment which is absent in a single-agent model.

[3]The problem of a single agent is in appendix. It is a straightforward modification of the above problem.

From a life-cycle perspective, it is important to understand whether or not the above intrahousehold insurance affects the marginal utility out of expenditures, as ultimately this latter affects savings behaviours. In the above model, this can be seen by studying the marginal utility of x_t or q_t. Let's consider the marginal utility u'_q relative to q_t:

$$u'_q = \Phi\psi q_t^{\rho-1} \left(h_t^\rho + \psi q_t^\rho\right)^{(1-\gamma-\rho)/\rho} > 0 \tag{4.5}$$

The cross derivative u'_{qh} relative to h is given by:

$$u'_{qh} = \Phi\psi \left(1-\gamma-\rho\right) q_t^{\rho-1} h_t^{\rho-1} \left(h_t^\rho + \psi q_t^\rho\right)^{(1-\gamma-2\rho)/\rho} \tag{4.6}$$

Under the previous assumptions, this cross-derivative is negative so that a fall in h_t will lead to a rise in the marginal utility of expenses q_t. Combining this expression with equation (4.4) shows that the presence of a spouse may limit the marginal utility out of expenditures. Indeed, a healthy spouse limits the extent of the fall in TSHPA for a given level of q_t. This, in turns, limits the rise in the marginal utility from q_t.

Finally, the model leads to the following log-linear equation:

$$\ln h_{m,t} - \ln h_{f,t} = \frac{1}{\eta} \ln\left(\frac{\phi}{1-\phi}\right) + \frac{1}{\eta}\left(\ln A_f - \ln A_m\right) \tag{4.7}$$

This equation simply tells that the ratio $h_{m,t}/h_{f,t}$, should be negatively related to the ratio A_f/A_m. Thus, if we can come up with objective factors likely to affect directly A_m and A_f, then we should observe a change in the log of the ratio $h_{m,t}/h_{f,t}$ (which I will call the *log ratio* in the reminding of the text for simplicity). An advantage of this equation is that it should not be sensitive on whether or not the household receives help from the outside as it does not depend on q_t or h_t, aside from elements potentially affecting the intercept through changes in the relative Pareto weights. Moreover, the fact that the relative household members' weights enter in a linear way in the above equation imply that it is possible to control for factors potentially affecting them by adding simple linear controls to this equation. Finally, the estimation of the previous equation gives the coefficients on the objective factors affecting A_m and A_f up to the scale factor η (except for the constants, see below). This is informative on the shocks to A_m and A_f . As a matter of fact, a slightly modified version of equation (4.7) will be given as a part of the moments to match for the estimation of the model[4]. All this can be seen from the derivations below.

For the structural model, I will assume that $A_f(\mathbf{s}_{f,t}, t-\Delta t) = \exp\left(\delta_f^o + \left(\mathbf{s}'_{f,t}, t-\Delta t, (t-\Delta t)^2\right)\delta_f\right)$ and $A_m(\mathbf{s}_{m,t}, t) = \exp\left(\delta_m^o + \left(\mathbf{s}'_{m,t}, t, t^2\right)\delta_m\right)$. δ_f^o and δ_m^o are constants. δ_f and δ_m are vectors of coefficients associated with the different health states and age. Equation (4.7) can then be rewritten:

$$\ln h_{m,t} - \ln h_{f,t} = \frac{1}{\eta}\ln\left(\frac{\phi}{1-\phi}\right) + \frac{1}{\eta}\left(\delta_f^o - \delta_m^o\right) + \frac{1}{\eta}\left(\mathbf{s}'_{f,t}, t-\Delta t, (t-\Delta t)^2\right)\delta_f - \frac{1}{\eta}\left(\mathbf{s}'_{m,t}, t, t^2\right)\delta_m \tag{4.8}$$

While in the estimation of the life-cycle model I consider that ϕ is similar for all couples, it is possible to relax this assumption here. Let's assume that $\phi = \frac{\exp\left(\Lambda_0 + \mathbf{Z}'\boldsymbol{\Lambda}^{\mathbf{Z}}\right)}{1+\exp\left(\Lambda_0' + \mathbf{Z}'\boldsymbol{\Lambda}^{\mathbf{Z}}\right)}$ as in Browning et al. [2013]. $\mathbf{Z}$ is a vector of controls and $\boldsymbol{\Lambda}^{\mathbf{Z}}$ is the associated vector of coefficients. Λ_0 is a constant. In this case (4.8) rewrites:

$$\ln h_{m,t} - \ln h_{f,t} = \frac{1}{\eta}\left(\Lambda_0 + \mathbf{Z}'\boldsymbol{\Lambda}^{\mathbf{Z}}\right) + \frac{1}{\eta}\left(\delta_f^o - \delta_m^o\right) + \frac{1}{\eta}\left(\mathbf{s}'_{f,t}, t-\Delta t, (t-\Delta t)^2\right)\delta_f - \frac{1}{\eta}\left(\mathbf{s}'_{m,t}, t, t^2\right)\delta_m \tag{4.9}$$

Under the assumption A1 that any element in $\left(\mathbf{s}'_{f,t}, t-\Delta t\right)$ or $\left(\mathbf{s}'_{m,t}, t\right)$ is not included in $\mathbf{Z}$, this leads to the following econometric specification:

$$\ln h_{m,t} - \ln h_{f,t} = \alpha_0 + \mathbf{Z}'\alpha^{\mathbf{Z}} + \left(\mathbf{s}'_{f,t}, t-\Delta t, (t-\Delta t)^2\right)\alpha_f + \left(\mathbf{s}'_{m,t}, t, t^2\right)\alpha_m + \varepsilon \tag{4.10}$$

where $\alpha_0 = \frac{1}{\eta}\Lambda_0 + \frac{1}{\eta}\left(\delta_f^o - \delta_m^o\right)$, $\alpha^{\mathbf{Z}} = \frac{1}{\eta}\boldsymbol{\Lambda}^{\mathbf{Z}}$, $\alpha_f = \frac{1}{\eta}\delta_f$, $\alpha_m = \frac{1}{\eta}\delta_m$ and ε is an error term. Hence under A1, the disutility stemming from changes in health conditions is perfectly identified from (4.10) up to a scale factor η.

Notice that A1 might not be perfectly true in reality. However, if we think that disability of the wife reduces both her ability to perform home production and her weight in the household decision making, then the coefficients on the variables affecting the ability of the wife to perform HPA will be biased downward. So it will tend to understate the effect of these variables on the ability to perform HPA. The same is true for men. A1 will however be a working assumption in the remaining of the paper.

[4]Notice that (4.7) depends only on the fact that the disutility from doing HPA is additive, takes the above rather standard functional form and that η is the same for both spouses. It does not depend on the production function or the utility function.

In the next section, I show that (4.10) is valid empirically. I also discuss the database used and document econometrically the main patterns in the data. The results in this part are very robust empirically. For the sake of not overcharging the paper, many additional tables for robustness can be found in the appendix.

4.3 Empirical Patterns

4.3.1 Data

The data for home production come from the Consumption and Activities Mail Survey (CAMS). Covariates usually come from the Health and Retirement Study[5] (HRS). The CAMS is a questionnaire asked to a random subsample of HRS respondents. It asks, in particular, questions about the time spent by individuals on activities linked to home production. As a core measure of home production I consider (i) house cleaning, (ii) washing, ironing, or mending clothes, (iii) yard work or gardening, (iv) shopping or running errands and (v) preparing meals and cleaning-up afterwards. All the data are converted in hours per year. The core measure of home production sums up activities (i) to (v). I considered different measures for home production as well and the main results appeared to be very robust. Some of these robustness checks are in appendix.

As the HRS, the CAMS is a biannual survey. It is asked during the fall. While the HRS is completed during even years, the CAMS is completed during odd years. I thus link a given wave of the CAMS (for instance the CAMS of year 2005) to the previous wave of the HRS (i.e. the one of 2004). The CAMS has been introduced in 2003. I use data from 2005 onwards as the CAMS started to ask questions about activities of both spouses then. Moreover, the questionnaire is almost exactly the same for the waves 2005, 2007, 2009, 2011 and 2013 while some changes (mainly about expenditures) occur between 2003 and 2005. So, to summarize, for data on home production, I use the CAMS waves for 2005, 2007, 2009, 2011 and 2013 and respectively link them to the HRS waves for 2004, 2006, 2008, 2010 and 2012 using household and personal identification numbers. In all the study I consider only retired individuals above 63 and below 100.[6]

I construct two separate datasets from the HRS and CAMS data whose constructions are detailed in the appendix. The first dataset use HRS data from 1998 onwards and is used to compute transition matrices, mortality risk and to study wealth patterns. The

[5] I use mainly the RAND version of the HRS except when I use data which are not in it but can be found in the HRS.

[6] I define as retired individuals those declaring 0 earnings as in Lockwood [2013]. For individuals in a couple, I also impose that the spouse has 0 earnings. The construction of the sample is described in details in the appendix.

second dataset is used to study home production patterns and is constructed from the HRS and the CAMS. This sample is mechanically smaller as the CAMS is more recent and asked only to a subsample of the HRS respondents.

From the HRS, I take demographic variables such as age as well as indices of disability (or health)[7]. The disability variable I use comes from the RAND version of the HRS and is called "mobila". In the HRS, individuals are asked whether or not they had difficulties (i) walking several blocks, (ii) walking one block, (iii) walking across the room, (iv) climbing several flight of stairs and (v) climbing one flight of stairs. The index is equal to the number of difficulties people declare to have. So if an individual answers no for each potential difficulty (i) to (v) mobila will be equal to 0, while, if an individual answers yes for each one, mobila will be equal to 5. I transform this measure in 5 dummies for each spouse denoted $mobij$ with $i = 1, ..., 5$ and $j = f, m$ (f for female, m for male). $mobij$ is equal to 1 if spouse j has $mobila = i$ and to 0 otherwise. So if $mob1f = 1$, the wife in the couple has $mobila = 1$. As an alternative to mobila, I also experimented with other measures and in particular with the often used measure of self-reported health. The results with self-reported health were very similar. The choice of mobila is mainly driven by the fact that it is more objective than the measure of self-reported health and that it does not suffer the potential endogeneity bias of measures such as instrumental activities of daily living. I also take from the HRS variables such as income[8] of the spouses, total household wealth and several other covariates.

Table 4.1 presents some summary statistics of the dataset used for home production. We clearly see that men do less hours of home production than women whether we consider the median or the mean. Notice that men which are in a couple do less hours of home production than single men. The reverse is true for women. This pattern is present if we consider all singles or only those which are widows or widowers. It is also robust when controlling for health and age. This pattern will actually help to set the parameter ϕ in the model. We also see that women have on average a higher level of disability than men and that women are 2 to 2.7 years younger than their husbands whether we consider the median or the mean. About 17% of households have some form of long-term care insurance (LTCI) and about 9% receive some help from family or friends.

[7] Notice that I will use disability or bad health interchangeably.

[8] Income in all the reminder is the sum of an individual's employer pension and annuity, social security disability and supplemental security income, income from social security retirement, veterans benefits, welfare and foodstamps. De Nardi et al. [2010] use a similar measure. All dollar measures in the paper are expressed in 1998 dollars using the price index for personal consumption expenditures for major types of products from the Bureau of Economic Analysis.

Table 4.1: Summary Statistics

	Median	Mean
Home Production Men	574	729
Home Production Men (Couple)	521	687
Home Production Men (Single)	730	850
Home Production Men (Single and Widower)	677	790
Home Production Women	991	1120
Home Production Women (Couple)	1199	1337
Home Production Women (Single)	782	929
Home Production Women (Single and Widowed)	782	900
Home Production Wife minus Home Production Husband	600	650
Disability Men	0	1.04
Disability Women	1	1.39
Disability Wife minus Disability Husband	0	.20
Age Men	75	75.9
Age Women	75	75.6
Age Wife minus Age Husband	-2	-2.7
LTCI	0	.17
Help from family or friends	0	.09
Number of households	5988	
Number of couple households	2409	

These figures are computed using the dataset for home production. The variable "LTCI" is equal to 1 if the household has some long-term care insurance and to 0 otherwise. "Help from family or friends" is equal to 1 if the household receives some help from family or friends and to 0 otherwise.

4.3.2 Home production inside couples

This subsection has two aims. The first one is to assess the empirical validity of equation (4.10). The second is to understand under which conditions the patterns in figure 4.2 are actually present.

To estimate equation (4.10), we face one difficulty which is the treatment of zeros. Indeed, $\ln h_{m,t} - \ln h_{f,t}$ (that I call the *log ratio*) cannot be computed if either $h_{m,t}$ or $h_{f,t}$ is zero. The case where $h_{m,t} = h_{f,t} = 0$ is not of much interest for this relation and applies to only 9 couples. It thus can be disregarded. However, 230 couples have one of the two members declaring zero hour of home production, which is about 9.5% of my sample. The theoretical model does not allow for zero hour of home production as the marginal disutility of doing 1 hour of home production at zero hour is zero. It can however allow for an arbitrary low positive number of hours of home production.

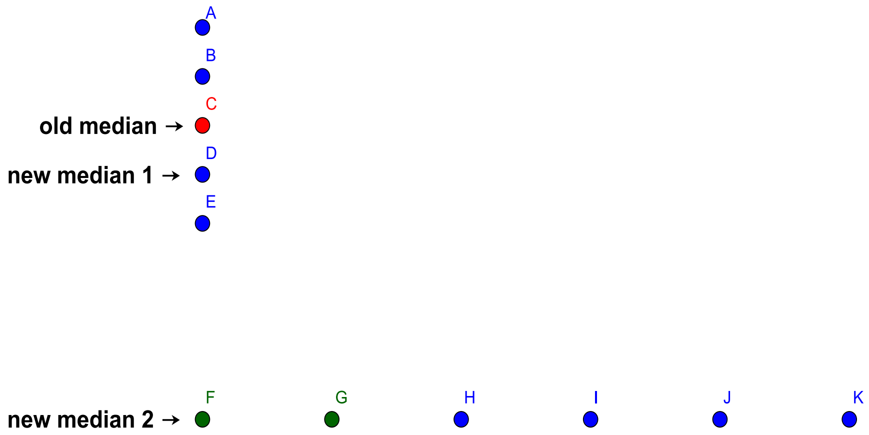


FIGURE 4.3: Bottomcoding and its effect on the median

Thus, one solution is to replace entries for which we observe 0 by some small number $\underline{h}$ when only one of the two spouses does zero hour of home production. It is natural to think that those declaring zero hour might do some home production but very little, so that they effectively declare zero when filling the survey. Bottomcoding in such a way is highly problematic when using OLS. Indeed, the choice of $\underline{h}$ will affect greatly the estimates in particular as the logarithm function is very steep at low values. This is much less of a problem when using median regressions under two conditions[9]. The first is that $\underline{h}$ should be low enough. The second is that the *new* median should not be located in the area where changes are made. The first condition is easy to understand. Most of the zeros actually occur when an individual is disabled, which is intuitive. If, for instance, we set $h_{m,t}$ to a large number when $h_{m,t} = 0$, we will actually move the median up when individuals are disabled so that we will find that people have less disutility from doing home production when considering the zeros than when we do not consider them. This goes clearly against the data which show that individuals have much more probability to declare zero hour when disabled. Moreover, zero is by definition the smallest "positive" number so that replacing it by a large number does not make sense.

The second condition is maybe more difficult to understand. I illustrate it in figure 4.3. Consider that before bottomcoding we are only dealing with points A to E, where A represents the highest value for the variable considered and E the lowest. The median of this sample is located at point C. On the one hand, imagine that by bottomcoding, we have two more observations represented by F and G. In this case, the median is shifted down and is now at point D. We clearly see that, as long as F and G are lower than D, whatever the value of F and G the median will be the same. On the other hand, if by bottomcoding we add observations represented by F to K, the new median will be located where our bottomcoding is done. As a consequence, the value given when

[9]Notice that the logic described here could be applied to other percentiles of the distribution.

bottomcoding will affect the median in an arbitrary way. At best, we may bottom code at E and get an upper bound for the median.

TABLE 4.2: Log difference of hours of home production of husbands and wives

	I	II	III	IV	V
mob1f	0.0997	0.0488	0.0488	0.0488	0.0488
	(0.0735)	(0.0814)	(0.0814)	(0.0804)	(0.0794)
mob1m	-0.223***	-0.254***	-0.254***	-0.254***	-0.254***
	(0.0765)	(0.0796)	(0.0796)	(0.0784)	(0.0787)
mob2f	0.167*	0.166*	0.166*	0.182**	0.182**
	(0.0853)	(0.0926)	(0.0926)	(0.0894)	(0.0898)
mob2m	-0.179**	-0.310***	-0.310***	-0.320***	-0.310***
	(0.0818)	(0.103)	(0.103)	(0.111)	(0.101)
mob3f	0.565***	0.588***	0.588***	0.588***	0.588***
	(0.0939)	(0.122)	(0.122)	(0.122)	(0.116)
mob3m	-0.128	-0.442**	-0.442**	-0.396**	-0.396**
	(0.120)	(0.176)	(0.176)	(0.159)	(0.156)
mob4f	0.756***	0.895***	0.895***	0.895***	0.872***
	(0.120)	(0.124)	(0.124)	(0.123)	(0.123)
mob4m	-0.377**	-0.801***	-0.821***	-0.821***	-0.799***
	(0.167)	(0.201)	(0.201)	(0.197)	(0.185)
mob5f	0.749***	1.835***	1.855***	1.856***	1.833***
	(0.195)	(0.416)	(0.416)	(0.457)	(0.448)
mob5m	-0.411**	-1.912***	-1.912***	-1.828***	-1.651***
	(0.195)	(0.501)	(0.501)	(0.470)	(0.289)
Constant	-0.821***	-0.811***	-0.811***	-0.811***	-0.811***
	(0.0436)	(0.0439)	(0.0439)	(0.0444)	(0.0439)
Observations	2170	2400	2400	2400	2400
R^2	0.054	0.105	0.118	0.115	0.113

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median regressions. The dependent variable is the log ratio. Column I is without bottomcoding. In column II, III, IV, and V, I bottomcode with .00001, 10, 24, and 40 hours respectively.

It is easy to check that this second condition is verified when bottomcoding here. Table 4.2 shows a median regression of $\ln h_{m,t} - \ln h_{f,t}$ on the disability dummies[10]. In column I, I do not bottomcode. Even when not bottomcoding, we see that equation (4.10) obtained directly from the theoretical framework appears valid empirically. As disability increases, the disutility from doing home production appears to increase. To grasp the magnitude of the effect, we see that the median of $\ln h_{m,t} - \ln h_{f,t}$ when both spouses

[10] I do not consider the age and age-square components here to ease the interpretation. Results of this regression with those components are in appendix.

have no disability is -0.821 which implies that $h_{m,t}/h_{f,t}$ is equal to .44. So a man spends about half the time his wife spends on home production. If his wife has now the highest level of disability, $h_{m,t}/h_{f,t} = \exp(-0.821 + .749) \simeq 0.93$. The magnitude of the time reallocation on HPA is thus large even when not bottomcoding.

In column II, I replace the zeros by .00001. In this case, the magnitude of the coefficients is usually higher. When both spouses are healthy $h_{m,t}/h_{f,t}$ is estimated to be approximately .44 as before. When the wife has now the highest level of disability $h_{m,t}/h_{f,t}$ is estimated to be 2.8. Hence, the reallocation appears even much larger in this case. The man, before his wife was disabled, was doing less than half of what she was doing. When she is highly disabled, he does about 3 times the amount of home production his wife does.

In column III to V, I bottomcode respectively by 10, 24 and 40 hours. A first indication that the second condition is verified under the bottomcoding procedure in column II is that there is almost no difference (or very minor ones) with column III. Another evidence is presented in figure 4.4. I plot in this graph the distribution of $\ln h_{m,t} - \ln h_{f,t}$ (the log ratio) for bottomcoded values when the value $\underline{h}$ is set to .00001 as in column II of table 4.2. The values at the left of the graph corresponds to those where $h_{m,t}$ is zero, while those on the right correspond to those where $h_{f,t}$ is zero. We see that the log ratio is in absolute value usually greater than 15 and in any case greater than 10. Would a median be located where the bottomcoding is done, we should obtain an estimated value for the log ratio of more than 10 in absolute value. The highest median we get in absolute value is 0.811+1.912 which is 2.723, hence much lower than 10.

As we increase the value of $\underline{h}$, the histogram shows that some of the values are located around the median. However, even when bottomcoding to 40, the very large majority (about 77%) of the values for the log ratio are above 2.723. When bottomcoding to 24, about 88% of the values for the log ratio are above 2.723 in absolute value. This explains why there is relatively little difference through column II to V. We can thus conclude that the value chosen to bottomcode has only a very minor effect on the estimated coefficients of the structural equation (4.10) when using median regressions. In the appendix, I assess the robustness of this relation and also discuss the OLS case.

There exist two potential channels for the change in the log ratio observed. Typically, if the ratio of TSHPA done by a man over the one done by his wife increases when the wife becomes disabled, it can be driven by a reduction in hours done by the woman, an increase of hours done by the man, or both. Table 4.3 shows the results from median regressions of hours done by either men or women in a couple on the disability dummies of the different household members. In column I to III, I consider hours done by men in a couple. Column I consider as regressors only the disability dummies. Not very

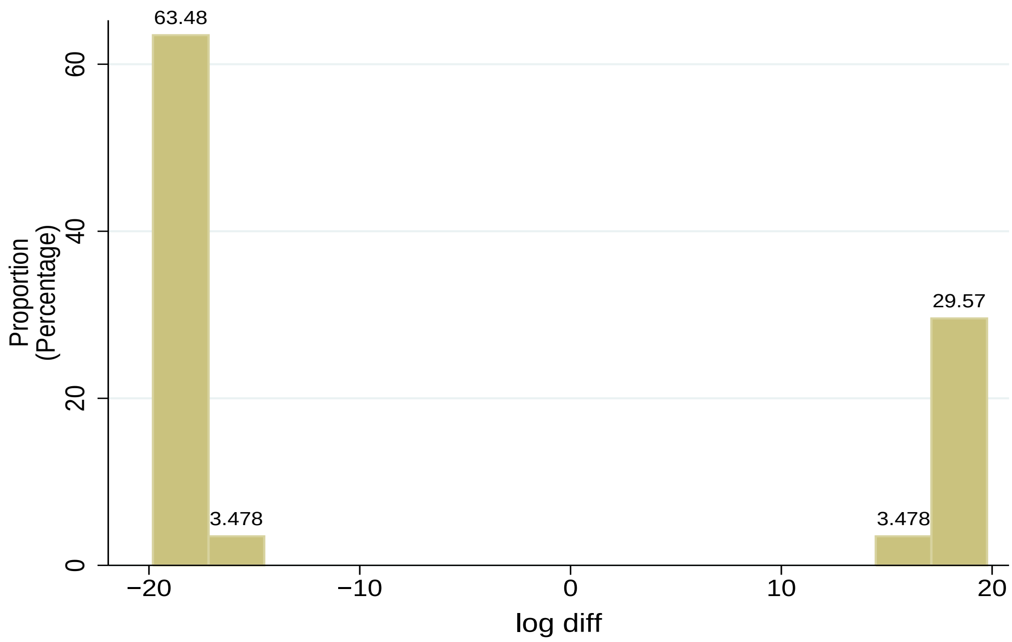


FIGURE 4.4: Distribution of the log ratio for bottomcoded observations in column II of table 4.2

surprisingly, we see that men in a couple decrease time spent on home production when they become disabled. More interestingly, we clearly see that husbands, when controlling for their own healths, increase time spent on home production when their wives get disabled. The increase is actually substantial. A man with no disability spends 521 hours annually when his wife has no disability as well. However, if his wife has mobila equal to 5, the hours done by the same man are estimated to be 913, an increase of 75%. This feature holds true if we control for whether or not the household receives some help from the family or friends, or whether or not it has some form of LTCI (column II). It also holds true if we consider only the sample of households without LTCI and not receiving help from the family or friends.

In column IV to VI, I consider hours done by women in a couple. Column IV is similar to column I. Once again, we clearly see that women decrease the hours of home production they do when they become disabled. We also see that they increase their hours of home production when their husbands get disabled, even though at the highest level of disability this effect is not significant and smaller than at more moderate levels of disability. When controlling for LTCI and help from the family or friends (column V), the effect at the highest level of disability is now large, though still not significant. Interestingly, having a LTCI is associated with lower hours of home production for women. This suggests that LTCI might partly cover the types of activities considered in this paper. Receiving help from the family has a strong negative effect. It is however clearly an endogenous variable as help from the family is more likely as disability is

Table 4.3: Home production of husbands and wives

	I	II	III	IV	V	VI
mob1f	52.14*	52.14*	-1.29e-12	-78.21	-104.3**	-130.4**
	(27.18)	(28.00)	(41.29)	(52.61)	(48.14)	(57.23)
mob1m	-52.14*	-52.14*	-104.3***	104.3*	104.3**	156.4**
	(29.20)	(29.97)	(38.73)	(57.60)	(51.10)	(64.35)
mob2f	52.14*	52.14*	-3.23e-12	-104.3	-52.14	-78.21
	(28.13)	(29.61)	(39.30)	(70.17)	(63.84)	(75.04)
mob2m	-156.4***	-156.4***	-156.4***	156.4**	156.4**	156.4**
	(29.01)	(30.10)	(46.26)	(61.83)	(62.73)	(66.27)
mob3f	156.4***	156.4***	104.3	-260.7***	-260.7***	-312.9***
	(55.07)	(57.72)	(71.90)	(68.91)	(65.40)	(66.62)
mob3m	-104.3*	-104.3*	-156.4**	182.5*	208.6**	208.6**
	(62.92)	(63.00)	(77.61)	(107.1)	(84.46)	(91.48)
mob4f	260.7***	260.7***	208.6***	-495.4***	-469.3***	-469.3***
	(46.00)	(47.45)	(59.22)	(84.04)	(78.50)	(90.56)
mob4m	-260.7***	-234.6***	-208.6**	234.6**	208.6**	260.7**
	(56.03)	(70.71)	(97.43)	(107.8)	(91.76)	(124.9)
mob5f	391.1***	391.1***	312.9***	-886.4***	-730.0***	-573.6***
	(88.08)	(88.18)	(106.0)	(246.7)	(123.1)	(206.2)
mob5m	-469.3***	-469.3***	-365.0***	78.21	156.4	391.1**
	(36.06)	(39.61)	(105.0)	(192.3)	(110.4)	(153.0)
has some LTCI		-1.31e-14			-156.4***	
		(23.17)			(42.95)	
receives help from family or friends		-52.14			-573.6***	
		(58.78)			(115.1)	
Constant	521.4***	521.4***	573.6***	1251.4***	1303.6***	1303.6***
	(15.59)	(17.13)	(21.29)	(33.70)	(36.83)	(38.00)
Observations	2409	2372	1742	2409	2372	1742
R^2	0.032	0.033	0.024	0.045	0.050	0.033

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median regressions. In column I to III the depend variable is hours done by husbands. In column IV to VI, the dependent variable is hours done by wives. In column III and VI, I remove households having a LTCI and/or receiving help from the family or from friends.

high. However, it suggests that help from the family might be important to consider as argued for instance in Barczyk and Kredler [2014]. Including this family dimension in the framework studied here might prove to be very interesting but is left for future research. In column VI, I remove households receiving some help from the family or having some form of LTCI. In this case, we see that women increase substantially hours of home production as their husbands get disabled. In this case, a woman with no disability spends 1,304 hours annually on home production when her husband has no disability as well. However, if her husband has mobila equal to 5, the hours done by the same woman are estimated to be 1,697, an increase of 30%. For the simulated model, I will consider only households with no LTCI and not receiving help from the family or friends to concentrate exclusively on the insurance channel which is the focus of this paper.

One alternative would have been to remove all households with children. Unfortunately, about 98% of the sample of couples for which I have data on home production have children. The proportions for single women and single men are respectively 88% and 82%. For single women, the number of observations does allow for some comparisons but I did not find any difference regarding home production between single women with and without children once controlling for disability, either using OLS or median regressions.

Overall, we can conclude that the movements in the log ratio are driven by a decrease in TSHPA when one gets disabled and by an increase in TSHPA when one's spouse gets disabled. In particular, the second mechanism appears to provide some sort of insurance and its magnitude can be considered to be large. The robustness of these results is assessed further in the appendix.

4.3.3 Other patterns for home production

In this subsection, I document some general patterns regarding home production including also single individuals. In table 4.4, I regress hours of home production done by men on the disability dummies for men, and on a dummy equal to 1 if the man is in a couple and to 0 otherwise. In columns I to III, I use OLS while in columns IV to VI I use median regressions. In column I (resp. IV), I use the full sample of men for which home production is observed. In column II (resp. V), I remove single men which are not widowers. On top of this, in column III (resp. VI), I remove all men in households receiving some help from the family or friends.

From this table, we clearly see that men in couples spend less time on home production than single men. This is true if we consider only widowers and when controlling for health. Controlling for age and its square (results not displayed) does not alter those conclusions. Also, the results when interacting the mobility dummies with the couple dummy are very similar. Such a regression (using OLS on the full sample of men) predicts, for instance, that men in couples spend 196 (vs 182 in table 4.4) hours less on home production than single men, all else equal.

Table 4.4: Home production of men - general patterns

	I	II	III	IV	V	VI
mob1m	-89.58***	-87.77***	-89.98***	-52.14	-52.14*	-52.14*
	(31.03)	(32.51)	(32.75)	(37.63)	(27.28)	(27.10)
mob2m	-62.29	-70.76	-59.86	-104.3*	-104.3***	-104.3***
	(42.16)	(43.56)	(44.77)	(55.62)	(31.69)	(34.77)
mob3m	-143.4***	-163.8***	-193.5***	-130.4**	-156.4***	-182.5***
	(50.97)	(52.91)	(52.15)	(59.15)	(53.57)	(58.81)
mob4m	-178.6***	-125.7*	-68.53	-260.7***	-234.6***	-156.4***
	(67.84)	(73.95)	(81.84)	(76.40)	(58.31)	(58.71)
mob5m	-415.9***	-432.4***	-381.8***	-495.4***	-521.4***	-365.0***
	(57.47)	(56.64)	(63.47)	(33.70)	(30.16)	(79.11)
in a couple	-181.9***	-129.5***	-156.0***	-234.6***	-156.4***	-208.6***
	(34.69)	(41.85)	(43.84)	(33.67)	(32.67)	(36.78)
Constant	923.8***	871.1***	893.5***	808.2***	730.0***	782.1***
	(33.78)	(42.02)	(43.63)	(32.67)	(32.87)	(36.93)
Observations	3234	2854	2712	3234	2854	2712
R^2	0.032	0.024	0.021	0.030	0.022	0.018

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column I to III OLS. Column IV to VI median regressions. The dependent variable is hours of home production done by a man. In column, I and IV, I consider the full sample of men for which home production is observed. In column II and V, I remove single men which are not widowers. In column III and VI, I remove also all men in a household receiving help from the family or friends.

Table 4.5 is similar but here I regress hours of home production done by women. Here, we observe the reverse pattern than the one for men: women in a couple spend roughly 363 to 417 hours more on home production annually than single women. This is true considering only widows, adding age and its square or interacting terms. Using OLS on the full sample adding interaction terms as well as age and its square, we still find that women in couple spend about 306 hours more annually on home production than single women.

The fact that men spend less time on home production when in a couple and women more actually will influence the value of ϕ in the simulated model if η is given. To see this, observe the first two terms in equation (4.8). The first term is directly influenced by ϕ, while the second term is, roughly speaking, the disutility to do home production of a woman minus the one of a man when both are healthy. δ_f^o and δ_m^o are actually

TABLE 4.5: Home production of women - general patterns

	I	II	III	IV	V	VI
mob1f	-77.59**	-79.05**	-63.29*	-91.25***	-104.3***	-78.21**
	(30.52)	(32.78)	(32.94)	(27.45)	(29.98)	(30.91)
mob2f	-135.5***	-123.1***	-95.04**	-104.3***	-104.3***	-39.11
	(36.44)	(39.19)	(40.38)	(34.80)	(39.65)	(40.83)
mob3f	-228.8***	-231.8***	-166.8***	-247.7***	-208.6***	-182.5***
	(44.13)	(48.69)	(52.30)	(38.83)	(45.68)	(50.63)
mob4f	-293.8***	-324.4***	-279.2***	-352.0***	-391.1***	-299.8***
	(51.23)	(55.81)	(61.83)	(51.95)	(60.35)	(77.48)
mob5f	-677.5***	-680.1***	-566.0***	-873.4***	-886.4***	-651.8***
	(55.07)	(60.76)	(79.62)	(26.57)	(29.72)	(93.81)
in a couple	362.5***	389.6***	364.3***	378.0***	417.1***	378.0***
	(29.30)	(30.68)	(31.64)	(23.98)	(25.93)	(27.07)
Constant	1070.2***	1044.1***	1061.8***	925.5***	886.4***	912.5***
	(25.85)	(28.83)	(29.20)	(19.51)	(21.08)	(20.34)
Observations	5163	4493	4111	5163	4493	4111
R^2	0.106	0.115	0.079	0.104	0.113	0.079

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column I to III OLS. Column IV to VI median regressions. The dependent variable is hours of home production done by a woman. In column, I and IV, I consider the full sample of women for which home production is observed. In column II and V, I remove single women which are not widows. In column III and VI, I remove also all women in households receiving help from the family or friends.

matched by fitting the hours of home production of single men and single women. ϕ then adjusts to fit hours done by men and women in a couple.

4.3.4 Wealth decumulation

In table 4.6, I show that disability is associated with lower wealth. I perform a median regression of the wealth of couples on the disability of their members[11]. In each regression, I control for age of the household, its square, cohort and wave effects. In column I (resp. II, III and IV), I consider households in the fourth (resp. third, second, first) income quartile. Those regressions suffer an evident bias as individuals with worse health might have exited the labour market earlier and thus may have lower wealth. Hence, it might be mainly a pattern stemming from before retirement. The regressions here should thus be interpreted only as correlations. The simulated model will correct for this bias by featuring a realistic initial distribution of wealth which will be a function of disability.

[11]The sample used for this regression is the one used when simulating the model. More details can be found in the appendix.

Table 4.6: Wealth as a function of disability - couple households

	I	II	III	IV
mob1m	-70187.7***	-26197.9*	-42041.6***	-14125.8
	(18534.7)	(13586.9)	(13288.0)	(15556.8)
mob2m	-102745.0***	-50095.8***	-54228.5***	-43757.7***
	(22195.8)	(15561.3)	(19803.8)	(14709.0)
mob3m	-123747.3***	-53474.9**	-89031.1***	-60172.8***
	(28793.9)	(22250.3)	(14557.3)	(13944.5)
mob4m	-120550.1***	-41053.4*	-108163.1***	-60719.3***
	(29544.5)	(21373.4)	(14742.0)	(11902.1)
mob5m	-245229.7***	-91519.1***	-94895.0***	-91208.0***
	(25420.8)	(25316.7)	(21283.2)	(13586.5)
mob1f	-5397.0	-30904.2**	-9465.4	-23708.9
	(20252.8)	(14124.9)	(14745.6)	(14632.5)
mob2f	-92081.8***	-73695.9***	-79812.0***	-57606.3***
	(19851.3)	(16184.4)	(14650.9)	(12656.1)
mob3f	-98662.0***	-90318.5***	-87136.3***	-48751.4***
	(27843.2)	(17344.5)	(16347.6)	(14656.5)
mob4f	-31091.1	-111677.0***	-99258.3***	-63851.3***
	(28083.1)	(16726.1)	(15206.6)	(14436.2)
mob5f	-140475.9***	-120782.4***	-134272.8***	-89157.2***
	(38642.1)	(25499.7)	(19560.9)	(15873.0)
Observations	2231	2543	2506	1779
R^2	0.039	0.042	0.059	0.041

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median regressions. The dependent variable is total wealth. In each regression, I control for age of the household, its square, cohort and wave effects. In column I to IV I consider respectively couple households in the fourth to first income quartile.

4.4 The intertemporal problem

The resolution of the problem is in two steps. First, we need to solve for the intratemporal problem presented in section 2. This gives three objects $u^{hh}(x, \mathbf{s}_t, t)$ (for couple households), $u^{sf}(x, \mathbf{s}_{f,t}, t)$ (for single female) and $u^{sm}(x, \mathbf{s}_{m,t}, t)$ (for single men). The utility of a couple depends on the age and health status of both spouses. In the application, I assume that the husband is two years older than the wife which is the median in the sample. The utility of singles for a given level of x is derived from a problem similar to the one in section 2 but with only one agent and no economies of scale (i.e. $\chi = 1$). The derivation of this problem can be found in appendix.

The above objects are taken as given for the exposition of the intertemporal problem below, which is the second step of the problem. I first start by the timing of the model. The maximum age T is set to 100 for both men and women. Each household is assumed to enter retirement when the man is aged 65 or when the wife is aged 63. First, a household draws a state S_t. This state is a function of $\mathbf{s}_t$ and whether household members are still living or not. The probability to draw a given S_t depends on the previous state S_{t-1} and on age $t-1$. As a matter of fact, given the standard assumption that health status follows a Markovian process, the current transition probability matrix is a function of health state. Roughly speaking, the probability of disability or death is higher for the disabled than for the non disabled. On top of this, each state is associated with a different mean of log medical expenditures $\mu\left(S_t,t\right)$. In a second time, the household draws a shock $\varepsilon_t \sim \mathcal{N}\left(0,\sigma_\varepsilon^2\right)$. This latter and the mean of log medical expenditures define the level of medical expenditures m_t of the household in t:

$$m_t = \exp\left\{\mu\left(S_t,t\right)+\varepsilon_t\right\} \tag{4.11}$$

This allows for a skewed distribution of medical expenditures. In a third time, the household decides upon how much to spend today x_t on goods and services given its intertemporal budget constraint. This constraint further depends on the level of initial wealth b_t and and on pension income $y\left(S_t\right)$. In the application, pension income depends on whether the household is a couple or a single household, and not on the level of disability. Given the gross rate of interest R, the budget constraint is given by:

$$Rb_t + y\left(S_t\right) - m_t = x_t + b_{t+1} \tag{4.12}$$

The constraint can be rewritten as a function of cash-on-hand w_t:

$$w_t = Rb_t + y\left(S_t\right) - m_t = x_t + b_{t+1} \tag{4.13}$$

$$w_{t+1} = R\left(w_t - x_t\right) + y\left(S_{t+1}\right) - m_{t+1} = x_{t+1} + b_{t+2} \tag{4.14}$$

As is standard, a non-borrowing constraint is assumed:

$$x_t \leq w_t \tag{4.15}$$

I also assume a minimum level of cash-on-hand $w_{min}\left(S_t\right)$, so that cash-on-hand should be replace in equations (4.13), (4.14) and (4.15) by:

$$w_t = \max\left(w_{min}\left(S_t\right), Rb_t + y\left(S_t\right) - m_t\right) \tag{4.16}$$

w_{min} is a short way to represent Medicaid. Concerning, Medicare the brochure entitled "Medicare and Home Health Care" explicitly states that Medicare covers skilled care but does not usually cover unskilled care. It says that "any service that could be done safely by a non-medical person (or by yourself) without the supervision of a nurse isn't skilled nursing care". This clearly does not include the type of activities which are considered here. Moreover, it is explicitly said in the brochure that the types of activities I consider here are usually not covered by Medicare. As a consequence, I do not model Medicare[12].

Given the above constraints the household solves for x_t which maximizes its expected utility. There are three types of problems: one for those still in a couple, one for single women and one for single men. I start by the exposition of the problem for couples. In its recursive form the problem is[13]:

$$\begin{aligned} v_t^{hh}\left(w_t, S_t\right) = \max_{x_t} u^{hh}\left(x_t, S_t, t\right) + p_t^f\left(S_t\right) p_t^m\left(S_t\right) \beta E_t\left[v_{t+1}^{hh}\left(w_{t+1}, S_{t+1}\right) \mid S_t\right] \\ + p_t^f\left(S_t\right)\left(1 - p_t^m\left(S_t\right)\right) \beta E_t\left[v_{t+1}^{hhsf}\left(W_{t+1}, S_{t+1}\right) \mid S_t\right] \\ + \left(1 - p_t^f\left(S_t\right)\right) p_t^m\left(S_t\right) \beta E_t\left[v_{t+1}^{hhsm}\left(W_{t+1}, S_{t+1}\right) \mid S_t\right] \\ + \left(1 - p_t^f\left(S_t\right)\right)\left(1 - p_t^m\left(S_t\right)\right) \beta\left(\phi v_F\left(w_{t+1}\right) + \left(1 - \phi\right) v_M\left(w_{t+1}\right)\right) \end{aligned} \tag{4.17}$$

$v_t^{hh}(.)$ is the value function of a household aged t. It depends on five objects. First, it depends on the utility flow $u^{hh}(.)$ the household gets in t by consuming x_t given its current state S_t and its age t. Second, it depends on the expected value in $t+1$ if the household remains a couple $v_{t+1}^{hh}(.)$. It is weighted by the respective survival probabilities of the woman and her husband $p_t^f(S_t)$ and $p_t^m(S_t)$, and by the discount factor β assumed to be the same for husbands and wives. The third element is the expected value the household obtains if the wife becomes widowed. Would there not be any bequest motive, this would correspond to the expected value function of a single woman weighted by ϕ. The fourth object is similar but corresponds to the case where only the husband survives. The fifth object is the value from bequest if both spouses die. Notice that in this case $w_{t+1} = Rb_{t+1}$.

[12]Medicare enters however in the coverage of medical expenditures. Out-of-pocket medical expenditures are net of Medicare reimbursements and exogenous in the model

[13]I assume constant Pareto weights and that a dead spouse has no influence on the decision making of the surviving spouse.

The case for a single woman and a single man are similar so I only expose the one for a single woman. It takes the form:

$$v_t^{sf}(w_t, S_t) = \max_{x_t} u^{sf}(x_t, S_t, t) + p_t^f(S_t)\beta E_t\left[v_{t+1}^{sf}(w_{t+1}, S_{t+1}) \mid S_t\right] + \left(1 - p_t^f(S_t)\right)\beta v_f(w_{t+1})$$

In this case, the value function depends on the current utility flow of the single wife, on her value in the next period if she survives and on her value from leaving a bequest. Slightly more complicated is the value that a couple household obtains if the single woman has cash-on-hand w_t in state S_t. Denoting with stars the level of variables chosen by the single wife given her optimal choice, it takes the following recursive form:

$$v_t^{hhsf}(w_t, S_t) = \phi u^{sf}(x_t^\star, S_t, t) + p_t^f(S_t)\beta E_t\left[v_{t+1}^{hhsf}\left(W_{t+1}^\star, S_{t+1}\right) \mid S_t\right] + \left(1 - p_t^f(S_t)\right)\beta\left(\phi v_f\left(w_{t+1}^\star\right) + (1-\phi)v_m\left(w_{t+1}^\star\right)\right)$$

It depends on the current flow of utility from the single wife given her optimal decision weighted by ϕ, on the expected value that the household gets if the wife survives and on the utility from bequest that *both* members get if the wife is not alive next period. It is this latter part that implies that $v_t^{hhsf}(w_t, S_t) \neq \phi v_t^{sf}(w_t, S_t)$. Here, I assume that bequest motives are similar for men and women and take a the following functional form:

$$v_f(w) = v_m(w) = \zeta\frac{(c_b + w)^{1-\gamma}}{1-\gamma}$$

This functional form is standard. ζ drives the strength of the bequest motive, while $c_b > 0$ is a parameter driving the extent to which bequests are luxury goods.

4.5 Model's estimation

The population is split in four income quartiles. I compute different income quartiles for couples, single women and single men. I assume that a woman in a couple belonging to the Xth quartile of the income distribution of couples will, when single, belong to the Xth quartile of single women. A similar assumption is made for men. For the simulations, I do not consider households with some LTCI or receiving help from the family or friends. The latter is done as the model does not include help from the family or friends though, as mentioned before, it might be an interesting extension.

4.5.1 First stage estimation

4.5.1.1 Mortality and health status

I regroup disability levels so as to have three possible levels of disability. Typically, I regroup people with *mobila* equal to 0 or 1 in a same group ($mob01 = 1$). I do the same for people with *mobila* equal to 2 or 3 ($mob23 = 1$) and 4 or 5 ($mob45 = 1$). This assumption is made so as to limit the computational burden. Given these three levels of disability and death, a household can be in $4 \times 4 = 16$ states, which imply already a transition matrix of size $16 \times 16 = 256$. I then compute the probability to transit between states using a multinomial logit regression[14]. For singles[15], the dependent variables are a cubic in age, current health state, health state interacted with age, income quartile, income quartile interacted with age, whether the person is in a couple, whether the person is a single woman. In addition, this two latter are also interacted with age. Finally, for those in a couple I also allow the disability of the spouse to affect one's health. This allows for the correlation between health states of spouses which is essential to assess the value of spousal insurance. Ultimately, we would think that this correlation is linked to the intrahousehold insurance at play here. Building this into the model is possible but would require defining an additional state variable, I thus abstract from this channel. Any analysis performed hereafter should be understood as conditional on an invariant transition probability matrix. This is by far the norm in the literature. For men, I found that having a spouse with *mobila* greater or equal to 2 has a significant positive impact on the probability to have mobility issues or to die. The bi-annual transition matrix is then converted to annual.

From table 4.7, we see that the implied longevity using the estimated transition matrix is very close to what is found in US life tables[16]. For men, I compute life expectancy at age 65 and for women life expectancy at 63. This corresponds to the ages at which I start the simulations. Men live 1 year less in my simulated sample than what is found in life tables and women live half a year less. We also see that individuals in higher income quartiles are expected to live longer. For instance, a man in the first income quartile is expected to live 3 years less than a man in the fourth income quartile.

[14]This can be considered as a standard approach. De Nardi et al. [2010] also use logit regressions to estimate transition probabilities.

[15]All singles considered from now on are widows or widowers.

[16]I discuss the initial distribution for the simulations afterwards.

Table 4.7: Life Expectancy

	Men (at age 65)	Women (at age 63)
Simulated Sample	16.7	21.2
US life tables	17.7	21.9
Income Quartile		
First	15.1	19.9
Second	16.0	20.9
Third	17.3	21.6
Fourth	18.1	22.4

The figures for US life tables are taken from the 2011 period life table for the Social Security area population from the Social Security Association. All other statistics are computed on the simulated sample used to fit the data. All figures are in years.

Table 4.8: Statistics about disability and marital status, Model vs Data

	Model	Data
Women in couple at age 90+	5.6	4.8
Women in couple at age 90+ and with mobila equal to 4 or 5	5.2	5.0
Men in couple at age 90+	32.4	43.8
Men in couple at age 90+ and with mobila equal to 4 or 5	32.9	44.3
Women with mobila equal to 0 or 1 at age 90+	29.5	29.3
Women with mobila equal to 2 or 3 at age 90+	28.5	28.5
Women with mobila equal to 4 or 5 at age 90+	42.0	42.2
Men with mobila equal to 0 or 1 at age 90+	34.4	42.0
Men with mobila equal to 2 or 3 at age 90+	29.0	27.2
Men with mobila equal to 4 or 5 at age 90+	36.5	30.8

Statistics from the model are those obtained on the simulated sample. Statistics from the data are obtained from the sample used to estimate the transition matrix. The table reads as follow. "Women in couple at age 90+" is the proportion of women aged 90 or more which are in a couple. "Women with mobila equal to 0 or 1 at age 90+" is the proportion of women aged 90 or more which have mobila equal to 4 or 5. All figures are in percentage.

In table 4.8, I show that the patterns of disability and marital status at age 90+ observed in the data are usually well reproduced in my simulated sample. In particular, the figures for women are very close to their data counterparts. For instance, a woman age 90 or more in the data has 42.2% of chances to have mobila equal to 4 or 5. In the simulated sample, this number is 42.0%. For men, the patterns are a bit less well reproduced, certainly reflecting the fact that men are less numerous, which implies that the estimation of transition probabilities is less precise. However, the results are still quite close to the data.

One important thing to notice is that women with high disability have a large probability to be single past aged 90. I find that about 95% of them are single which will have an important influence on the results.

4.5.1.2 Medical expense risk

As all dollar values, out-of-pocket medical expenditures are expressed in 1998 dollars. The log of two-year medical expenditures of the household is estimated as a function of a cubic in age, disability, disability interacted with age, mobility of a spouse, whether in couple, whether a single woman, income quartile and income quartile interacted with age. I use OLS rather than fixed-effects as a fixed-effect estimation might be imprecise to estimate the transition from couple to single. I then compute the standard deviation of the error term. Under the assumption of normality, I compute the corresponding mean expenditures over two years. Using the transition probability matrix and a realistic initial distribution (described below) of the population along the different states, I compute the corresponding annual mean medical expenditures. To reflect the fact that medical expenditures are more volatile at annual frequencies I multiply the standard deviation on two year medical expenditures by 1.4 and adjust the log mean accordingly. I consider only households in which the respondent has no long-term care insurance and where no member has been in a nursing home in the past two years.

The latter two assumptions are important for identification. The model above conveys the idea that part of medical expenditures are exogenous. However, some of what is recorded as out-of-pocket medical expenditures might be substitutable by a spouse. In particular, it is the part of nursing home which comprises services such as cleaning, cooking... The identification of the weight of hours of home production in the home production function (the parameter ψ) will thus stem from the part of asset decumulation (computed on the sample which includes those facing nursing home stays) which is not explained by the *exogenous* part of medical expenses (which does not use nursing home respondents). The model will thus associate most of the additional costs when spending some time in nursing home to the fall in home production.

4.5.1.3 Income

The log of pension income is computed as an OLS regression on income quartile. I perform such a regression separately for couple households, single men and single women.

4.5.1.4 Initial Distribution of states and wealth

To compute the initial distribution of marital status and health status, I classify each household along the 15 possible states (i.e. the combination of the three disability status and death minus the case where both spouses are dead). I do so for those aged less than 70, without any LTCI and not receiving help from the family. For each income quartile separately, I use the distribution of households along these different types to build the initial distribution of households in the model.

For initial wealth, I perform a median regression for households less than 70 on the disability status of husbands and wives and on the three possible marital status. I do so separately for each income quartile and consider a similar sample to the one for the initial distribution of state. To allow for heterogeneity in wealth conditional on these covariates I compute the distribution of the error term. I then allocate randomly an additional term to each household from this distribution.

To estimate annual medical expenditures, I simulate 1,000,000 household histories using the transition between states described in earlier. I assume that single men start aged 65, single women start aged 63, and couples start with the wife aged 63 and the husband aged 65. For the estimation of the model and the results presented below, I simulate 20,000 household histories.

4.5.2 Second stage estimation

Some parameters are initially fixed. I set β to 0.97 and R to 1.03. I also fix γ to 4. γ can be interpreted as the relative risk aversion over a "pure" consumption good. The parameter χ is set to 1.198 which corresponds to Mc Clements scale for a couple without children (i.e. a childless couple is equivalent to 1.67 adults) used by Attanasio et al. [2008].

I set x_{min} to be \$5,280, \$5,280 and \$20,000 for single individuals with respectively $mob01 = 1$, $mob23 = 1$ and $mob45 = 1$. I assume the same floor for no disability and moderate disability as the Medicare brochure suggests that the program is not very generous. Moreover, Medicaid is likely not to pay for small services when people are not heavily impaired. The value of \$5,280 corresponds to the pension income of single women in the first wealth quartile. For high disability, I assume a floor of \$20,000. This represents about two fifths of the annual cost for a nursing home (see Ameriks et al., 2011). Given that nursing homes also include medical services, this is a reasonable figure. In previous versions, I used a lower floor and did not find that results changed significantly. For a couple, I assume that x_{min} is the sum of the x_{min}s that each of the spouses would receive if they were singles given their health states. I further divide this number by χ assuming that the government takes into account household economies of scales. As an example, a couple with the wife having $mob01 = 1$ and the husband having $mob45 = 1$, would have $x_{min} = (5,280 + 20,000) / 1.198 = \$21,102$.

To avoid some numerical problems which could occur when dividing by low values, I re-express, when solving the model, all dollar values in 10,000 of dollars and all hour measures in 1,000 of hours. However, when displaying the results, I re-express all measures in their initial units.

As a baseline, I assume that:

$$A_m = \exp\left(\delta_m^o + \delta_m^{age}(t-63) + \delta_m^{age^2}(t-63)^2 + \delta_m^{mob23} mob23m + \delta_m^{mob45} mob45m\right)$$

$$A_f = \exp\left(\delta_f^o + \delta_f^{age}(t-\Delta t-63) + \delta_f^{age^2}(t-\Delta t-63)^2 + \delta_f^{mob23} mob23f + \delta_f^{mob45} mob45f\right)$$

This means that the disability to do home production depends on a component depending on the individual's age (minus 63) and its square and on her or his disability state. The parameters which will be set matching our moments are thus:

$$\left(\delta_m^o, \delta_m^{age}, \delta_m^{age^2}, \delta_m^{mob23}, \delta_m^{mob45}, \delta_f^o, \delta_f^{age}, \delta_f^{age^2}, \delta_f^{mob23}, \delta_f^{mob45}, \phi, \eta, \epsilon, \psi, \zeta, c_b\right)$$

$\left(\delta_m^{mob23}, \delta_m^{mob45}, \delta_f^{mob23}, \delta_f^{mob45}\right)$ are obtained by matching the median of the log ratio as a function of disability. $\left(\delta_m^o, \delta_f^o\right)$ are set to match the hours of home production done by single men and single women. $\left(\delta_m^{age}, \delta_m^{age^2}, \delta_f^{age}, \delta_f^{age^2}\right)$ help to match the overall pattern of home production as a function of age. ϕ helps to reproduce the fact that men do more home production when singles, while it is the reverse for women. ψ measures the importance of home production in consumption. If it is infinite then home production does not influence wealth patterns at all. η helps to reproduce the insurance channel as it drives the response of the supply of home production. If it is infinite home production would barely move. ϵ helps measures the degree of substitution between hours of home production and expenditures and helps to match the way wealth reacts when disability occurs. ζ and c_b help to reproduce the wealth distribution at older ages.

To set those parameters and assess how well the model can reproduce the patterns observed in the data I use the following moments. The first set of moments (M1) is the median of hours of home production done by woman with $mob01 = 1$ as a function of age where age is represented by 6 dummies (63-69, 70-74, 75-79, 80-84, 85-89, 90+). M2 and M3 are similar but for women with respectively $mob23 = 1$ and $mob45 = 1$. M4 to M6 are the same as M1 to M3 but for men. M7 is the median of hours of home production done by single women as a function of age. M8 is the median of hours of home production done by women in couple as a function of age. M9 and M10 are similar to M7 and M8 but for men. ϕ will help to capture the differences between M7 and M8, and M9 and M10. M11 is the median of the log ratio as a function of the disability of the wife in a couple. M12 is the median of the log ratio as a function of the disability of a husband in a couple. M13 represents the hours of home production done by married men as a function of the disability of their wives. M14 is similar but now the x-axis represents the health of those men. M15 and M16 are similar to M13 and M14 but here the "dependent" variable is hours done by married women. M17 to M20 plot total household wealth as a function of age[17] for income quartiles going from the highest to the lowest. M21 to M24 are similar but with the x-axis being the disability of the woman in the household (if a woman is present). M25 to M28 are similar but with disability of the man as the x-axis. As a total, we are dealing with 126 moments. The different parameters are set to minimize the distance between the data and the model. More details on the computation of the moments and the distance can be found in the appendix.

In the next section, I describe the model's fit and describe the results from some counterfactual experiments.

[17] Here age is age of the household. It is defined as the age of the husband in the case of a couple household. For single households, it is the age of the individual. It is converted in similar age dummies than before.

Table 4.9: Calibrated Parameters

	(I)	(II)	(III)
Parameters	Bequest	No Bequest	No Bequest + Tail
η	2.02	3.15	2.17
ψ	0.089	0.090	0.197
ϵ	2.96	3.36	3.19
ϕ	0.43	0.27	0.29
δ_m^o	0.43	0.53	-0.34
δ_f^o	-0.89	-0.74	-1.24
δ_m^{mob23}	0.46	0.87	0.49
δ_m^{mob45}	1.38	3.01	1.36
δ_f^{mob23}	0.46	0.45	0.45
δ_f^{mob45}	1.73	3.27	1.73
δ_m^{age}	-0.021	-0.017	-0.020
$\delta_m^{age^2}$	0.0032	0.0042	0.0031
δ_f^{age}	-0.021	-0.018	-0.020
$\delta_f^{age^2}$	0.029	0.0032	0.027
ζ	10.3		
c_b	1.00		

Calibrated parameters for different versions of the model. All parameters are set to minimize the distance between the data and the model.

4.6 Model's behaviours

4.6.1 Comparison of the model and the data

In this subsection, I describe the outcome relative to the data of three different versions of the model. The calibrated parameters for these models can be found in table 4.9. First of all, I will describe the outcome of the model with bequest motives.

Figure 4.5 shows the outcome of this version of the model relative to the data. This model can reproduce most of the observed patterns in the data. It replicates the fact that home production falls as women get disabled (M1 to M3). It also can replicate the decline of home production as a function of age. For men, the model is also able to replicate the fall of TSHPA as they get disabled (M4 to M6). Moreover, it reproduces well the fact that TSHPA for women in a couple is higher than TSHPA for single women (M7-M8). It also replicates well the fact that men in a couple spend less time on HPA than single men (M8-M9). For both men and women, these differences are close to those in the data. For instance, in the data, a woman between 63 and 69 spends about 950 hours on home production if single and 1,250 hours if in a couple. These figures are respectively around 1,000 and 1,300 in the model. Moreover, the model reproduces fairly well the insurance mechanism described before. Typically, we see that the model can generate an increase in time spent on home production by men if their wives get disabled (M13). A similar pattern is observed for women, though the increase is much smaller both in the model and the data. The reason why this increase is not as strong as the one in table 4.3 is that I do not control for the health of the woman here. It occurs that not controlling for health of the woman, in a regression of TSHPA by a woman on disability of her husband, makes the coefficients on disability of the man very small. It reflects the correlation of disability risk between spouses.

Wealth patterns are globally well reproduced and in particular we see that the model can generate little dissavings as in the data for the second to the fourth income quartile (M17 to M19). The model is less successful in replicating the fact that households in the first income quartile do not decumulate. Part of this might lie in the fact that other small sources of risk, not covered by public insurance, may play a role. For wealth, patterns as a function of disability, the model is also able to replicate well the patterns observed for the second to the fourth income quartile. As a consequence, we see that the theoretical model presented here is successful in replicating most of the observed patterns of home production and wealth decumulation observed in the data.

The model estimated without bequest motives is displayed in figure 4.6. Overall, the patterns are quite similar to those in the model without bequest, reflecting the fact that it is hard to disentangle what stems from bequest motives and precautionary motives in a model with bequest motives. This is a general problem in the literature (see for instance De Nardi et al., 2010). The rise in home production hours done by men, when their wives get disabled is a bit less well reproduced than in the previous model, which is reflected in the higher value found for η. Overall, for this version model as was the case for the former one, we can see that the patterns in the data are quite well reproduced.

However, both do not reproduce very well the fact that hours of home production done by disabled women at age 90+ falls close to zero. Given that about 42% of women at this age have mobila equal to 4 or 5, it is an important dimension to consider as it represents a significant "tail risk". To take into account this fact, I set the disutility from doing home production of a woman aged 90+ and with mobila equal to 4 or 5 to a large value

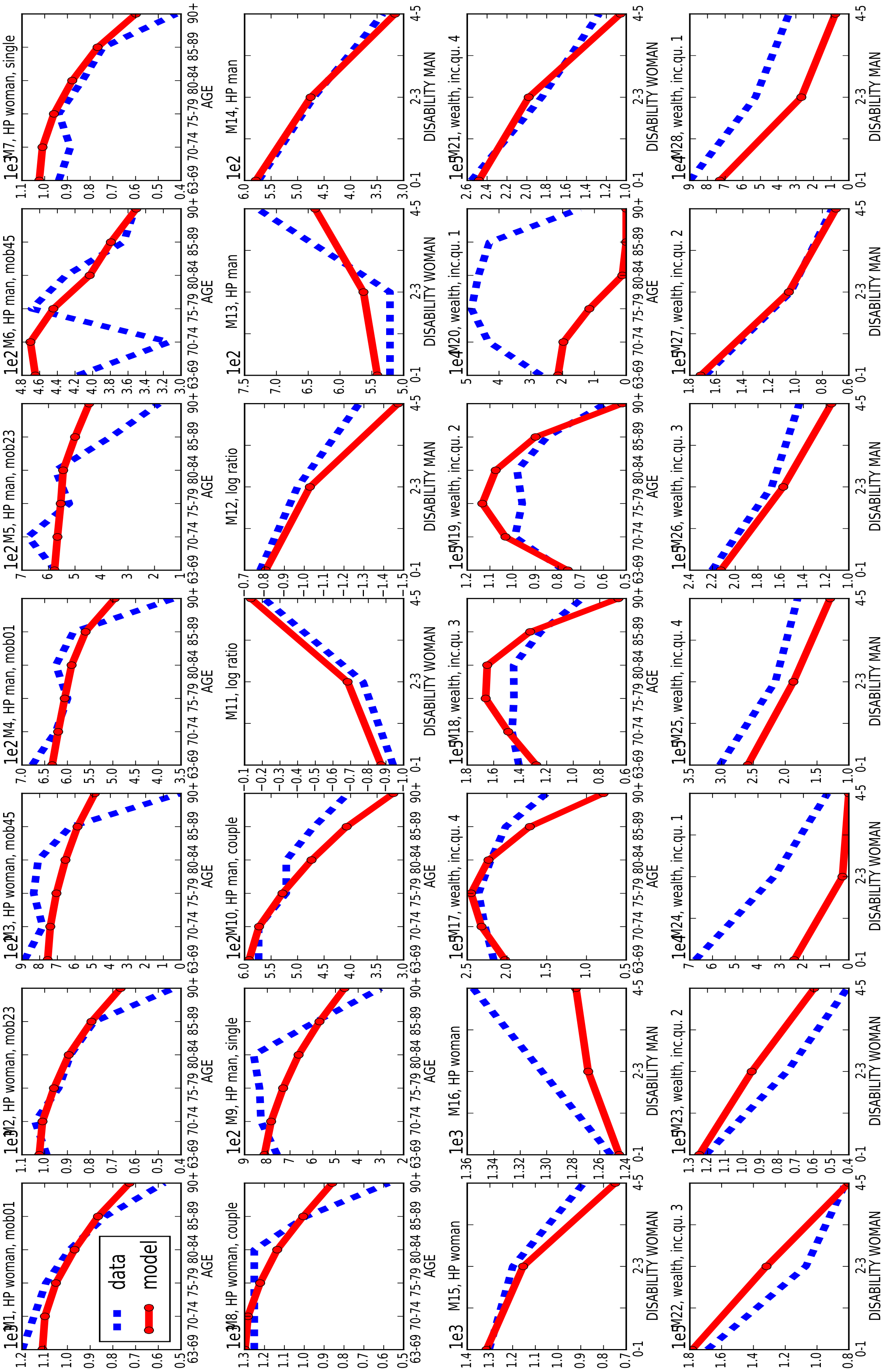


FIGURE 4.5: Model vs Data: Model with Bequest

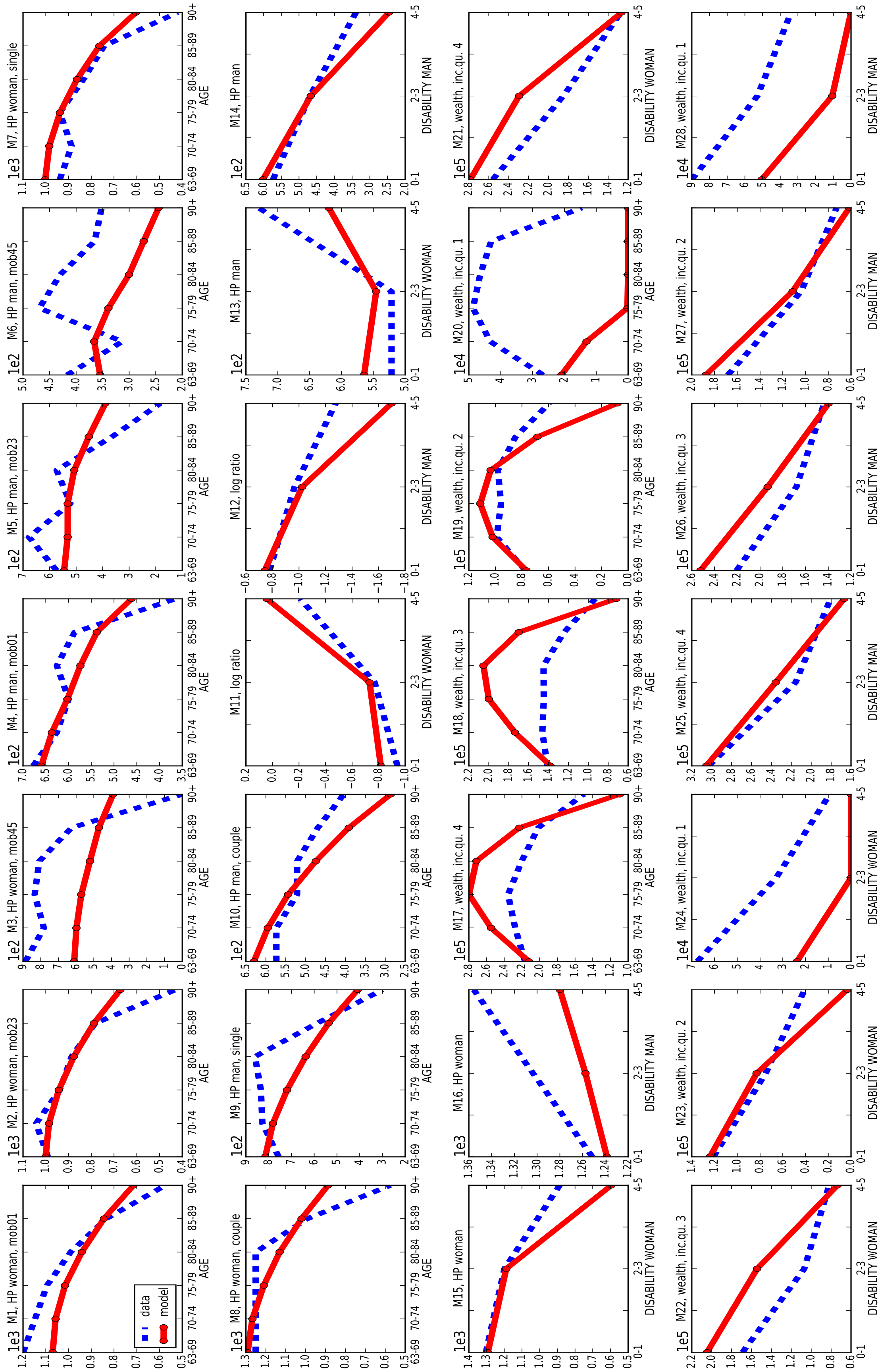


FIGURE 4.6: Model vs Data: Model without Bequest

so that she does approximately 0 hour of home production[18]. The model is otherwise similar and the values for the other parameters in this setting without bequest motives can be found in the third column of table 4.9.

The comparison of the model and the data can be found in figure 4.7. In this case, we see that the model reproduces (by construction) the very large fall in time spent on home production for women aged more than 90 and with mobila equal to 4 or 5. The other patterns of home production are still well reproduced, though the increase in TSHPA by men when their wives get disabled is a bit lower than before. This stems partly from the fact that ψ is now higher. ψ is naturally higher in this case as we increase the potential fall on TSHPA. As a matter of consequence, the value of ψ must rise in order not to generate too much precautionary motive.

Concerning wealth decumulation, this version of the model generates wealth decumulation patterns for households in the fourth wealth quartile in line with the data. It generates however too much precautionary behaviour for households in the second and third wealth quartile.

4.6.2 The effects of disability and age

A first question we may ask is: to which extent does disability, through its effect on home production, affect savings behaviours? This question can easily be answered in the case of the above model, as we just need to set some parameters to 0. The overall effect is quite similar from one version of the model to another so I will concentrate on the outcome from the model with bequest.

First of all, I set $\delta_m^{mob45} = \delta_f^{mob45} = 0$. All other parameters as well as the risk of longevity and medical expenditures are the same as before. The only modification in this case is that being disabled does not increase the disutility from performing HPA. Thus, I can clearly see the effect of disability on the model's behaviours. Figure 4.8 compares the original model with bequest to the one in which disability is shut down.

First of all, we see that hours of home production of men and women with mobila equal to 4 or 5 increases when we shut down the disability channel. This translates in a slight rise of median hours of home production done by women at older ages, whether single or in a couple. This reflects the fact that older women have a high risk of being disabled. The insurance channel provided by men disappears (M13). In particular, we see that

[18]Remember that the model cannot generate 0 hour of home production but that as A become very large it can get to values tending to 0.

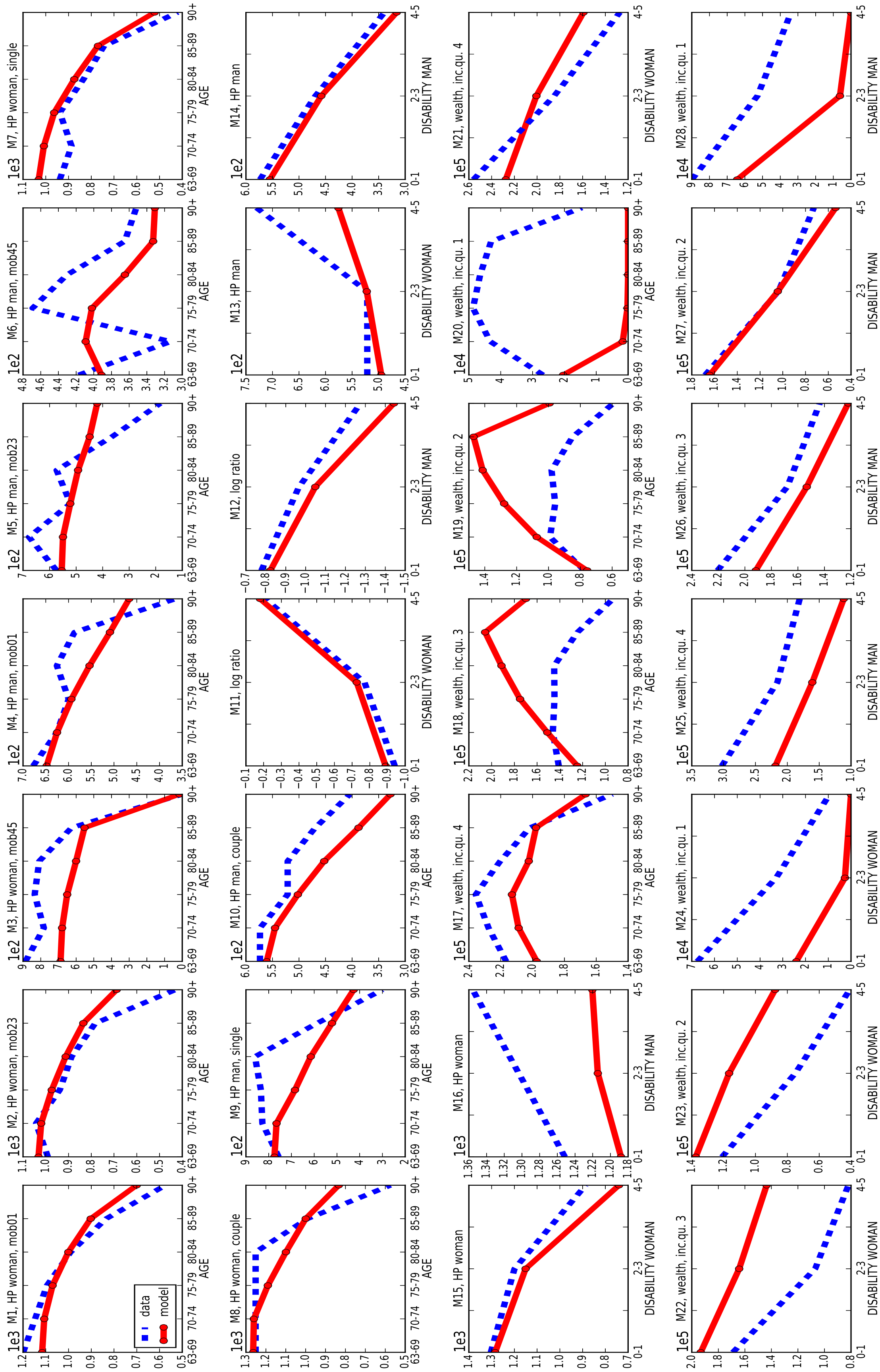


FIGURE 4.7: Model vs Data: Model without Bequest but with "Tail Risk"

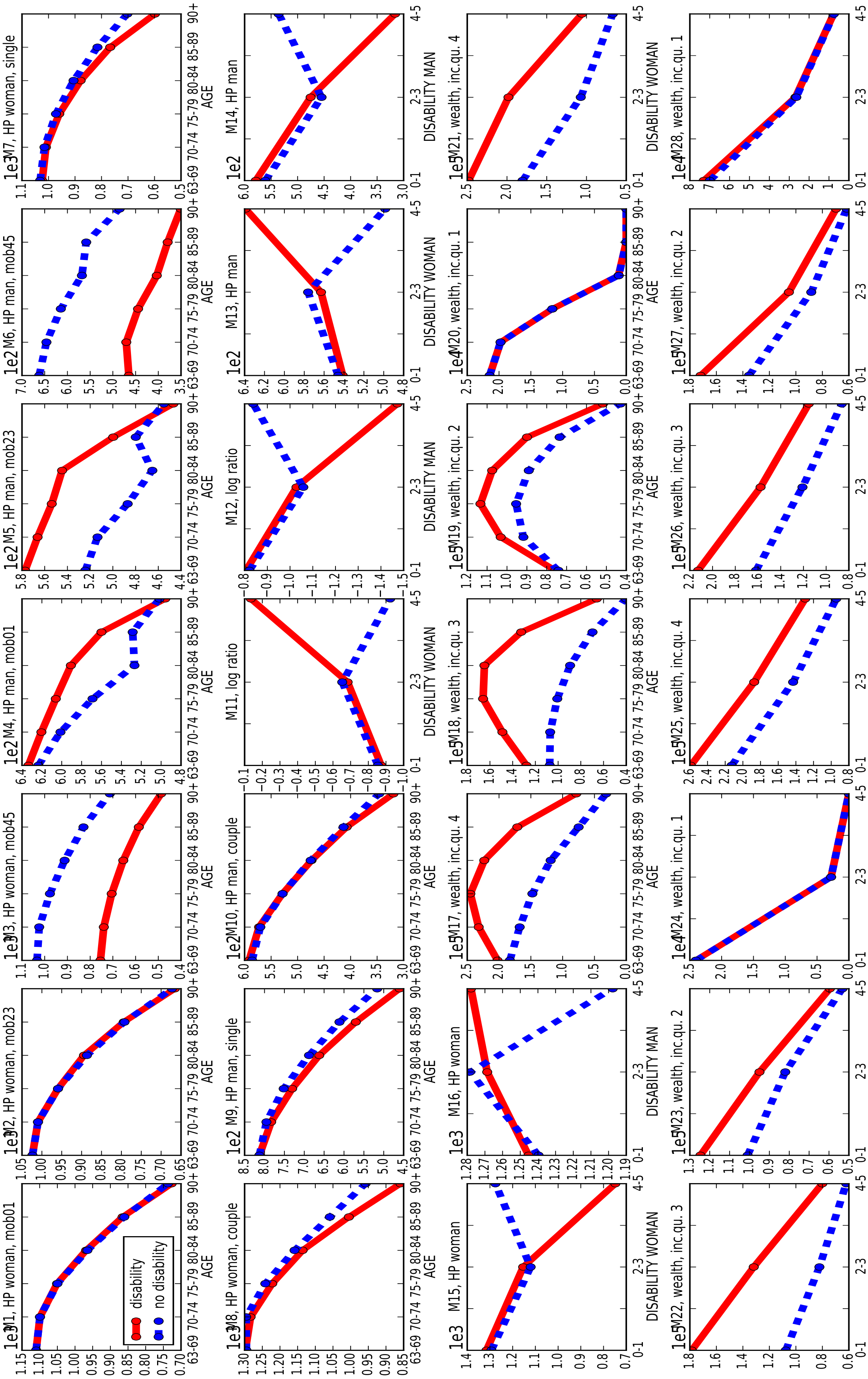


FIGURE 4.8: The Effect of Disability: Model with Bequest

hours of home production done by men fall when their wives are "disabled" which reflects mainly the fact that households spend more due to a lower expected lifetime[19].

Second, we see that disability has a high impact on savings behaviours for the second to the fourth income quartile (M17 to M19). Thus, it appears that disability generates a strong precautionary motive. In the model with tail risk, the disability at age 90+ is actually the key driver of savings behaviours with an impact even larger than what we observe here (figure not displayed). This would be in line with De Nardi et al. [2010] in which savings behaviours are driven by the rise in average medical expenses observed after age 90 (see figure 3 in their paper).

I then assess the effect of age. As we can see from figure 4.5, there is a strong decline of home production hours with age at every level of disability. In figure 4.9, I compare the model with bequest in the previous subsection to the same model in which $\delta_m^{age} = \delta_m^{age^2} = \delta_f^{age} = \delta_f^{age^2}$. We clearly see that home production of women for given level of disability is now constant. The fact that we see an increase with age for men (M4 to M7) reflects the fact that more of them become single. The insurance channel is here amplified as the age effect was applying mainly to elderly individuals, thus those more likely to have a sick spouse. As a consequence, it was more costly for them to provide the insurance with this age effect.

Clearly, age in the model has a large impact on wealth. This is true in all versions of the model, even the one with tail risk. This suggests that the fact that the ability to perform HPA is expected to deteriorate with age at every declared level of disability affects also importantly savings behaviours.

Overall, we see that the model under hand is able to replicate most of the observed patterns in the data and attributes a lot of importance to disability and age. In the next subsection, I study how the insurance channel highlighted before affects the model.

4.6.3 The value of spousal insurance

As seen above, the model reproduces fairly well the fact that men increase the hours of home production they do when their wives become disabled, what I called spousal insurance. To evaluate the importance of such an insurance on life-cycle behaviours, I now shut it down. To do so, denote by $h_{m,t}^{\star}(x_t, \mathbf{s}_{m,t}, t)$ the optimal hours of home production, from the problem in section 4.2, done by a man in state $\mathbf{s}_{m,t}$ at age t when the household is spending x_t and when the wife is in *good health*, i.e. when mobila is equal to 0 or 1.

[19] Remember that longevity has not been affected in the above procedure.

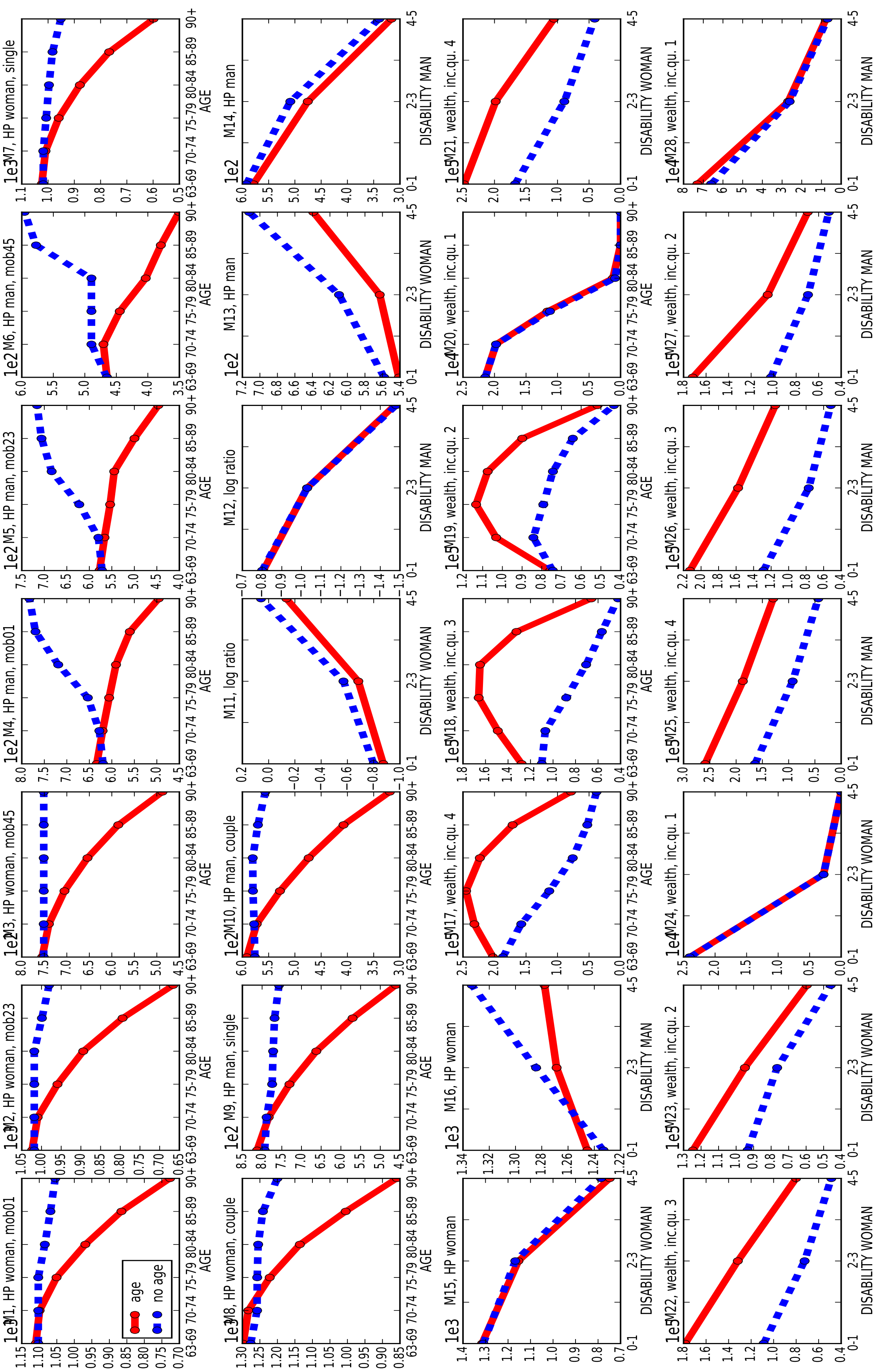


FIGURE 4.9: The Effect of Age: Model with Bequest

Now assume that the household problem is similar to the one in section 4.2 but with the additional constraint:

$$h_{m,t} = h^{\star}_{m,t}\left(x_t, \mathbf{s}_{m,t}, t\right), \ \forall \left(\mathbf{s}_{f,t}, \mathbf{s}_{m,t}\right), \ \forall t, \ \forall x_t$$

This constraint in fact imposes that hours of home production done by a man are always set to those normally done when his wife is in good health. That is, the man cannot increase hours spent on home production if his wife gets sick. The insurance channel in this case is thus shut done. The utility fiction under this constraint can be written as:

$$u^{hh}\left(c_{f,t}, c_{m,t}, h_{f,t}, h_{m,t} | \mathbf{s}_t = \left(\mathbf{s}_{f,t}, \mathbf{s}_{m,t}\right), t\right) = \phi\left(\frac{c_{f,t}^{1-\gamma}}{1-\gamma} - A_f\left(\mathbf{s}_{f,t}, t-\Delta t\right)\frac{h_{f,t}^{1+\eta}}{1+\eta}\right)$$

$$+\left(1-\phi\right)\left(\frac{c_{m,t}^{1-\gamma}}{1-\gamma} - A_m\left(\mathbf{s}_{m,t}, t\right)\frac{\left(h^{\star}_{m,t}\left(x_t, \mathbf{s}_{m,t}, t\right)\right)^{1+\eta}}{1+\eta}\right)$$

The constraints that apply in this case are:

$$h_t = h_{f,t} + h^{\star}_{m,t}\left(x_t, \mathbf{s}_{m,t}, t\right)$$

$$c_t = \left(h_t^{\rho} + \psi q_t^{\rho}\right)^{1/\rho}$$

$$c_t = c_{f,t} + c_{m,t}$$

$$q_t = \chi x_t$$

This problem can be solved in a very similar way to the one in section 4.2 except that now the hours done by the men are exogenously set. The value of spousal insurance can then be evaluated in two ways. First of all, I consider the value of spousal insurance from an intratemporal point of view.

Recall that the $u^{hh}\left(x, \mathbf{s}_t, t\right)$ denoted the utility level stemming from the resolution of the problem in section 4.2 as a function of x, $\mathbf{s}_t$ and t. Let's denote the solution from the problem just above, in which the insurance from the husband has been removed, by $\tilde{u}^{hh}\left(x, \mathbf{s}_t, t\right)$. It is then possible to evaluate the value of spousal insurance at different vectors $\left(x, \mathbf{s}_t, t\right)$ by solving for Δx in the equation:

$$u^{hh}\left(x, \mathbf{s}_t, t\right) = \tilde{u}^{hh}\left(x + \Delta x, \mathbf{s}_t, t\right) \tag{4.18}$$

TABLE 4.10: The intratemporal value of spousal insurance

	Bequest	No Bequest	No Bequest + Tail
Age 70			
$x =$ \$20,000	\$11,003	\$13,786	\$4,507
$x =$ \$30,000	\$10,654	\$13,248	\$3,501
$x =$ \$60,000	\$11,766	\$13,966	\$3,349
Age 80			
$x =$ \$20,000	\$10,113	\$12,558	\$4,202
$x =$ \$30,000	\$9,663	\$11,929	\$3,166
$x =$ \$60,000	\$10,690	\$12,503	\$2,990
Age 90			
$x =$ \$20,000	\$8,556	\$10,315	\$28,538
$x =$ \$30,000	\$7,966	\$9,591	\$26,325
$x =$ \$60,000	\$8,681	\$9,911	\$21,971

Value of Δx in equation (4.18) at different ages for the wife and different values of expenditures x.

$\Delta x\left(x, \mathbf{s}_t, t\right)$ is the additional dollar amount that a household currently benefiting from spousal insurance would require to give up this spousal insurance in a one-period setting. This is a natural way in the theoretical framework of this paper to evaluate the benefit stemming from this insurance channel. In table 4.10 I show the value of this intratemporal insurance at different values of x and for different ages of the wife. I consider in each case that the man is healthy and that his wife has mobila equal to 4 or 5. This is arguably the case in which the insurance channel is the strongest. The results (i.e. the value of Δx) are in dollars.

First of all, we see that these numbers are usually not small. Hence, the fact that men can increase hours of home production when their wives are disabled provides large welfare gains intratemporally. For the first two versions of the model, we see however that those gains are falling with age. This reflects the fact that disability is increasing with age, and hence that it becomes more difficult for the husband, as he ages, to provide this insurance.

Gains in the third version of the model are smaller before at age 70 and 80, but higher

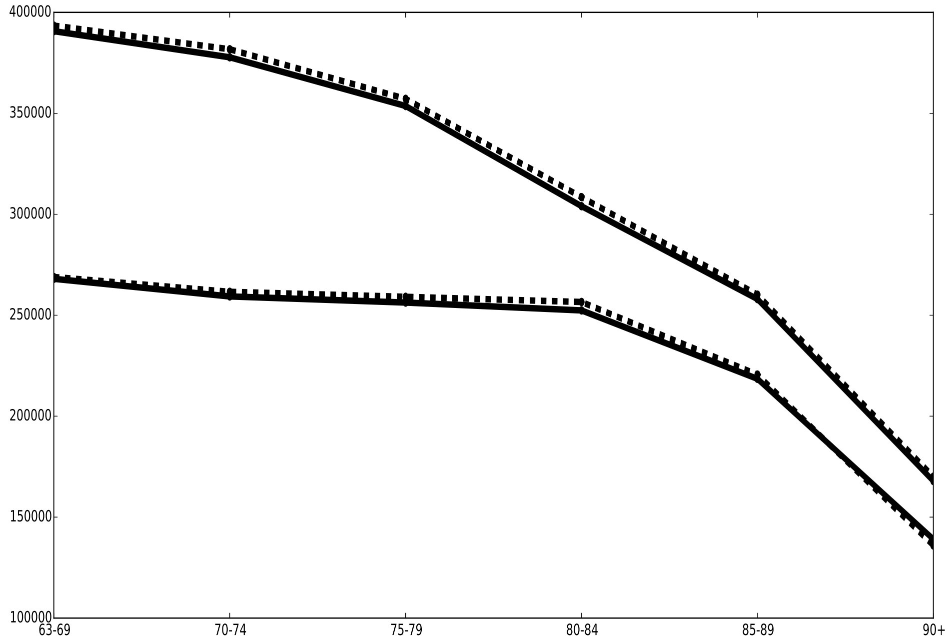


FIGURE 4.10: The effect of spousal insurance on wealth patterns

The y-axis is wealth and the x-axis is age. I use calibration (I) of table 4.9. The continuous lines represent wealth patterns of couple households in the third and fourth income quartiles in the model with insurance. The dotted lines are similar but for the model without insurance.

after age 90. Remember that, in this version of the model, ψ is higher in order not to generate extremely large precautionary behaviours. Hence, gains from spousal insurance are usually lower. However, when the wife is aged 90, the level of home production she can do falls close to zero if mobila is equal to 4 or 5. This feature was not well reproduced in the other two versions and that is why we see such large gains after age 90 in this version of the model.

However, studying the intratemporal case is not sufficient for our purpose. Indeed, the intratemporal case does not take into account the probability to provide this insurance, and hence cannot help us to understand the effect of this insurance on life-cycle savings. In figure 4.10, I show how wealth patterns differ for couples in the third and fourth income quartiles if the insurance channel is removed[20]. I use calibration (I) of table 4.9 which is the one which fits the data the best and which also reproduces well this insurance channel. Results do not differ qualitatively in the other versions. I show the results for calibration (III) of table 4.9 in appendix.

[20]Removing the insurance channel consists only in replacing u^{hh} by $\tilde{u}^{hh}$ in the intertemporal problem.

We see that removing this insurance channel has only minor effects on life-cycle behaviours. Even though wealth tends to rise when this insurance channel is removed, the change in wealth patterns is fairly small. The reason for this result is that, despite the large intratemporal gains from spousal insurance, its provision is very uncertain. This is evident from table 4.7 which shows that a woman aged 90 and disabled has only 5.2% chances of being in a couple. I found similar patterns in the other two versions of the model.

However, it is important to notice that spousal insurance does not only stem from the fact that spouses can increase the time they spend on home production when their spouses are disabled, but also from the fact that there is an imperfect correlation of risk. Said differently, if a spouse has a negative shock to her ability to do home production, the other has a positive probability not to be impaired at the same time. This means that hours of home production of this other spouse are maintained. I now compare the model under the calibration of column (I) of table 4.9 to a similar model but in which $A_m = A_f \exp\left(\delta_m^o - \delta_f^o\right)$. It means that I do not modify any of the transition probabilities but that when the wife has a negative shock to do home production, the husband faces a similar shock. I then compare dissavings behaviours of couples in the third and fourth income quartiles. The results from this exercise are displayed in figure 4.11. We see that changes in dissavings patterns are larger here. This suggests that the fact that risk is not perfectly correlated between spouses and that men face a lower risk of disability than their wives might affect more life-cycle savings. However, the change is fairly small. Hence, it appears that the spousal insurance at play here has much less effect on life-cycle behaviours than if we were to remove disability risk (see figure 4.8).

Finally, following the argument in Lakdawalla and Philipson [2002], I try to assess what would be the effect of having men facing similar longevity and disability risks than women. Remember that to estimate the transition probability matrix, I used logit regressions with dummies equal to 1 if the person was a woman, and to 0 otherwise. To perform, this exercise I keep the same estimates but assume that men are women, in the sense that I set these dummies to 1 for men as well when computing the transition matrix. I then simulate the model with this change. Once again, I use the calibration in column (I) of table 4.9. The results from this exercise for couples in the fourth income quartile are displayed in figure 4.12.

We clearly see that savings would increase if we make this change. It is simply due to the fact that higher longevity and a higher risk of disability for men increases the need for precautionary savings. Hence, if the rise in longevity for men leads to similar patterns of disability than for women, the need for savings would rise and not fall. So, it is not obvious that higher longevity of men would reduce savings by increasing the provision

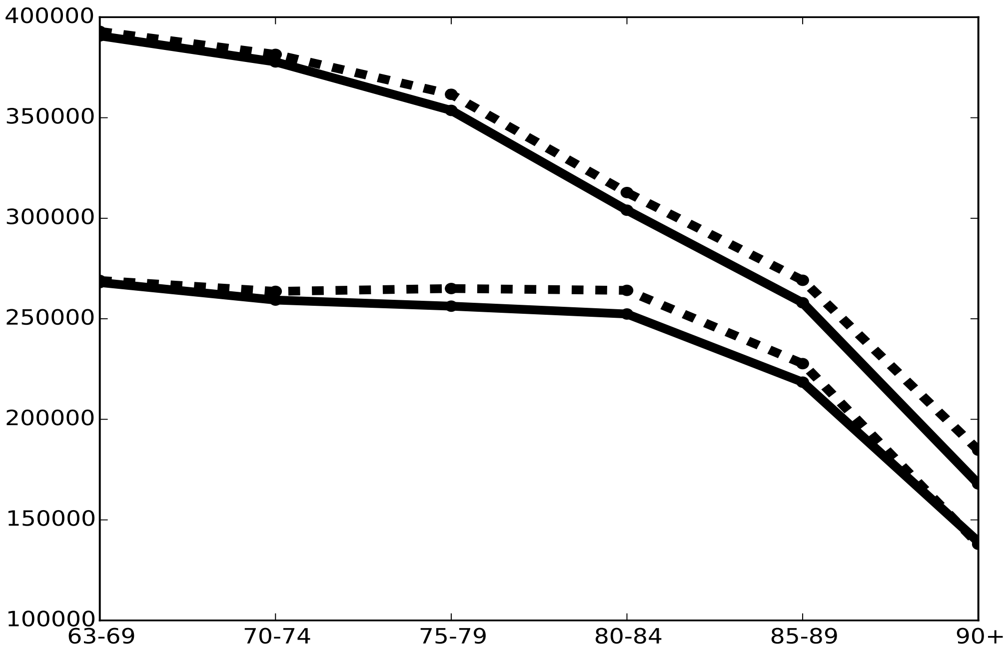


FIGURE 4.11: The effect of not perfectly correlated disability risk

The y-axis is wealth and the x-axis is age. I use calibration (I) of table 4.9. The continuous lines represent wealth patterns of couple households in the third and fourth income quartiles. The dotted lines are similar nut for a model in which $A_m = A_f \exp\left(\delta^o_m - \delta^o_f\right)$.

of informal insurance. Indeed, in the model here we find that savings would rise quite importantly. If we further assume that men have the same shocks to home production than their wives, then the needs for savings would increase even more.

Overall, we see that spousal insurance seems to have a fairly small effect on life-cycle savings despite non-trivial intratemporal gains from this insurance. Hence, it appears that having a spouse provides some insurance but that the correlation of risk, the fact that one might be single when disabled and that it is costly in terms of utility to increase hours of home production, all make this insurance a relatively weak one.

4.7 Conclusion

In this paper, I showed that a model with home production can reproduce well the main patterns in the data regarding home production and decumulation. In particular, I show that such a model can reproduce well the insurance-like mechanisms that take place within couples. However, I find that these mechanisms affect little dissavings behaviours as there is a high correlation of risk between spouses and as the chances for the wife to be

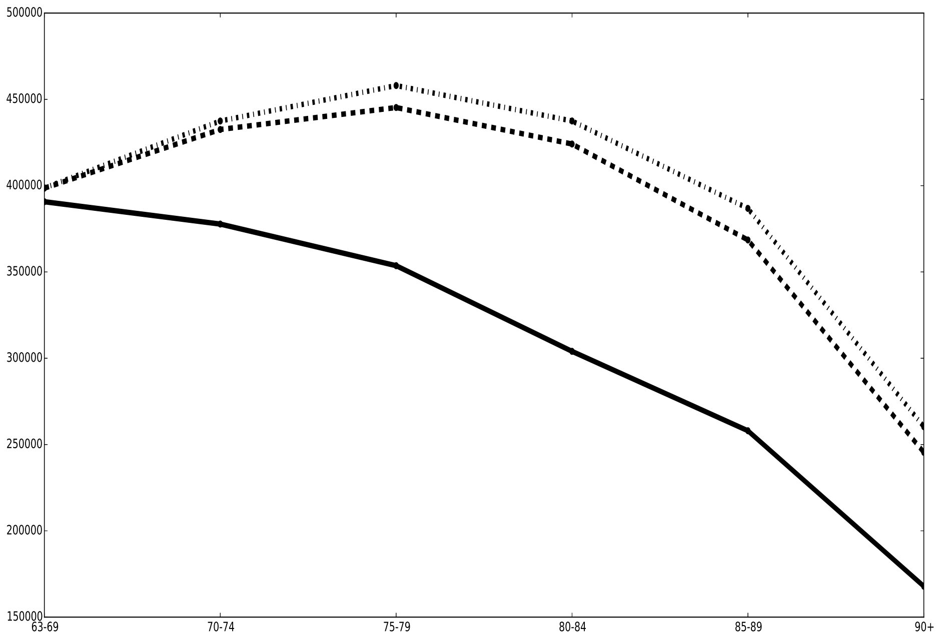


FIGURE 4.12: The effect of longevity

The y-axis is wealth and the x-axis is age. I use calibration (I) of table 4.9. The continuous line represents wealth patterns of couple households in the fourth income quartile with the original transition matrix. The dotted line is similar but with a transition matrix similar for men and women. The dotted-dashed line uses this latter transition matrix, and on top of this I assume that $A_m = A_f \exp\left(\delta^o_m - \delta^o_f\right)$.

widowed when disabled are large. This suggests that the potential insurance brought out by a spouse should not be over-evaluated in the design of entitlement reforms. Moreover, it suggests that the insurance brought out by a spouse has little chance to crowd-out the demand for other insurance products such as long-term care insurance.

This paper is one of the first attempts to study how retired couples might differ from retired singles, and to introduce informal insurance mechanisms within ta life-cycle model. Definitely more research is needed within this area. In the paper, I showed that help from children seemed to influence home production hours done by women. Studying this channel further is on the agenda.

Chapter 5

Sectoral Productivity, Collateral Constraints, and Housing Markets

joint with Hippolyte d'Albis and Eleni Iliopulos

Abstract

We show that a benchmark model with collateral constraints and an imperfect rental market can generate a partition of agents along three types: landlords, indebted homeowners and renters. This allows to introduce a market which is usually missing in the macroeconomics literature studying housing and debt dynamics: the rental market for houses. We extend this general framework to a real business cycle setting and show that it can replicate most of the volatilities and correlations observed in the data under technological shocks. We show that technological shocks might have been important drivers of the fluctuations of house prices prior to the great recession. The relaxation of borrowing constraints in our model has very little effect on the dynamics of house prices.

Introduction

In recent years, several countries experienced large variations in house prices. In the years 2000, Britain, France, Ireland, Spain or the United States reached real house prices[1] which were more than 50% higher than their levels at the beginning of 2000. Britain, France or Spain experienced increases as high as 90%. While Ireland, Spain and the US experienced a subsequent large drop in house prices, house prices in Britain and France are still more than 65% higher than their 2000 levels.

However, most macroeconomic models usually assume away the existence of the rental market for houses while in the US about a third of the population is renting. We believe it is important to take into account this market due to its size and that, for instance, the rent price ratio experienced sizeable fluctuations in recent years. Contrary to most of the literature on housing in dynamic stochastic general equilibrium models, we introduce a rental market in the housing sector which allows us to study the dynamics in housing and debt markets, taking into account the existence of the rental market for houses. Our first result is theoretical. Several papers interested in the dynamics in the housing sector (see for instance Iacoviello, 2005 and Iacoviello and Neri, 2010) have used a framework in which infinitely-lived agents have heterogeneous discountings and face collateral constraints. The benchmark structure of these models allows to take into account the realistic fact that many households have debt linked to real estate and generates amplification mechanisms which help explain some key empirical facts. Moreover, some authors have argued that mortgage credit has a significant effect on house prices (see for instance Favara and Imbs, 2015) which justify the importance of introducing debt while studying housing dynamics. However, as shown in D'Albis and Iliopulos [2013], introducing a rental market in such models leads impatient agents to rent in steady state. As a consequence, these models seem badly suited for the study of debt dynamics in parallel with the movements occurring in the rental sector. In fact, we show here that the framework in D'Albis and Iliopulos [2013] can be extended to address both aspects.

To do so we introduce an imperfection in the rental market. We show that, in steady state, the model can lead to a partition of agents along three types. The first type is a homeowner willing to lend money and/or rent housing services to other agents. This agent is the most patient one and is called the "dominant consumer". The second type is an indebted homeowner which borrows from the dominant consumer to finance housing purchases and consumption. This type of agent corresponds to the impatient agent in a model *à la* Kiyotaki and Moore [1997]. We show that such agents are more impatient than the dominant consumer but not too impatient. The third type is made of renters, which do not have any debt as they do not to have any collateral. Agents belonging to

[1] The data come from the website of the Economist (http://www.economist.com/blogs/dailychart/2011/11/global-house-prices) which provides an interactive graphical interface to compare the evolution of house prices in different countries. The data they provide come from national or international sources.

this type are those for which the time preference parameter is below a certain threshold. They are similar to the impatient agent in D'Albis and Iliopulos [2013].

This framework thus allows to study a setting in which some agents can be borrowing constrained and in which some other agents are renting. A key advantage of our simple model is that it is easily adaptable to standard business cycle models solved with usual perturbation methods. As a matter of fact, it is very flexible and can allow for a reach set of shocks. In particular, other models which feature a rental market are usually solved with global methods. Due to the curse of dimensionality, they sometimes have to cut on some potentially important aspects and are quite limited in the number of shocks they can deal with. While those models have some other qualities, we believe that our framework can be particularly useful to understand the joint dynamics in the housing market.

In a second time, we use our theoretical result to build a real business cycle model calibrated to US data with the different types of agents presented above. In particular, we calibrate it to match a realistic proportion of the different agents. We study the behaviour of the model under technological shocks in the consumption and construction sectors. We show that under realistically calibrated shocks the model reproduces volatilities and correlations of the key variables of interest which are in line with the data. We match particularly well the dynamics of debt and are able to explain about 60% of the fluctuations in house prices. In recent years, the US also experienced a large drop in the productivity in construction relative to the one in the consumption sector (see appendix C.4). We study the behaviour of the model under a positive productivity shock in consumption and a negative one in construction. We see that in this case, debt and house prices rise by a large amount. The model has however slightly more difficulty to generate a fall in the rent price ratio and in the real interest rate as has been observed prior to the great recession.

We also study the effect of relaxing borrowing constraints in our framework. While our model is quite different from the one in Kiyotaki et al. [2011] and Sommer et al. [2013], we find a similar result which is that relaxing borrowing constraints has little influence on house prices.

Our paper is related to the growing literature attempting to understand the impact of housing on macroeconomic outcomes. Iacoviello [2005] introduced a model with housing in which agents have heterogeneous discounting. In particular, he shows that demand shocks are amplified by the presence of a collateral constraint tight to house prices. The type of collateral constraints he considers is similar to ours and is taken from Kiyotaki and Moore [1997] which showed that such constraint generates powerful amplification mechanisms. Davis and Heathcote [2005] studied the impact of housing in a business cycle framework under technological shocks. In particular, their model can account for the fact that residential investment is more volatile than non-residential investment. Campbell and Hercowitz [2006] argue that the reduction in volatility that occurred prior to the recent crisis might be partly explained by a relaxation of borrowing constraints. Iacoviello and Neri [2010] estimate a DSGE model with housing using Bayesian estimation. They use it to evaluate the contributions of different shocks to the fluctuations observed in the US. Iacoviello and Pavan [2013] introduce a model with housing and a rental market. However, in their model there is no endogenous price of housing. Their model reproduces well the cyclical properties of housing investment and the procyclicality of debt. Justiniano et al. [2014] argue that a relaxation of lending constraints (and not a relaxation of borrowing constraints) was the key driver behind the movements in debt, interest rate and house prices observed prior to the great recession. Ferrero [2015] argues that a relaxation of borrowing constraints and taste shocks can explain most of the rise in debt and house prices that occurred during the same period. He attributes the fall in interest rate to loose monetary policy but argue that it had virtually no effect on house prices. All those papers do not consider the possibility to rent in parallel with endogenous house prices. Recently, Ngai and Sheedy [2015] studied transaction volumes in the housing market in a matching model but their framework did not feature a rental market for houses and did not feature debt.

To our knowledge there are three papers which study the dynamics of house prices and debt, in parallel to those in the rental market, or to those of the rent price ratio, in a general equilibrium setting. Favilukis et al. [2015] build a rich overlapping generation (OLG) model, with wealth heterogeneity and aggregate risk. They attribute the rise in house prices to a relaxation of borrowing constraints and a fall in the risk premium for housing. They argue that interest rates cannot explain the surge in house prices. They study also the behaviour of the rent price ratio though, differently from ours, their model does not feature an explicit rental market. Kiyotaki et al. [2011] build an OLG model with idiosyncratic risk. In this setting, they compare the transition from one steady state to another when fundamentals are changed. They argue that a relaxation of borrowing constraints has little effect on house prices, though it generates an increase in the homeownership rate. In a similar vein, Sommer et al. [2013], using a framework which is quite close, find results which are in line with the conclusions in Kiyotaki et al. [2011]. While our model does not feature the rich demographic structure present in those works, it has the advantage to allow for the analysis of an explicit rental market in parallel with aggregate uncertainty.

5.1 General Result

In this part, we extend the model in D'Albis and Iliopulos [2013] to allow for the possibility of an imperfect rental market. Their model featured collateral constraints and heterogeneous discounting. The innovation in their paper was to allow for a missing market in the benchmark model with collateral constraint often used in macroeconomic models studying debt and housing dynamics: the rental market for housing (see for instance Iacoviello and Neri, 2010). They showed that allowing for a *perfect* rental market lead impatient agents to rent rather than own housing in the neighbourhood of the steady state. The direct implication of this result was that agents were not indebted and that borrowing constraints did not play any role in local dynamics. Our objective here is to see if we can modify their framework such that, in steady state, some agents decide to rent and some other agents decide to buy houses while running into debt. Our final aim is to be able to study the dynamics for housing and debt, taking into account the existence of a rental market for housing, in the type of model with collateral constraints widely used in the macroeconomics literature. We show that it is possible to do so by introducing *imperfections* in the rental market. Indeed, in steady state, it generates a partition of agents with some indebted homeowners and some renters. Thus, this general result allows for the study of debt and housing dynamics in a business cycle model, taking into account the existence of the rental market for housing.

We consider an endowment economy. Let $i = 1, ..., N$ be the type of the agent. Let t denote time. The time discount of each agent is denoted β_i and satisfies $1 > \beta_1 > \beta_2 > .. > \beta_N > 0$. The agent characterized by β_1 is called the "dominant consumer". Each agent is assumed to be an expected-utility maximizer and faces a problem of the form:

$$\max_{\{c_{it}, x_{it}, h_{it}, z_{it}, d_{it}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t u_i \left(c_{it}, hs_{it}\right)$$

$$s.t. \left| \begin{array}{l} hs_{it} = h_{it} x_{it-1} + \phi z_{it}, \\ \\ y_{it} + d_{it} + p_t \left(1 - \delta_x\right) x_{it-1} + p_t l_t \left(1 - h_{it}\right) x_{it-1} = c_{it} + R_{t-1} d_{it-1} + p_t x_{it} + p_t l_t z_{it}, \\ \\ d_{it} \leq m \left(1 - \delta_x\right) x_{it} \mathbb{E}_t p_{t+1}, \\ \\ x_{it} \geq 0, z_{it} \geq 0, c_{it} \geq 0, 0 \leq h_{it} \leq 1 \end{array} \right.$$

The utility function u_i of the agent depends on a non-durable good (or consumption good) c_{it} and on the consumption of housing services hs_{it}. The first constraint shows that housing services can be consumed in two ways. Either agent i has inherited some housing, x_{it-1}, from period $t-1$, in which case he can decide to own-occupy a share $h_{it} \in [0, 1]$ of it and potentially rent a share $1 - h_{it}$ to other agents. Or, he can decide to rent housing services ϕz_{it} from other agents with $\phi \in [0,1]$. While ϕ could be interpreted as a preference parameter, we would rather interpret it as reflecting the extent of imperfections in the rental market. To see this imagine that agent i rents housing services from agent j. In this case, agent j has decided not to consume $(1-h_{jt})\,x_{jt-1} = z_{it}$ units of housing services. However, due to some imperfections, he can effectively only rent ϕz_{it} units to agent i. $1-\phi$ is akin to an iceberg transport cost. Indeed, in this case an agent owning z_{it} units of housing can only ship ϕz_{it} units to another agent, $(1-\phi)\,z_{it}$ units melting along the way. There are several reasons to think that the rental market for housing is imperfect. First of all, there is an obvious moral hazard concern as argued in Henderson and Ioannides [1983]. In terms of contract design, the renter might for instance be prevented from certain uses. Second, and somehow related, a renter is, in many cases, not allowed to modify a dwelling. As a consequence, this might reduce the utility he derives from it. While we do not model these mechanisms, the introduction of ϕ can be thought of as a simple way to introduce imperfections in the rental market. If $\phi = 1$, we are back to the perfect rental market case studied in D'Albis and Iliopulos [2013]. If $\phi = 0$, we are in the standard setting where there is no rental market[2].

The second constraint in the above problem is the budget constraint faced by agent i. He receives an exogenous income $y_{it} > 0$; he can borrow d_{it} from other agents; he resells the depreciated square meters that he owns $(1-\delta_x)\,x_{it-1}$ at price p_t, where this latter is the price for housing; finally, he receives income $p_t l_t\,(1-h_{it})\,x_{it-1}$ from the square meters he rents. $p_t l_t$ is the rent paid by renters, so that l_t is the rent-to-price or rent price ratio[3]. Those funds can be used: to purchase consumption goods c_{it}; to repay debt $R_{t-1} d_{it-1}$ (where R_{t-1} is the gross real interest rate in $t-1$); to purchase new housing x_{it} at price p_t; and to pay for the z_{it} rented units of housing.

The third constraint is a collateral constraint. It states that debt d_{it} of agent i cannot be larger that a proportion $m < 1$ of the expected value of the depreciated housing stock $(1-\delta_x)\,x_{it}$ owned by agent i.[4] This constraint is close to the one which can be found in Kiyotaki and Moore [1997]. The reason behind it is that it is thought that debt repayment cannot be enforced and thus that collateral constraints are needed to enforce it.

Finally, we assume that owned housing, rented housing and consumption cannot be negative. We also assume that the Inada conditions hold so that we can forget about the positivity constraint on c_{it}. The Lagrangian writes:

[2]There is still a possibility to rent, but in equilibrium no one will rent as it does not provide utility.

[3]Notice, however, that the effective rent paid by a renter for one unit of housing services is $p_t l_t/\phi$.

[4]The general result here can be easily extended to a case where $d_{it} \leq m\,(1-\delta_x)\,x_{it}\frac{\mathbb{E}_t p_{t+1}}{R_t}$ or $d_{it} \leq m x_{it}\mathbb{E}_t p_{t+1}$ for instance. It will simply change some thresholds.

$$\begin{gathered}\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t [u_i \left(c_{it}, h_{it} x_{it-1} + \phi z_{it}\right) \\ + \lambda_{it} \left(y_{it} + d_{it} + p_t \left(1 - \delta_x\right) x_{it-1} + p_t l_t \left(1 - h_{it}\right) x_{it-1} - c_{it} - R_{t-1} d_{it-1} - p_t x_{it} - p_t l_t z_{it}\right) \\ + \tilde{\mu}_{it} \left(m \left(1 - \delta_x\right) x_{it} \mathbb{E}_t p_{t+1} - d_{it}\right) + \tilde{\pi}_{it}^x x_{it} + \tilde{\pi}_{it}^z z_{it} + \tilde{\pi}_{it}^h h_{it} + \tilde{\tilde{\pi}}_{it}^h \left(1 - h_{it}\right)]\end{gathered}$$

We will denote $u'_{i,1t}$ ($u'_{i,2t}$) the derivative of the utility function u_i in t relative to its first (second) argument. The first order conditions with respect to h_{it}, z_{it}, d_{it} and x_{it} are[5]:

$$\begin{aligned} -u'_{i,1t} p_t l_t x_{it-1} + x_{it-1} u'_{i,2t} + \tilde{\pi}_{it}^h - \tilde{\tilde{\pi}}_{it}^h &= 0 \quad (5.1) \\ -u'_{i,1t} p_t l_t + \phi u'_{i,2t} + \tilde{\pi}_{it}^z &= 0 \quad (5.2) \\ -\tilde{\mu}_{it} - \beta_i R_t \mathbb{E}_t u'_{i,1t+1} + u'_{i,1t} &= 0 \quad (5.3) \\ -p_t u_{i,1t} + \tilde{\mu}_{it} m \left(1 - \delta_x\right) \mathbb{E}_t p_{t+1} + \tilde{\pi}_{it}^x + & \\ \beta_i \mathbb{E}_t \left[h_{it+1} u'_{i,2t+1} + u_{i,1t+1} \left(p_{t+1} \left(1 - \delta_x\right) + p_{t+1} l_{t+1} \left(1 - h_{it+1}\right)\right)\right] &= 0 \quad (5.4) \end{aligned}$$

Equation (5.1) is only relevant for homeowners. If $h_{it} \in (0, 1)$, this condition can be written as $p_t l_t = u'_{i,2t} / u'_{i,1t}$. It simply equates the relative price of housing services for a homeowner, which is the opportunity cost of not renting it, to the marginal rate of substitution between housing and consumption. Equation (5.2) is very similar when $z_{it} > 0$ as it writes $p_t l_t / \phi = u'_{i,2t} / u'_{i,1t}$. However, in this case, the relative price of housing services is usually higher as, for $\phi < 1$, $p_t l_t / \phi > p_t l_t$. Back to our previous discussion, we see that the imperfection that we introduced raises the relative price of housing services for renters relative to homeowners. Equation (5.3) states that the constraint on debt will be saturated if the marginal utility of consumption at time t, $u'_{i,1t}$, is greater than the expected discounted marginal utility of consumption in $t+1$, $\beta_i \mathbb{E}_t u'_{i,1t+1}$, multiplied by R_t, the return from additional savings. Equation (5.4) is understood easily in the case in which $\tilde{\pi}_{it}^x = 0$. Buying one unit of housing at price p_t reduces consumption in t ($-p_t u'_{i,1t}$) but also relaxes the borrowing constraint with a positive effect on consumption ($\tilde{\mu}_{it} m \left(1 - \delta_x\right) \mathbb{E}_t p_{t+1}$). Moreover, it increases future consumption of housing services in $t+1$ ($h_{it+1} u'_{i,2t+1}$) and can be resold and rented, also in $t+1$, which brings additional consumption ($u'_{i,1t+1} \left(p_{t+1} \left(1 - \delta_x\right) + p_{t+1} l_{t+1} \left(1 - h_{it+1}\right)\right)$).

The complementary slackness conditions are:

[5] The condition on c_{it} is simply $\lambda_{it} = u'_{i,1t}$ and has been replaced in equations (5.1) to (5.4).

$$\begin{aligned}
\lambda_{it}\left(y_t + d_{it} + p_t\left(1-\delta_x\right)x_{it-1} + p_t l_t\left(1-h_{it}\right)x_{it-1} - c_{it} - R_{t-1}d_{it-1} - p_t x_{it} - p_t l_t z_{it}\right) &= 0 \\
\tilde{\mu}_{it}\left(m\left(1-\delta_x\right)x_{it}\mathbb{E}_t p_{t+1} - d_{it}\right) &= 0 \\
\tilde{\pi}^x_{it} x_{it} &= 0 \\
\tilde{\pi}^z_{it} z_{it} &= 0 \\
\tilde{\pi}^h_{it} h_{it} &= 0 \\
\tilde{\hat{\pi}}^h_{it}\left(1-h_{it}\right) &= 0
\end{aligned}$$

Denoting $\mu_{it} = \tilde{\mu}_{it}/\lambda_{it}$, $\pi^x_{it} = \tilde{\pi}^x_{it}/\lambda_{it}$, $\pi^z_{it} = \tilde{\pi}^z_{it}/\lambda_{it}$, $\pi^h_{it} = \tilde{\pi}^h_{it}/\lambda_{it}$, $\hat{\pi}^h_{it} = \tilde{\hat{\pi}}^h_{it}/\lambda_{it}$, we can rewrite the system in steady state as:

$$\begin{aligned}
-plx_i + x_i\frac{u'_{i,2}}{u'_{i,1}} + \pi^h_i - \hat{\pi}^h_i &= 0 \quad (5.5)\\
-pl + \phi\frac{u'_{i,2}}{u'_{i,1}} + \pi^z_i &= 0 \quad (5.6)\\
-\mu_i - \beta_i R + 1 &= 0 \quad (5.7)\\
-p + \mu_i m\left(1-\delta_x\right)p + \pi^x_i + \beta_i\left[h_i\frac{u'_{i,2}}{u'_{i,1}} + p\left(1-\delta_x\right) + pl\left(1-h_i\right)\right] &= 0 \quad (5.8)
\end{aligned}$$

From now on, we assume that a steady state exists and we study the properties about tenure choice and indebtedness under this assumption[6].

Claim 1: **If $\phi \in [0,1)$, the agent does not simultaneously rent to someone and from someone.**

Proof. *Using equation (5.6), we have:*

$$\frac{u'_{i,2}}{u'_{i,1}} = \frac{pl - \pi^z_i}{\phi}$$

This allows to rewrite equation (5.5) as:

$$\hat{\pi}^h_i - \pi^h_i + \pi^z_i\frac{x_i}{\phi} = plx_i\left(\frac{1-\phi}{\phi}\right)$$

[6] In the real business cycle model using the theoretical results presented here, a steady state will effectively exist.

If $\pi_i^z = \hat{\pi}_i^h = 0$, then we have $\pi_i^h = plx_i\left(\frac{\phi-1}{\phi}\right)$. Under the assumption that $\phi \in [0,1)$, this implies that:

$$\begin{cases} \pi_i^h = 0 \text{ if } x_i = 0, \\ \\ \pi_i^h < 0 \text{ if } x_i > 0 \end{cases}$$

The fact that the Lagrange multiplier π_i^h is negative if $x_i > 0$ proves that it is impossible to have an agent with $x_i > 0$, $h_i < 1$ and $z_i > 0$. This proves the claim as anyone effectively renting to someone (i.e. with $(1-h_i)x_i > 0$) never rents from someone (i.e. $z_i > 0$). It is possible however to have an agent with $x_i = 0$, h_i indeterminate and $z_i > 0$.

To understand the reason behind this claim, notice that if agent i rents $\bar{z}$ to another agent he gets an additional income $pl\bar{z}$. If he uses this income to rent a similar quantity of housing, he gets a level of housing services $\phi\bar{z} < \bar{z}$. Hence, he is effectively trading $\bar{z}$ units of housing services against $\phi\bar{z} < \bar{z}$ units of housing services. This is clearly suboptimal.

A direct consequence of this claim is that three situations are possible:

- $x_i > 0$, $(1-h_i) > 0$ and $z_i = 0$, i.e. the case where an agent owns housing and rents part of it to other agents;
- $x_i > 0$, $h_i = 1$ and $z_i \geq 0$, i.e. the case where an agent owns housing and occupies all of it and possibly rents additional housing units;
- $x_i = 0$, h_i indeterminate and $z_i > 0$, i.e. where an agent rents housing from other agents and does not own any.

This claim can actually be generalized to the non steady-state case[7]. The proof is exactly the same except that equations (5.5) and (5.6) must be respectively replaced with equations (5.1) and (5.2).

As the following claim shows, there is in fact only one agent who rents to other agents in steady state.

Claim 2**: There is at most one agent who rents to other agents. This agent is the dominant consumer.**

Proof. *Suppose that $\pi_i^h = 0$ and $x_i > 0$ (implying $\pi_i^x = 0$) . Given our previous claim and the Inada conditions we know that $h_{it} \neq 1$, hence $\hat{\pi}_i^h = 0$. This implies that:*

[7]We thank Bertrand Wigniolle for pointing it to us.

$$\pi_i^z = pl\,(1-\phi)$$

This further implies that:

$$\frac{u'_{i,2}}{u'_{i,1}} = pl$$

Now, we can rewrite equation (5.8) using equation (5.7):

$$l = \frac{1-m\,(1-\delta_x)}{\beta_i} - (1-\delta_x)\,(1-mR)$$

There is at most one β_i such that l satisfies the above condition. This proves the first part of the claim.

For the second part of the claim, first notice that if $\mu_1 = 0$, then $R = 1/\beta_1$ and $\mu_i = 1-\beta_i/\beta_1 > 0$ for all $i \geq 2$ as $1 > \beta_1 > \beta_2 > .. > \beta_N > 0$. On the contrary, if $\mu_i = 0$ for a $i \geq 2$, then $R = 1/\beta_i$ and $\mu_1 = 1-\beta_1/\beta_i < 0$. This is impossible. As a consequence, the equilibrium interest rate is $R = 1/\beta_1$.

Second, we assume that $\pi_i^h = 0$ and $\hat{\pi}_i^h = 0$. However, we do not make any assumption about π_i^x. From the demonstration of our previous claim, we know that the agents with such features are either those with i) $x_i > 0$, $(1-h_i) > 0$ and $z_i = 0$ or ii) $x_i = 0$, h_i indeterminate and $z_i > 0$. We can write the expression of π_i^x:

$$\pi_i^x = p\left(1 - \left(1-\frac{\beta_i}{\beta_1}\right) m\,(1-\delta_x) - \beta_i\left[(1-\delta_x)+l\right]\right)$$

If $\beta_i = \beta_1$, we have:

$$\pi_i^x = p\,(1-\beta_1\left[(1-\delta_x)+l\right])$$

Furthermore, if $\pi_1^x = 0$, we have:

$$l = \frac{1}{\beta_1} + \delta_x - 1 \tag{5.9}$$

In this case, we have for the other agents:

$$\pi_i^x = p\left(1 - \frac{\beta_i}{\beta_1}\right)(1 - m(1 - \delta_x)) > 0$$

Hence, this case is possible.

Now, let's assume that $\pi_1^x > 0$ *and that there is (only) one* $i \neq 1$ *such that* $\pi_i^x = 0$*. In this case:*

$$l = \frac{1}{\beta_i} - \left(\frac{1}{\beta_i} - \frac{1}{\beta_1}\right) m(1 - \delta_x) + \delta_x - 1$$

Given this value for l*, we can rewrite* π_1^x*:*

$$\pi_1^x = p\left(1 - \frac{\beta_1}{\beta_i}\right)(1 - m\delta_x) < 0$$

Hence, this case is not possible.

This proves that the dominant consumer (characterized by β_1*) is the agent renting to the others. This concludes the claim.*

Finally, we show that under some conditions, we can obtain three types of agents.

Claim 3**: All agents with** $\beta_i \in \left(\frac{1-m(1-\delta_x)}{(1-\delta_x)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}, \beta_1\right)$ **own the square meters they live in, borrow funds from the dominant consumer, and do not rent; moreover, all agents with** $\beta_i < \frac{1-m(1-\delta_x)}{(1-\delta_x)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}$ **rent from the dominant consumer and do not own any real estate. There exists a threshold** $\bar{\phi} \in (0, 1)$ **such that for any** $\phi < \bar{\phi}$ **there is no rental market. This threshold** $\bar{\phi}$ **is equal to** $\frac{\frac{1}{\beta_1}+\delta_x-1}{\frac{1-m(1-\delta_x)}{\beta_N}+(1-\delta_x)\left(\frac{m}{\beta_1}-1\right)}$**.**

From our previous claims, we know that, if they exist, all agents $i \neq 1$ *such that* $\pi_i^x = 0$ *will have* $\hat{\pi}_i^h > 0$*, hence* $h_i = 1$*. This latter also implies that* $\pi_i^h = 0$*. Using the fact that* $R = 1/\beta_1$ *in combination with the fact that* l *is given by (5.9), we can combine equations (5.6) and (5.8) to get:*

$$\frac{\pi_i^z}{\phi p} = -\frac{1}{\beta_i} + \left(\frac{1}{\beta_i} - \frac{1}{\beta_1}\right) m\left(1-\delta_x\right) + \left(1-\delta_x\right) + \frac{l}{\phi}$$

Hence $\pi_i^z \geq 0$ *if and only if:*

$$\frac{\left(1-\delta_x\right)\left(1-\frac{m}{\beta_1}\right)+\frac{l}{\phi}}{1-m\left(1-\delta_x\right)} \geq \frac{1}{\beta_i}$$

If $\left(1-\delta_x\right)\left(1-\frac{m}{\beta_1}\right)+\frac{l}{\phi} \leq 0$*, then this case is impossible. Hence it must be that* $\left(1-\delta_x\right)\left(1-\frac{m}{\beta_1}\right)+\frac{l}{\phi} > 0 \Leftrightarrow \frac{l}{\phi} > \left(1-\delta_x\right)\left(\frac{m}{\beta_1}-1\right)$*. When* $\phi = 1$*, this condition writes* $\frac{1}{\beta_1} + \delta_x - 1 > \left(1-\delta_x\right)\frac{m}{\beta_1} - \left(1-\delta_x\right) \Leftrightarrow 1 > \left(1-\delta_x\right) m$*, which is always satisfied. It is easy to see that* $l > \left(1-\delta_x\right)\left(\frac{m}{\beta_1}-1\right) \Rightarrow \frac{l}{\phi} > \left(1-\delta_x\right)\left(\frac{m}{\beta_1}-1\right)$ *for* $\phi < 1$*. Hence, this condition is always satisfied. So* $\pi_i^z \geq 0$ *if and only if:*

$$\beta_i \geq \frac{1-m\left(1-\delta_x\right)}{\left(1-\delta_x\right)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}$$

If $\phi = 1$*, the above becomes:*

$$\beta_i \geq \beta_1$$

which is in line with the result in D'Albis and Iliopulos [2013] as this result implies that only the dominant consumer can be an owner and that all other agents will be renters.

If $\phi \to 0$ *then we have:*

$$\beta_i \geq \lim_{\phi \to 0} \frac{1-m\left(1-\delta_x\right)}{\left(1-\delta_x\right)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}} = 0$$

In the case of strict inequality, we obtain the result of the claim as any agent with $\beta_i > \frac{1-m(1-\delta_x)}{(1-\delta_x)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}$ *will be an owner with* $z_i = 0$ *(as in this case* $\pi_i^z > 0$*). As* $\mu_i > 0$*, these agents finance housing by borrowing from the dominant consumer. If* ϕ *tends to* 0*, all agents become homeowners. Notice moreover that the threshold is monotonic in* ϕ*.*

Given the consequence from the first claim, we know that any agent with $\beta_i < \frac{1-m(1-\delta_x)}{(1-\delta_x)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}$ *will be a renter as they are neither satisfying i)* $x_i > 0$, $(1-h_i) > 0$ *and* $z_i = 0$ *(which is only satisfied by agent 1), nor ii)* $x_i > 0$, $h_i = 1$ *and* $z_i \geq 0$ *as we just show.*

As the threshold for homeownership is monotonic in ϕ*, there will be no rental market if* $\beta_N > \frac{1-m(1-\delta_x)}{(1-\delta_x)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}$*, which implies that there will be no rental market if* ϕ *is such that:*

$$\phi < \frac{\frac{1}{\beta_1}+\delta_x-1}{\frac{1-m(1-\delta_x)}{\beta_N}+(1-\delta_x)\left(\frac{m}{\beta_1}-1\right)} = \bar{\phi}$$

The numerator is clearly positive. The denominator is decreasing in β_N*, so it is sufficient to prove that this denominator is positive for an upper bound of* β_N *to prove that* $\bar{\phi}$ *is positive. A natural upper bound for* β_N *is* β_1*. The denominator in this case rewrites* $\frac{1}{\beta_1}+\delta_x-1$ *which is clearly strictly greater than 0.*

These different claims prove that we can have three types of agents: i) the "dominant consumer" or agent of type 1, owning his home, potentially lending money and/or renting housing to other agents; ii) the agent of type 2, borrowing up to the limit imposed by the collateral constraint, occupying all the square meters of housing he owns and not renting; 3) the agent of type 3, renting housing from agent 1, not owning any housing and not borrowing as a consequence of the collateral constraint. The first agent, being the most patient, is the one effectively setting the interest rate and the rent price ratio. At those prices, the other agents are not willing to lend as their discount rates are higher. They face a trade-off: purchasing a home while running into debt or renting.

The moderately impatient agents of type 2 decides to go for the first option. The reason for it lies in the presence of the imperfection in the rental market. To simplify the intuition, let's consider that $\delta_x = 0$.[8] In this case, the equilibrium rent-to-price ratio and interest rate are $l = \frac{1}{\beta_1} - 1$ and $R = \frac{1}{\beta_1}$. At this interest rate an agent with $\beta_i < \beta_1$ is not willing to save and would be willing to borrow. The fact that $m < 1$ in the collateral

[8] The reasoning can easily be extended to the case where $\delta_x > 0$.

constraint effectively imposes him to save at R. If the rental market is perfect ($\phi = 1$), it is optimal to borrow housing at price $l < \frac{1}{\beta_i} - 1$ as it does not impose any saving at an interest rate considered too low. If $\phi < 1$, the effective rent-to-price ratio for a given level of housing services increases. As a matter of fact, if this rent-to-price ratio increases too much, some agents would rather borrow from agent 1 to purchase housing rather than rent. These agents are those for which the cost of saving at R is not too high. Thus, these agents must not be too impatient. For the most impatient agents, accumulating housing equities at R is so high that they prefer to rent housing and face the imperfection in the rental market rather than the one present in the credit market (i.e. $m < 1$).

In the next section we apply our theoretical result to a Real Business Cycle (RBC) setting.

5.2 Application of the Model to a RBC Setting

5.2.1 Households

The model features three different types of agents or households. Each type of agent has a different time preference parameter β. The most patient one, characterized by β_1, is called the dominant consumer or agent 1. The agent characterized by β_2 (resp. β_3) is called agent 2 (resp. 3). The ordering of the βs is such that $1 > \beta_1 > \beta_2 > \beta_3 > 0$. Time is quarterly. Each agent $i = 1,\ 2,\ 3$ maximizes an expected utility of the form:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left[\ln c_{it} + j \ln \left(h_{it} x_{it-1} + \phi z_{it} \right) - \chi_1 \frac{n_{1t}^{\eta}}{\eta} \right] \tag{5.10}$$

where c_{it} is his consumption of good 1, $h_{it} x_{it-1} + \phi z_{it}$ is his effective consumption of housing services and where n_{it} is the number of hours he works. η is thus the parameter driving the elasticity of labour supply. Effective housing consumption depends on four elements. First, the agent owns a stock of housing x_{it-1} inherited from the previous period. Of this housing stock he only consumes a share h_{it}. He can also consume housing services z_{it} by renting it from someone else. However, given the assumption of an imperfect rental market, he effectively gets only ϕz_{it}, with $\phi < 1$, as a utility flow. As we will show, the above functional form implies that ϕ only affects the partition of the different agents but will not affect the dynamics of the model.

5.2.1.1 Agent 1

Given our results from the previous section, we know that agent 1 will not rent from somebody else in equilibrium. Moreover, he will be the only one willing to save in steady state and so will be the only owner of capital. Hence, his expected utility can be simplified to:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_1^t \left[\ln c_{1t} + j \ln \left(h_{1t} x_{1t-1} \right) - \chi_1 \frac{n_{1t}^{\eta}}{\eta} \right] \tag{5.11}$$

and his budget constraint is:

$$\begin{aligned} p_t \left(1-\delta_x\right) x_{1t-1} + p_t l_t \left(1-h_{1t}\right) x_{1t-1} + \left[r_t^c + 1 - \delta_c\right] k_{1t-1}^c + \left[r_t^h + 1 - \delta_h\right] k_{1t-1}^h + p_t^q q_{t-1} + p_t^q l_t^q q_{t-1} \\ + d_{1t} + w_t n_{1t} = c_{1t} + R_{t-1}^d d_{1t-1} + k_{1t}^c + k_{1t}^h + p_t x_{1t} + p_t^q q_t + \tfrac{\phi_h}{2}\left(k_{1t}^h - k_{1t-1}^h\right)^2 + \tfrac{\phi_c}{2}\left(k_{1t}^c - k_{1t-1}^c\right)^2 \end{aligned} \tag{5.12}$$

The left-hand side of the equation corresponds to the resources of agent 1 available to finance future asset holdings and consumption. He resells the housing stock he inherited and gets $p_t \left(1-\delta_x\right) x_{1t-1}$ with p_t the price of housing and δ_x the depreciation rate of housing. He also receives a rent $p_t l_t$ on each of the $\left(1-h_{1t}\right) x_{1t-1}$ units he rents to someone else, l_t being the rent price ratio. In the model, there are two sectors of production c and h which are respectively the consumption sector and the housing sector. Each sector $s = c, h$ uses specific capital. Agent 1 which owns k_{t-1}^s unit of the capital of sector s resells the depreciated capital $\left[1-\delta_s\right] k_{1t-1}^s$ and receives in addition $r_t^s k_{t-1}^s$, with r_t^s the specific rate of return of capital in sector s. The housing sector also uses land to produce. Agent 1, who inherited, from period $t-1$, q_{t-1} units of this land, resells it and receives $p_t^q q_{t-1}$, with p_t^q the price of land. He additionally gets a return from land $p_t^q l_t^q$, with l_t^q being the rent price ratio for land, paid by the firms in the housing sector. Land is assumed not to depreciate and its quantity will be constant at $\bar{q} = 1$. The agent can borrow d_{1t} from other agents. In equilibrium, agent 1 will, however, lend to the others, hence $d_{1t} < 0$ and the borrowing constraint will not apply for this agent. This latter is thus omitted here. Finally, he receives income from working $w_t n_{1t}$.

He uses this money for consumption c_{1t}, debt repayment $R_{t-1}^d d_{1t-1}$, to purchase new capital in both sectors (k_{1t}^c, k_{1t}^h), new houses ($p_t x_{1t}$) and new land ($p_t^q q_t$). Finally, we assume that there exist quadratic adjustment costs for capital in both sectors, with ϕ_c and ϕ_h being the parameters driving the magnitude of these adjustment costs. The first order conditions for the different agents and for firms can be found in appendix C.1.

We allow the population of each agent to be of different size. This is to allow for the fact that, empirically, the number of renters is different from the number of homeowners. Also, among homeowners, those renting housing to others are only a fraction of homeowners. The size of agent 1, ω_1, is used as a normalizer and is set to 1, so that ω_1 will not appear in the rest of the paper.

5.2.1.2 Agent 2

The time preference parameter of agent 2, β_2, will be set such that he will borrow funds from agent 1 and use this funds to purchase houses that he will consume. As our results in the previous section showed, this agent will not lend housing to other agents in equilibrium. Moreover, as he is more impatient that agent 1, he will not invest in capital or land. Finally, he will face the borrowing constraint which will be binding in equilibrium. Thus, his problem can be simplified to the maximization of the expected utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_2^t \left[\ln c_{2t} + j \ln x_{2t-1} - \chi_2 \frac{n_{2t}^{\eta}}{\eta} \right] \tag{5.13}$$

under the constraints:

$$p_t (1 - \delta_x) x_{2t-1} + d_{2t} + w_t n_{2t} = c_{2t} + R_{t-1}^d d_{2t-1} + p_t x_{2t} \tag{5.14}$$

$$d_{2t} \leq \mathbb{E}_t \left[m p_{t+1} (1 - \delta_x) x_{2t} \right] \tag{5.15}$$

The size of agent 2 is ω_2 and is a priori different from 1.

5.2.1.3 Agent 3

The time preference parameter of agent 3, β_3, will be set such that agent 3 will rent housing services (from agent 1) in equilibrium. As agent 2, he will not buy capital or land. His problem is then very simple as no intertemporal condition emerges in this case (he does not save or borrow). He maximizes the expected utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_3^t \left[\ln c_{3t} + j \ln (\phi z_{3t}) - \chi_3 \frac{n_{3t}^{\eta}}{\eta} \right] \tag{5.16}$$

And he faces the budget constraint:

$$w_t n_{3t} = c_{3t} + p_t l_t z_{3t}$$

The size of agent 3 is ω_3. Our log-log specification implies that ϕ does not enter the first order conditions of agent 3. Hence, ϕ can be set to any arbitrary value such as to have the desired partition, without any effect the dynamics apart from the fact that the population is partitioned. As the problem of agent 3 is purely intratemporal, β_3 can also be set to any arbitrary value such that we have the desired partition.

5.2.2 Firms

The production side is made of two sectors: a consumption sector and a housing (or construction) sector. The environment is perfectly competitive.

5.2.2.1 Consumption sector firm

The firm in the consumption sector uses labour and capital to produce. The production technology is Cobb-Douglas:

$$Y_{ct} = K_{ct}^{\gamma_c} \left(A_{ct}^L L_{ct}\right)^{\alpha_c} \tag{5.17}$$

where K_{ct} and L_{ct} are respectively capital and labour used by the firm. A_{ct}^L is a productivity factor which is exogenous.

5.2.2.2 Housing sector firm

The firm in the housing sector uses labour, capital and land to produce. The production technology is Cobb-Douglas:

$$Y_{ht} = K_{ht}^{\gamma_h} \left(A_{ht}^L L_{ht}\right)^{\alpha_h} Q_{ht}^{1-\alpha_h-\gamma_h} \tag{5.18}$$

where K_{ht}, L_{ht} and Q_{ht} are respectively capital, labour and land used by the firm. A_{ht}^L is a productivity factor which is exogenous.

5.2.3 Equilibrium

In equilibrium, the market for capital in both sectors, the labour market and the land market clear:

$$K_{ht} = k^h_{1t-1} \tag{5.19}$$

$$K_{ct} = k^c_{1t-1} \tag{5.20}$$

$$L_{ht} + L_{ct} = n_{1t} + \omega_2 n_{2t} + \omega_3 n_{3t} \tag{5.21}$$

$$Q_t = q_{t-1} = \bar{q} \tag{5.22}$$

Finally, the good market, the housing market, the rental market and the market for debt clear:

$$K_{ct} + K_{ht} = (1 - \delta^c) K_{ct-1} + \left(1 - \delta^h\right) K_{ht-1} + Y_{ct} - c_{1t} - \omega_2 c_{2t} - \omega_3 c_{3t}. \tag{5.23}$$

$$x_{1t} + \omega_2 x_{2t} = (1 - \delta_x) x_{1t-1} + (1 - \delta_x) \omega_2 x_{2t-1} + Y_{ht} \tag{5.24}$$

$$\omega_3 z_{3t} = (1 - h_{1t}) x_{1t-1}. \tag{5.25}$$

$$d_{1t} + \omega_2 d_{2t} = 0 \tag{5.26}$$

All steady state equations can be found in appendix B. In the next section, we discuss our calibration.

5.3 Steady State Calibration

We calibrate β_1 such that the annual interest rate is 3% in steady state. This is similar to what is used in Iacoviello and Pavan [2013]. β_2 is set to 0.98 in line with the range of values in Hendricks (2007). δ_x is set such that the rent to price ratio is 4.8% annually. We chose this value based on the average of this variable, using data from the Lincoln Institute from 1980 onwards. We obtain an annual depreciation rate for housing of about 1.8%, which is close to the micro estimates for this variable. For instance, Nakajima and Telyukova [2014b] use a value of 1.7%.

ω_2 and ω_3 are set such i) that the homeownership rate is 66.6% in accordance with the average in the US from 1980 onwards and ii) that agent 1 represents 5% of the overall population. Previous literature, with collateral constraints and heterogeneous agents, has had difficulty to calibrate the size of the different agents in the population. The fact that our model provides a classification of agent types which can be observed in the data without getting rid of one third of the population (the renters) gives us the ability to set those sizes to realistic values.

χ_1, χ_2 and χ_3 are set such that $n_1 = n_2 = n_3 = 1/3$. The underlying assumption is that agents of different types spend the same amount of time working[9]. m is set to 0.8 in order to obtain a mortgage debt to quarterly GDP ratio of about 1.6, which is about the average from 1970Q1 to 2007Q4. Our measure of mortgage debt is similar to the one in Justiniano et al. [2014]. We use data on home mortgages from the balance sheet of U.S. households and nonprofit organizations from the flow of funds.

ϕ is set to an arbitrary value such that $\beta_2 > \frac{1-m(1-\delta_x)}{(1-\delta_x)\left(1-\frac{m}{\beta_1}\right)+\frac{\frac{1}{\beta_1}+\delta_x-1}{\phi}}$ and β_3 is set to a low value so that agent 3 rents in steady state. As mentioned before, these values just serve to obtain the partition and do not affect the dynamics of the model as neither ϕ nor β_3 enter the first order conditions.

We set γ_c to 0.3 which is in line with previous literature and, as a consequence, α_c is set to 0.7. The share of land in the construction sector is assumed to be 0.1 in line with Davis and Heathcote [2005]. α_h is set to 0.7 which is the share of labour in the housing sector in Iacoviello and Neri [2010]. δ_h and δ_c are assumed to be equal and set to have a similar rate of depreciation for capital to the one in Davis and Heathcote [2005].

j is set to have a ratio of residential real estate over quarterly GDP of about 4.3. $\bar{q}$ is set to 1 as well as A_L^c and A_L^h. These are just normalizations which do not affect the dynamics of the model. Table 5.1 summarizes the steady state values. The analytical derivation of our calibrated steady state can be found in appendix C.3.

5.4 Model Properties Under Shocks to Labour Productivity and Collateral Requirements

5.4.1 Labour Productivity Shocks

First of all, in the tradition of the RBC literature, we want to understand how our model behaves under shocks to labour productivity. We assume that the processes for A_{ct}^L and A_{ht}^L are of the form:

[9] We tried for instance to modify alternatively n_1, n_2 and n_3 while adjusting the other parameters and it did not modify our main conclusions.

TABLE 5.1: Parameters calibrated from steady state

Parameters	Values	Source/Targets
β_1	0.99264	3% annual interest rate
β_2	0.98	value in the range of Hendricks [2007]
χ_1	0.67268	$n_1 = 1/3$
χ_2	3.1897	$n_2 = 1/3$
χ_3	3.2517	$n_3 = 1/3$
j	0.072049	ratio of residential real estate over quarterly GDP of about 4.3
ω_2	12.33	66% homeownership rate and 5% of landlords
ω_3	6.67	66% homeownership rate and 5% of landlords
α_c	0.7	value in line with the literature
γ_c	0.3	value in line with the literature
δ_c, δ_h	0.013925	annual depreciation rate of capital in Davis and Heathcote [2005]
α_h	0.7	labour in construction in Iacoviello and Neri [2010]
γ_h	0.2	share of land in construction of 0.1
δ_x	0.0045829	annual rent price ratio of 4.8%
m	0.8	ratio of debt to quarterly GDP of about 1.6%

$$\log A^L_{ct} = \rho_c \log A^L_{ct-1} + \epsilon_{ct},\ \epsilon_{ct} \sim \mathcal{N}\left(0, \sigma_{\epsilon_c}\right) \tag{5.27}$$

$$\log A^L_{ht} = \rho_h \log A^L_{ht-1} + \epsilon_{ht},\ \epsilon_{ht} \sim \mathcal{N}\left(0, \sigma_{\epsilon_h}\right) \tag{5.28}$$

We need to calibrate these shocks as well as ϕ_h and ϕ_c. ρ_c and ρ_h are set to their values in Iacoviello and Neri [2010] over the period 1989-2006. σ_{ϵ_c} and σ_{ϵ_h} are set to match respectively the volatilities of non residential and residential investment. The adjustment costs are assumed to be equal to one another and are set to match the volatility of GDP. The values of the calibrated parameters are in table 5.2.

Table 5.2: Calibration of Productivity Shocks

Parameters	Values	Source/Targets
ρ_c	0.9	value in Iacoviello and Neri [2010]
ρ_h	0.98	value in Iacoviello and Neri [2010]
σ_{ϵ_c}	0.0122	volatility of non residential investment
σ_{ϵ_h}	0.031	volatility of residential investment
ϕ_h, ϕ_c	0.068	volatility of GDP

5.4.2 Business Cycle Properties - Model versus data

First, we compare the business cycle moments in the data to those in our model. The data moments are computed for the period 1975-2006. For GDP, consumption, non residential investment, residential investment, mortgage debt, house prices and rent prices, the data are log transformed, multiplied by 100 and HP-filtered with a smoothing parameters of 1600. Standard deviations are thus expressed in percentage deviation from steady state. The gross real interest rate, mortgage debt over GDP and the rent to price ratio are multiplied by 100 and HP-filtered with a smoothing parameter of 1600. Standard deviations for those variables are thus expressed in percentage points. For house prices, we use two different indices. For the rent price ratio, we use two different indices. For the interest rate, we use a measure similar to the one in Iacoviello and Neri [2010], i.e. we take the rate on 3-month treasury bills corrected by inflation.

Table 5.3 summarizes the data moments from the model and the data. The moments with stars are those that the model is aimed at reproducing. The other moments are not matched and thus are used as a test to assess the relevance of our model. We see that the model reproduces the volatilities for the main variables of interest relatively well. The volatility of consumption is lower than GDP as in the data, though our model understates somehow the volatility for this variable (0.91 vs. 1.20). We can explain about 60% of the volatility of house prices. The volatility of the rent price ratio is quite low both in the model and the data. The volatility of rents is higher than in the data but of a similar order of magnitude. The real interest rate is less volatile in the model than in the data. Our model under these shocks is able to explain the volatility of mortgage debt, though it overstates a bit the volatility of mortgage debt over GDP.

Table 5.3: Business Cycle Properties - Model vs Data

	Data	Model (Productivity Shocks)	Model (Shocks to Collateral)
Standard Deviations			
GDP	1.45	1.42*	0.11
Consumption (C)	1.20	0.91	0.06
Non Residential Investment (NRI)	3.86	3.86*	0.65
Residential Investment (RI)	9.79	9.80*	0.39
House Prices FHFA (HP-FHFA)	2.00	1.21	0.09
House Prices Freddie Mac (HP-FM)	2.28	1.21	0.09
Rent Price Ratio Case Shiller (RP-CS)	0.026	0.017	0.013
Rent Price Ratio FHFA (RP-FHFA)	0.021	0.017	0.013
Rent Prices FHFA (Rent-FHFA)	1.25	1.74	1.16
Real Interest Rate (R)	0.32	0.09	0.08
Mortgage Debt (D)	2.15	2.24	2.14*
Mortgage Debt over GDP (D/GDP)	2.69	3.68	3.58
Correlations			
NRI, GDP	0.66	0.68	0.21
RI, GDP	0.75	0.24	0.67
HP-FHFA, GDP	0.47	0.34	0.62
HP-FM, GDP	0.49	0.34	0.62
D, GDP	0.51	0.28	-0.74
D/GDP, GDP	-0.22	-0.34	0.76
C, HP-FHFA	0.47	0.63	0.03
RI, HP-FHFA	0.51	-0.76	0.33
RP-FHFA, HP-FHFA	-0.80	-0.10	0.40
Rent-FHFA, HP-FHFA	0.43	0.61	0.46
D, HP-FHFA	0.71	0.79	0.07
C, HP-FM	0.49	0.63	0.03
RI, HP-FM	0.55	-0.76	0.33
D, HP-FM	0.79	0.79	0.07

Statistics with stars (*) are statistics that the model is directly targeted to match.
The data moments are computed for the period 1975-2006. For GDP, consumption, non residential investment, residential investment, mortgage debt, house prices and rent prices, the data are log transformed, multiplied by 100 and HP-filtered with a smoothing parameters of 1600. Standard deviations are thus expressed in percentage deviation from steady state. Rent prices are obtained by multiplying the series for the rent price ratio from the FHFA by the price index obtained from the FHFA. The gross real interest rate, mortgage debt over GDP and the rent to price ratio are multiplied by 100 and HP-filtered with a smoothing parameter of 1600.

The model is also able to reproduce quite well the correlations in the data with two exceptions. First, the model reproduces the positive correlation between GDP and both residential and non residential investments. However, in our model, the correlation with residential investment turns out to be lower than in the data. The model is also able to reproduce the positive correlation between house prices and GDP, debt and GDP and the negative correlation between GDP and debt over GDP. The correlations with house prices for consumption and debt are also positive as in the data. In particular, the model generates a positive correlation between house prices and debt of 0.79, which is about what is found in the data.

Overall, technological shocks in our model can explain a large share of the volatilities and correlations observed in the data. However, there are two dimensions that the model has difficulties to reproduce. First of all, we obtain a negative correlation between residential investment and house prices. This is quite standard in a model with only productivity shocks (see Davis and Heathcote, 2005 and Iacoviello and Neri, 2010). The reason behind this feature lies in the fact that negative productivity shocks in the housing sector generate a fall in housing production which generates a rise in house prices. This is a standard negative supply shock. The second lies at the heart of our research interest. While, at business cycle frequencies, house prices and the rent price ratio are strongly negatively correlated (-0.8), our model generates only a moderate negative correlation (-0.1) . This can be understood directly from table 5.3. Typically, our model generates a positive correlation between house prices and rents. However, in our model this correlation is stronger than in the data (0.61 vs 0.43). As a consequence, house prices and rents comove too strongly which prevents the model from generating the strong negative correlation between house prices and the rent price ratio. Certainly, part of this weak negative correlation is also linked to the higher volatility of rents as we show from impulse response functions (IRF) to our shocks.

Figure 5.1 shows the dynamics of house prices, rents, the rent price ratio, x_1, $\omega_2 x_2$ and $\omega_3 z_3$ after a one-standard deviation positive productivity shock to labour in consumption. A positive shock to productivity in the consumption sector raises output which generates additional income and thus raises the demand for housing. This generates part of the rise in house prices that we observe in figure 5.1. As house prices increase, the collateral constraint for agent 2 is lowered. He increases his debt by about 1.4% (figure not shown). The fact that there is a positive leverage effect for agent 2 implies that he not only increases px_2 but also x_2. This leverage effect tends to amplify the rise in house prices as well. As he increases x_2 he buys part of it to agent 1 as the supply for housing is not perfectly elastic. This generates the fall of x_1 of a magnitude close to the rise in $\omega_2 x_2$. As agent 1 has less housing to rent in $t+1$, housing supplied to renters in $t+1$ is lowered which can be seen from the fall in $\omega_3 z_3$ on the figure. Higher wages for

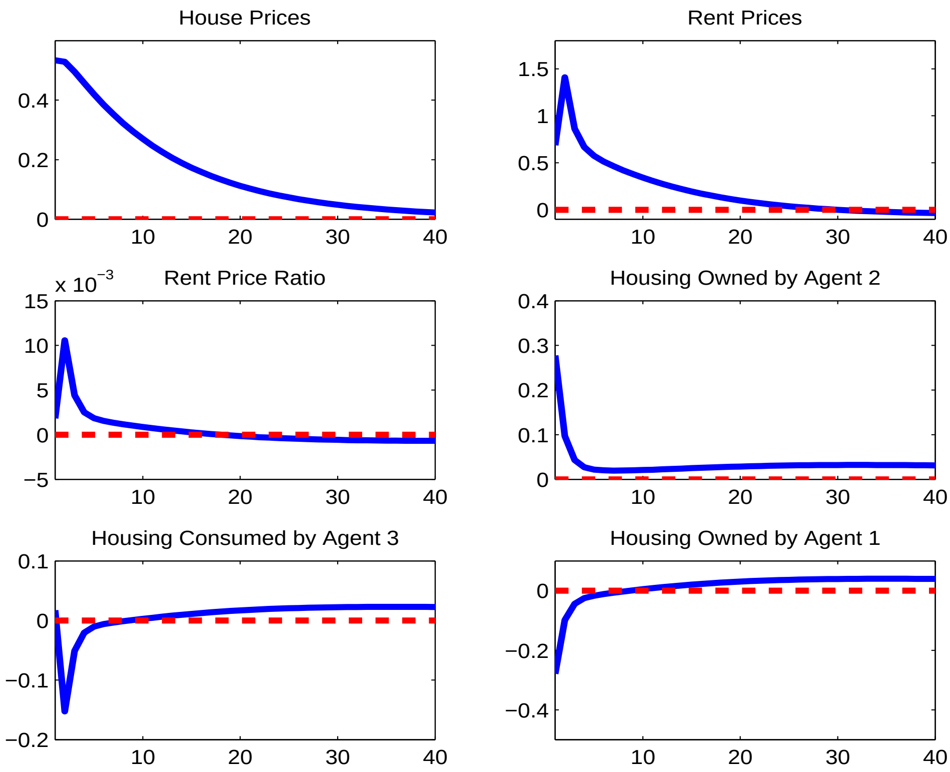


FIGURE 5.1: IRF following a positive productivity shock in the consumption sector

This figure plots the responses of some variables of the model after a one-standard deviation positive shock to labour productivity in the consumption sector. Time is in quarter. House prices and rent prices are expressed in percentage deviation from steady state. The rent price ratio is expressed in point deviation from steady state. Housing owned by agent 2 ($\omega_2 x_2$ in the model) and 1 (x_1), and housing consumed by agent 3 ($\omega_3 z_3$), are expressed in absolute deviation from steady state.

agent 3 and a lower supply of rented houses generate a large rise in rents which prevents a fall in the rent price ratio. This phenomenon is also likely to explain why rents are more volatile in our model than in the data. This phenomenon explain why our model has difficulties to generate a negative relation between house prices and the rent price ratio as negative as in the data.

Considering, preference shocks for housing (shocks to j) as in Iacoviello and Neri [2010] would help to have the positive correlation between house prices and residential investment but would not help to reproduce the dynamics of the rent price ratio. Indeed, preference shocks generate the same sort of comovements between house prices and rent prices as the one we observe under technological shocks.

There are two main roads we may pursue in the future to improve the model along this dimension to see if we can replicate along the successful dimensions of our model the strong negative correlation between house prices and the rent price ratio.

A first possibility is to generate movements in the homeownership rate. In the spirit of the model these would be changes in ω_2/ω_3. The idea behind it is that, at business cycle frequencies, the homeownership rate is positively correlated with house prices and residential investment, and negatively correlated with the rent price ratio and rents. Thus, it is possible that allowing for movements in the homeownership rate would help to reproduce the types of correlations that we observe in the data. Exogenous changes in this ratio could be considered as stemming from demographic changes. Another interpretation would be that some agents of type 2 may sometime be denied credit by financial institutions and thus act like agents of type 3 (remember that β_3 has no influence on the model's dynamics). There is some reason to think that the proportion of agents 2 for which credit is denied might vary across the cycle. While the DSGE literature has usually studied variations of m (a case we study in the next subsection) to assess the effect of financial constraints on house prices and the business cycle, this other dimension might be interesting to study. We could also allow for a fourth agent for which tenure might vary endogenously along the cycle. This would require dealing with occasionally binding constraints which might be possible (see Guerrieri and Iacoviello, 2015) but practically more difficult. A second possibility would be to allow for price rigidity in rents to generate more inertia in the rent price ratio. This would require modifying our competitive environment.

As we mentioned in the introduction, the period of the housing boom was characterized by an acceleration of the fall in labour productivity in construction relative to consumption. We try to assess here if this phenomenon might be responsible for part of the dynamics observed around the period 2000-2007. To do so, we study the IRF of the model after a positive productivity shock in the consumption sector and a negative one in the construction sector. The results from this exercise are presented in figure 5.2. We see that in this case, house prices increase substantially by about 1.2%. The same is true for debt which increases by about 3% and for debt over GDP which increases by about 4 percentage points. The rent price ratio has a tendency to rise after an initial fall due to the mechanism highlighted before. However, for most of the period after the shock the rent price ratio tends to be lower than its steady state value. A similar observation applies for the real interest rate. So, our model, under these shocks, seems able to explain why house prices and debt would have risen substantially in the early 2000s. It is slightly less successful in explaining the fall in the rent price ratio and the real interest rate.

Overall, our model with productivity shocks appears able to explain most of the volatilities and correlations observed in the data. It also generates a large rise in house prices

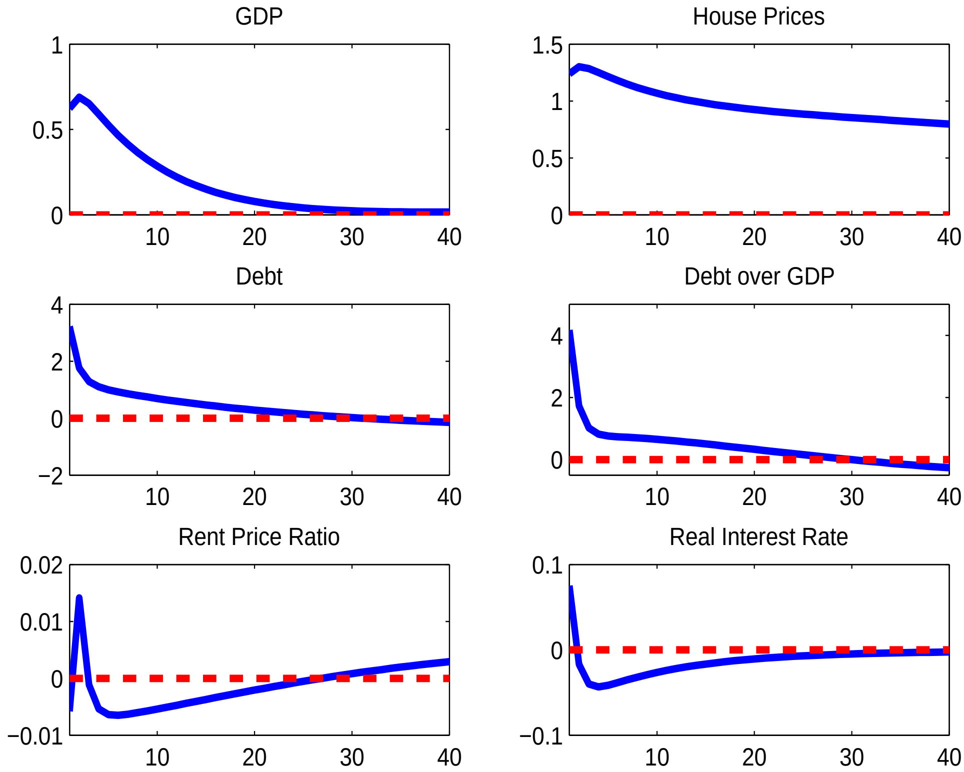


FIGURE 5.2: IRF following a positive productivity shock in the consumption sector and a negative productivity shock in construction

This figure plots the responses of some variables of the model after a one-standard deviation positive shock to labour productivity in the consumption sector and a one-standard deviation negative shock to labour prouctivity in construction. Time is in quarter. GDP, house prices and debt are expressed in percentage deviation from steady state. Debt over GDP, the rent price ratio and the real interest rate are expressed in point deviation from steady state.

and debt following a fall in productivity in housing and a rise in productivity in consumption as observed before the crisis. In the next subsection, we study the effect of another element which might be thought to have a sizeable impact on house prices: the relaxation of borrowing constraints.

5.4.3 Introducing Shocks to Collateral Requirements

In this part, we try to assess if the relaxation of borrowing constraints has a large impact on house prices. In this part, we assume away productivity shocks and assume that m is now a random variable following a stochastic process of the form:

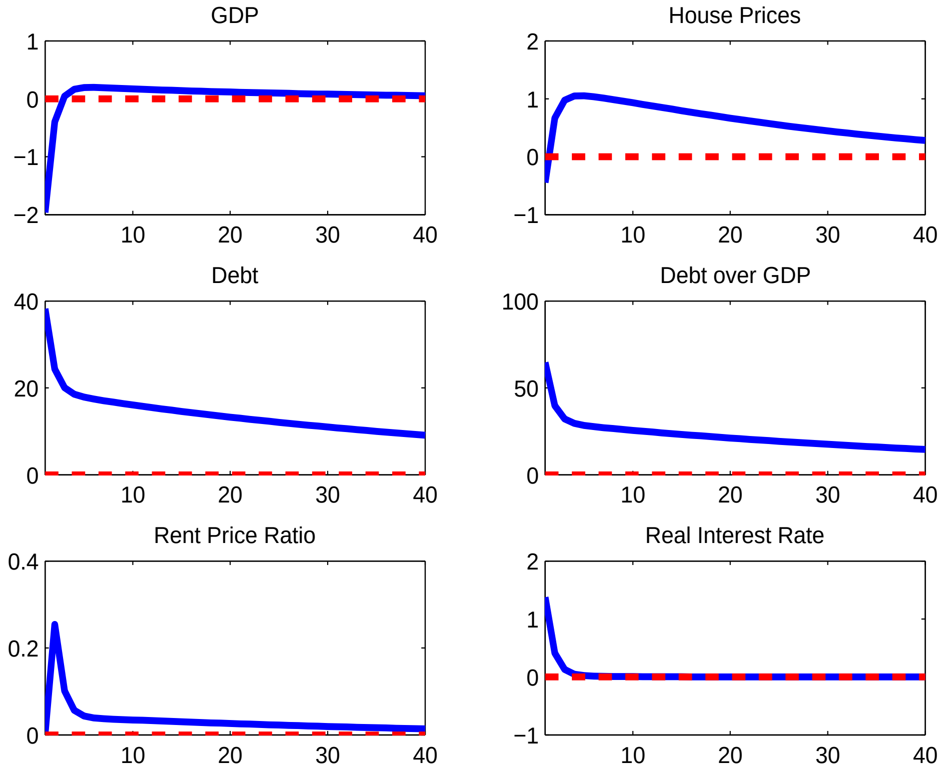


FIGURE 5.3: IRF following a large relaxation of the collateral constraint

This figure plots the responses of some variables of the model after an increase of 13% of the collateral constraint. Time is in quarter. GDP, house prices and debt are expressed in percentage deviation from steady state. Debt over GDP, the rent price ratio and the real interest rate are expressed in point deviation from steady state.

$$\log m_t = \rho_m \log m_{t-1} + (1 - \rho_m) \log \bar{m} + \epsilon_{mt}, \ \epsilon_{mt} \sim \mathcal{N}(0, \sigma_{\epsilon_m}) \tag{5.29}$$

We fix ρ_m to 0.98 following Ferrero [2015] which finds that the loan-to-value ratio is quite persistent. σ_m is set to 0.0073, which, generates a volatility of debt in line with the data. The results from this exercise are displayed in the last column of table 5.3.

While by construction, these shocks are quite extreme as we assume that only shocks to collateral constraints affect the volatility of debt, we see that they have only a minor effect on house prices. First of all, the volatility of house prices is very low at about 0.09% and house prices and debt are not correlated.

We show this in figure 5.3 in which we increase m by 13%. Despite this extremely large increase in the amount agents can borrow, the rise in house prices is at most of only 1% relative to its steady state value. At the same time debt rises by 40% and debt over GDP by 60 percentage points. Thus, contrary to technological shocks, it does not appear that relaxations of borrowing constraints generate large rise in house prices. Its main effect on housing variables is that a large share of housing is shifted from agent 2 to agent 1, with the magnitude of this redistribution about 25 times what we observed in figure 5.1. A similar type of redistribution also occurs in Kiyotaki et al. [2011] which use a very different model from ours.

Finally, we also lowered the volatility of our technological shocks by half and attributed the remaining volatility of debt to movements in the collateral constraint. Simulating the model with and without shocks to m generates almost the same volatility of output and house prices. This confirms our result that relaxation of borrowing constraints have very minor influence on house prices in our model.

Interestingly, our results seem to confirm those in Kiyotaki et al. [2011] and Sommer et al. [2013] which found that relaxation of borrowing constraints do not generate important variations in house prices. In their work, they studied transitions from one steady state to another after a change in fundamentals in a model with rental markets and borrowing constraints. Their models do not feature aggregate risk and are not designed to study business cycle fluctuations. Our results thus tends to complement theirs in the sense that they show that, in a realistically calibrated RBC model with borrowing constraints and a rental market, the relaxation of borrowing constraints play almost no role in the fluctuations in house prices and output along the business cycle. Moreover, it confirms the idea in Kiyotaki et al. [2011] that productivity shocks might be important drivers of aggregate fluctuations in house prices, while the relaxation of borrowing constraints has an influence which is only minor.

5.5 Conclusion

In this paper, we introduced a market usually missing in macroeconomic papers interested in the dynamics of debt and house prices: the rental market for houses. We show how we can modify the benchmark model with collateral constraint often used in the literature to allow for this market. A key advantage of our general framework is that it is easily adaptable to a standard business cycle framework. We use it to study the effect of productivity shocks and relaxation of collateral constraints on housing and debt. We show that the volatilities and correlations implied by the model are globally in line with those observed in the data. In particular, our model with only productivity shocks matches the key features of debt dynamics particularly well.

Moreover, we show that productivity shocks may have had an important effect on the fluctuations in house prices observed prior to the crisis. Our model seems also to confirm the results in Kiyotaki et al. [2011] and Sommer et al. [2013] that the relaxation of collateral constraints has only a minor impact on the dynamics of house prices.

One feature our model has still some difficulty to match is the strong negative correlation between the rent price ratio and house prices. We hope to be able to improve our model along this dimension in the near future.

Appendix A

Appendix to "Long-Term Care Insurance, Housing Demand, and Decumulation"

A.1 Computational Method

The method to solve for the numerical problems is standard. For the Davidoff-type model, I use a grid with 150 points on the bond grid and 2000 points on the consumption grid. The model is solved backward starting from the final date T. I use linear interpolation to find the values that lie between grid points.

For the Yao and Zhang type model I use a grid of 350 points for consumption, a grid of 60 points for bonds and a grid of 14 points for housing. In previous versions, I experimented with more denser grids. The results were practically unchanged. As in this case the computational time was quite long (about a day to solve), I opted for these smaller grids in order to perform more experiments.

A.2 Additional Figures and Tables

TABLE A.1: Optimal LTCI, "Davidoff-Type" Model - Women No Bequest

Parameters	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
β	0.97	0.97	0.97	0.97	0.97	0.97
γ	3.5	3.5	3.5	2.5	2.5	2.5
R	1.03	1.03	1.03	1.03	1.03	1.03
y	\$20,000	\$15,000	\$10,000	\$20,000	\$15,000	\$10,000
h	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000
b_{61}	\$170,000	\$180,000	\$190,000	\$190,000	\$200,000	\$200,000
y_{min}	\$7,000	\$7,000	\$7,000	\$7,000	\$7,000	\$7,000
No load						
Optimal LTCI Coverage	80%	80%	0%	90%	70%	0%
Welfare Gains	\$57,456	\$25,913	\$0	\$21,037	1,347\$	\$0
20%load						
Optimal LTCI Coverage	60%	70%	0%	80%	0%	0%
Welfare Gains	\$81,470	\$13,320	\$0	\$7,051	\$0	\$0
No load, no housing						
Optimal LTCI Coverage	100%	100%	100%	100%	100%	0%
Welfare Gains	\$99,276	\$62,268	\$11,841	\$55,470	\$27,537	\$0
20% load, no housing						
Optimal LTCI Coverage	100%	100%	0%	100%	100%	0%
Welfare Gains	\$81,470	\$43,834	\$0	\$37,798	\$9,164	\$0

Table A.2: Optimal LTCI, "Davidoff-Type" Model - Women Bequests

Parameters	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
β	0.97	0.97	0.97	0.97	0.97	0.97
γ	3	3	3	3.84	3.84	3.84
φ	1,521	1,521	1,521	2,360	2,360	2,360
ζ	234,600	234,600	234,600	273,000	273,000	273,000
R	1.03	1.03	1.03	1.03	1.03	1.03
y	\$20,000	\$15,000	\$10,000	\$20,000	\$15,000	\$10,000
h	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000
b_{61}	\$170,000	\$180,000	\$190,000	\$160,000	\$170,000	\$180,000
y_{min}	\$7,000	\$7,000	\$7,000	\$7,000	\$7,000	\$7,000
No load						
Optimal LTCI Coverage	80%	80%	0%	80%	80%	0%
Welfare Gains	\$40,421	\$16,398	\$0	\$66,956	\$32,857	\$0
20%load						
Optimal LTCI Coverage	80%	70%	0%	80%	70%	0%
Welfare Gains	\$27,393	\$4,113	\$0	\$53,479	\$20,198	\$0
No load, no housing						
Optimal LTCI Coverage	90%	100%	100%	100%	100%	100%
Welfare Gains	\$52,181	\$39,627	\$1,607	\$108,367	\$69,883	\$16,325
20% load, no housing						
Optimal LTCI Coverage	80%	100%	0%	100%	100%	0%
Welfare Gains	\$38,905	\$22,773	\$0	\$90,945	\$51,632	\$0

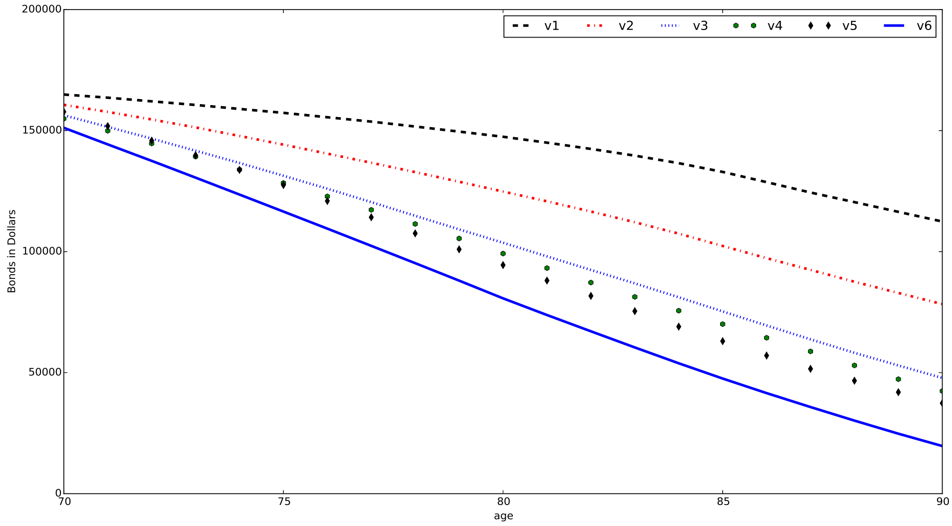


FIGURE A.1: Financial Wealth for Healthy Individuals without LTCI, Davidoff-Type Model - Women No Bequest

Notes: In this figure are plotted the bond paths as a function of age for individuals facing no negative heath shocks (i.e. which remain in state 0 from age 62 to age 90). The model used is the Davidoff-type model. The parametrizations v1 (for version 1) up to v6 (for version 6) correspond to the parametrizations displaid in table A.1.

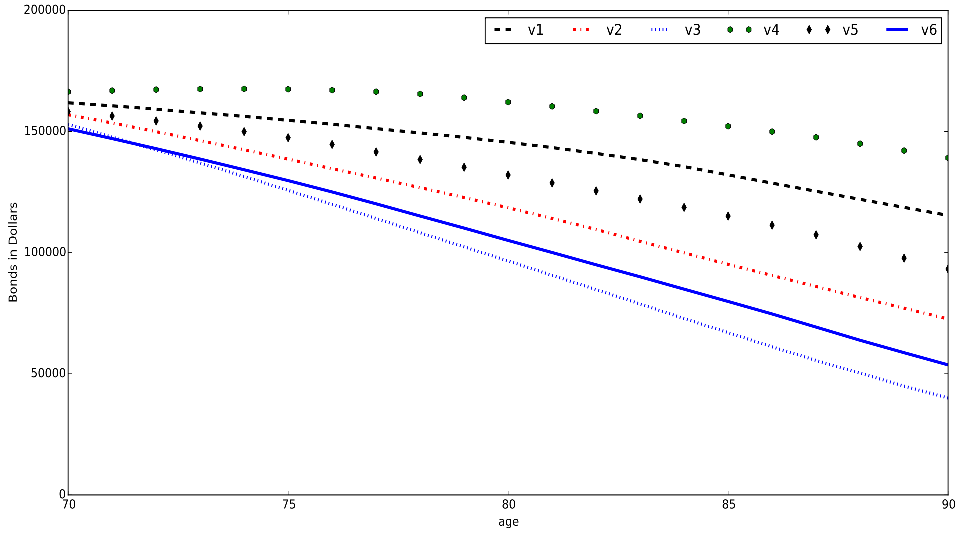


FIGURE A.2: Financial Wealth for Healthy Individuals without LTCI, Davidoff-Type Model - Women Bequest

Notes: In this figure are plotted the bond paths as a function of age for individuals facing no negative heath shocks (i.e. which remain in state 0 from age 62 to age 90). The model used is the Davidoff-type model. The parametrizations v1 (for version 1) up to v6 (for version 6) correspond to the parametrizations displaid in table A.2.

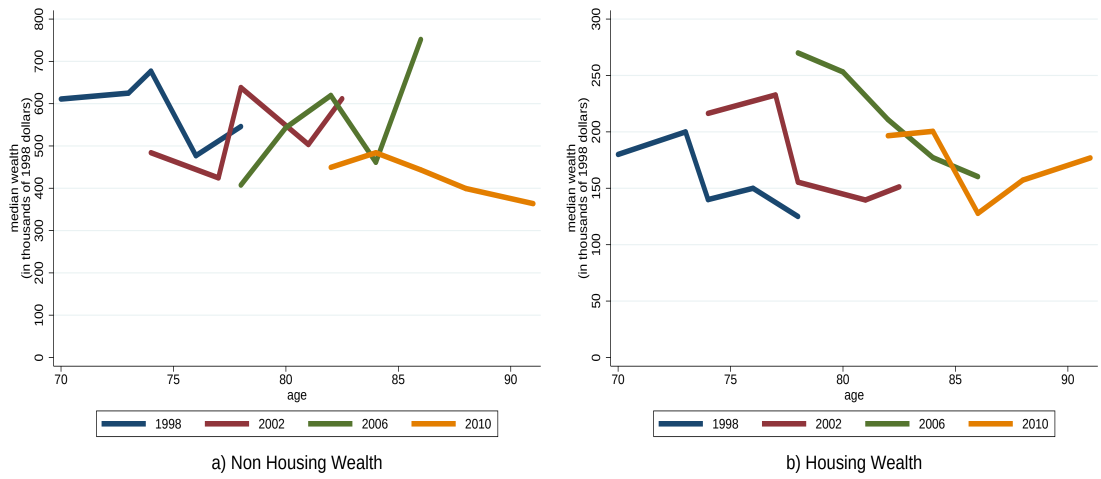


FIGURE A.3: Median of Non Housing and Housing Wealth of Continued Homeowners, Fourth Wealth Quartile, couples

Notes: These profiles are computed for couples using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. Continued homeowners are couples declaring a positive value for primary residence from wave 1998 to wave 2010.

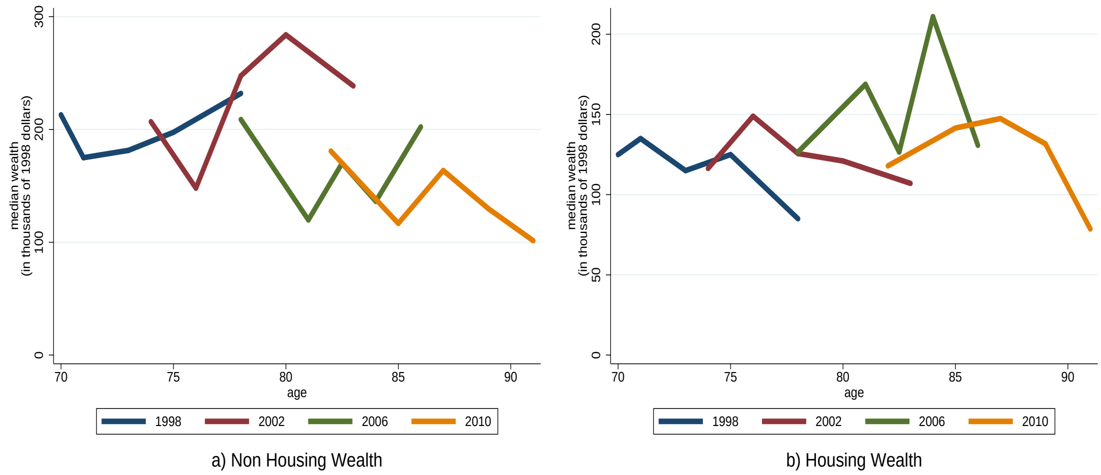


FIGURE A.4: Median of Non Housing and Housing Wealth of Continued Homeowners, Third Wealth Quartile, couples

Notes: These profiles are computed for couples using data from the RAND version of the HRS. Non housing wealth is total wealth minus the value of the primary residence. Housing wealth is the value of the primary residence. Continued homeowners are couples declaring a positive value for primary residence from wave 1998 to wave 2010.

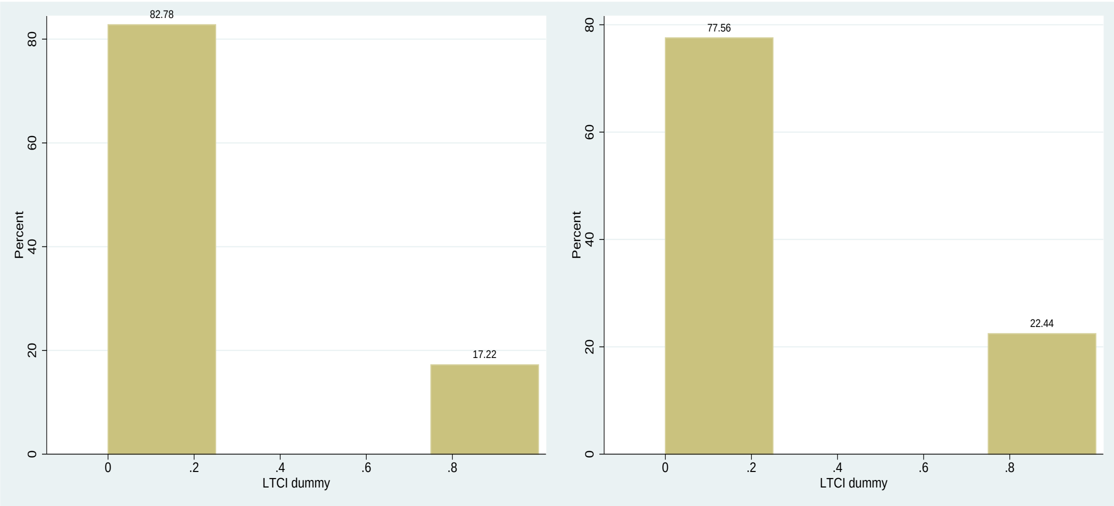


FIGURE A.5: LTCI coverage , Couples

Notes: These histograms are computed for couples using data from the RAND version of the HRS. The LTCI dummy is equal to 1 (resp. 0) if the couple has some LTCI (resp. no LTCI). The left panel considers all those in the third wealth quartile in the 1998 wave. The right panel is similar but considers those in the fourth weatlth quartile.

Appendix B

Appendix to "Disability in Retirement, Home Production, and Informal Insurance Between Spouses"

B.1 Robustness of the regressions

B.1.1 Home Production inside couples

In table B.1, I show that using OLS the choice of $\underline{h}$ in the bottomcoding procedure in table 4.2 generates very different estimates[1]. Once again in column I, I do not bottomcode. In columns II to V, I bottomcode using respectively .0001, 10, 24 and 40. We clearly see that the choice of $\underline{h}$ affects greatly the magnitude of the estimated coefficients. This confirms that when using such a procedure median regressions are better suited.

In table B.2, I bottomcode $\underline{h}$ to .00001 and perform the same median regression as in column II of table 4.2 but add controls. I increase the set of controls going from column I to column V. In column I, I just control for the age and age-square of both the husband and wife. In column II, I also add cohort effects. In column III, I also add wave fixed-effects. In column IV, I also add controls for income quartile, wealth quartile and relative pension of the two spouses. In column V, I finally add as a regressor whether a given spouse declares to have some memory difficulty[2].

[1] All standard errors in the OLS regressions are robust and clustered at the household level.

[2] In later waves, this variable has been replaced by a question about Alzheimer. For those answering that they have Alzheimer in later waves I set that they have memory issues. For the others, I assume that they have no memory problems.

TABLE B.1: Log difference of hours of home production of husbands and wives

	I	II	III	IV	V
mob1f	0.159**	-0.256	0.0734	0.0943	0.106
	(0.0645)	(0.290)	(0.0910)	(0.0814)	(0.0765)
mob1m	-0.192***	-0.670**	-0.301***	-0.277***	-0.264***
	(0.0688)	(0.261)	(0.0893)	(0.0816)	(0.0777)
mob2f	0.191**	0.243	0.237**	0.236**	0.236**
	(0.0831)	(0.362)	(0.113)	(0.101)	(0.0953)
mob2m	-0.240***	-1.544***	-0.516***	-0.451***	-0.413***
	(0.0863)	(0.382)	(0.122)	(0.109)	(0.103)
mob3f	0.485***	1.542***	0.734***	0.682***	0.652***
	(0.107)	(0.488)	(0.159)	(0.142)	(0.133)
mob3m	-0.204*	-2.742***	-0.772***	-0.647***	-0.575***
	(0.118)	(0.652)	(0.178)	(0.153)	(0.140)
mob4f	0.797***	1.871***	1.052***	1.000***	0.970***
	(0.148)	(0.711)	(0.226)	(0.200)	(0.186)
mob4m	-0.370**	-3.333***	-1.009***	-0.861***	-0.775***
	(0.165)	(0.804)	(0.228)	(0.198)	(0.182)
mob5f	1.112***	7.979***	2.737***	2.404***	2.211***
	(0.211)	(1.130)	(0.317)	(0.272)	(0.248)
mob5m	-0.543***	-6.569***	-1.643***	-1.331***	-1.149***
	(0.207)	(1.498)	(0.354)	(0.291)	(0.256)
Constant	-0.864***	-0.968***	-0.876***	-0.870***	-0.867***
	(0.0462)	(0.156)	(0.0572)	(0.0530)	(0.0508)
Observations	2170	2400	2400	2400	2400
R^2	0.058	0.115	0.127	0.124	0.120

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

OLS. The dependent variable is the log ratio. Column I is without bottomcoding. In column II, III, IV, and V, I bottomcode with .00001, 10, 24, and 40 hours respectively.

We first see that the coefficients on the disability dummies are very robust across the different specifications. So the results presented in the main text regarding the log ratio are robust to the inclusions of a large set of different controls. Second, we can see that the presence of memory difficulties also affect the log ratio. I do not include this dimension in the simulated model in order not to increase the state space[3], but it could be included in future works.

Table B.3 is similar to table B.2. The same bottomcoding is use and the same sets of controls. However, I include also home maintenance and car maintenance. None of the conclusions are changed. I do not include home maintenance and car maintenance in the main measure of home production as those two activities can be considered as some sort of investment and as the model does not feature durable goods.

[3]We would need in this case to multiply by 2 each dimension of the transition matrix.

TABLE B.2: Log difference of hours of home production of husbands and wives

	I	II	III	IV	V
mob1f	0.0484	0.0425	0.0584	0.0470	0.0310
	(0.0804)	(0.0818)	(0.0841)	(0.0797)	(0.0811)
mob1m	-0.219***	-0.226***	-0.264***	-0.220***	-0.250***
	(0.0786)	(0.0841)	(0.0769)	(0.0808)	(0.0834)
mob2f	0.159*	0.140	0.126	0.122	0.140
	(0.0940)	(0.0953)	(0.0995)	(0.0993)	(0.103)
mob2m	-0.359***	-0.359***	-0.375***	-0.312***	-0.335***
	(0.0972)	(0.0998)	(0.107)	(0.110)	(0.112)
mob3f	0.596***	0.590***	0.576***	0.644***	0.644***
	(0.119)	(0.123)	(0.111)	(0.123)	(0.134)
mob3m	-0.378**	-0.357**	-0.421**	-0.311*	-0.367**
	(0.173)	(0.160)	(0.183)	(0.159)	(0.173)
mob4f	0.865***	0.869***	0.839***	0.917***	0.938***
	(0.130)	(0.128)	(0.129)	(0.160)	(0.157)
mob4m	-0.701***	-0.700***	-0.694***	-0.640***	-0.753***
	(0.190)	(0.191)	(0.175)	(0.188)	(0.193)
mob5f	1.718***	1.699***	1.710***	1.712***	1.736***
	(0.411)	(0.412)	(0.356)	(0.485)	(0.498)
mob5m	-1.793***	-1.786***	-1.821***	-1.764***	-1.830***
	(0.405)	(0.414)	(0.416)	(0.646)	(0.606)
age of the wife	-0.374***	-0.397**	-0.403**	-0.465**	-0.397*
	(0.121)	(0.199)	(0.192)	(0.196)	(0.209)
age of the husband	0.265*	0.273	0.217	0.198	0.169
	(0.153)	(0.215)	(0.212)	(0.226)	(0.235)
age of the wife squared	0.00265***	0.00282**	0.00290**	0.00334**	0.00286**
	(0.000818)	(0.00138)	(0.00133)	(0.00136)	(0.00145)
age of the husband squared	-0.00185*	-0.00192	-0.00158	-0.00147	-0.00123
	(0.00100)	(0.00144)	(0.00143)	(0.00154)	(0.00159)
husband has memory difficulties					-0.945***
					(0.294)
wife has memory difficulties					1.320***
					(0.435)
Constant	2.853	3.487	5.860	8.542	7.089
	(5.209)	(6.462)	(6.255)	(6.498)	(6.388)
Observations	2400	2400	2400	2367	2339
R^2	0.107	0.107	0.110	0.109	0.153

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median Regressions. The dependent variable is the log ratio with $\underline{h}$ set to .00001. I increase the set of controls going from column I to column V. In column I, I just control for the age and age-square of both the husband and wife. In column II, I also add cohort effects. In column III, I also add wave fixed-effects. In column IV, I also add controls for income quartile, wealth quartile and relative pension of the two spouses. In column V, I finally add as a regressor whether a given spouse declares to have some memory difficulty

TABLE B.3: Log difference of hours of home production of husbands and wives

	I	II	III	IV	V
mob1w	0.0172	0.0158	0.0728	0.0861	0.0643
	(0.0750)	(0.0745)	(0.0777)	(0.0789)	(0.0793)
mob1m	-0.179**	-0.181**	-0.214***	-0.216***	-0.225***
	(0.0698)	(0.0724)	(0.0738)	(0.0726)	(0.0750)
mob2w	0.115	0.106	0.125	0.162	0.158
	(0.0918)	(0.0927)	(0.0900)	(0.101)	(0.102)
mob2m	-0.299***	-0.313***	-0.272***	-0.326***	-0.340**
	(0.104)	(0.106)	(0.101)	(0.127)	(0.133)
mob3w	0.591***	0.579***	0.555***	0.639***	0.669***
	(0.102)	(0.105)	(0.107)	(0.108)	(0.117)
mob3m	-0.391**	-0.396**	-0.391**	-0.405**	-0.488**
	(0.161)	(0.159)	(0.184)	(0.191)	(0.194)
mob4w	0.742***	0.738***	0.759***	0.800***	0.799***
	(0.127)	(0.141)	(0.136)	(0.141)	(0.157)
mob4m	-0.621***	-0.630***	-0.662***	-0.670***	-0.801***
	(0.196)	(0.197)	(0.184)	(0.175)	(0.220)
mob5w	1.476***	1.475***	1.460***	1.591***	1.487***
	(0.405)	(0.358)	(0.345)	(0.362)	(0.388)
mob5m	-1.712***	-1.714***	-1.712***	-1.581***	-1.520**
	(0.603)	(0.608)	(0.603)	(0.490)	(0.617)
age of the wife	-0.374***	-0.416**	-0.409**	-0.447**	-0.383
	(0.124)	(0.194)	(0.187)	(0.200)	(0.238)
age of the husband	0.344**	0.374*	0.274	0.329	0.274
	(0.163)	(0.223)	(0.200)	(0.227)	(0.251)
age of the wife squared	0.00266***	0.00297**	0.00299**	0.00326**	0.00281*
	(0.000842)	(0.00136)	(0.00129)	(0.00138)	(0.00165)
age of the husband squared	-0.00240**	-0.00260*	-0.00190	-0.00229	-0.00190
	(0.00107)	(0.00150)	(0.00135)	(0.00152)	(0.00169)
husband has memory difficulties					-1.024***
					(0.356)
wife has memory difficulties					1.742
					(1.173)
Constant	0.0760	0.373	3.606	2.746	2.457
	(5.836)	(6.998)	(5.931)	(7.073)	(6.304)
Observations	2349	2349	2349	2319	2291
R^2	0.109	0.108	0.111	0.117	0.169

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median Regressions. The dependent variable is the log ratio with $\underline{h}$ set to .00001. I use as hours of home production the core measure plus time spent on home maintenance and car maintenance. I increase the set of controls going from column I to column V. In column I, I just control for the age and age-square of both the husband and wife. In column II, I also add cohort effects. In column III, I also add wave fixed-effects. In column IV, I also add controls for income quartile, wealth quartile and relative pension of the two spouses. In column V, I finally add as a regressor whether a given spouse declares to have some memory difficulty

Table B.4 is exactly similar to table 4.3 in the main text except that I use OLS rather than fixed effects. The patterns are very similar to those obtained with median regressions.

TABLE B.4: Home production of husbands and wives

	I	II	III	IV	V	VI
mob1f	56.49	56.60	45.80	-50.91	-49.43	-82.85
	(36.12)	(36.51)	(43.53)	(47.04)	(47.46)	(53.02)
mob1m	-98.81***	-98.18***	-126.4***	81.89	85.90*	117.1**
	(34.71)	(35.15)	(41.16)	(50.60)	(51.17)	(59.25)
mob2f	70.69	83.97*	27.03	-120.3**	-101.5*	-118.9*
	(43.76)	(44.83)	(51.65)	(59.89)	(60.50)	(70.91)
mob2m	-105.8**	-98.67**	-101.6*	124.0**	136.5**	124.4*
	(46.45)	(47.55)	(55.98)	(60.13)	(60.26)	(68.05)
mob3f	199.3***	210.2***	217.8***	-251.4***	-249.4***	-268.1***
	(65.70)	(67.35)	(84.03)	(73.76)	(74.81)	(84.40)
mob3m	-179.8***	-170.7***	-200.5***	115.6	134.9*	98.41
	(56.76)	(57.82)	(66.51)	(76.37)	(77.63)	(82.96)
mob4f	251.7***	266.2***	205.9***	-437.3***	-417.0***	-434.3***
	(67.24)	(68.82)	(74.19)	(83.92)	(84.31)	(89.17)
mob4m	-159.0*	-151.2*	-99.62	180.4*	186.9**	177.8*
	(86.31)	(86.59)	(99.56)	(93.38)	(92.13)	(100.5)
mob5f	375.2***	397.0***	297.9***	-783.8***	-726.1***	-647.0***
	(83.64)	(84.25)	(101.5)	(108.5)	(110.2)	(145.1)
mob5m	-438.5***	-416.8***	-371.4***	1.089	70.12	187.2
	(66.31)	(68.50)	(83.16)	(129.5)	(123.9)	(157.8)
Constant	684.4***	686.5***	707.3***	1391.4***	1419.8***	1424.8***
	(26.79)	(30.03)	(32.71)	(34.46)	(37.20)	(39.70)
Observations	2409	2372	1742	2409	2372	1742
R^2	0.036	0.038	0.029	0.045	0.053	0.037

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

OLS regressions. In column I to III the depend variable is hours done by husbands. In column IV to VI, the dependent variable is hours done by wives. In column III and VI, I remove households having a LTCI and/or receiving help from the family or from friends.

Table B.5 is similar to table 4.3. However, in this case, I control for age, its square, cohort effects, wave fixed effects, income quartile, wealth quartile and the ratio of income between husbands and wives. Adding all these controls does not modify the any of the conclusions of the main text.

Finally, table B.6 is similar to B.5 but I use as a measure of home production the core measure plus home maintenance and car maintenance. Results are similar.

Table B.5: Home production of husbands and wives

	I	II	III	IV	V	VI
mob1w	60.17**	53.15*	56.76	-85.78	-85.83*	-161.4**
	(30.07)	(30.28)	(40.71)	(52.64)	(50.50)	(64.58)
mob1m	-75.65**	-77.94**	-91.98**	85.47	118.7**	183.0**
	(32.02)	(31.49)	(40.99)	(53.30)	(52.12)	(72.35)
mob2w	56.17	76.11**	-1.403	-137.5**	-58.96	-124.6
	(34.40)	(33.59)	(39.12)	(67.65)	(63.79)	(77.35)
mob2m	-130.0***	-117.4***	-100.9**	159.3**	153.5***	170.3**
	(37.74)	(37.84)	(49.30)	(65.01)	(58.38)	(80.83)
mob3w	156.6**	150.7**	116.9	-280.3***	-275.1***	-289.2***
	(66.77)	(58.69)	(87.01)	(79.80)	(84.26)	(90.71)
mob3m	-109.5	-107.3	-118.4*	167.3**	208.6**	180.0**
	(70.12)	(70.02)	(63.66)	(79.80)	(90.21)	(91.30)
mob4w	281.9***	264.2***	250.4***	-448.8***	-436.0***	-505.6***
	(61.47)	(53.13)	(63.67)	(86.73)	(84.46)	(96.51)
mob4m	-222.0***	-222.5***	-146.0*	223.0**	222.0**	216.3*
	(81.64)	(58.78)	(75.29)	(108.1)	(99.32)	(113.0)
mob5w	390.3***	377.3***	336.6***	-767.0***	-601.3***	-660.0***
	(87.20)	(73.79)	(109.7)	(127.4)	(100.4)	(198.7)
mob5m	-431.2***	-415.6***	-288.4**	104.6	194.1	369.1**
	(59.09)	(63.81)	(128.3)	(165.8)	(122.1)	(155.7)
has some LTCI		-34.29			-149.9***	
		(28.12)			(44.62)	
receives help		-109.5			-428.2***	
from the family or friends		(87.64)			(110.4)	
Constant	-2882.7	-1768.9	-1163.1	-6099.3*	-7156.9**	-5107.0
	(2462.6)	(2576.1)	(3375.1)	(3469.0)	(3398.0)	(5350.6)
Observations	2375	2338	1715	2375	2338	1715
R^2	0.040	0.043	0.038	0.057	0.061	0.051

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median regressions. In column I to III the depend variable is hours done by husbands. In column IV to VI, the dependent variable is hours done by wives. In column III and VI, I remove households having a LTCI and/or receiving help from the family or from friends. All regressions control for age, its square, cohort fixed effects, wave fixed effects, income quartile, wealth quartile and the ratio of income between husband and wives.

B.2 Data Selection

Here, I describe here the procedure to construct the database. I mention the names of the files used. Though, they are not publicly available, they are intended to be if this work gets published in the future.

Table B.6: Home production of husbands and wives

	I	II	III	IV	V	VI
mob1f	60.17**	53.15*	56.76	-85.78	-85.83*	-161.4**
	(30.07)	(30.28)	(40.71)	(52.64)	(50.50)	(64.58)
mob1m	-75.65**	-77.94**	-91.98**	85.47	118.7**	183.0**
	(32.02)	(31.49)	(40.99)	(53.30)	(52.12)	(72.35)
mob2f	56.17	76.11**	-1.403	-137.5**	-58.96	-124.6
	(34.40)	(33.59)	(39.12)	(67.65)	(63.79)	(77.35)
mob2m	-130.0***	-117.4***	-100.9**	159.3**	153.5***	170.3**
	(37.74)	(37.84)	(49.30)	(65.01)	(58.38)	(80.83)
mob3f	156.6**	150.7**	116.9	-280.3***	-275.1***	-289.2***
	(66.77)	(58.69)	(87.01)	(79.80)	(84.26)	(90.71)
mob3m	-109.5	-107.3	-118.4*	167.3**	208.6**	180.0**
	(70.12)	(70.02)	(63.66)	(79.80)	(90.21)	(91.30)
mob4f	281.9***	264.2***	250.4***	-448.8***	-436.0***	-505.6***
	(61.47)	(53.13)	(63.67)	(86.73)	(84.46)	(96.51)
mob4m	-222.0***	-222.5***	-146.0*	223.0**	222.0**	216.3*
	(81.64)	(58.78)	(75.29)	(108.1)	(99.32)	(113.0)
mob5f	390.3***	377.3***	336.6***	-767.0***	-601.3***	-660.0***
	(87.20)	(73.79)	(109.7)	(127.4)	(100.4)	(198.7)
mob5m	-431.2***	-415.6***	-288.4**	104.6	194.1	369.1**
	(59.09)	(63.81)	(128.3)	(165.8)	(122.1)	(155.7)
has some LTCI		-34.29			-149.9***	
		(28.12)			(44.62)	
receives help		-109.5			-428.2***	
from the family or friends		(87.64)			(110.4)	
Constant	-2882.7	-1768.9	-1163.1	-6099.3*	-7156.9**	-5107.0
	(2462.6)	(2576.1)	(3375.1)	(3469.0)	(3398.0)	(5350.6)
Observations	2375	2338	1715	2375	2338	1715
R^2	0.040	0.043	0.038	0.057	0.061	0.051

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Median regressions. In column I to III the depend variable is hours done by husbands. In column IV to VI, the dependent variable is hours done by wives. Home production is the core measure plus home maintenance and car maintenance. In column III and VI, I remove households having a LTCI and/or receiving help from the family or from friends. All regressions control for age, its square, cohort fixed effects, wave fixed effects, income quartile, wealth quartile and the ratio of income between husband and wives.

B.2.1 Restrictions which apply to both samples

File used: DATA_SELECTION.DO and the other cleaned files. The base file is the RAND HRS database which is at the individual level. I drop observations for which we do not have the couple/single variable. Retired individuals are considered to be those between 63 and 100 declaring 0 earnings. For couples, I also impose that the spouse must have 0 earnings. I drop observations for which the cohort is unknown (if fact 0 observation deleted). All dollar measures are converted in 1998 dollars using the price index for personal consumption expenditures for major types of products from the

Bureau of Economic Analysis (BEA). I consider households from 4 cohorts : AHEAD (born before 1924), CODA (born between 1924 and 1930), HRS (born between 1931 and 1941) and war babies (born between 1942 and 1947).

B.2.2 Restrictions for home production database

Order to use the files:

1. run *data_for_hh_reg.do*, this file keeps only the individuals for which we observe home production
2. then reorganize the database at the household level using *hh_file.py*
3. then run *data_for_hh_reg2.do*, this file keeps only the individuals for which we observe home production. This file generates the database used for the regression analysis (see below)
4. then run *hh_reg.do*. This file generates the results from the regression analysis and, at the end, generate the sample used for the structural estimation (see below)
5. then run *moment_computations_hp.do*. This file generates the database necessary for the moment computations in Python. In particular, it generates the data moments and the variance of the data moments.

B.2.2.1 For regression analysis

I drop all observations for which home production is not observed or for which home production is larger than 365*12. Using the python file hh_file.py I reorganize the database at the household level using household identification number. I keep only couples for which home production is known for both. I drop household for which couple variable is equal to zero for both. I drop also "couples" for which couple variable is not equal to 1 for both. I also remove couple households with more than 2 members and single households with more than 1 member.

B.2.2.2 For structural estimation

On top of the previous selection. I drop all household receiving help from family or friends. I also drop all households with some form of LTCI.

B.2.3 Estimation for transition probabilities and health

For this part I use data from 1998 onwards. I use as much data as possible.

The file used is *income_quartiles_transition_matrices_and_med.do.*

B.2.3.1 Income quartiles

I use the dataset generated by *DATA_SELECTION.DO.* I use the whole dataset to compute a measure of income quartiles. Income is pension income and its definition is similar to the one in De Nardi et al. [2010]. It is the sum of social security benefits, defined-pension benefits, annuities, veteran's benefits, welfare and food stamps. Notice that the database used is at the individual level and not at the household level. I drop the households above the 95 percentile of the wealth distribution. And I drop also households for which income is higher than the 99 percentile.

For couples, I take all men (remember the data are at the individual level) in a couple and add their income to the one of their spouse. I then compute the different thresholds for income quartiles using this dataset for men. For singles the procedure is straightforward. The correlation between income quartile and its lag is about 66%.

B.2.3.2 Transition probability

I estimate two year transition probabilities at the individual level using a multinomial logit. There exists four different outcomes in $t+1$: i) being in mob01, ii) being in mob23, iii) being in mob45, iv) being dead.Hence I create a variable called dependent equal to 1,2,3 and 4 respectively. The regressors are:

- a cubic in age
- mob23 and mob45
- mob23*age and mob45*age
- income quartile * age
- whether a woman
- whether in couple
- income quartile dummies
- whether a woman * age

- whether in couple * age
- mob23 of the spouse (if any) * couple (if single this dummy is zero)
- mob45 of the spouse (if any) * couple (if single this dummy is zero)

The pseudo R^2 of this regression is about 22%.

B.2.3.3 Medical expense risk

I want to have a measure out-of-pocket medical expense risk which removes the highest share of what may be substituted by informal care. For singles, I consider only those not in nursing homes, without LTCI, and widowed. For couples I consider only those in which no member is in nursing home, in which none of the spouses have some form of LTCI. The log of out-of-pocket medical expenditures is regressed on:

- a cubic in age
- mob23 and mob45
- mob23*age and mob45*age
- mob23 of the spouse (if any) * couple (if single this dummy is zero)
- mob45 of the spouse (if any) * couple (if single this dummy is zero)
- whether in couple
- income quartile
- income quartile * age

The R^2 is about 11%. I then generate the error term and compute its standard deviation.

B.2.3.4 Notes on usage

income_quartiles_transition_matrices_and_med.do generates a database which is used to generate the final database for the estimation. After having run this program, run:

- *hh_file.py* from the same folder

- then run *generate_db_for_python.do:* I keep only couples for which wealth and income are known. I drop households for which the couple variable is equal to zero for both. Drop also "couples" for which the couple variable is not equal to 1 for both. I also remove couple households with more than 2 members and single households with more than 1 member. I drop all households receiving help from the family and having a LTCI.
- I then perform a series of task on this sample (see next section)

B.2.4 Estimation for income, initial distribution and initial wealth

B.2.4.1 Income

In the same program I compute mean income by income quartile using an OLS regression. I regress total household income on income quartile. I do it separately for single men, single women and couples. The Rˆ2 for those regressions is higher than 65%.

B.2.4.2 Initial states

In the same program, I compute the distribution of states (15 states remember) for those less than 70. I do so separately for each income quartile.

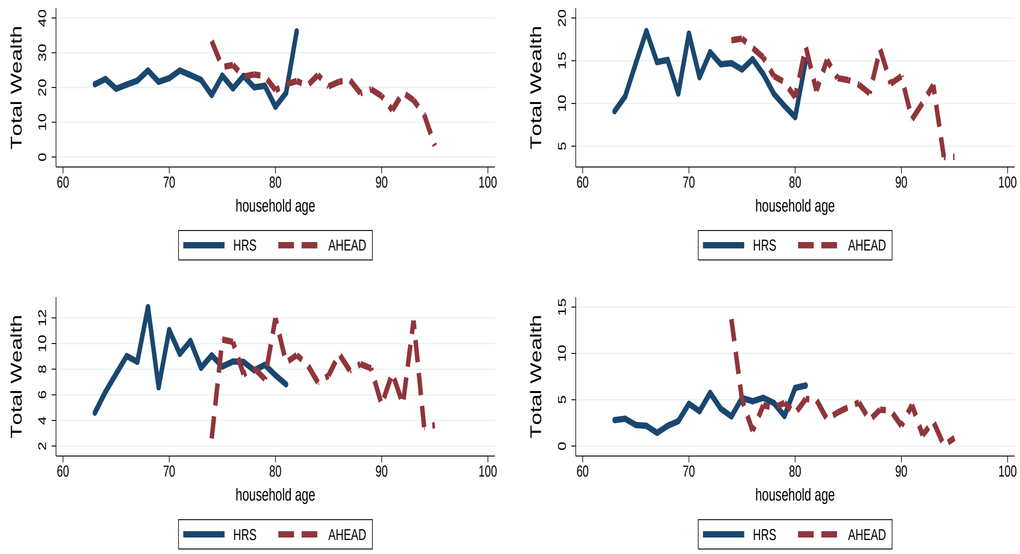
B.2.4.3 Wealth and cohort effects

There might be some issues with cohort effects in particular for wealth. However, cohort differences at similar ages seem small. To see this, I plot median wealth as a function of age separately for the HRS and AHEAD cohort for each income quartiles. The differences between the two curves at similar ages do not appear very important. In any case, they are of a comparable order. This is the main reason why I do not control for cohort differences.

B.2.4.4 Initial wealth

I perform a median regression of wealth for those less than 70 on the 15 state dummies. I do so separately for each income quartile. This gives the median of wealth for each state. I then compute the error term and generate the percentiles of the distribution of error terms (once again, for each income quartiles separately). Each household initially will then draw randomly a state from the realistic initial distribution of states. Its wealth

FIGURE B.1: Cohort effects for wealth



will then be equal to the median in its income quartile and state + a random draw from the distribution of error terms corresponding to its income quartile.

B.3 Moments

In order to compute the moments I use a method similar to the one in De Nardi et al. [2010]. I use data medians with the unit of analysis being a household. Each moment consists in the median of a variable X for households in a certain group. This group of households is characterized by a vector of dummy variables $\left(d^1, ..., d^N\right)$ with each equal to 1. Imagine that we are considering the median of wealth for households aged 63-69 in the fourth income quartile. In this case, we have X which is wealth. d_1 is the variable equal to 1 if the household is aged 63-69 and 0 otherwise. And d_2 is the variable equal to 1 if the household belongs to the fourth income quartile. Finally, notice that the sample considers only observed households.

Let $\bar{X}_{d^1,...,d^N}$ be the median of X for households in my *simulated* dataset with $\left(d^1, ..., d^N\right) = (1, ..., 1)$. Let X_i be the value of X for the ith household observation in my *original* dataset. In this case, the unconditional moment is:

$$\mathbb{E}_i\left[\left(1\left\{X_i \leq \bar{X}_{d^1,...,d^N}\right\} - \frac{1}{2}\right) \times \prod_{j=1}^{N} d_i^j\right] = 0$$

with $1\left\{X_i \leq \bar{X}_{d^1,...,d^N}\right\}$ an indicator variable equal to 1 if $X_i \leq \bar{X}_{d_1,...,d_N}$ and 0 otherwise. For some households X_i is not observed, but these are households for which at least of the elements $\left(d^1,...,d^N\right)$ is zero. In this case, the term inside the expectation will be zero. This is the case for instance when X is hours of home production of a woman and that the household considered is a single man.

Practically, the median is computed on the *simulated* data. I then compute the indicator variable and multiply it with the set of dummies for *real* households. And I then take the expectation.

For the computation of the variance, I use the median in the *original* dataset denoted $\hat{X}_{d_1,...,d_N}$. The variance for a given moment is then:

$$\begin{aligned} V\left(\hat{X}_{d^1,...,d^N}\right) = \mathbb{E}_k[(&\left(1\left\{X_k \leq \hat{X}_{d^1,...,d^N}\right\} - \frac{1}{2}\right) \times \prod_{j=1}^{N} d_k^j - \\ &\mathbb{E}_i\left[\left(1\left\{X_i \leq \hat{X}_{d^1,...,d^N}\right\} - \frac{1}{2}\right) \times \prod_{j=1}^{N} d_i^j\right])^2] \end{aligned} \tag{B.1}$$

Which can be simplified as by definition $\mathbb{E}_i\left[\left(1\left\{X_i \leq \hat{X}_{d^1,...,d^N}\right\} - \frac{1}{2}\right) \times \prod_{j=1}^{N} d_i^j\right] = 0$:

$$V\left(\hat{X}_{d^1,...,d^N}\right) = \mathbb{E}_k\left\{\left(\left(1\left\{X_k \leq \hat{X}_{d^1,...,d^N}\right\} - \frac{1}{2}\right)^2 \times \prod_{j=1}^{N} d_k^j\right)^2\right\}$$

B.4 Derivation of the model

B.4.1 The problem of a single agent

The utility function of a single individual $i = f, m$ age t is:

$$u^i\left(c_{i,t}, h_{i,t}|\mathbf{s}_{i,t}, t\right) = \frac{c_{i,t}^{1-\gamma}}{1-\gamma} - A_i\left(\mathbf{s}_{i,t}, t\right)\frac{h_{i,t}^{1+\eta}}{1+\eta}$$

$$\max_{\{c_{i,t}, h_{i,t},\}} u^i\left(c_{i,t}, h_{i,t}|\mathbf{s}_{i,t}, t\right)$$

subject to:

$$c_{i,t} = \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{1/\rho}$$

$$q_t = x_t$$

The first order condition (FOC) relative to $h_{i,t}$ is:

$$\rho h_{i,t}^{\rho-1} \frac{1-\gamma}{\rho} \frac{\left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}}}{1-\gamma} - A_i\left(\mathbf{s}_{i,t}, t\right) h_{i,t}^{\eta} = 0$$

$$h_{i,t}^{\rho-1-\eta} \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}} = A_i\left(\mathbf{s}_{i,t}, t\right) \tag{B.2}$$

This is a rootfinding problem which can be solved numerically.

I assume that $\gamma > 1-\rho$ and $\rho > 0$ as in the text. For each $A_i\left(\mathbf{s}_{i,t}, t\right) > 0$, a solution exists. Indeed:

$$\lim_{h_{i,t} \to 0^+} h_{i,t}^{\rho-1-\eta} \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}} = +\infty$$

$$\lim_{h_{i,t} \to +\infty} h_{i,t}^{\rho-1-\eta} \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}} = 0$$

The solution is moreover unique. Indeed, differentiating we obtain:

$$(\rho-1-\eta) h_{i,t}^{\rho-2-\eta} \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}} + (1-\gamma-\rho) h_{i,t}^{2\rho-2-\eta} \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-2\rho}{\rho}} < 0$$

Practically speaking, I create a sparse grid for h. For each of those h, I compute $|h_{i,t}^{\rho-1-\eta} \left(h_{i,t}^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}} - A_i\left(\mathbf{s}_{i,t}, t\right)|$. I then pick the h which minimizes this absolute difference. Then from this h I use a Newton algorithm to approximate for the solution of B.2.

It is then straightforward to compute consumption and utility.

B.4.2 The problem of a couple

From the text we know that:

$$u^{hh}\left(c_{f,t},c_{m,t},h_{f,t},h_{m,t}|\mathbf{s}_t=\left(\mathbf{s}_{f,t},\mathbf{s}_{m,t}\right),t\right)=\phi\left(\frac{c_{f,t}^{1-\gamma}}{1-\gamma}-A_f\left(\mathbf{s}_{f,t},t-\Delta t\right)\frac{h_{f,t}^{1+\eta}}{1+\eta}\right)$$
$$+\left(1-\phi\right)\left(\frac{c_{m,t}^{1-\gamma}}{1-\gamma}-A_m\left(\mathbf{s}_{m,t},t\right)\frac{h_{m,t}^{1+\eta}}{1+\eta}\right)$$

And the overall problem is:

$$\max_{\left\{c_t,c_{f,t},c_{m,t},h_t,h_{f,t},h_{m,t},q_t\right\}} u^{hh}\left(c_{f,t},c_{m,t},h_{f,t},h_{m,t}|\mathbf{s}_t=\left(\mathbf{s}_{f,t},\mathbf{s}_{m,t}\right),t\right)$$

subject to:

$$h_t=h_{f,t}+h_{m,t}$$

$$c_t=\left(h_t^{\rho}+\psi q_t^{\rho}\right)^{1/\rho}$$

$$c_t=c_{f,t}+c_{m,t}$$

$$q_t=\chi x_t$$

First: we have:

$$\phi\left(...-A_f\frac{h_{f,t}^{1+\eta}}{1+\eta}\right)+\left(1-\phi\right)\left(...-A_m\frac{\left(h_t-h_{f,t}\right)^{1+\eta}}{1+\eta}\right)$$

Taking the derivative and setting it equal to zero gives:

$$\phi A_f h_{f,t}^{\eta}=\left(1-\phi\right)A_m h_{m,t}^{\eta}$$

Hence:

$$h_{f,t}=\left(\frac{\left(1-\phi\right)A_m}{\phi A_f}\right)^{1/\eta}h_{m,t}$$

And

$$h_t=h_{f,t}+h_{m,t}=\left[1+\left(\frac{\left(1-\phi\right)A_m}{\phi A_f}\right)^{1/\eta}\right]h_{m,t}\Rightarrow h_{m,t}=\left[1+\left(\frac{\left(1-\phi\right)A_m}{\phi A_f}\right)^{1/\eta}\right]^{-1}h_t$$

$$h_t = h_{f,t} + h_{m,t} = \left[1 + \left(\frac{\phi A_f}{(1-\phi)\,A_m}\right)^{1/\eta}\right] h_{f,t} \Rightarrow h_{f,t} = \left[1 + \left(\frac{\phi A_f}{(1-\phi)\,A_m}\right)^{1/\eta}\right]^{-1} h_t$$

Utility can then be rewritten:

$$\phi\left(... - A_f \frac{h_{f,t}^{1+\eta}}{1+\eta}\right) + (1-\phi)\left(... - A_m \frac{h_{m,t}^{1+\eta}}{1+\eta}\right)$$

$$= \phi\,(...) + (1-\phi)\,(...) - \phi A_f \frac{h_{f,t}^{1+\eta}}{1+\eta} - A_m\,(1-\phi)\,\frac{h_{m,t}^{1+\eta}}{1+\eta}$$

$$= ... - \left[\phi A_f \left[1 + \left(\frac{\phi A_f}{(1-\phi)\,A_m}\right)^{1/\eta}\right]^{-1-\eta} - (1-\phi)\,A_m \left[1 + \left(\frac{(1-\phi)\,A_m}{\phi A_f}\right)^{1/\eta}\right]^{-1-\eta}\right] \frac{h_t^{1+\eta}}{1+\eta}$$

$$= ... - \Omega\,(A_m, A_f)\,\frac{h^{1+\eta}}{1+\eta}$$

with

$$\Omega\,(A_m, A_f) = \phi A_f \left[1 + \left(\frac{\phi A_f}{(1-\phi)\,A_m}\right)^{1/\eta}\right]^{-1-\eta} + (1-\phi)\,A_m \left[1 + \left(\frac{(1-\phi)\,A_m}{\phi A_f}\right)^{1/\eta}\right]^{-1-\eta}$$

$$= \left[(\phi A_f)^{-1/\eta} + ((1-\phi)\,A_m)^{-1/\eta}\right]^{-\eta}$$

We can do a similar thing for consumption:

$$\phi\left(\frac{c_{f,t}^{1-\gamma}}{1-\gamma} - ...\right) + (1-\phi)\left(\frac{(c_t - c_{f,t})^{1-\gamma}}{1-\gamma} - ...\right)$$

which gives:

$$\phi c_{f,t}^{-\gamma} = (1-\phi)\,c_{m,t}^{-\gamma}$$

Which gives:

$$c_{m,t}^{\gamma} = \frac{1-\phi}{\phi} c_{f,t}^{\gamma}$$

$$c_{m,t} = \left(\frac{1-\phi}{\phi}\right)^{1/\gamma} c_{f,t}$$

Leading to:

$$c_t = c_{f,t} + c_{m,t} = \left(1 + \left(\frac{1-\phi}{\phi}\right)^{1/\gamma}\right) c_{f,t} \Rightarrow c_{f,t} = \left(1 + \left(\frac{1-\phi}{\phi}\right)^{1/\gamma}\right)^{-1} c_t$$

$$c_t = c_{f,t} + c_{m,t} = \left(1 + \left(\frac{\phi}{1-\phi}\right)^{1/\gamma}\right) c_{m,t} \Rightarrow c_{m,t} = \left(1 + \left(\frac{\phi}{1-\phi}\right)^{1/\gamma}\right)^{-1} c_t$$

So we can rewrite our utility as:

$$\phi \frac{c_{f,t}^{1-\gamma}}{1-\gamma} + (1-\phi) \frac{c_{m,t}^{1-\gamma}}{1-\gamma} + ...$$

$$= \phi \left(1 + \left(\frac{1-\phi}{\phi}\right)^{1/\gamma}\right)^{\gamma-1} \frac{c_t^{1-\gamma}}{1-\gamma} + (1-\phi) \left(1 + \left(\frac{\phi}{1-\phi}\right)^{1/\gamma}\right)^{\gamma-1} \frac{c_t^{1-\gamma}}{1-\gamma} + ...$$

$$= \left[\phi \left(1 + \left(\frac{1-\phi}{\phi}\right)^{1/\gamma}\right)^{\gamma-1} + (1-\phi) \left(1 + \left(\frac{\phi}{1-\phi}\right)^{1/\gamma}\right)^{\gamma-1}\right] \frac{c_t^{1-\gamma}}{1-\gamma} + ...$$

$$= \Phi \frac{c_t^{1-\gamma}}{1-\gamma} + ...$$

with

$$\Phi = \left[\phi \left(1 + \left(\frac{1-\phi}{\phi}\right)^{1/\gamma}\right)^{\gamma-1} + (1-\phi) \left(1 + \left(\frac{\phi}{1-\phi}\right)^{1/\gamma}\right)^{\gamma-1}\right]$$

The utility function of the household is then:

$$= \Phi \frac{c_t^{1-\gamma}}{1-\gamma} - \Omega\left(A_m, A_f\right) \frac{h^{1+\eta}}{1+\eta}$$

The FOC relative to h is then:

$$\Phi \rho h_t^{\rho-1} \frac{1-\gamma}{\rho} \frac{\left(h_t^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}}}{1-\gamma} - \Omega\left(A_m, A_f\right) h_t^{\eta} = 0$$

Which gives:

$$h_t^{\rho-\eta-1} \left(h_t^{\rho} + \psi q_t^{\rho}\right)^{\frac{1-\gamma-\rho}{\rho}} = \Omega\left(A_m, A_f\right) \Phi^{-1}$$

Which is the FOC in the paper.

The solution method for h is similar to the case for singles.

Once h is solved for, it is easy to compute all the variables of interests.

B.4.3 The problem of a couple with no insurance

The utility in this case is:

$$u^{hh}\left(c_{f,t}, c_{m,t}, h_{f,t}, h_{m,t} | \mathbf{s}_t = \left(\mathbf{s}_{f,t}, \mathbf{s}_{m,t}\right), t\right) = \phi \left(\frac{c_{f,t}^{1-\gamma}}{1-\gamma} - A_f\left(\mathbf{s}_{f,t}, t - \Delta t\right) \frac{h_{f,t}^{1+\eta}}{1+\eta} \right)$$

$$+ (1-\phi) \left(\frac{c_{m,t}^{1-\gamma}}{1-\gamma} - A_m\left(\mathbf{s}_{m,t}, t\right) \frac{\left(h_{m,t}^{\star}\left(x_t, \mathbf{s}_{m,t}, t\right)\right)^{1+\eta}}{1+\eta} \right)$$

The constraints that apply in this case are:

$$h_t = h_{f,t} + h_{m,t}^{\star}\left(x_t, \mathbf{s}_{m,t}, t\right)$$

$$c_t = \left(h_t^{\rho} + \psi q_t^{\rho}\right)^{1/\rho}$$

$$c_t = c_{f,t} + c_{m,t}$$

$$q_t = \chi x_t$$

The problem can be simply rewritten as:

$$\Phi \frac{c_t^{1-\gamma}}{1-\gamma} - \phi A_f \frac{h_{f,t}^{1+\eta}}{1+\eta} - (1-\phi) A_m \frac{\left(h_{m,t}^{\star}\left(x_t, \mathbf{s}_{m,t}, t\right)\right)^{1+\eta}}{1+\eta}$$

subject to:

$$h_t = h_{f,t} + h^{\star}_{m,t}\left(x_t, \mathbf{s}_{m,t}, t\right)$$

$$c_t = \left(h_t^{\rho} + \psi q_t^{\rho}\right)^{1/\rho}$$

$$c_t = c_{f,t} + c_{m,t}$$

$$q_t = \chi x_t$$

Then the optimality condition to find the hours of the woman is:

$$\Phi\left(h_{f,t} + h^{\star}_{m,t}\left(x_t, \mathbf{s}_{m,t}, t\right)\right)^{\rho-1}\left(\left(h_{f,t} + h^{\star}_{m,t}\left(x_t, \mathbf{s}_{m,t}, t\right)\right)^{\rho} + \psi q_t^{\rho}\right)^{(1-\gamma-\rho)/\rho} = \phi A_f h_{f,t}^{\eta}$$

Then we just need to solve for this root finding problem.

B.5 Robustness Main Results from the Model

Here, I assess the robustness of the results in 4.6.3 by performing similar experiments but with calibration (III) of table 4.9.

In figure B.2, I show how wealth patterns differ for couples in the third and fourth income quartiles if the insurance channel is removed[4].

We see that removing this insurance channel has only minor effects on life cycle behaviours. Even though wealth tends to rise when this insurance channel is removed, the change in wealth patterns is fairly small[5]. This result is similar to the one in the main text.

I now compare the model under the calibration of column (III) of table 4.9 to a similar model but in which $A_m = A_f \exp\left(\delta^o_m - \delta^o_f\right)$. The results from this exercise are displayed in figure B.3. We see that changes in dissavings patterns are larger here and slightly larger than what was found in the main text. But the effect is quite moderate until age 85-89.

[4]Removing the insurance channel consists as in the text to replace u^{hh} by $\tilde{u}^{hh}$ in the intertemporal problem.

[5]The fact that wealth of couples in the third income quartile is higher than wealth of those in the fourth income quartile at advanced ages is mainly due to differences in pension income. As couples in the fourth wealth quartile have higher pension income, they are also better protected against risk.

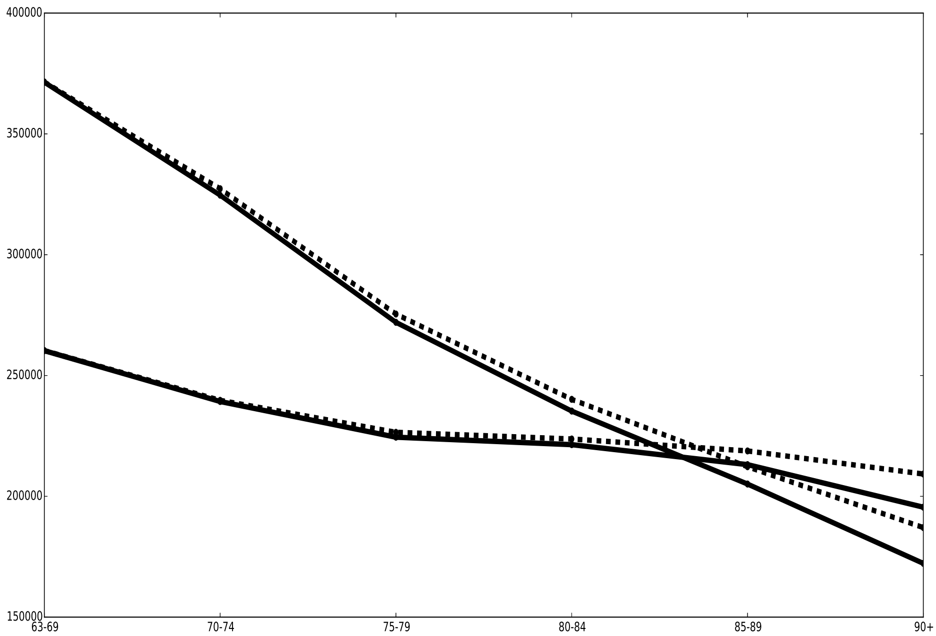


FIGURE B.2: The effect of spousal insurance on wealth patterns

The y-axis is wealth and the x-axis is age. I use calibration (III) of table 4.9. The continuous lines represent wealth patterns of couple households in the third and fourth income quartiles in the model with insurance. The dotted lines are similar but for the model without insurance.

Finally, I try to assess what would be the effect of having men facing similar longevity and disability risks than women. Figure B.4 is similar to figure 4.12 but with the calibration (III) of table 4.9. The results are here quite similar to those in the main text.

B.6 Numerical Solution

The solution method is standard. I work with two grids: a grid for cash-on-hand with 30 non equally spaced grid points in order to have higher density at lower values; and a grid for expenditures with 130 non-equally spaced points in order to have higher density around lower values. The stochastic component of medical expenditures is represented by three grid points. Such grid points and the integration over this dimension follow the Gauss-Hermite quadrature method. For interpolation between grid points on the cash-on-hand grid I use linear interpolation. Increasing the number of grid points did not appear to affect substantially the decision rules. In order to avoid some numerical problems stemming from division by large numbers I solve the model expressing h in 1,000 of hours and q in \$10,000.

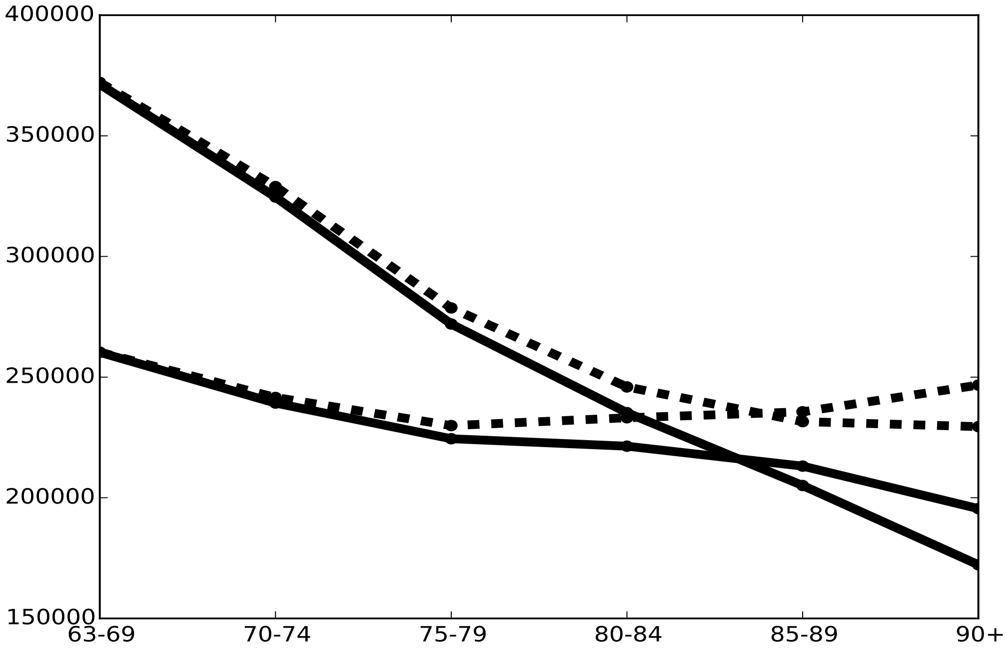


Figure B.3: The effect of not perfectly correlated disability risk

The y-axis is wealth and the x-axis is age. I use calibration (III) of table 4.9. The continuous lines represent wealth patterns of couple households in the third and fourth income quartiles. The dotted lines are similar nut for a model in which $A_m = A_f \exp\left(\delta^o_m - \delta^o_f\right)$.

The model is solved backwards starting from age T. For each level of cash-on-hand on the grid, for each exogenous state and age, I find the decision rules. Those decision rules are then used when simulating the model forward. I first store a set of household histories regarding the different shocks. These simulated histories are then used in all the estimation process. Using the decision rules, I can generate different databases which are used to see if the model fits the data well. For levels of cash-on-hand at the beginning of t which do not lie on the grid, I use linear interpolation to determine the decision rule.

Performing these different steps takes about 40 seconds on a laptop with 16GB of RAM and Core I7 processor. All codes are in Python. For the estimation, I first use a sparse grid for several of the parameters. For some others, I give educated guesses conditional of those parameters. This allows to limit the number of computations. I then pick the set of parameters which give the ten lowest values for the GMM criterion used. From each one of them, I then perform a Nelder-Mead simplex algorithm. I then pick the vector of parameter which gives the lowest value for the GMM criterion.

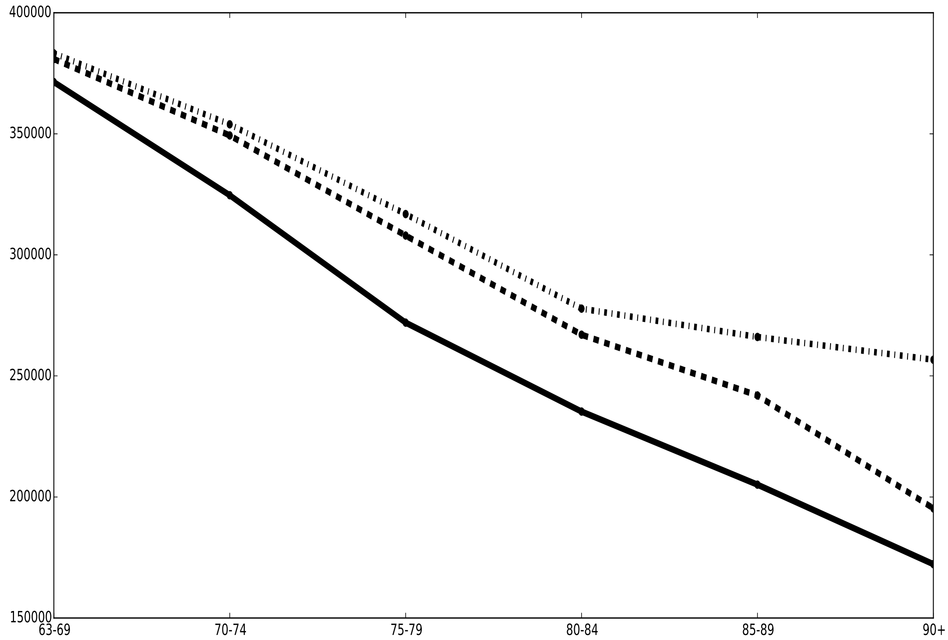


FIGURE B.4: The effect of longevity

The y-axis is wealth and the x-axis is age. I use calibration (III) of table 4.9. The continuous line represents wealth patterns of couple households in the fourth income quartile with the original transition matrix. The dotted line is similar but with a transition matrix similar for men and women. The dotted-dashed line uses this latter transition matrix, and on top of this I assume that $A_m = A_f \exp\left(\delta_m^o - \delta_f^o\right)$.

Appendix C

Appendix to "Sectoral Productivity, Collateral Constraints, and Housing Markets"

C.1 First order conditions

The first order conditions relative to agent 1 are:

$$-\frac{j}{p_t l_t h_{1t} x_{1t-1}} + \frac{1}{c_{1t}} = 0 \tag{C.1}$$

$$-\frac{p_t}{c_{1t}} + \beta_1 E_t \left[\frac{p_{t+1}\left(1-\delta_x + l_{t+1}\right)}{c_{1t+1}} \right] = 0 \tag{C.2}$$

$$-\left(1+\phi_c\left(k^c_{1t} - k^c_{1t-1}\right)\right)\frac{1}{c_{1t}} + \beta_1 E_t \left[\left(r^c_{t+1} + 1 - \delta_c + \phi_c\left(k^c_{1t+1} - k^c_{1t}\right)\right)\frac{1}{c_{1t+1}} \right] = 0 \tag{C.3}$$

$$-\left(1+\phi_h\left(k^h_{1t} - k^h_{1t-1}\right)\right)\frac{1}{c_{1t}} + \beta_1 E_t \left[\left(r^h_{t+1} + 1 - \delta_h + \phi_h\left(k^h_{1t+1} - k^h_{1t}\right)\right)\frac{1}{c_{1t+1}} \right] = 0 \tag{C.4}$$

$$-\frac{p^q_t}{c_{1t}} + \beta_1 E_t \left[\frac{p^q_{t+1}\left(1 + l^q_{t+1}\right)}{c_{1t+1}} \right] = 0 \tag{C.5}$$

$$-\frac{-\left(1+\phi_d\left(d_{1t} - d_{1t-1}\right)\right)}{c_{1t}} + \beta_1 E_t \left[\frac{\left(R^d_t + \phi_d\left(d_{1t+1} - d_{1t}\right)\right)}{c_{1t+1}} \right] = 0 \tag{C.6}$$

$$-\chi_1 n^{\eta-1}_{1t} + \frac{w_t}{c_{1t}} = 0 \tag{C.7}$$

Denoting μ_{2t} the Lagrange multiplier on the no borrowing constraint (5.15) multiplied by c_{2t}, the first-order conditions of agent 2 are:

$$-\chi_2 n^{\eta-1}_{2t} + \frac{w_t}{c_{2t}} = 0 \tag{C.8}$$

$$-p_t + \mu_{2t} m \left(1-\delta_x\right) \mathbb{E}_t \left[p_{t+1}\right] + \beta_2 j \frac{c_{2t}}{x_{2t}} + \beta_2 \left(1-\delta_x\right) \mathbb{E}_t \left[\frac{c_{2t}}{c_{2t+1}} p_{t+1} \right] = 0 \tag{C.9}$$

$$-\beta_2 \mathbb{E}_t \left[\frac{c_{2t}}{c_{2t+1}} R^d_{t-1} \right] - \mu_{2t} + 1 = \tag{C.10}$$

The first order conditions of agent 3 are:

$$-\chi_3 n^{\eta-1}_{3t} + \frac{w_t}{c_{3t}} = 0 \tag{C.11}$$

$$-\frac{p_t l_t}{c_{3t}} + j \frac{1}{z_{3t}} = 0 \tag{C.12}$$

Maximization of profits of firms in consumption implies the first-order conditions:

$$\gamma_c \frac{Y_{ct}}{K_{ct}} = r_t^c \tag{C.13}$$

$$\alpha_c \frac{Y_{ct}}{L_{ct}} = w_t \tag{C.14}$$

Maximization of profits in construction implies the first-order conditions:

$$\gamma_h \frac{Y_{ht}}{K_{ht}} = \frac{r_t^h}{p_t} \tag{C.15}$$

$$\alpha_h \frac{Y_{ht}}{L_{ht}} = \frac{w_t}{p_t} \tag{C.16}$$

$$(1 - \alpha_h - \gamma_h) \frac{Y_{ht}}{Q_{ht}} = \frac{p_t^q l_t^q}{p_t} \tag{C.17}$$

C.2 Steady State

The steady state equations are summarized in this part.

C.2.1 Agent 1

We have:

$$\frac{jc_1}{plx_1} = h_1$$

$$-1 + \beta_1 (1 - \delta_x + l) = 0$$

$$-1 + \beta_1 (r^c + 1 - \delta^c) = 0$$

$$-1 + \beta_1 \left(r^h + 1 - \delta^h\right) = 0$$

$$-1 + \beta_1 (1 + l^q) = 0$$

$$-1 + R^d \beta_1 = 0$$

$$\frac{w}{c_1} - \chi_1 n_1^{\eta-1} = 0$$

$$p (\delta_x - l (1 - h_1)) x_1 + k_1^c (\delta^c - r^c) + k_1^h \left(\delta^h - r^h\right) + c_1 + \left(R^d - 1\right) d_1 - wn_1 - p^q l^q q = 0$$

C.2.2 Agent 2

$$\beta_2 j \frac{c_2}{x_2} - p + \beta_2 p (1 - \delta_x) + \mu_2 m (1 - \delta_x) p = 0$$

$$\mu_2 = 1 - \beta_2 R^d$$

$$\frac{w}{c_2} - \chi_2 n_2^{\eta-1} = 0$$

$$\mu_2 = 1 - \beta_2 R^d$$

$$d_2 = m (1 - \delta_x) x_2 p$$

C.2.3 Agent 3

$$-\frac{pl}{c_3} + j\frac{1}{z_3} = 0$$
$$\frac{w}{c_3} - \chi_3 n_3^{\eta-1} = 0$$

$$c_3 = wn_3 - plz_3$$

C.2.4 Firms

Notice that A_h^L and A_c^L are set to 1.

$$\gamma_h \frac{Y_h}{K_h} = \frac{r^h}{p}$$
$$\alpha_h \frac{Y_h}{L_h} = \frac{w}{p}$$
$$(1-\alpha_h-\gamma_h)\frac{Y_h}{q} = \frac{p^q l^q}{p}$$

$$\gamma_c \frac{Y_c}{K_c} = r^c$$
$$\alpha_c \frac{Y_c}{L_c} = w$$

$$Y_c = K_c^{\gamma_c} L_c^{\alpha_c}$$
$$Y_h = K_h^{\gamma_h} L_h^{\alpha_h} q^{1-\alpha_h-\gamma_h}$$

C.2.5 Equilibrium

$$K_h = k_1^h$$

$$K_c = k_1^c$$

$$L_h + L_c = n_1 + \omega_2 n_2 + \omega_3 n_3$$

$$d_1 + \omega_2 d_2 = 0$$

$$Q = q = \bar{q}$$

$$\omega_3 z_3 = (1 - h_1)\, x_1$$

$$\delta^c k_1^c + \delta^h k_1^h = Y_c - c_1 - \omega_2 c_2 - \omega_3 c_3$$

$$x_1 + \omega_2 x_2 = (1 - \delta_x)\, x_1 + (1 - \delta_x)\, \omega_2 x_2 + Y_h$$

C.3 Calibration and derivation of the steady state

In this part, we show the derivations to be able to compute the steady state and how it is linked to our calibration. The procedure below is repeated for different values of j and m such as to have a ratio of residential real estate over output and a ratio of debt over output in line with our targets. We assume throughout that $A_c^L = A_h^L = 1$ and thus omit those terms.

Using the equations of agent 1, we have:

$$\beta_1 = \frac{1}{R^d}$$

and

$$l^q = R^d - 1$$

Fixing a value for R^d, we obtain the value for β_1 and l^q. Fixing a steady state value for the rent price ratio, we obtain δ_x as:

$$\delta_x = l + 1 - \frac{1}{\beta_1}$$

We can also determine χ_3 using the steady state value for n_3:

$$n_3^{\eta} = \frac{(1+j)}{\chi_3}$$

We can also easily determine r^c and r^h:

$$r^c = \frac{1}{\beta_1} + \delta^c - 1$$

$$r^h = \frac{1}{\beta_1} + \delta^h - 1$$

We now need to do some algebra to determine some equilibrium quantities. We first have the different values for the variables for agent 2. Notice that p and w will be determined later:

First,

$$\mu_2 = 1 - \beta_2 R^d$$

Then,

$$-p + j\frac{c_2}{x_2} + \mu_2 m p \left(1 - \delta_x\right) + \beta_2 p \left(1 - \delta_x\right) = 0$$

$$\Rightarrow \frac{jc_2}{px_2} = 1 - \beta_2 (1 - \delta_x) - \left(1 - \beta_2 R^d\right) m (1 - \delta_x)$$

$$\Rightarrow px_2 = \frac{jc_2}{1 - \beta_2 (1 - \delta_x) - (1 - \beta_2 R^d) m (1 - \delta_x)}$$

The BC of agent 2 is:

$$p\delta_x x_2 + \left(R^d - 1\right) d_2 + c_2 - wn_2 = 0$$

Moreover

$$d_2 = m (1 - \delta_x) x_2 p$$

So we have:

$$p\delta_x x_2 + \left(R^d - 1\right) m (1 - \delta_x) x_2 p + c_2 - wn_2 = 0$$

$$\Rightarrow px_2 = \frac{wn_2 - c_2}{\delta_x + (R^d - 1) m (1 - \delta_x)}$$

Combining the expressions we obtain:

$$\frac{wn_2 - c_2}{\delta_x + (R^d - 1) m (1 - \delta_x)} = \frac{jc_2}{1 - \beta_2 (1 - \delta_x) - (1 - \beta_2 R^d) m (1 - \delta_x)}$$

$$\Rightarrow c_2 = wn_2 \left[\frac{j \left(\delta_x + \left(R^d - 1\right) m (1 - \delta_x)\right)}{1 - \beta_2 (1 - \delta_x) - (1 - \beta_2 R^d) m (1 - \delta_x)} + 1 \right]^{-1}$$

We then have:

$$\Rightarrow px_2 = \frac{wn_2 - c_2}{\delta_x + (R^d - 1) m (1 - \delta_x)}$$

$$d_2 = m (1 - \delta_x) x_2 p$$

$$\chi_2 = \frac{wn_2^{1-\eta}}{c_2}$$

And then for agent 3, we get:

$$\chi_3 = \frac{w}{c_3} n_3^{1-\eta}$$

$$c_3 = \frac{wn_3}{1 + j}$$

$$z_3 = j \frac{c_3}{pl}$$

$$c_3 = \frac{wn_3}{1 + j}$$

$$plz_3 = j\frac{wn_3}{1+j}$$

Now we need to determine the quantity of labour in each sector. We use the following equilibrium conditions

$$\omega_3 z_3 = (1-h_1)\, x_1$$

$$\delta^c K_c + \delta^h K_h = Y_c - c_1 - \omega_2 c_2 - \omega_3 c_3$$

$$\delta_x \left(x_1 + \omega_2 x_2\right) = Y_h$$

Using the FOC from agent 1, we have:

$$\delta^c K_c + \delta^h K_h = Y_c - \frac{plx_1 h_1}{j} - \omega_2 c_2 - \omega_3 c_3$$

$$\delta^c K_c + \delta^h K_h = Y_c - \frac{pl}{j} x_1 h_1 - \omega_2 c_2 - \omega_3 c_3$$

$$\delta^c K_c + \delta^h K_h = Y_c - \frac{pl}{j}\left(x_1 - \omega_3 z_3\right) - \omega_2 c_2 - \omega_3 c_3$$

$$\delta^c K_c + \delta^h K_h = Y_c - \frac{pl}{j}\left(\frac{Y_h}{\delta_x} - \omega_2 x_2 - \omega_3 z_3\right) - \omega_2 c_2 - \omega_3 c_3$$

And then we use the FOC from the firms to rewrite as a function of L_h and L_c

$$\delta^c \frac{\gamma_c}{\alpha_c}\frac{w}{r^c} L_c + \delta^h \frac{\gamma_h}{\alpha_h}\frac{w}{r^h} L_h = \frac{wL_c}{\alpha_c} - \frac{pl}{j}\left(\frac{1}{\delta_x}\frac{wL_h}{p\alpha_h} - \omega_2 x_2 - \omega_3 z_3\right) - \omega_2 c_2 - \omega_3 c_3$$

And then algebra

$$\delta^c \frac{\gamma_c}{\alpha_c}\frac{w}{r^c}\left(L - L_h\right) + \delta^h \frac{\gamma_h}{\alpha_h}\frac{w}{r^h} L_h = \frac{w}{\alpha_c}\left(L - L_h\right) - \frac{pl}{j}\left(\frac{1}{\delta_x}\frac{w}{p\alpha_h} L_h - \omega_2 x_2 - \omega_3 z_3\right) - \omega_2 c_2 - \omega_3 c_3$$

$$\delta^c \frac{\gamma_c}{\alpha_c}\frac{w}{r^c}\left(L - L_h\right) + \delta^h \frac{\gamma_h}{\alpha_h}\frac{w}{r^h} L_h + \frac{1}{\delta_x}\frac{w}{\alpha_h}\frac{l}{j} L_h - \omega_2 \frac{pl}{j} x_2 - \omega_3 \frac{pl}{j} z_3 = \frac{w}{\alpha_c}\left(L - L_h\right) - \omega_2 c_2 - \omega_3 c_3$$

After some manipulations, we get:

$$L_h = \frac{\left(\frac{1}{\alpha_c} - \delta^c \frac{\gamma_c}{\alpha_c}\frac{1}{r^c}\right) wL - \omega_2 c_2 - \omega_3 c_3 + \frac{pl}{j}\omega_2 x_2 + \frac{pl}{j}\omega_3 z_3}{w\left(\frac{1}{\alpha_c} - \delta^c \frac{\gamma_c}{\alpha_c}\frac{1}{r^c} + \delta^h \frac{\gamma_h}{\alpha_h}\frac{1}{r^h} + \frac{1}{\delta_x}\frac{1}{\alpha_h}\frac{l}{j}\right)}$$

Using the expressions we obtained for c_2, x_2, c_3 and z_3 as a function of n_2 and n_3, we can get rid of the wage and obtain:

$$L_h = \frac{\left(\frac{1}{\alpha_c} - \delta^c \frac{\gamma_c}{\alpha_c}\frac{1}{r^c}\right) L - \omega_2 n_2 \left[\frac{j\left(\delta_x + \left(R^d-1\right)m(1-\delta_x)\right)}{1-\beta_2(1-\delta_x)-\left(1-\beta_2 R^d\right)m(1-\delta_x)} + 1\right]^{-1}}{\left(\frac{1}{\alpha_c} - \delta^c \frac{\gamma_c}{\alpha_c}\frac{1}{r^c} + \delta^h \frac{\gamma_h}{\alpha_h}\frac{1}{r^h} + \frac{1}{\delta_x}\frac{1}{\alpha_h}\frac{l}{j}\right)}$$

$$+ \frac{\frac{l}{j}\omega_2 n_2 \frac{1-\left[\frac{j\left(\delta_x+\left(R^d-1\right)m(1-\delta_x)\right)}{1-\beta_2(1-\delta_x)-\left(1-\beta_2 R^d\right)m(1-\delta_x)}+1\right]^{-1}}{\delta_x+\left(R^d-1\right)m(1-\delta_x)}}{\left(\frac{1}{\alpha_c} - \delta^c \frac{\gamma_c}{\alpha_c}\frac{1}{r^c} + \delta^h \frac{\gamma_h}{\alpha_h}\frac{1}{r^h} + \frac{1}{\delta_x}\frac{1}{\alpha_h}\frac{l}{j}\right)}$$

We can then use the value for L_h to get the equilibrium price of land as a function of wage. First notice that:

$$\bar{q} = \frac{1-\alpha_h-\gamma_h}{\alpha_h}\frac{w}{p^q l^q} L_h$$

We thus have:

$$\frac{p^q}{w} = \left(l^q \bar{q}\right)^{-1} \frac{1-\alpha_h-\gamma_h}{\alpha_h} L_h$$

We can rewrite this last formula as:

$$p^q = \zeta w$$

with $\zeta = \left(l^q \bar{q}\right)^{-1} \frac{1-\alpha_h-\gamma_h}{\alpha_h} L_h$.

Then we use the first order conditions from the firms to get w and p. Plugging the FOC of the firm in the production functions we have:

$$1 = \left(\frac{\gamma_c}{r^c}\right)^{\gamma_c} \left(\frac{\alpha_c}{w}\right)^{\alpha_c}$$

$$\Rightarrow w = \left[(\gamma_c)^{\gamma_c} (\alpha_c)^{\alpha_c} (r^c)^{-\gamma_c}\right]^{\frac{1}{\alpha_c}}$$

Using a similar procedure in the housing sector gives:

$$Y_h = A_h \left(\frac{\gamma_h}{r^h} p Y_h\right)^{\gamma_h} \left(\frac{\alpha_h}{w} p Y_h\right)^{\alpha_h} \left(\frac{1-\alpha_h-\gamma_h}{p^q l^q} p Y_h\right)^{1-\alpha_h-\gamma_h}$$

$$p^{-1} = A_h (\alpha_h)^{\alpha_h} (\gamma_h)^{\gamma_h} (1-\alpha_h-\gamma_h)^{1-\alpha_h-\gamma_h} \left(r^h\right)^{-\gamma_h} w^{\gamma_h-1} (\zeta l^q)^{\alpha_h+\gamma_h-1}$$

Hence, we have found the equilibrium wage and house prices.

Now that we have wages and house prices we can determine easily all the equilibrium values in steady state:

$$c_2 = wn_2 \left[\frac{j\left(\delta_x + \left(R^d-1\right)m(1-\delta_x)\right)}{1-\beta_2(1-\delta_x)-(1-\beta_2 R^d)\,m(1-\delta_x)} + 1 \right]^{-1}$$

$$x_2 = p^{-1}\frac{wn_2 - c_2}{\delta_x + (R^d-1)\,m(1-\delta_x)}$$

$$d_2 = m(1-\delta_x)\,x_2 p$$

$$\chi_2 = \frac{wn_2^{1-\eta}}{c_2}$$

And then for agent 3, we get:

$$\chi_3 = \frac{w}{c_3}n_3^{1-\eta}$$

$$c_3 = \frac{wn_3}{1+j}$$

$$z_3 = j\frac{c_3}{pl}$$

$$c_3 = \frac{wn_3}{1+j}$$

Now it is straightforward:

$$L_c = L - L_h$$

$$K_h = \frac{\gamma_h}{\alpha_h}\frac{w}{r^h}L_h$$

Now we have, given our normalization that $\bar{q} = 1$:

$$\frac{q}{L_h} = \frac{1-\alpha_h-\gamma_h}{\alpha_h}\frac{w}{p^q l^q} \Rightarrow l^q = \frac{1-\alpha_h-\gamma_h}{\alpha_h}\frac{w}{p^q \bar{q}}L_h$$

$$Y_h = K_h^{\alpha_h} L_h^{\alpha_h} q^{1-\alpha_h-\gamma_h}$$

$$K_c = \frac{\gamma_c}{\alpha_c}\frac{w}{r^c}L_c$$

$$Y_c = K_c^{\alpha_c} L_c^{\alpha_c}$$

$$k_1^h = K_h$$

$$k_1^c = K_c$$

$$x_1 = \frac{Y_h}{\delta_x} - \omega_2 x_2$$

$$c_1 = Y_c - \omega_2 c_2 - \omega_3 c_3 - \delta^c k_1^c - \delta^h k_1^h$$

$$h_1 = 1 - \frac{\omega_3 z_3 + z_c}{x_1}$$

$$\chi_1 = \frac{w n_1^{1-\eta}}{c_1}$$

Residential real estate over GDP is simply given by:

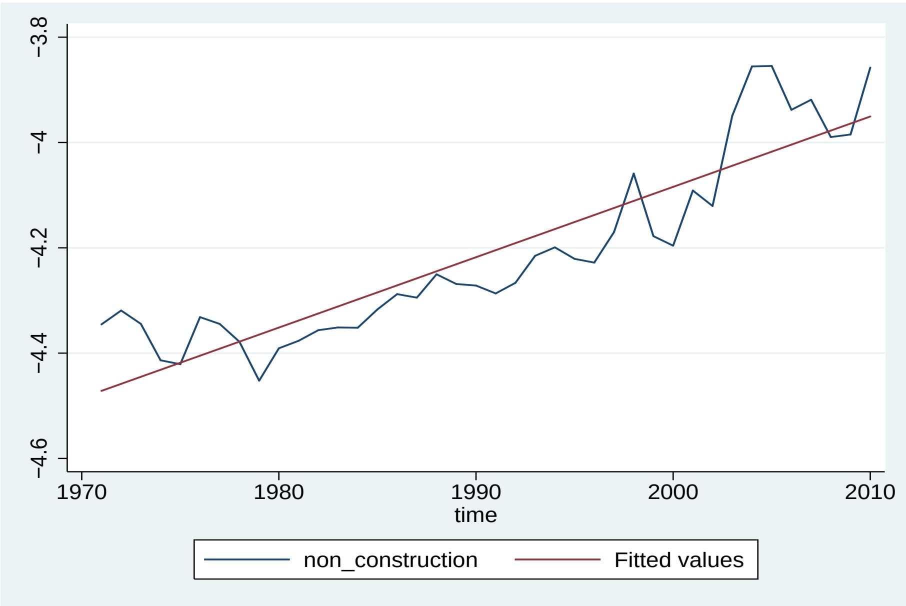
$$\frac{p\left(x_1 h_1 + \omega_2 x_2 + \omega_3 z_3\right)}{Y_c + pY_h}$$

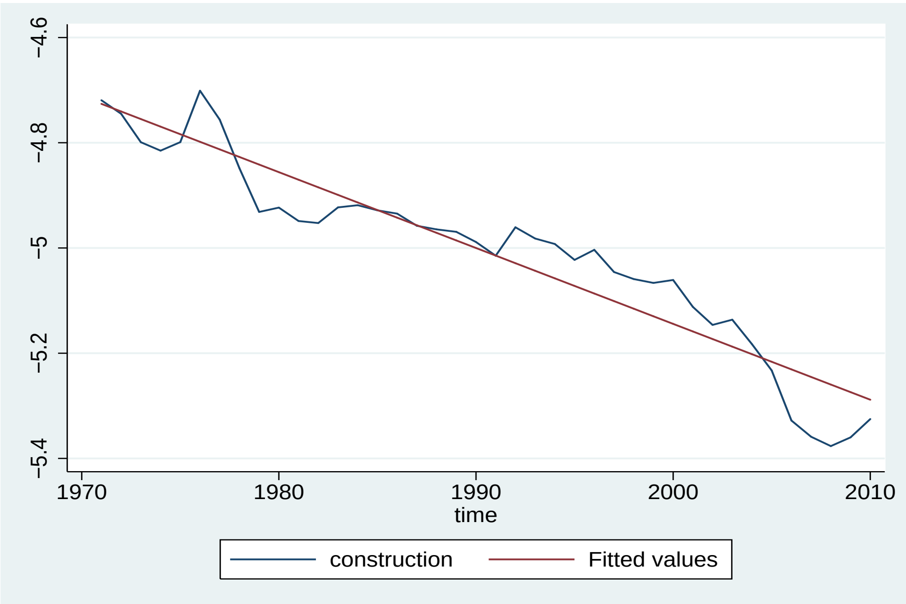
and debt over GDP is given by:

$$\frac{Y}{d_2}$$

C.4 Evolution of Productivity

The first graph shows the evolution of labour productivity in the non construction sector. The second shows the evolution of productivity in the construction sector. As can be seen the early 2000 display a very strong divergence in the two patterns, with an acceleration in the diverging trends. The long run diverging trend might be due to the fact that there has been little innovation in the construction sector and that there has been a shortage of skilled workers in this sector (see Huang et al., 2009).





Bibliography

Aguiar, M. and Hurst, E. (2005). Consumption versus Expenditure. *Journal of Political Economy*, 113(5):919–948.

Aguiar, M. and Hurst, E. (2007). Life-cycle prices and production. *American Economic Review*, 97(5):1533–1559.

Aguiar, M. and Hurst, E. (2013). Deconstructing Life Cycle Expenditure. *Journal of Political Economy*, 121(3):437–492.

Alessie, R., Angelini, V., and Pasini, G. (2014). Is It True Love? Altruism Versus Exchange in Time and Money Transfers. *De Economist*, 162(2):193–213.

Ameriks, J., Caplin, A., Laufer, S., and Van Nieuwerburgh, S. (2011). The Joy of Giving or Assisted Living? Using Strategic Surveys to Separate Public Care Aversion from Bequest Motives. *Journal of Finance*, 66(2):519–561.

Apps, P. F. and Rees, R. (1988). Taxation and the household. *Journal of Public Economics*, 35(3):355–369.

Attanasio, O., Low, H., and Sánchez-Marcos, V. (2008). Explaining Changes in Female Labor Supply in a Life-Cycle Model. *The American Economic Review*, 98(4):1517–1552.

Attanasio, O. and Weber, G. (1995). Is consumption growth consistent with intertemporal optimization? evidence from the consumer expenditure survey. *Journal of Political Economy*, 103(6):1121–1157.

Barczyk, D. and Kredler, M. (2014). Evaluating Long-Term Care Policy Options , Taking the Family Seriously. *Working Paper*.

Becker, G. S. (1965). A Theory of the Allocation of Time. *The Economic Journal*, 75(299):493–517.

Becker, G. S. (1974). A Theory of Social Interactions. *Journal of Political Economy*, 82(6):1063–1093.

Bernheim, B. D., Shleifer, A., and Summers, L. H. (1985). The Strategic Bequest Motive. *Journal of Political Economy*, 93(6):1045–1076.

Bolin, K., Lindgren, B., and Lundborg, P. (2008). Informal and formal care among single-living elderly in Europe. *Health Economics*, 17(3):393–409.

Bonsang, E. (2009). Does informal care from children to their elderly parents substitute for formal care in Europe? *Journal of Health Economics*, 28(1):143–154.

Bonsang, E. and van Soest, A. (2014). Home Production and Retirement in Couples : A Panel Data Analysis. *Working Paper*, pages 1–38.

Brown, J. R. and Finkelstein, A. (2007). Why is the market for long-term care insurance so small? *Journal of Public Economics*, 91(10):1967–1991.

Brown, J. R. and Finkelstein, A. (2008). The Interaction of Public and Private Insurance: Medicaid and the Long-Term Care Insurance Market. *American Economic Review*, 98(3):1083–1102.

Brown, J. R. and Finkelstein, A. (2009). The Private Market for Long-Term Care Insurance in the United States: A Review of the Evidence. *Journal of Risk and Insurance*, 76(1):5–29.

Brown, S. L. and Lin, I. F. (2012). The gray divorce revolution: Rising divorce among middle-aged and older adults, 1990-2010. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, 67 B(6):731–741.

Brown, S. L., Lin, I.-f., and Payne, K. K. (2014). Age Variation in the Divorce Rate , 1990-2012. *Family Profiles, National Center for Family & Marriage Research*, FP-14-16.

Browning, M., Chiappori, P. A., and Lewbel, A. (2013). Estimating consumption economies of scale, adult equivalence scales, and household bargaining power. *Review of Economic Studies*, 80(4):1267–1303.

Browning, M. and Gø rtz, M. (2012). Spending Time and Money within the Household. *Scandinavian Journal of Economics*, 114(3):681–704.

Campbell, J. R. and Hercowitz, Z. (2006). The Role of Collateralized Household Debt in Macroeconomic Stabilization. *Unpublished*.

Campbell, J. Y. and Cocco, J. a. F. (2003). Household Risk Management and Optimal Mortgage Choice. *The Quarterly Journal of Economics*, 118(4):1449–1494.

Campbell, J. Y., Giglio, S., and Pathak, P. (2011). Forced sales and house prices. *American Economic Review*, 101(5):2108–2131.

Carroll, C. D. (1997). Buffer-Stock Saving and the Life Cycle/Permanent Income Hypothesis. *The Quarterly Journal of Economics*, 112(1):1–55.

Cherchye, L., De Rock, B., and Vermeulen, F. (2012). Married with children: A collective labor supply model with detailed time use and intrahousehold expenditure information. *American Economic Review*, 102(7):3377–3405.

Chiappori, P.-A. (1988). Rational Household Labor Supply. *Econometrica*, 56(1):63–90.

Chiappori, P.-A. (1992). Collective Labor Supply and Welfare. *Journal of Political Economy*, 100(3):437–467.

Cocco, J. a. F. (2005). Portfolio choice in the presence of housing. *Review of Financial Studies*, 18(2):535–567.

Cox, D. (1987). Motives for Private Income Transfers. *Journal of Political Economy*, 95(3):508–546.

D'Albis, H. and Iliopulos, E. (2013). Collateral constraints and rental markets. *Economics Letters*, 121(3):436–439.

Davidoff, T. (2009). Housing , Health , and Annuities. *The Journal of Risk and Insurance*, 76(1):31–52.

Davidoff, T. (2010). Home equity commitment and long-term care insurance demand. *Journal of Public Economics*, 94(1-2):44–49.

Davidoff, T., Brown, J. R., and Diamond, P. A. (2005). Annuities and Individual Welfare. *The American Economic Review*, 95(5):1573–1590.

Davis, M. A. and Heathcote, J. (2005). Housing and the Business Cycle. *International Economic Review*, 46(3):751–784.

De la Croix, D. and Michel, P. (2002). *A Theory of Economic Growth*. Cambridge University Press.

De Nardi, M., French, E., and Jones, J. (2010). Why Do the Elderly Save? The Role of Medical Expenses. *Journal of Political Economy*, 118(1):39–75.

De Nardi, M., French, E., and Jones, J. B. (2014). Medicaid Insurance in Old Age. *Working Paper*, pages 1–36.

Dobrescu, L. I. (2015). To Love or to Pay: Savings and Health Care in Older Age. *Journal of Human Resources*, 50(1):254–299.

Favara, G. and Imbs, J. (2015). Credit Supply and the Price of Housing. *American Economic Review*, 105(3):958–992.

Favilukis, J., Ludvigson, S. C., and Van Nieuwerburgh, S. (2015). The macroeconomic effects of housing wealth, housing finance, and limited risk-sharing in general equilibrium. *Working Paper.*

Ferrero, A. (2015). House Price Booms , Current Account Deficits , and Low Interest Rates. *Journal of Money, Credit and Banking*, 47(S1):261–293.

Fisher, I. (1933). The Debt-Deflation Theory of Great Depressions. *Econometrica*, 1(4):337–357.

French, E. (2005). The Effects of Health, Wealth, and Wages on Labour Supply and Retirement Behaviour. *The Review of Economic Studies*, 72(2):395–427.

French, E. and Jones, J. B. (2004). On the distribution and dynamics of health care costs. *Journal of Applied Econometrics*, 19(6):705–721.

French, E. and Jones, J. B. (2011). The Effects of Health Insurance and Self-Insurance on Retirement Behavior. *Econometrica*, 79(3):693–732.

Goda, G. S., Shoven, J. B., and Slavov, S. N. (2013). Does widowhood explain gender differences in out-of-pocket medical spending among the elderly? *Journal of Health Economics*, 32(3):647–658.

Gourinchas, P.-o. and Parker, J. A. (2002). Consumption over the Life Cycle. *Econometrica*, 70(1):47–89.

Guerrieri, L. and Iacoviello, M. (2015). OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70:22–38.

Henderson, J. V. and Ioannides, Y. M. (1983). A Model of Housing Tenure Choice. *The American Economic Review*, 73(1):98–113.

Hendricks, L. (2007). How important is discount rate heterogeneity for wealth inequality? *Journal of Economic Dynamics and Control*, 31(9):3042–3068.

Hong, J. H. and Ríos-Rull, J.-V. (2007). Social security, life insurance and annuities for families. *Journal of Monetary Economics*, 54(1):118–140.

Hong, J. H. and Ríos-Rull, J.-V. (2012). Life Insurance and Household Consumption. *The American Economic Review*, 102(7):3701–3730.

Huang, A. L., Chapman, R. E., and Butry, D. T. (2009). Metrics and tools for measuring construction productivity: Technical and empirical considerations. *US Department of Commerce, National Institute of Standards and Technology.*

Hubbard, R. G., Skinner, J., and Zeldes, S. P. (1995). Precautionary Saving and Social Insurance. *Journal of Political Economy*, 103(2):360.

Hurd, M. D. (1987). Savings of the Elderly and Desired Bequests. *The American Economic Review*, 77(3):298–312.

Hurd, M. D. (1989). Mortality Risk and Bequests. *Econometrica*, 57(4):779–813.

Hurd, M. D. and Rohwedder, S. (2008). The Retirement Consumption Puzzle: Actual Spending Change in Panel Data. *National Bureau of Economic Research Working Paper Series*, No. 13929.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3):739–764.

Iacoviello, M. and Neri, S. (2010). Housing Market Spillovers: Evidence from an Estimated DSGE Model. *American Economic Journal: Macroeconomics*, 2(2):125–164.

Iacoviello, M. and Pavan, M. (2013). Housing and debt over the life cycle and over the business cycle. *Journal of Monetary Economics*, 60(2):221–238.

Johnson, R. W. and Lo Sasso, A. T. (2006). The impact of elder care on women's labor supply. *Inquiry*, 43(3):195–210.

Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2014). Credit supply and the housing boom. *Working Paper*.

Kalwij, A., Pasini, G., and Wu, M. (2012). Home care for the elderly: the role of relatives, friends and neighbors. *Review of Economics of the Household*, pages 1–26.

Kiyotaki, N., Michaelides, A., and Nikolov, K. (2011). Winners and Losers in Housing Markets. *Journal of Money, Credit and Banking*, 43(2-3):255–296.

Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248.

Kopczuk, W. and Lupton, J. P. (2007). To leave or not to leave: The distribution of bequest motives. *Review of Economic Studies*, 74(1):207–235.

Kotlikoff, L. J. and Spivak, A. (1981). The Family as an Incomplete Annuities Market. *Journal of Political Economy*, 89(2):372–391.

Lakdawalla, D. and Philipson, T. (2002). The Rise in Old-Age Longevity and the Market for Long-Term Care. *The American Economic Review*, 92(1):295–306.

Liu, Z., Wang, P., and Zha, T. (2013). Land-Price Dynamics and Macroeconomic Fluctuations. *Econometrica*, 81(3):1147–1184.

Lo Sasso, A. T. and Johnson, R. W. (2002). Does informal care from adult children reduce nursing home admissions for the elderly? *Inquiry*, 39(3):279–297.

Lockwood, L. M. (2012). Bequest motives and the annuity puzzle. *Review of Economic Dynamics*, 15(2):226–243.

Lockwood, L. M. (2013). Incidental Bequests : Bequest Motives and the Choice to Self-Insure Late-Life Risks. *Working Paper*, pages 1–64.

Mazzocco, M. (2007). Household Inter Temporal Behaviour: A Collective Characterization and a Test of Commitment. *The Review of Economic Studies*, 74(3):857–895.

Nakajima, M. and Telyukova, I. (2014a). Housing in Retirement Across Countries. *Working Paper*.

Nakajima, M. and Telyukova, I. A. (2012). Home Equity in Retirement. *Working Paper*, pages 1–46.

Nakajima, M. and Telyukova, I. A. (2014b). Reverse Mortgage Loans : A Quantitative Analysis. *Working Paper*, pages 1–34.

Ngai, R. L. and Sheedy, K. D. (2015). Moving House. *Working Paper*.

Palumbo, M. G. (1999). Uncertain Medical Expenses and Precautionary Saving Near the End of the Life Cycle. *The Review of Economic Studies*, 66(2):395–421.

Peijnenburg, K., Nijman, T., and Werker, B. J. (2010). Health Cost Risk and Optimal Retirement Provision: a Simple Rule for Annuity Demand. *Working Paper*.

Pezzin, L. E., Kemper, P., and Reschovsky, J. (1996). Does Publicly Provided Home Care Substitute for Family Care? Experimental Evidence with Endogenous Living Arrangements. *The Journal of Human Resources*, 31(3):650–676.

Scholz, J. K., Seshadri, A., and Khitatrakun, S. (2006). Are Americans Saving “Optimally” for Retirement? *Journal of Political Economy*, 114(4):607–643.

Sommer, K., Sullivan, P., and Verbrugge, R. (2013). The equilibrium effect of fundamentals on house prices and rents. *Journal of Monetary Economics*, 60(7):854–870.

Stancanelli, E. and Soest, A. V. (2012). Retirement and Home Production: A Regression Discontinuity Approach. *The American Economic Review*, 102(3):600–605.

Van Houtven, C. H. and Norton, E. C. (2004). Informal care and health care use of older adults. *Journal of Health Economics*, 23(6):1159–1180.

Venti, S. F. and Wise, D. a. (2004). Aging and housing equity: another look. In *Perspectives on the Economics of Aging*, number June, pages 127–180.

Yaari, M. E. (1965). Uncertain Lifetime, Life Insurance, and the Theory of the Consumer. *The Review of Economic Studies*, 32(2):137–150.

Yang, F. (2009). Consumption over the life cycle: How different is housing? *Review of Economic Dynamics*, 12(3):423–443.

Yao, R. and Zhang, H. H. (2005). Optimal consumption and portfolio choices with risky housing and borrowing constraints. *Review of Financial Studies*, 18(1):197–239.

Yogo, M. (2009). Portfolio Choice in Retirement: Health Risk and the Demand for Annuities, Housing, and Risky Assets. *National Bureau of Economic Research Working Paper Series*, (No. 15307).

Zeldes, S. P. (1989). Optimal Consumption with Stochastic Income: Deviations from Certainty Equivalence. *The Quarterly Journal of Economics*, 104(2):275–298.