Old, Sick, Alone and Poor: A Welfare Analysis of Old-Age Social Insurance Programs *

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Abstract

All individuals face some risk of ending up old, sick, alone and poor. Is there a role for social insurance for these risks and if so what is a good program? A large literature has analyzed the costs and benefits of pay as you go public pensions and found that the costs exceed the benefits. This paper, instead, considers means-tested social insurance programs for retirees such as Medicaid and food stamp programs. We find that the welfare gains from these programs are large. Moreover, the current scale of means-tested social insurance in the U.S. is too small in the following sense. If we condition on the current Social Security program, increasing the scale of means-tested social insurance by 1/3 benefits both the poor and the affluent when a payroll tax is used to fund the increase.

Keywords: Means-tested Social Insurance; Medicaid; Welfare; Elderly; Medical Expenses. **JEL Classification numbers: E62, H31, H52, H55.**

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1 Introduction

All individuals face some risk of ending up old, sick, alone and poor. These risks are significant. Poverty rates of the elderly are large and increase with age. They rise from a level of 17% for those aged 75–79 to 19% for those aged 80 and over.[1] Important determinants of these poverty outcomes are lifetime earnings risk, longevity, sickness/disability and marital status risk. Some individuals enter retirement with low assets due to bad luck in the labor market. Medical and long-term care expenses are tightly connected with longevity because they increase with age and are highest in the final periods of life. Spousal death events are costly because large nursing home or hospital expenses often precede the death of a spouse.

Poverty among the aged is a particularly troubling problem for society. In contrast to younger individuals, the aged are often unable to self-insure against a medical or spousal death event by re-entering the labor force. Is there a role for social insurance for the aged and if so what is a good program?

The largest U.S. social insurance program for retirees is Social Security (SS). Outlays for SS were 4.87% of GDP in 2011 and are predicted to increase to 6.19% of GDP by 2036.[2] A large macroeconomics literature has analyzed the role of social security and found that a pay-as-you-go SS program is a bad public policy. This result has been documented in models with dynastic households as in Fuster, İmrohoroğlu and İmrohoroğlu (2007) and also life-cycle OLG models starting with the research of Auerbach and Kotlikoff (1987). İmrohoroglu, Imrohoroglu and Joines (1999) show that this result holds in dynamically efficient economies. Conesa and Krueger (1999) find that this result holds when agents face life-time earnings risk. Hong and Ríos-Rull (2007) show that this result holds when the economy is open and the pre-tax real interest rate is fixed. They also show that the result does not depend on the availability of private market substitutes such as private annuities and private life insurance. İmrohoroglu, Imrohoroglu and Joines (1995) reach the same conclusion in a model with catastrophic health risk but no Medicaid or any other means-tested transfers. Perhaps the strongest argument in favor of continuing SS is that it would be even more costly to remove. Nishiyama and Smetters (2007) find that the transition costs of privatizing SS can exceed the long-term benefits associated with a smaller SS program in a setting with uninsured labor market risk.

It would be a mistake to conclude from these results that there is no role for society to

[1] For purposes of comparison poverty rates for the general population are 16%. These numbers are based on the Bureau of Census Supplemental Poverty Measure which is designed to give a more comprehensive picture of the situation of the poor by including tax and other government benefits and accounting for out-of-pocket medical expenses. For more details see: http://www.ssa.gov/policy/docs/ssb/v73n4/v73n4p49.html

[2] These numbers are from CBO "The 2012 Long-Term Projections for Social Security" (2012).

provide insurance to retirees. We assess the welfare effects of means-tested social insurance (MTSI) programs for the aged and find that these programs are highly valued. MTSI programs that benefit the aged include Medicaid, Supplemental Social Security Income, food stamps and housing and energy assistance programs. MTSI provides good insurance against longevity risk and is a particularly effective way to insure against large medical expenses, spousal death events and poor lifetime earnings outcomes. MTSI works well because the transfers induced by the means-test line up well with states where demand for the insurance is high. For example, large shocks are particularly costly at the end of life because agents cannot easily self-insure by reentering the labor market and, absent a bequest motive, would like to keep their savings low. At the same time the disutility of low consumption is very high. Thus, insurance that pays off when wealth is very low is highly valued.

We use a large quantitative model of the U.S. economy to demonstrate that removing MTSI for the elderly has a large negative effect on welfare. This occurs even when SS is maintained at its current U.S. level. Our finding raises the question as to whether there is an opportunity to increase the scale of current MTSI programs. Indeed we document broad based welfare gains if the scale of these programs is increased by 1/3 and financed with a proportionate payroll tax.

Perhaps the most striking feature of MTSI is that its state-contingent nature allows it to deliver valuable insurance with programs that are much smaller than SS. Medicaid, which subsidizes medical costs, is the largest means-tested government program for retirees. Yet, Medicaid expenditures for 65+ only constitute 0.6% of GDP. SSI, the second largest program, is even smaller. Only about 5% of 65+ receive SSI assistance and expenditures on this program are only about 0.3% of GDP.[3]

To assess the welfare effects of MTSI, we start by providing new empirical evidence on risks faced by the aged. A large literature has already documented that individuals in the U.S. face significant lifetime earnings risk.[4] Individuals also face significant risks after retirement. We show that widowhood, poor health, and hospital and nursing home stays are all associated with higher transitions into poverty and longer persistence of poverty. Then we go on to explore the welfare effects of MTSI in a two period model. The two period model illustrates the welfare enhancing role of MTSI in insuring against life-time earnings risk, medical expense risk, longevity risk and the risk of being born with low resources in a transparent way and also highlights the incentive effects of MTSI.

[3]Medicaid figure is taken from: U.S. Centers for Medicare and Medicaid Services, Office of the Actuary, "National Health Expenditure Accounts" and is an average from 2000 to 2010. The SSI numbers are from CBO "Growth in Mean-tested Programs and Tax Credits for Low-Income Households" (2013).

[4]See for example Heathcote, Storesletten and Violante (2008), Guvenen (2009), Heathcote, Perri and Violante (2010a) and Huggett, Ventura and Yaron (2011).

Our main objective is to assess MTSI programs for retirees in the U.S. and this requires a quantitative model. We thus develop a general equilibrium, life-cycle model of the U.S. economy. Individuals enter the economy with a given level of educational attainment and a spouse and stay married throughout their working life. Labor productivity of working-age households evolves stochastically over the life-cycle and a borrowing constraint limits their ability to self-insure. Men's labor is supplied to the market inelastically, while female's labor supply is optimally chosen by the household. At age 65, all individuals retire.

Retired individuals in our model are subject to survival risk, health and out-of-pocket (OOP) medical expense risk, including the risk of a lengthy nursing home stay, and spousal death risk. These risks vary with age, gender and marital status of the retiree and are correlated with the retiree's education type. Thus retired households are heterogeneous not only in the size of their accumulated wealth (private savings and pensions), but also in the life expectancies of their members, household OOP medical expenses and household composition. We assume that there are no markets to insure against productivity, health, or survival risk. Partial insurance, however, is available to retirees through a progressive pay-as-you-go SS program that includes spousal and survivor benefits, and a MTSI program that guarantees a minimum consumption level to retirees. We also model Medicare in that medical expenses are net of Medicare transfers and the payroll tax includes Medicare contributions.

We calibrate the model to match a set of aggregate and distributional moments for the U.S. economy, including demographics, earnings, medical and nursing home expenses, as well as features of the U.S. means-tested social welfare, SS and income tax systems. We then assess the model's ability to reproduce key facts observed in the data but not targeted in the calibration. In particular, we show that the model generates patterns consistent with the data with regards to Medicaid take-up rates, flows into Medicaid and OOP medical expenses by age and marital status. Moreover, we show that the model delivers an increased likelihood of impoverishment for individuals who experience: large acute and long-term care OOP expenses; shocks to health status; or a spousal death event. These patterns of impoverishment in the model are in line with impoverishment statistics in our dataset obtained from the Health and Retirement Survey (HRS).

This economy is then used to investigate the welfare effects of MTSI. We have already described our principal findings so we will briefly mention some of our other results. Removing MTSI from our baseline model of the U.S. results in large welfare losses for all types of households. Indeed, there is general support for increasing the scale of MTSI for retirees provided that it is financed by increasing the payroll tax. Both poor households and affluent households as indexed by either educational attainment or life time earnings quintile of the male prefer a larger scale of MTSI. In contrast, welfare of all types of households *increases* when SS is removed even though the fraction of retirees consuming at the MTSI consumption floor more than doubles. Interestingly, the welfare benefits of MTSI are even larger when SS is not available. When MTSI is available SS is redundant in the following sense. MTSI provides meaningful insurance against longevity risk and other risks but at a lower social cost. Finally, we find important interaction effects between the two programs. One benefit of offering SS in a world where MTSI is available is that it alters savings patterns of poorer households and this in turn lowers the fraction of households that roll-in to MTSI at retirement.

To our knowledge our paper is the first to investigate the welfare effects of MTSI for U.S. retirees. It relates to the previous literature in the following ways. The idea that a MTSI program is more efficient than a universal SS program dates back to a debate by Wilbur Cohen and Milton Friedman. Friedman argued that the negative incentive effects of universal SS were so large that welfare would be improved if SS was replaced with a MTSI program (Cohen and Friedman, 1972). In subsequent work, Feldstein (1987) has argued that MTSI for retirees has a particularly strong, negative incentive effect on some individuals. When MTSI is available and sufficiently liberal, these individuals will choose to consume all of their income when young and to rely on MTSI when they retire. As we explained above these negative incentives are also present in our model. However, the benefits of MTSI greatly exceed the welfare costs that these negative incentive effects create.[5]

Most subsequent research on the U.S. economy has focused on public pension reform and abstracted from MTSI as we have discussed above. Other recent research analyzes means-tests in the context of public pension reform in Australia and the UK. In Australia all public pensions are means-tested. Tran and Woodland (2012) compare Australia's current means-tested public pension system with an alternative economy with no means-tested public pension in a computable OLG model. Agents face uninsured earnings and life expectancy risk. In their model the negative incentive effects of Australia's current system are so strong that they dominate the positive insurance effects of MTSI and individuals prefer to be born into an economy with a universal public pension. However, they find that means-tested public pensions may be preferred to a universal public pension plan if means-tested benefits are tapered off in a suitable way.

Sefton, van de Ven and Weale (2008) compare a universal SS public pension program with two UK means-tested programs: the Minimum Income Guarantee program which was in place prior to 2003 and the post-2003 UK Pension Credit program. The former narrowly targeted the poor, while the latter relaxed the means-test by lowering the maximum effective

[5]We wish to emphasize that following Feldstein we focus on MTSI for retirees. It is not clear that the costs and benefits of offering MTSI to workers is the same.

marginal tax rate on benefits from 100 to 40% of private income. Individuals in their model are exposed to earnings and life expectancy risk. They find that young individuals prefer means-tested public pension system over a universal SS system when factor prices are allowed to adjust and the fiscal budget is balanced.

The focus of these papers is rather different from ours. They consider the role of means-testing of public pensions in economies where individuals face survival and permanent earnings risks. However, neither paper models medical expenses or long-term care expenses for retirees. Given that medical expenses are zero, there is no need for these papers to model the public programs that help retirees cope with medical expenses and their associated risks. Our results reveal that modeling medical expenses has a large impact on the size of the welfare benefits of MTSI in the U.S. We also document significant interactions between programs such as Medicaid that cover medical expenses and the U.S. social security system. Finally, the focus of these papers is on public pension programs in Australia and the UK. Both the current form of public pensions and likely directions for future reform are quite different in the U.S. as compared to Australia and the UK.

The remainder of the paper is organized as follows. In Section 2, we motivate our analysis by providing evidence on sources of impoverishment for the elderly. Section 3 describes the two period model. Section 4 develops our quantitative model of the U.S. economy. Section 5 reports how we estimate and calibrate the various parameters and profiles that are needed to solve the model. In Section 6, we assess the ability of the model to reproduce statistics not targeted in the calibration, including flows into Medicaid by age and martial status, as well as a variety of wealth mobility statistics for retirees. Section 7 reports results from our welfare analysis. Finally, Section 8 contains our concluding remarks.

2 Motivation

As we pointed out in the introduction, a large literature had analyzed earnings risk. Much less is known about shocks that occur during retirement. This section provides new empirical evidence that these shocks are important sources of impoverishment for retirees. In particular, we show that longevity, widowhood, self-reported health status and long-term care medical expenses are all associated with higher probabilities of transitions into the first wealth quintile and longer durations in this quintile.

We start by comparing wealth mobility between elderly married women and widows. Table 1 reports probabilities of two year transitions from the five wealth quintiles to quintile 1 using a sample of data from the 1995–2010 waves of the HRS/AHEAD survey. The transitions are pooled two-year transitions for married and widowed women grouped into

Table 1: Percentage of retired women moving from each quintile of the wealth distribution to quintile 1 two years later by marital status

	65–74 Year-olds		75–84 Year-olds		85+ Year-olds	
Quintile	**Married**	**Widowed**	**Married**	**Widowed**	**Married**	**Widowed**
1	72.5	80.0	69.6	75.9	80.2	76.1
2	17.3	22.9	17.2	20.6	28.1	28.0
3	3.4	6.5	4.4	6.9	8.1	11.5
4	1.0	1.6	1.1	2.4	3.7	6.2
5	0.4	1.1	0.3	0.5	2.6	2.8

The percentage of women moving down to quintile 1 from quintiles 2–5 in a 2-year period by marital status in the initial period. The first row is the percentage of women who stay in quintile 1. Authors' computations. Data: 1995–2010 HRS/AHEAD retired women aged 65+. See 9.1.1 for more details.

three age brackets 65–74, 75–84 and 85+. Wealth consists of total wealth excluding the primary residence. More details on the construction of our HRS sample can be found in Appendix 9.1.

Table 1 has three noteworthy properties. Observe first that impoverishment increases with age among both married and widowed women. This observation is clearest if one compares women aged 65-74 with those aged 85+. Observe that the probability of a transition into wealth quintile 1 is higher for those starting in each of quintiles 2-5 for older women. This regularity is equally apparent among married and widowed women and can also be seen if one compares women aged 75-84 with those aged 85+ instead.

A second interesting property of Table 1 is that a higher percentage of widows experience impoverishment as compared to married women. In particular, a higher percentage of widows transit to quintile 1 from each other wealth quintile as compared to married women. This pattern is robust across wealth quintiles and also across age with one exception. For 85+ year old women in the second wealth quintile, the percentage experiencing transitions to quintile 1 is about the same for married women and widows.

The third property is that poverty is more persistent for widows than married women aged 65–74 and 75–84.[6] The percentage of quintile 1 to quintile 1 transitions for married women and widows is respectively 73% and 80% for women aged 65–74 and 70% for married versus 76% for widows in the 75–84 age group.

These same statistics for males can be found in Appendix 9.2. We do not report them here because the patterns for males are very similar to the patterns for females.

[6]Throughout this paper we will use the term "poverty" to refer to those in quintile 1. These are the poorest people in our economy in a relative sense.

Table 2: Percentage of retired individuals moving from each quintile of the wealth distribution to quintile 1 two years later by health status

	65–74 Year-olds		75–84 Year-olds		85+ Year-olds	
Quintile	**Healthy**	**Unhealthy**	**Healthy**	**Unhealthy**	**Healthy**	**Unhealthy**
1	69.7	80.9	70.8	79.3	67.8	73.1
2	15.6	22.6	15.1	22.1	17.7	27.5
3	3.4	5.5	3.8	7.2	7.8	8.2
4	0.9	2.2	1.3	4.1	4.1	4.7
5	0.4	1.5	0.5	1.3	1.4	2.8

The percentage of individuals moving down to quintile 1 from quintiles 2–5 in a 2-year period by health status in the initial period. The first row is the percentage of individuals who stay in quintile 1. Authors' computations. Data: 1995–2010 HRS/AHEAD retired individuals aged 65+. See 9.1.1 for more details.

A second empirical regularity is that poor health is associated with higher flows into poverty. Table 2 shows that a self report of poor health is associated with a higher frequency of moves from quintiles 2–5 to quintile 1 two years later.[7] Some of the differences are small, but we find it remarkable that the pattern is consistent across quintiles and all three age groups. A report of poor health is also associated with higher persistence of poverty. The difference is largest for the 65–74 age group and narrows a bit as individuals age.

Poor health is often associated with higher medical expenditures. Medical expenditures fall into two broad categories: acute (immediate and severe) expenses and long-term care expenses. In our HRS data the largest acute medical expenses are those associated with a hospital stay. Both hospital stays and long-term care expenses are associated with impoverishment. To conserve on space we only report results for nursing home expenses, which are are the largest long-term care expense.[8] The cost of a one-year stay in a nursing home can easily exceed $60,000 and while the average duration is only approximately two years, Brown and Finkelstein (2008) estimate that approximately 9% of entrants will spend more than five years in a nursing home. Table 3 reports wealth transitions for individuals who experience nursing-home-stay events and those who do not. The pattern for hospital stays is similar but the differences are less pronounced. Given the cost and, for some, long duration of nursing home stays, it is not surprising that differences are more pronounced for this event compared to a hospital stay.

The pattern of correlations that emerges in these transitions yields a surprisingly consistent picture. Impoverishment is positively associated with age, widowhood, poor health and

[7] See 9.1 for a description of our health variable.
[8] Results for hospital stays are reported in Appendix 9.2.

Table 3: Percentage of retired individuals moving from each quintile of the wealth distribution to quintile 1 two years later conditional on whether or not they spent time in a nursing home (NH) in the initial period

	65–74 Year-olds		75–84 Year-olds		85+ Year-olds	
Quintile	**None**	**NH Stay**	**None**	**NH Stay**	**None**	**NH Stay**
1	75.7	87.9	74.6	86.0	69.3	75.6
2	18.0	25.6	17.4	23.7	20.2	31.8
3	3.8	9.6	4.5	11.8	7.1	14.3
4	1.0	5.3	1.8	5.0	3.5	8.2
5	0.5	3.3	0.5	3.9	1.5	4.6

The percentage of individuals moving down to quintile 1 from quintiles 2–5 in a 2 year period conditional on a nursing home stay in the initial period. The first row is the percentage of individuals who stay in quintile 1. Authors' computations. Data: 1995–2010 HRS/AHEAD retired individuals aged 65+. See 9.1.1 for more details.

both acute and long-term medical events. In particular, old individuals who are widowed, in poor health or who experience one of these medical events have a higher likelihood of transiting into the first wealth quintile. All of these characteristics are also associated with a higher expected stay in the first quintile.

3 A Two Period Model

We next present a two-period model that allows us to document in a transparent way the welfare enhancing role of MTSI in insuring medical expense, earnings and longevity risks.

3.1 Economy

Consider a small open economy such that r is fixed and exogenous. Assume that the economy consists of a measure 1 of individuals. The fraction θ receive a high endowment y_h and the remaining $1-\theta$ receive y_l with $y_l \leq y_h$ at the start of period 1. A fraction, γ, survive to period 2 and the remaining agents die after they consume in period 1. Individuals who survive to the second period face high expenditures m with probability ϕ. We will refer to these as medical expenditures, but at the level of generality of this small model $y_i - m$ could also represent a poor outcome in the labor market. Without loss of this generality, in what follows we will refer to this shock as a medical expense shock. We omit private insurance markets for longevity and medical expenses in this model and also our baseline model. Our reasons for this modeling decision are discussed in Section 7.5.

There is a government that levies a proportional tax on the agents' endowments when they are young. The government can save at the same rate as individuals, r. It saves the revenues and uses them to finance a means-tested transfer to agents when old. The government budget constraint is

$$(1+r)\left[\theta y_h + (1-\theta)y_l\right]\tau = \gamma\Big\{\phi\left[\theta TR_h^b + (1-\theta)TR_l^b\right] + (1-\phi)\left[\theta TR_h^g + (1-\theta)TR_l^g\right]\Big\},$$

where TR_i^b are transfers to individuals of type $i \in \{h,l\}$ who find themselves in state b with associated expenditures m and TR_i^g is the transfer to agents of type i for whom $m = 0$. We assume that accidental bequests are taxed and consumed by the government.[9] Thus government consumption g is given by

$$g = (1-\gamma)(1+r)(\theta a_h + (1-\theta)a_l),$$

where a_i is the savings of agents of type i where $i \in \{h,l\}$. The aggregate resource constraint is

$$\begin{aligned}&\theta c_h^y + (1-\theta)c_l^y + \gamma\left[\phi(\theta c_h^b + (1-\theta)c_l^b) + (1-\phi)\left(\theta c_h^g + (1-\theta)c_l^g\right) + \phi m\right] + g = \\ &(1+r\tau)(\theta y_h + (1-\theta)y_l) + r(\theta a_h + (1-\theta)a_l),\end{aligned}$$

where c_i^y is the consumption of individuals of type $i \in \{h,l\}$ when young and c_i^j, $j \in \{b,g\}$ is their consumption when old in each medical expenses state.

3.2 Individual's problem

The individual chooses consumption when young, c^y, consumption when old if he experiences positive medical expenses, c^b, consumption when old if he does not incur a medical expense shock, c^g, and savings a that solve

$$V(y) = \max\Big\{\log(c^y) + \gamma\beta\left[\phi\log\left(c^b\right) + (1-\phi)\log(c^g)\right]\Big\},$$

subject to

$$c^y = y(1-\tau) - a,$$

$$c^b = (1+r)a - m + TR^b,$$

$$c^g = (1+r)a + TR^g,$$

[9] This assumption is made because we want to omit the potentially large redistributional consequences of giving the bequests to survivors. More details are provided in Section 4.

$$TR^j = \max\{0, \underline{c} + mI(j = b) - a(1+r)\}, j \in \{b, g\},$$

and

$$a \geq 0.$$

Note that the subscripts denoting type have been omitted. Transfers to the old, TR^j, are subject to a means-test. They are zero for those whose wealth net of medical expenses exceeds $\underline{c}$. Otherwise, they are large enough to provide the agent with $\underline{c}$ units of consumption.

3.3 The Welfare Effects of Means-tested Social Insurance

3.3.1 Homogenous Agents

We start by setting $y_l = y_h = 1$. This allows us to highlight many of the key effects of MTSI. Then we consider a specification with heterogeneous endowments.

Medical Expense Risk Only Consider first a situation where $\gamma = 1$ so that there is no longevity risk. Under this assumption introducing MTSI into a Laissez-Faire (LF) economy with no social insurance program is welfare improving if medical risks are sufficiently large. This is because MTSI provides a state-contingent transfer against the medical expense shock that reduces ex-post inequality. However, welfare is not monotonically increasing in the scale of the MTSI program. Means-testing creates non-convexities in agent's budget sets that produce jumps in savings policies as disposable income falls.[10] In our economy these jumps in the savings policies imply that a marginal increase in the consumption floor is sometimes associated with a discrete increase in the tax rate needed to fund it.

The left panel of Figure 1 illustrates compensating variations for different scales of MTSI as compared to LF.[11] Notice that MTSI is welfare improving over LF in two distinct ranges of the consumption floor. In region 1 private savings are positive and individuals only receive a transfer only when they have medical expenses. In region 2 all individuals receive transfers and private savings are zero. Underlying the result that MTSI is Pareto improving in the two regions is a positive welfare effect provided by the state-contingent nature of the program and a negative effect due to the asset test. The positive insurance effect is clearest in region 1 where welfare rises monotonically with the scale of the program. In this region, MTSI reduces ex-post consumption inequality. In region 2 the program fully

[10]This non-convexity is due to the fact that in certain states of nature MTSI is a 100% tax on wealth. See Hubbard, Skinner and Zeldes (1995) for more details.

[11]We set the endowment $y = 1$, $m = 0.5$ and $\phi = 0.05$. These choices imply that average medical expenses are 2.5% of the endowment and that there is a welfare enhancing role for MTSI. We also assume that $r = 1/\beta - 1 = 0$.

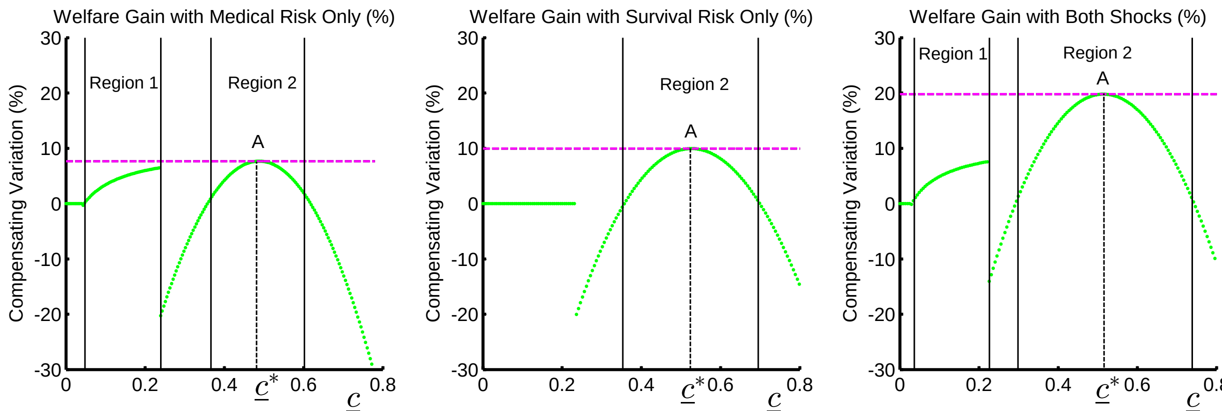

Figure 1: Welfare effects of MTSI for varies levels of the guaranteed consumption floor, $\underline{c}$, in three versions of the two period model.

insures against medical expense risk and the only reason why welfare varies is because the size of the consumption floor affects the time profile of consumption. The allocation at point A provides the optimal amount of insurance and time profile of consumption and is thus Pareto Optimal (PO).

The results illustrated in the left panel of Figure 1 presume a particular scale of expected medical expenses. As expected medical expenses are increased the sizes of regions 1 and 2 also increase and at some point all consumption floors less than $\underline{c}^*$ are Pareto preferred to LF.

Longevity Risk only We next briefly discuss the case with longevity risk only by setting ϕ, the probability of positive medical expenditures, to zero and γ, the survival probability, to 0.9. As the middle panel of Figure 1 shows, MTSI also implements the PO allocation in this setting and it is once again associated with zero private savings. The intuition for this result is the same as before. However, now there is no region 1. It follows that MTSI only improves on LF when private savings are zero. This result is not robust. For instance, a welfare improving region with positive savings emerges when medical expense and longevity risk are modeled simultaneously, agents have different endowments or when the number of periods is extended beyond two.

Longevity Risk and Medical Expense Risk The right panel of Figure 1 reports compensating variations for alternative scales of MTSI in comparison with LF for the case where both longevity risk and medical expense risk are present. The general shape of the welfare function in this panel is similar to that of the left panel. MTSI improves over LF in two re-

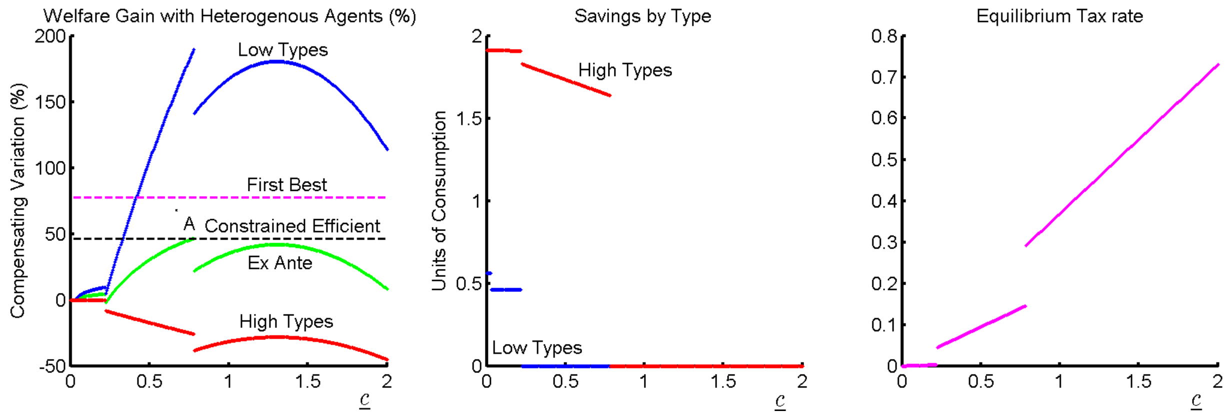

Figure 2: The left panel shows the welfare effects of MTSI for varies values of the guaranteed consumption floor, $\underline{c}$, for the heterogenous agent version of the two period model. The middle graph shows the levels of savings of the two types for each value of the floor and the right panel shows the tax rate at each value.

gions, one with positive private savings and the second with zero private savings, and MTSI can implement the PO allocation. The most significant new feature of the right panel of Figure 1 is that the welfare benefit of MTSI is now higher in regions 1 and 2. The reason for this result is that the two risks are positively correlated. In other words, it is more costly to save for period 2 medical expenses when the probability of surviving to that period is less than one. Thus, a higher value is placed on insurance that reduces the need for savings.

3.3.2 Heterogenous Agents

We now consider a parameterization where agents have different initial endowments and thus face a new risk of being born with a low endowment. MTSI can help insure against this risk as well but the distortions we described above may also be larger. We now proceed to describe a scenario where MTSI is, on net, welfare improving for a range of values of the consumption floor.

Figure 2 shows results for an economy with medical expense and longevity risk, endowments of $y_l = 1$ and $y_h = 4$, and an equal fraction of each type ($\theta = 1/2$). The left panel of Figure 2 shows ex-ante and type-specific compensating variations relative to LF of a newborn individual. This scenario has several interesting properties. First observe that MTSI is ex-ante welfare improving for the entire range of consumption floors.

Second observe that the equilibrium with the ex-ante optimal consumption floor (point A) illustrates a negative incentive effect that has been emphasized by Feldstein (1987) and Hubbard et al. (1995). They have shown that when MTSI is available to retirees, poorer households will choose not to save. Instead they will consume all of their earnings while working and then roll directly onto MTSI at retirement. In this equilibrium both types are receiving transfers when they experience the medical expense event. However, as the middle panel shows, the low endowment types choose not to save and live off government transfers when they are old. As a result, the welfare of the poor is particularly high and the welfare of the rich is particularly low at this point. In fact, the rich prefer LF over having to fund transfers to poor individuals who have no medical expenses.

Third, observe that when endowments are heterogenous the allocation associated with the optimal scale of MTSI is not PO. The ex-ante consumption equivalent of the optimal MTSI program is 46% while the first best consumption equivalent is 77%. One way to see why this is the case is to observe that rich individuals have positive savings at point A and their savings decisions are thus influenced by the means-test. Implementing the PO allocations would require a type-specific tax in period one. The fact that the optimal scale of MTSI occurs in a region with positive saving is of independent interest. In our quantitative model most individuals choose to save and it is interesting to see that the optimal scale of MTSI can occur in such a region.

Figure 2 has several other noteworthy features. With two types there are more jumps in the individual savings policies, taxes and thus in welfare. As a result there may be as many as three distinct regions where MTSI can be Pareto preferred to LF. Two of these regions have positive levels of private savings. Although not pursued here it is easy to alter the number and size of the regions. This can be accomplished by varying the extent of wealth inequality and/or by varying θ, the fraction of individuals who have high wealth. For instance, reducing wealth inequality shifts the ex-ante welfare function down.

Taken together our results show that MTSI can provide valuable insurance against a variety of risks faced by retirees. Our conclusion, however, depends on the specification of the risk environment, the pattern of endowments and the scale of the MTSI program. This analysis while suggestive is inadequate for assessing the welfare effects of MTSI currently offered to retirees in the U.S. We turn now to develop a quantitative model of the U.S. that we will use to address this substantive question.

4 The Model

Our quantitative model is an overlapping generations model with two-member households that face earnings, health, medical expense and survival risk. Factor markets are competitive and there are no private insurance markets. Households' ability to self-insure is further limited by a no-borrowing constraint.

4.1 Demographics

Time is discrete. The economy is populated by overlapping generations of households. Population grows at a constant rate n. Newborn individuals are assigned to two-member households at age 1. Each member is endowed with a gender and an education type. We use x_s^i to denote the fraction of individuals of gender $i \in \{m, f\}$ with either high school or college educational attainment $s \in \{hs, col\}$. The distribution of households across education types $\mathbf{s} \equiv (s^m, s^f)$ is $\Gamma_{\mathbf{s}}$.

Each individual works during the first R periods of his/her life. We assume that all working-age individuals are married. Individuals retire at age $R+1$ and become subject to survival risk. Thus retired households consist of either married couples, widows or widowers. Marital status of a household is described by the variable d: $d = 0$ for married, $d = 1$ for a widow and $d = 2$ for a widower. Individuals die no later than at age J.

4.2 The Structure of Uncertainty

The sources of uncertainty vary by age. Working individuals are only exposed to earnings risk. At retirement, individuals face survival and health risk and households face medical expense risk. We describe each of these risks in detail.

Individual productivity evolves over the working period according to functions $\Omega^i(j, \boldsymbol{\varepsilon_e}, s^i)$, $i \in \{m, f\}$, that map individual age j, household earning shocks $\boldsymbol{\varepsilon_e} \equiv (\varepsilon_e^m, \varepsilon_e^f)$ and education type s^i into efficiency units of labor. The vector of household earning shocks $\boldsymbol{\varepsilon_e}$ follows an age-invariant Markov process with transition probabilities given by $\Lambda_{ee'}$. Efficiency units of newborn households are distributed according to Γ_e.

Starting at retirement, individuals face uncertainty about their health. An individual's health status, h^i, takes on one of two values: good ($h^i = g$) and bad ($h^i = b$). The probability of having good health next period, $\nu_j^i(h, d)$, depends on age, gender, current health status and marital status. The initial distribution of health status, $\Gamma_h^i(s^i)$, depends on the individual's education. Finally, denote a household's health status by $\mathbf{h} \equiv (h^m, h^f)$.

Medical and long-term care expenses are incurred at the household level and evolve stochastically according to the function $\Phi(j, \mathbf{h}, \boldsymbol{\varepsilon_M}, d)$ that depends on household age j, household health status $\mathbf{h}$, the vector of medical expense shocks $\boldsymbol{\varepsilon_M}$ and demographic status d. There are two medical expense shocks. The first shock follows an age-invariant Markov process with transition probabilities $\Lambda_{MM'}$ and initial distribution Γ_{M_1}. The second shock is a transient, *iid* shock with probability distribution Γ_{M_2}.

Upon reaching retirement age, individuals face survival risk. This risk has two components. First, there is a death shock at age 65 which depends on that individual's lifetime earnings if male and their spouse's if female. This shock is used when calibrating the model to pin-down the age-65, marital status distribution $\Gamma_d(\bar{e})$. The rationale for this assumption is discussed in more detail in Section 5.1.3. Second, once retired, the probability of surviving to age $j+1$ conditional on surviving to age j is given by $\pi_j^i(h,d)$ and depends on age, gender, health status and marital status.

Given these definitions, denote the survival rate from $j-1$ to age j of a household with health and marital status of $(\mathbf{h}, d)$ by $\lambda_j(\mathbf{h}, d)$. The laws of motion for $\lambda_j(\mathbf{h}, d)$ are provided in the Appendix. It follows that the size of cohort j is given by

$$\eta_j = \eta_{j-1} \sum_{\mathbf{h}} \sum_{d} \lambda_j^d(\mathbf{h}, d), \text{ for } j = 2, 3, ..., J.$$

.

4.3 Government

The government uses revenues from corporate, payroll and income taxes to finance SS payments, means-tested transfers and government expenditures, G.

4.3.1 Social Security

Currently, the U.S. Social Security system levies a payroll tax and uses its revenues to pay full benefits to eligible workers who retire at age 65. The program also provides benefits to spouses and survivors of eligible workers. We model SS as a pay-as-you go system.

Benefits In order to capture the spousal and survivor benefits, we assume that the benefit function $S(\bar{\mathbf{e}}, d)$ depends on lifetime earnings of both household members, $\bar{\mathbf{e}}$ and the household's current marital status, d. The specific benefit formula is reported in the Appendix. We note here that it captures the following features of the U.S. Social Security system. First, married couples have the option of either receiving their own benefits or 1.5 times the benefit of the highest earner in the household. Second, widows/widowers have the choice of taking their own benefit or their dead spouses benefit.

Sources of Finance The tax that finances SS benefits in the U.S. is a proportional tax levied on individual earnings, or payroll, up to a specified ceiling. In our model, this payroll tax is reflected by function $\tau_{ss}(\cdot)$, which we calibrate consistently with the U.S. Social Security system.

4.3.2 Medicaid and Other Means-Tested Programs

Benefits Medicaid has grown into the largest means-tested program in the U.S. Its primary beneficiaries are the elderly, the disabled, children and single women with children. The focus of this paper is on Medicaid and other means-tested welfare for the *elderly*, so we discuss benefits to the elderly first.

General guidelines for Medicaid benefits for the elderly are determined by the Federal government. However, states establish and administer their own Medicaid programs and determine the scope of coverage. For example, most states require copayments. The size of copayments varies depending on the type and amount of the expense incurred. In addition, some States cover prescription drugs, hearing aids and eye glasses, other States do not. A result is that many Medicaid recipients still have significant OOP expenses.[12]

Retirees may qualify for other means-tested welfare benefits including Supplemental Social Security Income, subsidized housing, food stamps and energy assistance. The federal government determines the Supplemental Social Security Income eligibility and most states use the same means test to determine eligibility for Medicaid and other state-run welfare programs. We choose to model these programs using a single means-tested transfer:

$$Tr^R \equiv \begin{cases} \max\left\{\underline{y}^d + \varphi M - I^R, \underline{c}^d + M - I^R, 0\right\}, & \text{if } \underline{y}^d > I^R - M, \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

Equation 1 describes the various situations that a retired household can find itself in. If its cash-in-hand, I^R, net of medical expenses, M, exceeds the means-test income threshold $\underline{y}^d$, the household receives no Medicaid benefits. If the household's cash-in-hand net of medical expenses falls below $\underline{y}^d$, it does receive a Medicaid benefit but is responsible for a Medicaid copayment of $(1-\varphi)M$. However, we cap this copayment in a way that insures that the household's consumption is at least $\underline{c}^d$.

In our model working households do not face medical expenses. We thus abstract from Medicaid for them. However, working households do face earnings risk and we model means-tested transfers that are a stand-in for programs such as unemployment insurance and food-stamps. Let I^W denote cash-in-hand for a working household, then the transfer is

$$Tr^W \equiv \max\left\{0, \underline{c} - I^W\right\}, \tag{2}$$

where $\underline{c}$ is the consumption floor.

[12]A third reason that we see significant OOP expenses is that there is a medically needy path to Medicaid. See De Nardi, French and Jones (2012) for more discussion of this path to Medicaid.

Sources of Finance Medicaid and other means-tested social welfare programs are jointly financed by states and the federal government using a variety of revenue sources. In the model, we assume that all funding for means-tested transfers comes out of general government revenues.

4.3.3 Medicare and Government Purchases

Medicare outlays are financed by a payroll tax τ_{mc}. It follows that total payroll taxes are $\tau_e(e) = \tau_{ss}(e) + \tau_{mc}(e)$. We do not formally model the distribution of Medicare benefits. The main reason for this is a lack of data on individual or household level Medicare benefits. HRS only reports post-Medicare OOP medical expenses. In our model, medical expenses covered by Medicare are included in government purchases, G, instead.

The government budget is balanced period-by-period. It follows that revenues from the corporate tax τ_c, income taxes T_y^W and T_y^R, and Medicare tax $\tau_{mc}(\cdot)$ finance means-tested transfers and G.

4.4 Household's Problem

We start by describing the household's preferences. For married households, most of the variation in labor supply is due to changes in labor force participation and hours worked by the female (see e.g. Keane and Rogerson (2012) for a survey). For this reason, we abstract from the male labor supply decision but model both margins of labor supply by the female. We assume that households have preferences over consumption c and non-market time of the female member l_f.

The utility function of a working household is given by

$$U^W(c, l_f, \mathbf{s}) = 2^{N-1} \frac{\left(c/(1+\chi)^{N-1}\right)^{1-\sigma}}{1-\sigma} + \psi(\mathbf{s}) \frac{l_f^{1-\gamma}}{1-\gamma} - \phi(\mathbf{s}) \mathbf{I}(l_f < 1), \quad (3)$$

where N is the number of living household members ($N = 2$ for all working households), $\mathbf{I}$ is the indicator function, $\sigma, \gamma > 0$ and $\psi(\mathbf{s}), \phi(\mathbf{s}) > 0$ for all $\mathbf{s}$. This specification of preferences assumes a unitary household in which each member is fully altruistic towards their spouse. The parameter $\chi \in [0, 1]$ determines the degree to which consumption is joint within the household. For instance, when χ is 1, all consumption is individual and when χ is 0, all consumption is joint. The third term in the utility function captures the utility cost of female participation in the labor force. Modeling this cost helps us match both the intensive and extensive margins of female labor supply. We allow the parameters $\psi(\mathbf{s})$ and $\phi(\mathbf{s})$ to vary by household type when we calibrate the model. This helps capture the variation in hours and participation rates of females by household type in U.S. data.

The utility function of a retired household with N living members (determined by d) is defined similarly:

$$U^R(c,d) = 2^{N-1}\frac{\left(c/(1+\chi)^{N-1}\right)^{1-\sigma}}{1-\sigma} + \psi^R\frac{l_f^{1-\gamma}}{1-\gamma}, \tag{4}$$

where $l_f = 1$ and $\psi^R > 0$.

The constraints and decisions of working households and retired households are quite different. We thus describe each problem separately.

4.4.1 Working Household's Problem

A working household of age j with education type $\mathbf{s} \equiv \{s^m, s^f\}$ enters each period with assets a and average lifetime earnings of the male and female $\bar{\mathbf{e}} \equiv \{\bar{e}^m, \bar{e}^f\}$. It then receives the current labor productivity shocks $\boldsymbol{\varepsilon_e} \equiv \{\varepsilon_e^m, \varepsilon_e^f\}$ and chooses consumption c, savings a' and female labor supply l_f. Let earnings be $e^i = w\Omega^i(j, \boldsymbol{\varepsilon_e}, s^i)(1 - l\mathbf{I}_{i=f})$, $i \in \{m, f\}$. The optimal choices are given by the solution to the following problem:

$$V^W(j, a, \bar{\mathbf{e}}, \boldsymbol{\varepsilon_e}, \mathbf{s}) = \max_{c, l_f, a'}\Big\{U^W(c, l_f, \mathbf{s}) + \beta\mathbf{E}\big[V(j+1, a', \bar{\mathbf{e}}', \boldsymbol{\varepsilon_e'}, \mathbf{s})|\boldsymbol{\varepsilon_e}\big]\Big\}, \tag{5}$$

subject to the law of motion for $\boldsymbol{\varepsilon_e}$ and its initial distribution, as described in Section 4.2, and the following constraints:

$$c \geq 0, \quad 0 \leq l_f \leq 1, \quad a' \geq 0, \tag{6}$$

$$\bar{e}^{i\prime} = (e^i + j\bar{e}^i)/(j+1), \quad i \in \{m, f\}, \tag{7}$$

$$c + a' = a + y^W - T_y^W + Tr^W, \tag{8}$$

where

$$y^W \equiv e^m + e^f + (1-\tau_c)ra, \tag{9}$$

$$T_y^W \equiv \tau_y\left(y^W - \tau_e(e^m)e^m - \tau_e(e^f)e^f\right) + \tau_e(e^m)e^m + \tau_e(e^f)e^f, \tag{10}$$

$$I^W \equiv a + y^W - T_y^W. \tag{11}$$

Equation (6) describes regularity conditions on consumption and leisure and imposes a borrowing constraint which rules out uncollateralized lending. The dynamics of average lifetime earnings, which determine social security benefits, are given in (7) and the household budget constraint is given by (8). The definition for Tr^W is given in (2). Household income (9) has two components: labor income and capital income. Capital income is subject to a corporate tax τ_c, and (10) states that households also pay an income tax $\tau_y(\dot{})$ and a payroll tax, $\tau_e(e)$. Finally, (11) defines cash-in-hand.

4.4.2 Retired Household's Problem

During retirement the household's problem changes. Men and women spend all of their time endowment enjoying leisure. Retirees face health, medical expense and survival risk.

We will assume that individuals observe their own and their spouses death event one period in advance. It follows that bequests are zero for households with a single member. This assumption has the following motivations. First, there is considerable evidence that bequests and inheritances are low. One reason for this is that wealth is low in the final year of life. Poterba, Venti and Wise (2011) find that many individuals die with very low levels of assets. They report that 46.1% of individuals have less than $10,000 in financial assets in the last year observed before death and 50% have zero home equity using data from HRS. In a separate study of the Survey of Consumer Finances (SCF) Hendricks (2001) reports direct measurements of inheritances. He finds that most households receive very small or no inheritances. Fewer than 10% of households receive an inheritance larger than two mean annual earnings and the top 2% account for 70% of all inheritances.

The second reason for this assumption is that it allows us to capture the fact that both OOP and Medicaid medical expenses are large in the final year of life. In our HRS sample of retirees, OOP expenses in the last year of life are 3.43 times as large as OOP expenses in other years. Medicaid expenses are not available in our dataset. However, Hoover, Crystal, Kumar, Sambamoorthi and Cantor (2002) report that in final year of life Medicaid expenses are 25% of total Medicaid expenses for those aged 65 and older. This result is based on Medicare Beneficiary Survey data from 1992–1996.

An attractive outcome of this assumption is that accidental bequests are zero. Previous research has found that the pattern of redistribution of accidental bequests has important incentive effects. Changes in government policy that alter the size and distribution of these bequests have big incentive effects and this acts to muddle any analysis of the welfare effects of policy reform. For examples of this see Kopecky and Koreshkova (2013) and Hong and

Ríos-Rull (2007).

For retirees the household's education type is no longer a state variable. Education does enter indirectly since the initial distribution of individual health status varies with educational attainment. Health, and thus education, affect both individual survival probabilities and household medical expenses as described in Section 4.2.

The probability that an age-j individual of gender i with health status h^i and marital status d survives to age $j+1$ is denoted by $\pi^i_{j+1}(h^i, d)$. It follows that an age-j household faces survival probabilities $\pi_j(d'|\mathbf{h}, d)$ given by

	$d'=0$	$d'=1$	$d'=2$
$d=0$	$\pi^m_{j+1}(h^m,0)\pi^f_{j+1}(h^f,0)$	$\left[1-\pi^m_{j+1}(h^m,0)\right]\pi^f_{j+1}(h^f,0)$	$\pi^m_{j+1}(h^m,0)\left[1-\pi^f_{j+1}(h^f,0)\right]$
$d=1$	0	$\pi^f_{j+1}(h^f,1)$	0
$d=2$	0	0	$\pi^m_{j+1}(h^m,2)$

An age-j household with assets a, average lifetime earnings $\bar{\mathbf{e}}$, health $\mathbf{h}$, medical expense shock $\boldsymbol{\varepsilon_M}$, current demographic status d and next period demographic status d' chooses c and a' by solving

$$V^R(j,a,\bar{\mathbf{e}},\mathbf{h},\boldsymbol{\varepsilon_M},d,d') = \max_{c,a'}\left\{U^R(c,d)+\beta\mathbf{E}\Big[\sum_{d''=0}^{2}\pi_j(d''|\mathbf{h}',d')V(j+1,a',\bar{\mathbf{e}},\mathbf{h}',\varepsilon'_M,d',d'')|\mathbf{h},\boldsymbol{\varepsilon_M}\Big]\right\} \tag{12}$$

subject to the laws of motion for $\mathbf{h}$, $\boldsymbol{\varepsilon_M}$ and their initial distributions, as described in Section 4.2 and the following constraints:

$$c \geq 0, \quad a' \geq 0, \tag{13}$$

$$c + M + a' = a + y^R - T^R_y + Tr^R, \tag{14}$$

where

$$M \equiv \Phi(j,\mathbf{h},\boldsymbol{\varepsilon_M},d,d'), \tag{15}$$

$$y^R \equiv S(\bar{\mathbf{e}},d) + (1-\tau_c)ra, \tag{16}$$

$$T^R_y \equiv \tau^R_y\left((1-\tau_c)ar, S(\bar{\mathbf{e}},d), d, M\right), \tag{17}$$

$$I^R \equiv a + y^R - T_y^R, \tag{18}$$

and the expectations operator $\mathbf{E}$ is taken over $\boldsymbol{\varepsilon}'_{\boldsymbol{M}}$ and $\mathbf{h}'$. The means-tested transfer Tr^R is defined in equation (1).

The main differences between the working household's problem and the retired household's problem are as follows. Medical expenses M now enter the household's budget constraint (14). Households have no labor income but instead may receive social security benefits. Retired households also face a nonlinear income tax schedule. In particular, their social security benefits are also subject to income taxation if these benefits exceed the exemption level specified in the U.S. tax code. We also allow for a deduction of medical expenses that exceed κ percent of taxable income. The specific formulas used to compute income taxes are reported in the appendix.

4.4.3 Problem for a Household about to Retire

The previous two cases cover all situations except that of a household in its last working period, R. Such a household enters the period with the state variables of a working household and chooses consumption, savings and female labor supply, recognizing that in period $R+1$ it will face the problem of a retired household. Consequently, when evaluating next period's value function, they form expectations using the distributions Γ_h^m, Γ_h^f, Γ_{M_1}, Γ_{M_2} and $\Gamma_d(\bar{e}^m)$.

4.5 Technology

Competitive firms produce a single homogeneous good by combining capital K and labor L using a constant-returns-to-scale production technology:

$$Y \equiv F(K, L) = AK^\alpha L^{1-\alpha},$$

and rent capital and labor in perfectly competitive factor markets. The aggregate resource constraint is given by

$$Y + (r + \delta)(\bar{K} - K) = C + (1 + n)\bar{K}' - (1 - \delta)\bar{K} + \tilde{M} + G,$$

where $\bar{K}$ is per capita private wealth, C denotes per capita consumption, $\tilde{M}$ is per capita medical expenses, G is government purchases and δ is the depreciation rate on capital.

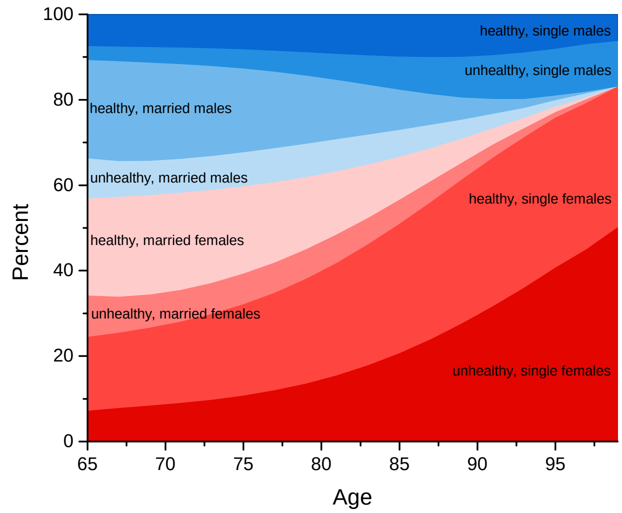

Figure 3: The population distribution of retirees by age. Individuals are classified by gender, health and marital status. The data for this figure is our HRS sample.

4.6 General Equilibrium

We consider a steady-state competitive equilibrium for a small open economy. Even though the U.S. is a large economy, capital markets are integrated and thus it is not clear how important changes in domestic savings are for determination of the real interest rate. We therefore choose to hold the real interest rate fixed. The definition of equilibrium for our economy can be found in Appendix 9.4.

5 Calibration

The model is parameterized to match a set of aggregate and distributional moments for the U.S. economy, including demographics, earnings, medical and nursing home expenses, as well as features of the U.S. social welfare, Medicaid, social security and income tax systems. Some of the parameter values can be determined ex-ante, others are calibrated by making the moments generated by a stationary equilibrium of the model target corresponding moments in the data. The calibration procedure minimizes the differences between the data targets and model's predicted values.[13] We focus in this section on the most novel aspects of the calibration. The remaining details of the calibration including: preferences, technology, income tax functions, and contribution and benefit formulas for SS can be found in Section 9.5.

[13] Solving the quantitative model takes over thirty minutes on a computer with 16 cores due to the computational complexity. For this reason it is not feasible to implement a formal method-of-moments estimation strategy.

5.1 Demographics

This section reports how we calibrate the parameters of the model that pertain to demographics. Agents are born at age 21 and can live to a maximum age of 100. Given that the focus of our analysis is on retirees, we want to reproduce the demographic structure of those 65 and older. Figure 3 reports the evolution of the distribution of retirees by marital status, health and gender estimated from our HRS sample. At the beginning of retirement, half of the population is healthy and married. As individuals age, three things happen: the fraction of singles increases, the fraction of unhealthy increases and males die faster than females. Below we will describe how we estimate this demographic structure and build it into our model.

5.1.1 Age Structure

We set the model period to two years because the data on OOP medical expenses is only available bi-annually. The maximum life span is $J = 40$ periods. Agents work for the first 44 years of life, i.e. the first 22 periods. At the beginning of period $R + 1 = 23$, they retire and begin to face survival risk.

The target for the population growth rate n is the ratio of population 65 years old and over to that 21 years old and over. According to U.S. Census Bureau, this ratio was 0.18 in 2000. We target this ratio rather than directly setting the population growth rate because the weight of the retired in the population determines the tax burden on workers, which is an object of primary interest in our policy analysis. The resulting annual growth rate of population is 1.8 percent.

5.1.2 Education

Newborn individuals are endowed with either high school or college educational attainment which is fixed throughout their working life. The model distribution of schooling types is set to reproduce its empirical counterpart in our HRS data sample for 65–66 year-old married households. In our data, both spouses have college degrees in 14 percent of households, in 14 percent only the male has a college degree, in 5 percent only the female has a college degree, and in 67 percent neither spouse has a college degree.

5.1.3 Marital Status

Newborn individuals are matched with a spouse and remain married until at least age 65. In our HRS sample, only 48 percent of 65–66 year-olds households are married couples, 36

Table 4: Marital status distribution of households with 65–66 year-old household heads by social security benefit quintiles

	Quintile				
	1	2	3	4	5
Married	0.19	0.24	0.36	0.67	0.95
Single Female	0.56	0.55	0.45	0.21	0.03
Single Male	0.25	0.21	0.20	0.12	0.02

The fraction of households in each social security income quintile who are married, single female or single male households. Authors' computations. Data: 1995–2010 HRS/AHEAD retired households aged 65+. See 9.1.1 for more details.

percent are single females and 16 percent are single males. For the most part, these figures reflect the cumulative effects of divorce and spousal death in the ages prior to age 65. Since our primary objective is to model retirees, we summarize these effects with a spousal death event at age 65. This event, which is distinct from the health-related survival risk agents face throughout retirement, ensures that $\Gamma_d(\bar{e})$ reproduces the marital status distribution of 65 year-olds in the data.

Another feature of our HRS data is that social-security income varies with martial status. Table 4 shows that there are very large differences in social security benefits across the three types of households. Married households have the highest benefits and single males receive higher benefits than females. In order to reproduce these observations, we assume that the spousal death shock has a negative relation with the distribution of average life-time earnings of the male. We then calibrate the death shock so that it reproduces the fractions of married, single male and single female households by social security benefit quintiles shown in Table 4.

5.1.4 Survival Probabilities and Health Status

Table 5 reports estimates of expected remaining years of life for 65-year-old individuals by marital status, health status and gender. All three factors have large effects on longevity. Having a spouse at age 65 is particularly beneficial for males extending their longevity by 2.9 years compared to 1.7 years for females. Good health extends life by about five years for both genders. Finally, females live on average 2.9 years longer than males.

These results are based on estimated survival probabilities, $\pi^i_{j+1}(h^i, d)$, for males and females from our HRS sample. Survival probabilities are assumed to be a logistic function of age, age-squared, health status, marital status, health status interacted with age and marital

Table 5: Expected additional years of life at age 65 by health status, marital status and gender

	Female	Male	All
	19.5	16.6	18.2
By health			
good	20.5	17.6	19.2
bad	15.8	12.2	14.3
By marital status			
married	20.1	17.2	18.6
single	18.4	14.3	17.0

Authors' computations. Data: 1995–2010 HRS/AHEAD retired households aged 65+. See 9.1 for more details on the data. Note that life expectancies in our HRS sample are lower than those in the 2000 U.S. Census. We thus scaled up the survival probabilities to match Census life expectancies at age 65.

status interacted with age. Transition probabilities for health status are also estimated separately for males and females, using the same logistic functions. The initial distributions of individuals across health status at age 65, $\Gamma^i_h(s^i)$, are set to match the distribution of health status by education in the HRS sample for 65–66 year-olds.

5.2 Earnings Process

The basic strategy for calibrating the labor productivity process follows Heathcote, Storesletten and Violante (2010b) who also consider earnings for married households. However, their earnings process cannot account for the fact that some households in our HRS sample receive very little social security income during their retirement. To address this problem, we augment their earnings process to allow for a low earnings state for males and set the value of earnings in this state to reproduce the SS income Gini coefficient. We assume that this state has the same persistence as other states. The resulting earnings process is non-Gaussian.[14] Table 6 reports the Gini and other moments of the SS income distribution in the model and the data. Notice that the model does a good job of reproducing the bottom tail of this distribution. This specification of the earnings process also improves the model's implications for the bottom tail of the earnings distribution. Additional details on the earnings process can be found in Section 9.5.4.

[14] In order to make this process consistent with the estimates of Heathcote et al. (2010b), we use the same simulated method of moments strategy described in 9.5.1.

Table 6: Social security income distribution in the data and the model.

	Quintiles					*Top Percentiles*			*Gini*
	Q1	Q2	Q3	Q4	Q5	10	5	1	
	share of total, %								
Data	8.2	14.2	18.6	24.5	34.5	19.3	10.6	2.5	.27
Model	8.3	14.1	17.7	25.4	34.5	18.4	9.3	2.1	.27

Data source: Authors' computations using 1995–2010 HRS/AHEAD retired households aged 65+. Data was adjusted for cohort-effects. See 9.1 for more details.

5.3 Medical Expense Process

Medical expenses vary systematically with age, gender, health and marital status. Moreover, when motivating our model, we found evidence that suggested medical expense shocks are important sources of impoverishment for retirees. We assume the medical expenses have a deterministic and stochastic component. We now describe each of these components.

5.3.1 Deterministic Medical Expense Profiles

In the model, medical expenses are household-specific. We start by estimating deterministic medical expense profiles for individuals and then sum these expenses over spouses for married couples. The shape of the medical expense profiles is determined by regressing individual medical expenses on a quartic in age and a quartic in age interacted with gender, marital status, mortality status (a dummy variable that takes on the value of one if death occurs in the next period) and health status using a fixed-effects estimator.[15]

Our HRS data only reports household expenses paid out of pocket and not those covered by Medicaid. However, when solving the model, we need to specify *pre-Medicaid* medical expenses, defined as the sum of OOP and Medicaid payments. To resolve this issue, we exploit the fact that individuals in the top lifetime earnings quintile (or who have/had spouses in the top lifetime earnings quintile) are unlikely to be eligible for means-tested Medicaid transfers, and hence their OOP medical expenses are, on average, very close to their pre-Medicaid expenses. Thus, the control variables in our medical expense regression include permanent income quintile dummies and their age-interaction terms. These latter controls reduce the estimation bias arising from the fact that Medicaid transfers increase with age. The estimated coefficients from this regression for permanent earnings quintile

[15] As pointed out by De Nardi, French and Jones (2010), the fixed effects estimator overcomes the problem with the variation in the sample composition due to differential mortality as well as accounts for cohort effects.

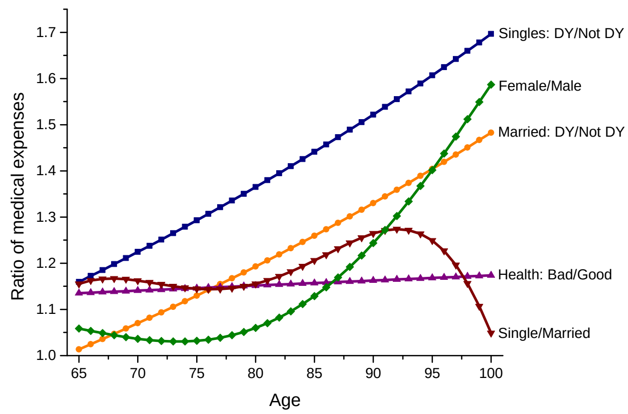

Figure 4: Estimated effects of marital status, health and death year (DY) conditional on marital status on individual medical expenses by age. The vertical axis is the ratio of estimated medical expenses for each type pair. Data: 1995–2010 HRS/AHEAD retired individuals aged 65+. See 9.1 for more details.

5 pin down the shape of the deterministic age-profile of the pre-Medicaid medical expense process.[16]

The obtained medical expense profiles are similar to profiles reported in De Nardi et al. (2010) and Kopecky and Koreshkova (2013). OOP expenses increase with permanent income and age. Moreover, OOP medical expenses are higher for females relative to males and higher if self-reported health status is poor.

Our estimated medical expense profiles also provide new information about how medical expenses vary by marital status and death year. Figure 4 shows the effects of marital status and death year on medical expenses. For purposes of comparison, we also report how medical expenses vary with gender and health. The most striking feature of the figure is that death year has a very large effect on medical expenses and its importance increases with age. At age 65 medical expenses for singles in their death year are 15% higher than for singles not in their death year. By age 85 the difference has risen to 45%. The effect of death year is smaller for married individuals but still important. A second result is that the effect of marital status on medical expenses is as large as or larger than the effect of health for those under age 95.

5.3.2 Stochastic Structure of Medical Expenses

The stochastic component of medical expenses has a persistent and a transitory component. The standard deviation of the transitory component is 0.816 and the persistent component

[16] All of the coefficients documented here are significant at conventional significance levels. Estimated coefficients and standard errors from these regressions are available upon request.

is assumed to follow an AR(1) at annual frequencies with an autocorrelation coefficient of 0.922 and a standard deviation of 0.579. These values are taken from French and Jones (2004).[17] The initial distribution of the persistent medical expense shock, Γ_{M_1}, is set to the distribution of OOP expenses at age 65–66 in our HRS data sample.

Previous work has found that an important source of variation in retirees medical expenses is long-term care needs.[18] To capture long-term care risk, we approximate the persistent shock with a five state Markov chain. In particular, we assume that the fifth state is associated with nursing home care. This calibration of the Markov chain captures both the small variation in medical expenses due to acute costs and the large variation due to long-term care costs. In particular, we target data facts pertaining to the cost of nursing home care for a Medicaid recipient, the expected duration of nursing home stays, the distribution of age at first entry and the overall size of nursing home expenses. The resulting Markov process recovers the serial correlation and standard deviation of the AR(1) process but is not Gaussian. More details on this aspect of the calibration are reported in 9.5.1.

Finally, we scale the medical expense profiles so that aggregate medical expenses in the model are 2.1% of GDP. This target corresponds to the average total expenses on medical care paid OOP or by Medicaid during the period 1999 to 2005.[19]

5.4 Government

We divide our discussion of the calibration of fiscal policy variables into two parts. We start by discussing calibration of the sources of government revenue and then turn to discuss the uses of government revenue.

5.4.1 Sources of Government Revenue

The government raises revenue from three taxes: a proportionate corporate profits tax, and nonlinear income and payroll taxes. We choose the size of the corporate profits tax and income taxes to reproduce the revenues of each of these taxes expressed as a fraction of GDP in U.S. data. The specific targets are 2.8% of GDP for the corporate profits tax and 8% of GDP for the income tax. These targets are averages over years 1950–2008 as reported in Table 11 of "Present Law and Historical Overview of the Federal Tax System."

[17] Their estimates are based on individuals. We use these values for the household but assume that the medical expense shocks to husbands and wives are independent.

[18] See for example Kopecky and Koreshkova (2013) who find that nursing home expenses are important drivers of life-cycle savings.

[19] Total medical expenses paid OOP or by Medicaid are taken from the "National Health Expenditure Accounts," U.S. Centers for Medicare and Medicaid Services and include payments for insurance premia.

U.S. income tax schedules vary with marital status. In our model, all workers are married but retirees can be single or married. Using the IRS Statistics of Income Public Use Tax File for the year 2000, Guner, Kaygusuz and Ventura (2012) estimate effective income tax functions for both married households and singles following the methodology of Kaygusuz (2010). We use their estimates (see Section 9.5.5 for more details.).

Contributions for SS and Medicare are financed by the payroll tax, $\tau_e = \tau_{ss} + \tau_{mc}$. The SS component of this tax, τ_{ss} is subject to a cap. We set the cap to be twice average earnings. This choice reproduces the cap of $\$72,000$ for the year 2000 in U.S. data. The Medicare component of this tax, τ_{mc}, is set to the total (employee + employer) Medicare tax rate which in year 2000 was equal to 2.3%.

5.4.2 Uses of Government Revenue

Recall that the government has three principal uses of funds: it pays social security benefits to retirees, provides means-tested social welfare benefits, and purchases goods and services from the private sector. We discuss the calibration of each of these types of expenditures in turn. The social security benefit function in our model reproduces the progressivity of the U.S. social security system and provides spousal and survivor benefits (see 9.5.6 for details).

The welfare program in our model represents public assistance programs in the U.S., including Medicaid, Supplemental Social Security Income, food stamps, unemployment insurance, Aid to Families with Dependent Children, and energy and housing assistance programs. For working individuals, we set the consumption floor, $\underline{c}$, in equation (2) to 15% of average earnings of full-time, prime-age, male workers. In year 2000 dollars, it amounts to approximately \$7,100. This magnitude is consistent with estimates from the previous literature.[20]

The means-test income thresholds $\underline{y}^d$ and consumption floors $\underline{c}^d$, of retirees vary with marital status. We set the consumption floors to 1/2 the level of the income thresholds and then set the income thresholds to target Medicaid take-up rates for retirees in our HRS dataset. The values of the targets are 22% for widows, 17% for widowers and 7% for married individuals. The resulting means-test income thresholds are close to 32% of average earnings of full-time, prime-age, male workers for all three types of individuals.[21] That is, they are approximately \$15,200 in year 2000 dollars. It follows that the consumption floors for retirees are about 16% of male average earnings or approximately \$7,600. The target for the Medicaid copay rate, $1 - \varphi$, is the ratio of average OOP medical expenses of Medicaid recipients to average OOP medical expenses of all retirees. In our HRS sample, this ratio is

[20] See Kopecky and Koreshkova (2013) for a discussion of the literature on consumption floors.

[21] The precise values are $\underline{y}^0 = 0.31$, $\underline{y}^1 = 0.33$ and $\underline{y}^2 = 0.32$.

Table 7: Medicaid take-up rates by age and marital status

	65–74	75–84	85+
Married			
data	0.07	0.07	0.11
model	0.05	0.07	0.12
Widows			
data	0.22	0.19	0.24
model	0.21	0.23	0.25
Widowers			
data	0.19	0.15	0.19
model	0.17	0.16	0.17

The fraction of individuals receiving Medicaid transfers by age group and marital status in the data and the model. Data: 1995–2010 HRS/AHEAD retired individuals aged 65+. See 9.1 for more details.

0.46. The resulting copay rate is 20%.

Finally, we adjust government purchases, G, of goods and services to close the government budget constraint. This results in a G/Y ratio of 0.11 for our baseline parameterization of the model.

6 Assessment of Baseline Calibration

In this section we compare some moments from the model with the data that were not targeted when parameterizing the model. One way to assess the model is in terms of its implication for wealth. In U.S. data the share of wealth held by individuals aged 65 and older ranges from 0.25 to 0.33.[22] The share in our baseline model at 0.26 is consistent with the data. This suggests that the overall extent of precautionary savings for retirement in the model is about right.

We will now show that the model also delivers patterns close to the data on Medicaid take-up rates, flows into Medicaid and OOP medical expenses by age and marital status. Then we will show that the model delivers an increased likelihood of impoverishment for individuals with large acute and long-term care OOP expenses, bad health status and those whose spouse has died, that is in line with the evidence on impoverishment documented in Section 9.2.

[22]These numbers are taken from Kopecky and Koreshkova (2013).

Table 8: Bi-annual Flows into Medicaid by Age and Marital Status

Age	65–74	75–84	85+
Marital Status			
Married			
data	0.028	0.029	0.043
model	0.021	0.023	0.040
Widows			
data	0.065	0.055	0.088
model	0.089	0.050	0.051
Widowers			
data	0.077	0.066	0.090
model	0.078	0.056	0.061

The flows are the fraction of retirees with given initial marital status not receiving Medicaid but who become recipients over the next two years. Data: 1995–2010 HRS/AHEAD retired individuals aged 65+. See 9.1 for more details.

6.1 Medicaid Take-up Rates and Flows

We start by discussing Medicaid take-up rates. In calibrating the model, we set the consumption floors to reproduce the fractions of each type of retired household on Medicaid. The Medicaid take-up rates by age were not explicitly targeted and thus are a way to assess the model's performance. Table 7 compares the take-up rates of Medicaid by age for the three household types. Inspection of Table 7 indicates that the model does a good job of reproducing Medicaid take-up rates for each age group. Allowing for a low earnings state plays a central role in reproducing the size of take up rates for younger retirees. When this shock is removed poor households have higher SS benefits and the model understates Medicaid take-up rates for those aged 65-74.

Another implication of the model that was not targeted is flows into Medicaid. Table 8 reports flows into Medicaid by age and marital status. Observe that in the data, the flows into Medicaid are much lower for married than singles. Moreover, the flows increase monotonically with age for married but follow a U-shaped pattern for singles. Model flows into Medicaid reproduce all of these features of the data. The model also reproduces the magnitudes of the flows into Medicaid for married households, although it overstates the flows of widows aged 65–74. This may be due to the fact that we do not allow people to qualify for Medicaid before age 65 in the model. In the data some widows qualify for Medicaid before age 65 and thus the flow at age 65 is lower.

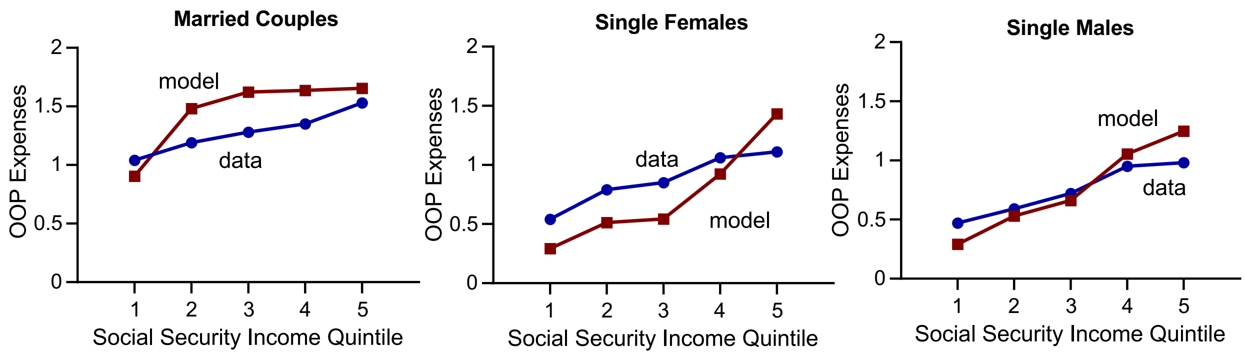

Figure 5: Out-of-pocket health expenses of married couples (left panel), single females (middle panel) and single males (right panel) relative to mean OOP expenses of all households by social security income quintile in the model (red squares) and the data (blue circles).

Table 9: Conditional transitions into poverty

	Model			Data		
Cohort	65–74	75–84	85+	65–74	75–84	85+
Marital Status (Women)						
married	1.15	1.02	4.30	5.49	5.76	10.64
widow	3.85	4.47	5.61	8.01	7.59	12.11
Marital Status (Men)						
married	0.77	1.72	4.30	6.08	5.93	5.90
widower	3.14	3.42	5.61	10.36	8.05	8.89
Health Status						
good	2.09	3.77	4.83	5.06	5.16	7.76
bad	2.60	4.65	5.56	7.94	8.68	10.78
Hospital						
no hospital stay	1.41	3.43	4.14	5.80	5.76	8.74
hospital stay	6.06	9.15	8.27	6.51	7.00	9.07
Nursing Home						
no NH stay	2.13	3.85	4.65	5.85	6.05	8.06
NH stay	9.16	9.05	7.94	10.94	11.12	14.73

The numbers are the percentage of individuals in wealth quintiles 2–5 who move to quintile 1 two years later conditional on their initial status. Wealth quintiles are determined from an individual wealth distribution specific to each age group. Married individuals are assigned half of the household wealth.

6.2 Out-of-pocket medical expenses

Figure 5 reports OOP medical expenses of households in the data and the model by marital status and social security income quintile. De Nardi et al. (2010) show that OOP medical expenses of single individuals are increasing by permanent income quintile.[23] Consistent with these findings, Figure 5 shows that household's OOP expenses increase with social security income in the data. Observe that OOP expenses also increase with social security income in the model. The primary reason for this is that, as income increases, the fraction of medical expenses covered by Medicaid falls. If the increase in OOP expenses with income in the data is, at least, in part due to wealthier households purchasing more quantity or quality of care, one might expect the model to understate OOP expenses of high income households. However, the model actually overstates OOP expenses of high income widowers and widows. We believe that these gaps are due to the fact that in the model there is no medically-needy path to Medicaid. In the data, some high income household are eligible for Medicaid under this path and have reduced OOP expenses as a result.[24]

6.3 Probability and Persistence of Impoverishment

We next discuss how well the model reproduces the differentials in downward mobility discussed in Section 9.2. Recall that we found evidence in the data that singles face a higher probability of impoverishment as compared to married individuals and that poverty is a more persistent state for singles. Poor health status, hospital stays and nursing home expenses also increase the likelihood and the persistence of impoverishment.

Our model exhibits these properties of the data. Table 9 reports conditional transitions into poverty and Table 10 reports the persistence of impoverishment over the period of two years for the same indicators that were described in Section 9.2. Frequencies of impoverishment are reported as the percentage of individuals in the upper wealth quintiles (Q2 through Q5) moving to the bottom wealth quintile (Q1). The persistence of impoverishment is measured by the fraction of individuals in wealth quintile Q1 staying in the same quintile.

Inspection of both tables indicates that the model is in reasonably good accord with the data. First, observe that widows and widowers of all ages face a higher probability and a higher persistence of impoverishment compared to married individuals of the same gender. Next, consider the effects of health and medical expenses on the probability of impoverishment and its persistence. In the model, bad health is associated with a higher

[23] De Nardi et al. (2010) use annuitized income to proxy for permanent income. Constructing annuitized income for households is subtle. So we use social security income instead. It is the largest component of annuitized income and we can observe it at the household level in both the model and the data.

[24] Source: Kaiser Commission on Medicaid and the Uninsured, December 2012.

Table 10: Conditional persistence of poverty

	Model			Data		
Cohort	65–74	75–84	85+	65–74	75–84	85+
Marital Status (Women)						
married	75.6	71.1	68.5	72.5	69.6	80.2
widow	94.4	88.5	78.3	80.0	75.9	76.1
Marital Status (Men)						
married	89.0	81.7	34.3	74.5	73.9	70.7
widower	99.2	96.5	100	75.7	79.0	73.9
Health Status						
good	90.7	83.3	79.8	69.7	70.8	67.8
bad	92.4	85.7	79.9	80.9	79.3	73.1
Hospital						
no hospital stay	89.1	80.2	77.2	75.3	73.1	71.0
hospital stay	97.8	92.7	85.8	79.0	78.8	70.8
Nursing Home						
no NH stay	91.0	83.8	78.7	75.7	74.6	69.3
NH stay	99.3	85.9	85.9	87.9	86.0	75.6

The numbers are the percentage of individuals in wealth quintile 1 who are still in quintile 1 two years later conditional on their initial status. Wealth quintiles are determined from an individual wealth distribution specific to each age group. Married individuals are assigned half of the household wealth.

probability of moving to the bottom wealth quintile and a higher probability of staying there. One way to compare the effects of medical expenses in the model with those in the data is to interpret the highest draw of the medical expense shock in the model as a nursing home stay and the second highest draw as a hospital stay. Both events increase the likelihood and persistence of impoverishment in the model as well as in the data.

The fact that the model understates the magnitudes of the flows into poverty is not surprising. Our model is quite detailed, but it does not consider all risks faced by retirees. Divorce, remarriage, inheritances, real estate returns and stock market returns are all absent from the model. Moreover, even if we could model all of these risks, the model would still understate the wealth mobility in our data. As pointed out by Poterba et al. (2011), there is a serious possibility that many of the bigger moves in the data are due to reporting and/or measurement errors. We have made an effort to control for these measurement problems but it is quite likely that there are some remaining spurious transitions in our data. It is consequently to be expected that the model will understate the transition percentages in the data.

7 Welfare Analysis

We now consider the welfare effects of MTSI in our quantitative model of the U.S. economy. The analysis of the two period model in Section 3 demonstrates that MTSI can improve welfare by insuring medical expense/lifetime earnings, life expectancy and type risk. However, the welfare benefits depend on the pattern of endowments, the extent of the risks and the size of the consumption floors. Our quantitative model specifies these parameters to reproduce features of the U.S. economy and this makes it possible to understand whether the effects documented in the two period model are empirically relevant.

7.1 The Value of Means-Tested Social Insurance for Retirees

One way to assess the welfare effects of MTSI is to consider how welfare changes when MTSI is removed. This approach requires us to describe what insurance opportunities would be available to retirees if MTSI were absent. We know from the two-period model above that wealthier households value MTSI less than poorer households and may prefer laissez-faire if the consumption floor is too high. Our strategy is to assume that, absent MTSI, retirees are guaranteed what we refer to as a Townsendian consumption floor. This is the largest consumption floor that all types of households, as indexed by education, can agree on. Our implicit assumption here is that if all households can agree on a particular consumption floor that, given enough time, social arrangements would arise that deliver it.[25]

Table 11 reports the welfare effects from removing MTSI in our baseline economy and two other versions of our quantitative model. The 'no medical expenses' economy has no medical expenses whereas the 'no earnings risk' economy has no idiosyncratic shocks to earnings. Welfare effects of removing MTSI are computed by comparing welfare of newborn households across steady-states. Welfare is measured as an equivalent consumption variation — a constant percentage change in consumption of each household in every period of its life which makes the household indifferent between the economy with MTSI and an alternative economy with no MTSI. The top rows of Table 11 display ex-ante welfare, welfare by male permanent earnings quintiles and welfare by educational status of the female and male members of the household.[26] The bottom two rows of the table report take-up rates of MTSI by retirees in each economy when this insurance is provided and the size of the associated government transfers expressed as a percentage of GNP. Removing MTSI requires adjustments

[25] The Townsendian consumption floor for retirees is 0.1% of average earnings. At this level 0.20% of retirees are on the floor.

[26] We wish to emphasize that male permanent earnings are distinct from household wealth or household earnings. We use male permanent earnings because they are exogenous. This makes it possible to compare the same individuals across economies.

Table 11: Welfare effects of removing MTSI from three economies

Economy	Baseline	No Medical Expenses	No Earnings Risk
Welfare			
Ex-ante	-4.87	-0.26	0.64
By male permanent earnings:			
quintile 1	-7.55	-0.42	0.34
quintile 2	-5.43	-0.28	0.34
quintile 3	-4.42	-0.23	0.34
quintile 4	-3.65	-0.19	0.88
quintile 5	-1.82	-0.10	1.73
By HH education type (female, male):			
high school, high school	-6.04	-0.34	0.34
high school, college	-2.87	-0.16	1.33
college, high school	-1.53	0.03	1.15
college, college	0	0.05	1.92
MTSI for retirees			
take-up rates, %	12.9	0.78	1.52
outlays, % of GNP	0.80	0.03	0.16

The welfare effects of removing MTSI from the baseline (first column), an economy in which medical expenses have been set to zero (second column) and an economy in which each household faces the average earnings profile conditional on its education type (third column). The bottom two rows show the take-up rates and total outlays to retirees of MTSI in each baseline economy. Welfare is measured as the percentage change in consumption in every period of life that makes a household indifferent between the economy with MTSI and the economy with no MTSI.

to the government budget constraint. We hold the ratio of government purchases to GDP fixed and adjust the proportional tax coefficient in the income tax schedule to satisfy the government budget constraint.

The first column of Table 11 shows that MTSI provides valuable insurance against old-age risks in the quantitative model. The fall in ex-ante, newborn welfare when the MTSI program is replaced by the Townsendian floor is equivalent to a 4.9% decrease in consumption. The insurance benefits of MTSI are broadly based. All newborn households experience welfare loses when welfare is indexed by permanent earnings quintile. If welfare is indexed by educational attainment instead, all but the household with college-educated females and males benefit from MTSI. This final group is by construction indifferent between the current scale of MTSI and the Townsendian floor.

Columns 2 and 3 provide additional welfare results that help to understand why the welfare gains are so large and broadly based. Comparing column 1 with column 2 shows that medical expenses significantly increase the benefits of MTSI. In the economy with no medical expenses the baseline scale of MTSI is still preferred to the Townsendian floors on average, however, the benefit of this program is much smaller (0.26%). The single biggest reason for this large difference in welfare is that MTSI is an effective way to insure against old-age medical expense related risks. As we pointed out in Section 3, this is because MTSI transfers pay out in situations where medical expenses are large and thus the need for insurance is largest. A second noteworthy feature of the welfare results for the no medical expense economy is that there is now disagreement among educational types. Households with college-educated females prefer the Townsendian floor.[27]

Notice that the benefits of MTSI are larger when medical expenses are present even though the negative incentive effects of MTSI are larger as well. One of the negative incentive effects is due to taxes to finance means-tested transfers to retirees. These transfers are 0.8% of GNP in the baseline economy but only 0.03% of GNP in the no medical expense economy. A second negative incentive effect was described above in the two-period model. When MTSI is available to retirees, poorer households will choose not to save and roll directly onto MTSI at retirement. In the baseline economy this effect is very pronounced and 8.5% of individuals start receiving means-tested benefits when they retire at age 65. In the economy with no medical expenses, the fraction of individuals who receive MTSI immediately upon retirement is only 0.69%.

A comparison of the results in column 1 with column 3 shows that the presence of lifetime earnings risk has an even bigger effect on the value of MTSI. When lifetime earnings risk is removed ex-ante utility is higher under the Townsendian consumption floor as compared to the baseline floor. Moreover, all types of newborn households prefer the Townsendian consumption floor. The main reason why households don't value MTSI in the economy with no lifetime earnings risk is because it has less dispersion in wealth at retirement and social security retirement income. In particular, there are fewer poor households and thus fewer beneficiaries of MTSI. This can be seen by the fact that MTSI take-up rates fall from 12.9% in the baseline economy to 1.52% once lifetime earnings risk is removed.

[27] The fact that households with college-educated females and high-school-educated males prefer the Townsendian floors is a bit surprising given that their earnings are lower than households with high-school-educated females and college-educated males and that the welfare effects by male permanent earnings are monotonic. We discuss the reason for this result to Section 7.5.

Table 12: Welfare and fiscal effects of changes in the MTSI consumption floor

MTSI floors **Tax Adjusting**	No change	30% up Payroll	30% up Income	30% down Income
Welfare				
Ex-ante	0.0	0.54	-0.44	0.04
By HH education type (female, male):				
high school, high school	0.0	0.62	-0.24	-0.13
high school, college	0.0	0.35	-0.91	0.45
college, high school	0.0	0.48	-0.69	0.28
college, college	0.0	0.29	-1.20	0.65
MTSI for retirees				
take-up rates, %	12.9	23.7	24.1	6.0
outlays, % of GNP	0.80	1.53	1.57	0.33

The first column is the baseline economy. The second column shows the welfare and fiscal effects of increasing the MTSI floor by 30% financed by an an increase in payroll taxes. The third column shows the effect if the increase is financed by income taxes instead. The final column shows the effect if the floor is instead reduced by 30% and income taxes are adjusted.

7.2 Reforming Means-Tested Social Insurance for Retirees

Removing MTSI entirely is an interesting counterfactual because it measures the overall value of this program. Given that the overall value of the program is positive, it is worthwhile to consider some policy relevant reforms of MTSI. Table 12 reports welfare changes associated with moving from the baseline economy to alternative economies in which consumption floors for retirees are either 30% higher or 30% lower. We report ex-ante utility and utility by educational type.

The most interesting result in this table is that the welfare of all newborn households increases if the expansion of MTSI is financed with a payroll tax. This point is illustrated in column 2. When MTSI expansion is financed by a payroll tax, ex-ante welfare of newborn households increases by 0.54%. More importantly, all education types are better off. Since educational status is the only source of initial heterogeneity, these results imply that all newborn households would prefer to be born into the economy with higher means-tested benefits and higher payroll taxes even after they know their educational type. A novel feature of this policy reform is that it benefits both newborn households and current retirees. As a result the costs of transition are not an issue.

Welfare falls, however, if the same expansion of MTSI is financed by higher income taxes instead. Ex-ante welfare of a newborn household declines by 0.44% and all educational types are worse off. The main reason for this difference is that the payroll tax only applies to labor income and is proportional, while the income tax applies to both labor and capital income and is progressive. As a result an expansion of MTSI financed by the income tax leads to a larger reduction in savings and a greater increase in MTSI take-up rates.

Our finding that households don't want to increase MTSI if it is financed with a higher income tax raises the question of whether they would prefer a smaller MTSI program and lower income taxes. The final column of Table 12 shows that ex-ante utility is in fact marginally (0.04%) higher when consumption floors are reduced by 30%. However, there is disagreement among newborn households. Households with two high school educated members are worse off. However, this loss is smaller than the combined gain of other types of newborn households.

7.3 The Value of Social Security

A large previous literature, which we discussed in the introduction, has failed to find a welfare enhancing role for the U.S. social security program. As we have shown above, this does not mean that there is no role for social insurance for the elderly. Medicaid and other U.S. means-tested social insurance programs for retirees significantly enhance welfare. Our model is different from those used by previous literature to evaluate SS, in particular, we model medical expenses and MTSI. This raises the question of whether the U.S. social security program is also valued by households in our model. In this section we show that the answer is no.

Columns 1 and 2 of Table 13 document the welfare effects of removing SS from our baseline economy and from an economy with no MTSI. Notice that removing SS has large positive welfare effects whether MTSI is present or not. When SS is removed from the baseline economy, ex-ante welfare of a newborn household increases by 11.8%. The welfare gains from removing SS are due to several factors. First, SS is a pay-as-you-go system and it is well known that the effective real return on SS contributions is lower than the return on capital in dynamically efficient economies such as ours. Second, SS is a much larger program than MTSI and financing it requires higher distortionary taxes. Third, many of the benefits provided by SS overlap with benefits that are provided by MTSI. In particular, as column 2 shows, when SS is removed from an economy with no MTSI, ex-ante welfare increases by only 7.2%.[28]

[28] The welfare cost of removing social security in the economy with no MTSI, though positive, is small in our model as compared to e.g. Hong and Ríos-Rull (2007) who consider a similar economy. They report about a 12% welfare gain from removing SS. An important distinction between our analysis and theirs is that we model medical expenses and their associated risks. When medical expenses are removed the welfare gains from removing SS increases to 11.5%.

Table 13: A comparison of the welfare effects of removing SS with the welfare effects of removing MTSI

	Removing SS		Removing MTSI	
Economy	Baseline	No MTSI	Baseline	No SS
Welfare				
Ex-ante	11.8	7.2	-4.9	-9.4
By HH education type (female, male):				
high school, high school	11.8	6.5	-6.0	-11.3
high school, college	11.1	8.8	-2.9	-5.19
college, high school	12.8	9.0	-1.5	-5.41
college, college	12.2	10.8	0	-1.43
MTSI for retirees				
take-up rates, %	12.9 (33.7)	0.00	12.9	33.7
outlays, % of GNP	0.80 (2.52)	0.00	0.80	2.52

The first two columns show the percentage change in welfare when SS is removed from the baseline economy and the economy with no MTSI. The second two columns show the welfare change when MTSI is removed from the baseline and the economy with no SS. The last two rows show the MTSI take-up rates and outlays for retirees in the initial economies. Numbers in parenthesis are the levels after removal of SS. After removal of MTSI all levels are essentially zero.

Observe next that all types of newborn households prefer the economies with no SS. However, the distribution of benefits differs depending on whether or not MTSI is available. In the presence of MTSI, lower income households are significantly happier about the removal of SS. This is because SS transfers during retirement reduce these households' ability to qualify for means-tested transfers. We now turn to discuss this and other interactions between MTSI and SS in more detail.

7.4 The Interactions of Means-Tested Social Insurance and Social Security

One of the most significant interactions between MTSI and SS pertains to the size of the welfare costs of removing MTSI. These costs are much higher when SS is absent. The final two columns of Table 13 report the welfare effects of removing MTSI from two economies. Column 3 removes MTSI from the baseline economy and was previously reported in Table 11. Column 4 considers removing MTSI in an economy with no SS. Comparing across these two economies shows that the benefits of MTSI are even larger when SS is absent. Reducing MTSI to the Townsendian consumption floor results in an ex-ante welfare loss of 9.4% of consumption absent SS. This is almost double the decline in welfare that occurs when MTSI is lowered in the baseline economy.

Given that all agents prefer the economy with MTSI but no SS it is of interest to consider in more detail how the properties of the model change when SS is removed. Removing SS increases MTSI take-up rates from 13% to 34%. As a result, government expenditures on MTSI for retirees increase from 0.8% to 2.52% of GNP.

This large increase in takeup rates can be decomposed into two effects. First, there is an insurance effect. Some of the insurance against survival, lifetime earnings and medical expense risks that was provided by SS is no provided by MTSI. Second, there is an incentive effect. SS forces some households to save for retirement who would choose not to save otherwise. This forced savings increases the expected return from private savings and some households alter their strategy and choose to save on their own as well. Thus removing SS exacerbates the negative incentive effects that MTSI has on savings behavior.

These two effects can be seen in Figure 6 which displays the increase in Medicaid take-up rates by age for each male permanent earnings quintile when social security is removed. The negative incentive effect can be measured by the change in the fraction of households who choose to roll into MTSI at retirement when SS is removed. This percentage increases by 15% for permanent earnings quintile 1, 15% for quintile 2 and 18% for quintile 3. Interestingly, there is no increase in take-up rates at retirement for those in quintiles 4 and 5.

The insurance effect can be seen in the change in the pattern of Medicaid enrollment by age. In quintiles 1 and 2, the change in enrollment rises sharply and then subsequently decreases with age. In quintile 3, the rise in enrollment continues until age 83. And for the top two quintiles take-up rates are zero until very late in life. It is clear from this that all quintiles experience shocks after retirement and rely on MTSI to help insure them.

The 21% increase in takeup rates when SS is removed depends on the presence of both medical expenses and earnings risk. For takeup rates to increase significantly we need both poor people and significant shocks after retirement. If either one of these features is absent both the insurance and incentive effects of SS removal decline. In particular, if we consider and economy with no medical expneses takeup rates only increase by 11% if SS is removed. If instead we consider an economy no earnings risk, takeup rates increase by 5% when SS is removed.

Financing the 21% increase in takeup rates leads government expenditures on MTSI for retirees to increase from 0.80% to 2.52% of GNP. Despite this, taxes are lower in the economy with no SS. The negative effect of SS on private savings that we discussed above are still significant and wealth is lower in the baseline economy as compared to the economy with MTSI only. Despite the large fiscal costs we have described, welfare of a newborn household

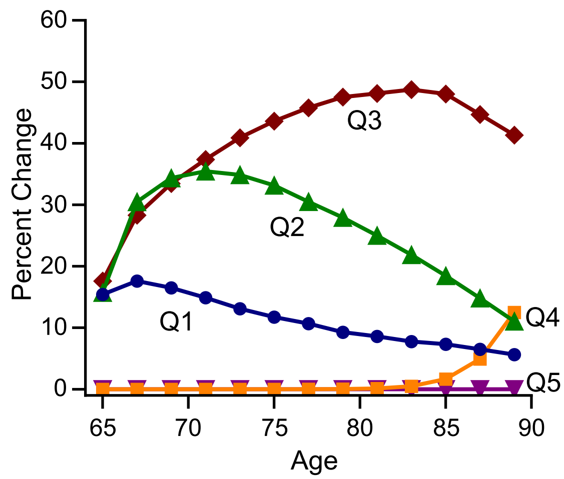

Figure 6: The percentage increase in MTSI take-up rates of retirees when social security is removed from the baseline economy. The change in the take-up rates is shown by age and male permanent earnings quintile. The percentage increase is calculated by subtracting the take-up rates in the baseline economy from those in the economy with MTSI only.

increases when this program is removed. Rich households dislike higher means-tested take-up rates because they raise government outlays but the poor do. SS was effectively forcing the poor to save which lowered their utility.

Our result that welfare is much higher in the economy with MTSI only is very robust to some of the other details of the model. As long as lifetime earnings risk and medical expenses are present, changes to the model, including removing anticipated death, closing the economy, or holding taxes fixed as is done in partial equilibrium analyses, do not overturn our result. Utility of newborn households is higher when MTSI is the only form of social insurance available to retirees regardless of whether these changes in the model are made individually or jointly.[29]

7.5 Robustness

We have found that the welfare benefits of MTSI are large. Are we overstating them? One concern is the size of the consumption floor that is provided when MTSI is unavailable. On the one hand, results reported in Table 14 suggest that we may be understating the welfare benefits of MTSI by using the Townsendian consumption. When the consumption floor is lowered by a factor of 10 ex-ante welfare increases by 50%. At this point the fraction of households on the consumption floor is essentially zero. It follows that further reductions in the floor do not increase the welfare loss further. On the other hand, we could also

[29]Simulations that demonstrate this point are available from the authors upon request.

Table 14: Welfare effects of removing MTSI under different assumptions about the alternative consumption floor and the low-earnings shock

Economy	Baseline $\underline{c} = 0.001$	$\underline{c} = 0.01$	$\underline{c} = 0.0001$	HS only shock
Welfare				
Ex-ante	-4.9	-2.5	-7.3	-3.0
By household education type (female, male):				
high school, high school	-6.0	-3.3	-8.9	-6.4
high school, college	-2.9	-1.1	-4.9	0.72
college, high school	-1.5	-0.69	-2.7	-1.7
college, college	0	0.47	-0.77	0.15
No MTSI				
percent of retirees at floor	0.02	0.20	0.00	

The welfare effects of replacing MTSI in the baseline economy with the Townsendian consumption floor (first column), a consumption floor that is 10 times larger than the Townsendian level (second column) and a floor that is 10 times smaller (third column). The last row of the table shows the percent of retirees at the floors when MTSI is not available. The last column is the welfare effects of replacing MTSI with the Townsendian consumption floor in an economy where only high-school-educated males can get the low-earnings shock.

be overstating the welfare benefits of MTSI. Suppose that the consumption floor in the no MTSI economy is increased by a factor of 10 instead. Ex-ante welfare still falls when MTSI is lowered to the alternative consumption floor but the size of the benefit is now 50% lower. Note also that three out of the four education types still prefer the economy with MTSI. Welfare for college-educated female and male households increases but this is to be expected given that the no MTSI consumption floor is above the Townsendian floor. Clearly, the overall size of the welfare benefits do depend on the size of the consumption floor when MTSI is not available. However, MTSI is a valuable program for a broad interval of consumption floors around the Townsendian floor.

There is an entirely distinct reason to believe that our estimates of the value of MTSI may be too conservative. We have assumed that medical expenses are not growing. Since 1980 health-expenses as a fraction of GDP have doubled.[30] If we were to model this observation the welfare benefits of MTSI would be even larger.

We have posited a non-Gaussian process for earnings. In particular, we have included a low earnings state that helps us reproduce the left tail of the earnings distribution. In the baseline model this shock hits all households with equal probability. For retirees in the

[30] See OECD Health Data.

HRS this was a reasonable assumption. However, in more recent cohorts the poverty rate of high-school educated individuals relative to college-educated individuals has doubled.[31] The final column of 14 reports illustrates how the welfare effects of removing MTSI change when the low earnings shock is assumed to hit households with high-school-educated males only. The ex-ante welfare benefits of MTSI are smaller and there is now disagreement among households. Households with college-educated males now prefer the economy with Townsendian consumption floors to the one with MTSI.[32]

Our conclusions are premised on a model that abstracts from private insurance markets for the risk of being born into a particular type of household, experiencing low lifetime earnings, high medical expenses after retirement and/or a long life. For some of these risks such as lifetime earnings risk the extent of private insurance markets is very small and the coverage is incomplete.[33] For other risks such as long-term care and life insurance, private insurance products exist but appear to be imperfect. It is doubtless the case that if these markets were modeled and no social insurance was available, demand for products such as life insurance and long-term care insurance would increase. However, it is our view that the increase in take-up rates in these markets would be small. Hendren (2013) finds that rejection rates in nongroup life, disability and long-term care insurance markets are high. He argues that an important reason for this is asymmetric information. Namely, individuals have superior information about their health status as compared to issuers and this information is significant in the sense that it can have a very large impact on payouts and thus pricing. Adverse selection limits the functioning of these markets in several ways. Insurers deny coverage to individuals who have observable characteristics that predispose them to these risks. Other individuals who know they have low risk will choose not to purchase insurance. Moreover, some poor individuals will not be able to afford private insurance even if they want it. Absent a government mandate or other types of regulation it is likely that many individuals will end up old, sick alone, poor and uninsured.

In the baseline specification, medical expenses are increasing with age and SS is partially insuring these risks. Some intuition for this result can be found in Conesa and Krueger (1999) who show that the value of SS is higher when markets are incomplete and agents face

[31]Pew Research Center (2014) "The Rising Cost of Not Going to College"

[32]Notice that the welfare rankings also change. In the baseline economy, the households with high-school-educated females value MTSI the most as it is more costly for these households to self-insure by increasing female labor supply when MTSI is removed. However, once college males no longer face the risk of incurring the low-income shock, households with high-school-educated females and college-educated males value MTSI much less.

[33]The only private market we know of that offers even partial coverage against lifetime earnings risk is private disability insurance. Only 3% of nongovernment workers directly participate in this market and only 30% participate indirectly through their employer (see Hendren (2013)).

uninsured idiosyncratic risk.

The reason why introducing SS has such a dramatic impact on MTSI take-up rates is because it ameliorates the negative saving effect of MTSI described above. SS forces some households to save for retirement who would choose not to save otherwise. This forced savings increases the expected return from private savings and some households alter their strategy and choose to save on their own as well.

The effect of introducing SS on means-tested take-up rates is most pronounced when medical expenses are present. This can be seen by comparing the left-hand and right-hand panels of Figure 6.

8 Conclusion

One of the central objectives of public policy is to provide for those who are sick and do not have the financial means to cover their medical and living expenses. For the aged, this risk is significant and can be compounded by a spousal death event leaving the retiree not only sick and poor but also alone. We have shown that there is a large, welfare-enhancing role for means-tested social insurance when these risks are modeled. We have also found that there would be general agreement among all households to increase the scale of current U.S. means-tested social insurance programs by 1/3 if that increase was financed with a higher payroll tax.

Our results are consistent with Friedman's claim. A pay-as-you-go social security program is a bad social insurance program in that it lowers welfare for all newborn households in our economy. Indeed, the welfare benefits of MTSI are even larger when SS is absent. Even though agents do not like SS, there are interesting interaction effects between SS and MTSI. For example, as we pointed out above, SS reduces the fraction of households that choose not to save and to roll into MTSI at retirement. These interaction effects have differential welfare implications for different types of agents. However, the welfare implications are overwhelmed by the large negative welfare effects of the low effective return on SS contributions. These findings suggest that an alternative type of public pension program, such as the defined contribution program considered by McGrattan and Prescott (2012), might have a welfare-enhancing role in an economy with MTSI. We leave further exploration of this conjecture to future work.

9 Appendix

9.1 Our HRS sample

The principal data set used in this paper the 1995–2010 waves of HRS and AHEAD and includes retired individuals aged 65 and above who are single or married to retired spouses. Our sample is essentially the same as that of Kopecky and Koreshkova (2013) and we refer the interested reader to that paper for more specifics on the construction of the sample. We define healthy individuals to be those who self-report their health status to be excellent, very good or good.

9.1.1 Wealth Transitions

We use the wealth variable (ATOTN) which is reported at the household level in the HRS. This wealth measure is the sum of the value of owned real estate (excluding primary residence), vehicles, businesses, IRA/Keogh accounts, stocks, bonds, checking/savings accounts, CDs, treasury bills and "other savings and assets," less any debt reported. To carry out an analysis of individuals, wealth is divided by two for married couples (and is left as is for single people). Additionally, irregular patterns in the dataset are fixed to eliminate spurious wealth transitions. For example, if a person has wealth > 0 in period 1, wealth $= 0$ in period 2, and wealth > 0 in period 3, the wealth in period 2 is replaced by the average of the wealth in period 1 and period 3. These patterns are present in less than 1 percent of the total number of observations. Finally, wealth is censored at -\$500 (if -\$500 $<$ wealth < 0) and at \$500 (if $0 \leq$ wealth $<$ \$500) to avoid problems of dividing by 0 or very small numbers when calculating percent changes in wealth from period to period.

Wealth is reported in real terms. This is accomplished by deflating reported nominal wealth using the CPI.

For the unconditional wealth transitions, we omit most imputations of wealth performed by RAND. In particular, we only include observations where there is no imputation or wealth lies in a reported range.

For the conditional wealth transitions, the resulting samples are too small if we omit the wealth imputations performed by RAND so we include all of their imputed wealth data. Their imputations of wealth only use a households current characteristics. As a result, we are concerned that some of these imputations create spurious wealth transitions. These effects are partially controlled for by the interpolation scheme we described above. To further control for these effects, we trim the top and bottom 1% of wealth transitions in each two year interval. The omitted observations do not appear to be clustered in any systematic way.

Table 15: Percentage of retired men moving from each quintile of the wealth distribution to quintile 1 two years later by marital status

	65–74 Year-olds		75–84 Year-olds		85+ Year-olds	
Quintile	**Married**	**Widowed**	**Married**	**Widowed**	**Married**	**Widowed**
1	74.5	75.7	73.9	79.0	70.7	73.9
2	18.3	24.1	17.4	18.8	15.0	19.2
3	3.9	12.2	3.5	9.6	4.6	8.1
4	1.3	3.5	2.0	2.0	4.1	4.3
5	0.7	1.7	0.9	1.8	0.0	4.0

The percentage of men moving down to quintile 1 from quintiles 2–5 in a 2-year period by marital status in the initial period. The first row is the percentage of men who stay in quintile 1. Authors' computations. Data: 1995–2010 HRS/AHEAD retired men aged 65+. See 9.1.1 for more details.

9.2 Wealth Transitions

Table 16 reports wealth mobility transitions to the first wealth quintile for married men and widowers. Observe that the results for older men are similar to the results that we reported in for women. Men aged 85+ also exhibit higher transitions into quintile 1 than men aged 65-74. However, this only occurs for those starting in wealth quintiles 3-5. Widowers have higher probabilities of impoverishment as compared to married men and poverty is more persistent for widowers.

Table 16 reports wealth mobility transitions to the first wealth quintile for individuals who experience a hospital stay and those who do not. Hospital stays are associated with an increased frequency of transitions to quintile 1. The differences here are weaker compared to some of the previous indicators with two ties and one reversal. But the impoverishing effect of a hospital stay is clearly discernible in Table 16. Quintile 1 is also a more persistent state conditional on a hospital stay event for the two youngest age groups. Given that acute medical expenses are transient in nature, it is not surprising at all to see that the pattern of impoverishment is a bit weaker here as compared to e.g. self-reported health status.

9.3 Model Objects

9.3.1 Model Survival Rates

The survival rate from $j-1$ to age j for each household type and health status $(\mathbf{h}, d)$ is given by $\lambda_j(\mathbf{h}, d)$ and has the following laws of motion:

Table 16: Percentage of retired individuals moving from each quintile of the wealth distribution to quintile 1 two years later conditional on whether or not they stayed overnight in a hospital in the initial period

	65–74 Year-olds		75–84 Year-olds		85+ Year-olds	
Quintile	**None**	**Hospital Stay**	**None**	**Hospital Stay**	**None**	**Hospital Stay**
1	75.3	79.0	73.1	78.8	71.0	70.8
2	18.1	18.9	16.9	18.2	20.9	22.9
3	3.6	5.1	3.8	6.6	7.8	7.7
4	0.9	1.6	1.7	2.5	4.0	4.3
5	0.6	0.4	0.6	0.6	2.2	1.3

The percentage of individuals moving down to quintile 1 from quintiles 2–5 in a 2-year period conditional on an overnight hospital stay in the initial period. The first row is the percentage of individuals who stay in quintile 1. Authors' computations. Data: 1995–2010 HRS/AHEAD retired individuals aged 65+. See 9.1.1 for more details.

$$\lambda_j(h^m = g, h^f = g, 0) = 1, \quad \text{for} \quad j = 1, 2, 3, ...R$$

$$\begin{aligned}\lambda_j(h^m = g, & h^f = g, 0) = \\ & \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)\pi_j^m(g,0)\pi_j^f(g,0)\nu_j^m(g,0)\nu_j^f(g,0) \\ & + \lambda_{j-1}(h^m = b, h^f = g, 0)\pi_j^m(h = b, 0)\pi_j^f(g,0)\nu_j^m(b,0)\nu_j^f(g,0) \\ & + \lambda_{j-1}(h^m = g, h^f = b, 0)\pi_j^m(h = g, 0)\pi_j^f(b,0)\nu_j^m(g,0)\nu_j^f(b,0) \\ & + \lambda_{j-1}(h^m = b, h^f = b, 0)\pi_j^m(h = b, 0)\pi_j^f(b,0)\nu_j^m(b,0)\nu_j^f(b,0)\Big]\end{aligned}$$

$$\begin{aligned}\lambda_j(h^m = b, & h^f = g, 0) = \\ & \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)\pi_j^m(g,0)\pi_j^f(g,0)\left(1-\nu_j^m(g,0)\right)\nu_j^f(g,0) \\ & + \lambda_{j-1}(h^m = b, h^f = g, 0)\pi_j^m(b,0)\pi_j^f(g,0)\left(1-\nu_j^m(b,0)\right)\nu_j^f(g,0) \\ & + \lambda_{j-1}(h^m = g, h^f = b, 0)\pi_j^m(g,0)\pi_j^f(b,0)\left(1-\nu_j^m(g,0)\right)\nu_j^f(b,0) \\ & + \lambda_{j-1}(h^m = b, h^f = b, 0)\pi_j^m(b,0)\pi_j^f(b,0)\left(1-\nu_j^m(b,0)\right)\nu_j^f(b,0)\Big]\end{aligned}$$

$$
\begin{aligned}
&\lambda_j(h^m = g, h^f = b, 0) = \\
&\qquad \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)\pi_j^m(g,0)\pi_j^f(g,0)\nu_j^m(g,0)\left(1-\nu_j^f(g,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = b, h^f = g, 0)\pi_j^m(b,0)\pi_j^f(g,0)\nu_j^m(b,0)\left(1-\nu_j^f(g,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = g, h^f = b, 0)\pi_j^m(g,0)\pi_j^f(b,0)\nu_j^m(g,0)\left(1-\nu_j^f(b,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = b, h^f = b, 0)\pi_j^m(b,0)\pi_j^f(b,0)\nu_j^m(b,0)\left(1-\nu_j^f(b,0)\right)\Big]
\end{aligned}
$$

$$
\begin{aligned}
&\lambda_j(h^m = b, h^f = b, 0) = \\
&\qquad \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)\pi_j^m(g,0)\pi_j^f(g,0)\left(1-\nu_j^m(g,0)\right)\left(1-\nu_j^f(g,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = b, h^f = g, 0)\pi_j^m(b,0)\pi_j^f(g,0)\left(1-\nu_j^m(b,0)\right)\left(1-\nu_j^f(g,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = g, h^f = b, 0)\pi_j^m(g,0)\pi_j^f(b,0)\left(1-\nu_j^m(g,0)\right)\left(1-\nu_j^f(b,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = b, h^f = b, 0)\pi_j^m(b,0)\pi_j^f(b,0)\left(1-\nu_j^m(b,0)\right)\left(1-\nu_j^f(b,0)\right)\Big]
\end{aligned}
$$

$$
\begin{aligned}
&\lambda_j(h^f = b, 1) = \\
&\qquad \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)(1-\pi_j^m(g,0))\pi_j^f(g,0)\left(1-\nu_j^f(g,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = b, h^f = g, 0)(1-\pi_j^m(b,0))\pi_j^f(g,0)\left(1-\nu_j^f(g,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = g, h^f = b, 0)(1-\pi_j^m(g,0))\pi_j^f(b,0)\left(1-\nu_j^f(b,0)\right) \\
&\qquad + \lambda_{j-1}(h^m = b, h^f = b, 0)(1-\pi_j^m(b,0))\pi_j^f(b,0)\left(1-\nu_j^f(b,0)\right) \\
&\qquad + \lambda_{j-1}(h^f = b, 1)\pi_j^f(b,0)\left(1-\nu_j^f(b,0)\right) \\
&\qquad + \lambda_{j-1}(h^f = g, 1)\pi_j^f(g,0)\left(1-\nu_j^f(g,0)\right)\Big]
\end{aligned}
$$

$$\lambda_j(h^f = g, 1) = \\ \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)(1-\pi_j^m(g,0))\pi_j^f(g,0)\nu_j^f(g,0) \\ + \lambda_{j-1}(h^m = b, h^f = g, 0)(1-\pi_j^m(b,0))\pi_j^f(g,0)\nu_j^f(g,0) \\ + \lambda_{j-1}(h^m = g, h^f = b, 0)(1-\pi_j^m(g,0))\pi_j^f(b,0)\nu_j^f(b,0) \\ + \lambda_{j-1}(h^m = b, h^f = b, 0)(1-\pi_j^m(b,0))\pi_j^f(b,0)\nu_j^f(b,0) \\ + \lambda_{j-1}(h^f = b, 1)\pi_j^f(b,0)\nu_j^f(b,0) \\ + \lambda_{j-1}(h^f = g, 1)\pi_j^f(g,0)\nu_j^f(g,0)\Big]$$

$$\lambda_j(h^m = b, 2) = \\ \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)(1-\pi_j^f(g,0))\pi_j^m(g,0)\left(1-\nu_j^m(g,0)\right) \\ + \lambda_{j-1}(h^m = b, h^f = g, 0)(1-\pi_j^f(g,0))\pi_j^m(b,0)\left(1-\nu_j^m(b,0)\right) \\ + \lambda_{j-1}(h^m = g, h^f = b, 0)(1-\pi_j^f(b,0))\pi_j^m(g,0)\left(1-\nu_j^m(g,0)\right) \\ + \lambda_{j-1}(h^m = b, h^f = b, 0)(1-\pi_j^f(b,0))\pi_j^m(b,0)\left(1-\nu_j^m(b,0)\right) \\ + \lambda_{j-1}(h^m = b, 2)\pi_j^m(b,0)\left(1-\nu_j^m(b,0)\right) \\ + \lambda_{j-1}(h^m = g, 2)\pi_j^m(g,0)\left(1-\nu_j^m(g,0)\right)\Big]$$

$$\lambda_j(h^m = g, 2) = \\ \frac{1}{1+n}\Big[\lambda_{j-1}(h^m = g, h^f = g, 0)(1-\pi_j^f(g,0))\pi_j^m(g,0)\nu_j^m(g,0) \\ + \lambda_{j-1}(h^m = b, h^f = g, 0)(1-\pi_j^f(g,0))\pi_j^m(b,0)\nu_j^m(b,0) \\ + \lambda_{j-1}(h^m = g, h^f = b, 0)(1-\pi_j^f(b,0))\pi_j^m(b,0)\nu_j^m(g,0) \\ + \lambda_{j-1}(h^m = b, h^f = b, 0)(1-\pi_j^f(b,0))\pi_j^m(b,0)\nu_j^m(b,0) \\ + \lambda_{j-1}(h^m = b, 2)\pi_j^m(b,0)\nu_j^m(b,0) \\ + \lambda_{j-1}(h^m = g, 2)\pi_j^m(g,0)\nu_j^m(g,0)\Big]$$

for $j = R+1, ..., J$.

9.4 Definition of Equilibrium

For the purposes of defining an equilibrium in a compact way, we suppress the individual state into a vector (j, x), where

$$x = \begin{cases} x_W \equiv (a, \bar{\mathbf{e}}, \boldsymbol{\varepsilon_e}, \mathbf{s}), & \text{if } 1 \le j \le R, \\ x_R \equiv (a, \bar{\mathbf{e}}, \mathbf{h}, \boldsymbol{\varepsilon_M}, d, d'), & \text{if } R < j \le J, \end{cases}$$

Accordingly, we redefine value functions, decision rules, income taxes, means-tested transfers and SS benefits to be functions of the individual state (j, x):$V^W(j,x)$, $V^R(j,x)$, $c(j,x)$, $a'(j,x)$, $l_f(j, x_W)$, $T_y(x)$, $Tr(j,x)$ and $S(x_R)$. Define the individual state spaces:

$$X_W \subset [0,\infty) \times [0,\infty) \times [0,\infty) \times \{(hs,hs),(hs,col),(col,hs),(col,col)\},$$
$$X_R \subset [0,\infty) \times [0,\infty) \times \{(g,g),(b,g),(g,b),(b,b)\} \times [0,\infty) \times \{0,1,2\} \times \{0,1,2\}.$$

and denote by $\Xi(X)$ the Borel σ-algebra on $X \in \{X_W, X_R\}$. Let $\Psi_j(X)$ be a probability measure of individuals with state $x \in X$ in cohort j. Note that these agents constitute a fraction $\eta_j \Psi_j(X)$ of the total population.

DEFINITION. Given a fiscal policy $\{S(\bar{\mathbf{e}}, d), G, \tau_c, \tau_{mc}(e), \underline{c}^d, \underline{y}^d, \kappa\}$ and a real interest rate r, a steady-state competitive equilibrium consists of household policies $\{c(j,x), a'(j,x), l_f(j,x)\}_{j=1}^J$ and associated value functions $\{V^W(j,x)\}_{j=1}^R$, $\{V^R(j,x)\}_{j=R+1}^J$, taxes and prices $\{\tau_{ss}(e), T_y(x), w\}$, per capita capital stocks $\{\bar{K}, K\}$ and an invariant distribution $\{\Psi_j\}_{j=1}^J$ such that

1. At the given prices and taxes, the household policy functions $c(j,x)$, $a'(j,x)$ and $l(j,x)$ achieve the value functions.

2. At the given prices, firms are on their input demand schedules: $w = F_L(K,L)$ and $r = F_K(K,L) - \delta$.

3. Aggregate savings are given by $\sum_j \eta_j \int_X a'(j,x) d\Psi_j = (1+n)\bar{K}$.

4. Markets clear:

   (a) Goods $\sum_j \eta_j \int_X c(j,x) d\Psi_j + (1+n)\bar{K} + \tilde{M} + G = F(K,L) + (1-\delta)\bar{K} + (r+\delta)(\bar{K} - K)$, where $\tilde{M} = \sum_{j=R}^J \eta_j \int_{X_R} \Phi(j, \mathbf{h}, \boldsymbol{\varepsilon_M}, d, d') d\Psi_j$.

   (b) Labor: $\sum_j \eta_j \int_X \left\{(1 - l_f(j,x))\Omega^f(j, \boldsymbol{\varepsilon_e}, s^f) + \Omega^m(j, \boldsymbol{\varepsilon_e}, s^m)\right\} d\Psi_j = L$.

5. Distributions of agents are consistent with individual behavior:

$$\Psi_{j+1}(X_0) = \int_{X_0} \left\{ \int_X Q_j(x,x') \mathbf{I}_{j'=j+1} d\Psi_j \right\} dx',$$

for all $X_0 \in \Xi$, where $\mathbf{I}$ is an indicator function and $Q_j(x, x')$ is the probability that an agent of age j and current state x transits to state x' in the following period. (A formal definition of $Q_j(x, x')$ is provided in the Appendix.)

6. SS budget is balanced: $SSbenefits = PayrollTaxes$, where

$$SSbenefits = \sum_{j=R+1}^{J} \eta_j \int_{X_R} S(x) d\Psi_j$$

and

$$PayrollTaxes = \sum_{j=1}^{R} \eta_j \int_{X_W} \left\{ \tau_{ss} \left(e^m(j,x) \right) e^m(j,x) + \tau_{ss} \left(e^f(j,x) \right) e^f(j,x) \right\} d\Psi_j$$

7. The government's budget is balanced:

$$IncomeTaxes + CorporateTaxes + MedicareTaxes = Transfers + G$$

where income tax revenue is given by

$$IncomeTaxes = \sum_{j=1}^{J} \eta_j \int_{X} T_y(x) d\Psi_j,$$

corporate profits tax revenue is

$$CorporateTaxes = \sum_{j=1}^{R} \eta_j \int_{X_W} \tau_c r a(j,x) d\Psi_j,$$

and Medicare tax revenue is

$$MedicareTaxes = \sum_{j=1}^{R} \eta_j \int_{X_W} \left\{ \tau_{mc} \left(e^m(j,x) \right) e^m(j,x) + \tau_{mc} \left(e^f(j,x) \right) e^f(j,x) \right\} d\Psi_j,$$

and means-tested transfer payments are

$$Transfers = \sum_{j=1}^{J} \eta_j \int_{X} Tr(j,x) d\Psi_j.$$

9.5 Calibration Details

9.5.1 Stochastic Structure of Medical expenses

When calibrating the five state Markov process of medical expense shocks, we allow one of the states to be associated with nursing home stays. We set the fifth state to reproduce the average annual cost of a nursing home stay for a Medicaid recipient. This cost is $33,500 in year 2000 dollars and includes both the cost of care and the cost of room and board.[34] We focus on Medicaid recipients because it allows us to decompose this expense into a consumption and medical expense component. In particular, for these individuals, the consumption component is given by $\underline{c}$. One way to assess this calibration is to consider the situation of a private payer. Under the assumption that 1/2 of total consumption is room and board for nursing home care, total average nursing home expenses for a private payer in the model are about $70,000 per year in year 2000 dollars. For purposes of comparison the average annual cost of a semi-private room was $60,000 in 2005 and the cost of a private room was $75,000 in 2005 according to the Metlife Market Survery of Nursing Home and Assisted Living Costs.

The probabilities of a nursing home stay are assumed to vary with age. We estimate the transition probabilities in and out of this state using the following targets. The probabilities of entry into the nursing home state are chosen to match the distribution of age of first nursing home entry for individuals aged 65 and above. This distribution is taken from Murtaugh, Kemper, Spillman and Carlson (1997). They find that 21% of nursing home stayers have their first entry between ages 65–74, 46% between ages 75–84, and 33% after age 85. The probabilities of exiting the nursing home state are chosen to match the average years of nursing home stay over their lifetime organized by age of first entry. We limit attention to stays of at least 90 days because we want to focus on true long-term care expenses. Murtaugh et al. (1997) do not report the figures we need. However, we are able to impute these durations by combining data they provide with data from Liu, McBride and Coughlin (1994). The specific targets are as follows. For those who had a first entry between 65-74, the average duration of all nursing home stays is 3.9 years. For those whose first entry is between the ages of 75-84 the average duration is 3.2 years and for those with first entry after age 85 the average duration is 2.9 years.

The above targets are all conditional on a nursing home entry. In order to estimate the unconditional probability of a nursing home entry, we target the probability that a 65 year old will enter a nursing home before death for a long term stay. That probability is 0.295 and is imputed using data from the two sources above.

In order to hit these targets, as well as the French and Jones (2004) AR(1) targets, we

[34] This number is based on Medicaid per diem rates in Meyer (2001).

use a simulated method of moments procedure that does a bias correction for the well known downward bias in estimated AR(1) coefficients.

9.5.2 Preferences

We set $\beta = 0.98$. Following the macro literature, we set σ equal to 2.0.[35] The degree of joint consumption is governed by χ. We set χ to 0.67 following Attanasio, Low and Sanchez-Marcos (2008).

We set γ, the leisure exponent for females to 2. This is the baseline value used by Erosa, Fuster and Kambourov (2012). This choice in conjunction with steady-state hours worked implies a theoretical Frisch-elasticity of 2.43. This choice implies that the correlation between the year-on-year growth rate of the husbands wages and the corresponding growth rate of the wive's hours worked is -0.34 in our model. For purposes of comparison, the model of Heathcote et al. (2010b) produces a correlation of -0.11 for the same statistic.

We allow the parameter $\psi(\mathbf{s})$ to vary with the education level of each household member. The targets, taken from McGrattan and Rogerson (2007), are average female hours by educational attainment of both household members. Expressed as a fraction of a total time endowment of 100 hours per week, they are 0.16 for high-school-educated households, 0.17 for households where the female has a high-school degree and her spouse has a college degree, 0.24 for households where the female has a college degree and her husband has a high-school degree, and 0.21 for college-educated households. The corresponding parameter values are 3.2, 1.6, 2.4, and 2.1. For retired households, the value of ψ^R is set to the weighted average of $\psi(\mathbf{s})$ for the working population.

The parameter that governs the extent of disutility the household experiences if the female is participating in the labor market, $\phi(\mathbf{s})$, also varies with education. The targets for this parameter, taken from Kaygusuz (2010), are female participation rates by educational attainment of each household member. The participation rates are for married females aged 50 to 59. For high-school-educated households the rate is 0.48. For households with high-school-educated females and college-educated males the rate is 0.45. For households with college-educated females and high-school-educated males the rate is 0.68 and for college-educated households the rate is 0.58. The corresponding parameter values we obtain are 0.33, 0.22, 0.16, and 0.15.

[35] See for example Castañeda, Díaz-Giménez and Ríos-Rull (2003), Heathcote et al. (2010b) and Storesletten, Telmer and Yaron (2004).

9.5.3 Technology

Consumption goods are produced according to a production function,

$$F(K, L) = AK^{\alpha}L^{1-\alpha},$$

where capital depreciates at rate δ. The parameters α and δ are set using their direct counterparts in the U.S data: a capital income share of 0.3 and an annual depreciation rate of 7% (Gomme and Rupert, 2007). The parameter A is set such that the wage per efficiency unit of labor is normalized to one under the baseline calibration.

9.5.4 Earnings Process

The basic strategy for calibrating the labor productivity process follows Heathcote et al. (2010b) who also consider earnings for married households. We assume that college graduates begin their working career four years later than high school graduates. The specific form of the labor productivity process is:

$$\log \Omega^i(j, \epsilon_e, s^i) = \alpha_1 \mathbf{I}(s^i = col) + \alpha_2 \mathbf{I}(i = f) + \beta_1 j + \beta_2 j^2 + \beta_3 j^3 + \epsilon_e^i,$$

where α_1 and α_2 are intercepts that capture the college premium and the gender gap. The β's determine the experience premium. The specific values of these parameters are $\alpha = 4.96 \times 10^{-1}$, $\alpha_2 = -4.78 \times 10^{-1}$, $\beta_1 = 4.80 \times 10^{-2}$, $\beta_2 = -8.06 \times 10^{-4}$ and $\beta_3 = -6.46 \times 10^{-7}$. All these values are taken from Heathcote et al. (2010b).

Following Heathcote et al. (2010b), we assume that females and males face a persistent productivity shock process. In particular, ϵ_e^i is assumed to follow an AR(1) process with a serial correlation coefficient of $\epsilon_e^i = 0.973$ and a standard deviation of 0.01. We allow the innovation to earning productivity to be correlated with the spouse's innovation. Heathcote et al. (2010b) choose this correlation to reproduce a targeted correlation of male wage growth and female wage growth of 0.15. We set the correlation of the earnings innovations to match this same target. The resulting correlation between the two earnings innovations is 0.05.

Heathcote et al. (2010b) also allow for a transient shock to labor productivity. We abstract from this second shock. This reduces the size of the state space for working households and allows us to model the problem of retirees in more detail.

The distribution of initial productivity levels Γ_e is assumed to be bivariate normal with a standard deviation of 0.352, a correlation of 0.517 and a gender productivity gap of 0.62 in 1970. All of these targets are taken from Heathcote et al. (2010b) and apply to males and females.[36]

One difference between us and Heathcote et al. (2010b) is that we allow for an earnings state that has a much lower level of earnings as compared to what Gaussian quadrature methods would imply. See Section 5.2 for more details.

9.5.5 Progressive Income Tax Formula

The effective progressive income tax formula is given by:

$$\tau^y(y^{disp}, d) = \left[\eta_1^d + \eta_2^d \log\left(\frac{y^{disp}}{\bar{y}}\right)\right] y^{disp} \tag{19}$$

where y^{disp} is disposable household income, $\bar{y}$ is mean income in the economy. Guner et al. (2012) estimate $\eta_1^0 = 0.113$ and $\eta_2^0 = 0.073$ for married households and $\eta_1^{d\in\{1,2\}} = 0.153$ and $\eta_2^{d\in\{1,2\}} = 0.057$ for single households.

The U.S. Federal tax code allows tax-filers a deduction for medical expenses that exceed 7.5% of income. Our income tax schedules indirectly account for deductions when estimating effective tax functions. However, their effective tax functions are averages across many households and do not capture the full benefit of this deduction to those who experience large medical expense shocks such as long-term care. We allow for a deduction for medical expenses that exceed 7.5% of income.

U.S. Federal tax code provides for an exemption of SS benefits. This exemption is phased out in two stages as income rises. Table 17 reports exemption thresholds and minimum income levels by marital status. The left column of Table 17 reports the actual dollar amounts in the year 2000. The right column expresses these figures as a fraction of average earnings of full-time, prime-age male workers in 2000 which according to SSA was \$47,552.16. According to our source, the thresholds and minimum income are not indexed to inflation or wage growth.

We use these thresholds to compute the exemptions formulas in the following way. We start by calculating provisional income, Y, which is defined as asset income,Y^a, plus half of the household's SS income, Y^{ss}. If $Y < T_i^1, i \in \{s, m\}$, there is a full exemption for SS benefits and taxable income for that household is equal to Y^a net of the medical expense tax deduction. If $T_i^1 < Y < T_i^2, i \in \{s, m\}$, taxable income is given by

$$Y^a + 0.5\min(Y^{ss}, Y - T_i^1),$$

[36] Specifications similar to this have been used by Attanasio et al. (2008) and Heathcote et al. (2008) to model the joint earnings of married couples.

Table 17: Exemption thresholds and minimum income levels for taxation of social security benefit income

Description	Levels ($)	% of ave. earnings
Threshold 1		
Single (T_s^1)	25,000	53
Married (T_m^1)	32,000	67
Threshold 2		
Single (T_s^2)	34,000	72
Married (T_m^2)	44,000	93
Minimum income		
single ($\underline{Y}_s$)	4,500	9
married ($\underline{Y}_m$)	6,000	13

Source: Scott, C. and J. Mulvey (2010). "Social Security: Calculation and History of Taxing Benefits", *Congressional Research Service.*

net of the medical expense tax deduction if eligible. If $Y > T_i^2, i \in \{s, m\}$, then taxable income is given by

$$Y^a + \min\Big\{0.85Y^{ss}, 0.85\big[Y - T_i^2 + \min(\underline{Y}_i, 0.5Y_i^{ss})\big]\Big\},$$

net of medical expense tax deduction if eligible.

9.5.6 Social Security Benefits

The U.S. Social Security system links a worker's benefits to an index of the worker's average earnings, $\underline{e}$. Benefits are adjusted to reflect the annual cap on contributions and there is also some progressivity built into the U.S. Social Security system. We use the following formula to link contributions to benefits for an individual

$$\hat{S}(\bar{e}) = \begin{cases} s_1\bar{e}, & \text{for } \bar{e} \leq \tau_1, \\ s_1\tau_1 + s_2(\bar{e} - \tau_1), & \text{for } \tau_1 \leq \bar{e} \leq \tau_2, \\ s_1\tau_1 + s_2(\tau_2 - \tau_1) + s_3(\bar{e} - \tau_2), & \text{for } \tau_2 \leq \bar{e} \leq \tau_3, \\ s_1\tau_1 + s_2(\tau_2 - \tau_1) + s_3(\tau_3 - \tau_2), & \text{for } \bar{e} \geq \tau_3. \end{cases}$$

Following the Social Security administration, we set the marginal replacement rates, s_1, s_2, and s_3 to 0.90, 0.33, and 0.15, respectively. The threshold levels, τ_1, τ_2, and τ_3, are set to 20%, 125% and 246% of average earnings for all workers. The U.S. Social Security system also provides spousal and survivor benefits. We model these benefits. Household benefits are determined using the following formula

$$S(\bar{\mathbf{e}}, d) = \begin{cases} \hat{S}\left(\max_{i \in \{m,f\}} \{\bar{e}^i\}\right) + \max\left\{0.5\hat{S}\left(\max_{i \in \{m,f\}} \{\bar{e}^i\}\right), \hat{S}\left(\min_{i \in \{m,f\}} \{\bar{e}^i\}\right)\right\}, & \text{if } d = 0, \\ \max\left\{\hat{S}\left(\bar{e}^m\right), \hat{S}\left(\bar{e}^f\right)\right\}. & \text{if } d \in \{1, 2\}. \end{cases}$$

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