How Well Did Social Security Mitigate the Effects of the Great Recession?*

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Abstract

This paper quantitatively assesses the consequences of the U.S. Social Security program during a business cycle episode comprised of large losses to wealth and increases in unemployment such as the Great Recession. We find that Social Security mitigates the average welfare losses for agents living at the time of the shock by 1.6% of future expected lifetime consumption. Social Security reduces the welfare losses since, unlike private wealth which the shock causes to depreciate, Social Security benefits are unaffected. We find that Social Security is particularly effective at mitigating welfare losses for agents who are older at the time of the shock and who experience lower lifetime incomes. Social security is more effective for the agents who are older at the time of the shock because they have less time before retirement to increase their labor supply and therefore must absorb more of the depreciation in wealth through a reduction in their consumption. Moreover, Social Security is relatively more effective at mitigating losses for lower income agents because these benefits represent a larger share of their post-retirement consumption. Importantly, we find that Social Security mitigates welfare losses for these vulnerable groups during this business cycle episode mainly by lowering welfare in the steady state as opposed to exacerbating welfare losses for other living agents.

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1 Introduction

Established in the wake of the Great Depression, Social Security was developed in part in response to high poverty rates for older individuals.[1] In particular, Social Security was developed to provide these individuals with both inter- and intra-generational insurance.[2] However, the insurance does not come without costs. According to the Congressional Budget Office, Social Security is the single largest federal program, with outlays representing roughly one-fifth of total federal expenditures in 2012. Moreover, both the retirement benefits and the taxes associated with Social Security distort labor and savings decisions. Generally, previous studies have found that these distortions dominate leading Social Security to be welfare reducing.[3] Nonetheless, Social Security has been cited as a likely driver of the decline in the elderly poverty rate over the last century (see, Engelhardt and Gruber (2004), for an example). Given that older and poorer individuals, along with other demographic groups, may be particularly vulnerable to a business cycle episode this paper shifts its focus away from the program's general welfare consequences. Instead, motivated by the Great Recession, this paper examines the distribution of the welfare effects of the program during business cycle episodes. In particular, this paper determines the role Social Security plays in either mitigating or exacerbating the welfare consequences of the Great Recession for agents of different ages, income groups, and abilities.

This paper begins by documenting that the Great Recession adversely affected U.S. households through two channels. First, between 2007 and 2009, the median change in household wealth was approximately a 20 percent decline. Furthermore, the median changes in wealth were fairly similar irrespective of age, wealth, or income. Second, the Great Recession is associated with large persistent increases in the frequency and duration of unemployment spells. These increases were particularly large for younger and less educated

[1] For example, upon signing the Social Security Act President Roosevelt said, "We can never insure one hundred percent of the population against one hundred percent of the hazards and vicissitudes of life, but we have tried to frame a law which will give some measure of protection to the average citizen and to his family against the loss of a job and against poverty-ridden old age."

[2] Social Security does not only provide consumption insurance for older individuals, but also provides insurance for other groups. However, this paper only focuses on the aspect of the program that provides older individuals with benefits.

[3] One exception is Imrohoroglu et al. (2003), which find that if preferences are time-inconsistent then the benefits of Social Security outweigh the costs.

households. Given these two findings, we model the Great Recession as a twenty percent loss of physical wealth, combined with increases in the likelihood and duration of unemployment spells that mimic the data.

We quantitatively assess Social Security's role during the Great Recession using a computational experiment. We begin by building a benchmark life cycle model which includes idiosyncratic earnings risk, endogenous labor supply, endogenous retirement, and a Social Security program that includes many realistic features of the U.S. Social Security program. Second we build a counterfactual life cycle model which is identical to the benchmark model except it excludes the Social Security program. In each model we calculate the welfare lost for the living agents due to the exogenous unemployment and depreciation shock. Comparing the welfare losses in each of the models illuminates the role Social Security plays in either mitigating or exacerbating the effects of these shocks. Although this study focuses on the role Social Security plays in affecting the welfare consequences of the shocks, it is useful to examine three sets of results for completeness: (i) the welfare effects of Social Security in the steady state, (ii) the welfare effects of the Great Recession in the model with Social Security, (iii) the distribution of the welfare effects of Social Security during the Great Recession.

In the steady state, the primary benefit of Social Security is the inter-generational insurance against agent's idiosyncratic productivity shocks due to the progressive nature of the program's benefit formula. In contrast, there are two channels by which Social Security reduces general welfare in the steady state. First, the Social Security benefits "crowd out" private productive savings. Second, the Social Security tax makes it more difficult for agents to accumulate savings which are desired to help facilitate consumption smoothing during periods of bad idiosyncratic productivity shocks. On average, in the steady state, Social Security reduces welfare by the equivalent of 7.5% of expected lifetime consumption (CEV). We find that individuals in the first, second, and fifth quintile of the lifetime income and wage distributions dislike Social Security more than other agents. The agents who experience lower income (wages) have a larger dislike for Social Security because the taxes make it particularly more difficult for these lower earners to accumulate savings. Moreover, the agents with higher income (wages) tend to dislike Social Security more because the progressive benefits formula means their income is being redistributed.

Turning to the effects of the Great Recession in the model with Social Security, we find that the shock causes an average loss of welfare for living agents equivalent to 4.3% of their future expected consumption. Examining the distribution of the welfare losses, we find that the Great Recession is particularly painful for agents who are older at the time of the shock and agents who experience a higher lifetime income. Older agents lose more welfare due to the shock for two reasons. First, these agents have more wealth accumulated so the depreciation from the shock is associated with a larger level of lost wealth. In addition, these agents are either near retirement or already retired meaning that they have less ability to offset their lost wealth by working more and instead must absorb more of these wealth losses with a decrease in consumption. Moreover, living agents who experience a higher lifetime income tend to be more adversely affected by the shock because they tend to have more savings so the level of their wealth losses are also greater.

Finally, comparing the welfare losses due to the Great Recession in the two models, we find that the average welfare losses for living agents are smaller in the model with Social Security by the equivalent of 1.6% of expected future lifetime consumption. Social Security is valuable during this business cycle episode since in the benchmark model agents fund part of their post-retirement consumption from Social Security benefits which, unlike private savings, are unaffected by the shock. In contrast in the model without Social Security, agents must fund all of their post-retirement consumption with savings which are vulnerable to the depreciation associated with the Great Recession. Turning to the role Social Security plays for different demographic groups, we find that Social Security is particularly effective at mitigating the welfare losses due to the Great Recession for agents who are 65 and older at the time of the shock. Social Security is responsible for reducing the average welfare losses for these agents by the equivalent of 8.7% of their expected future consumption. In contrast, Social Security has a negligible effect on the welfare losses for agents who are younger at the time of the shock. Additionally, we find that Social Security tends to mitigate a bit more of the welfare losses for living agents who experience lower income or lower productivity because Social Security makes up a larger composition of their post-retirement consumption.

Moreover, examining agents who are alive at the time of the shock or enter the model after the shock, we do not find any specific age, income or ability group for which Social Security substantially exacerbates the welfare consequences of the Great Recession. Instead the role that Social Security plays in mitigating the welfare consequences of the shock is due to a more general welfare tradeoff with agents who live during the steady state. Although the welfare consequences of Social Security in the steady state are larger than the benefits during the business cycle episode, the ability of Social Security to mitigate welfare losses for some of the most vulnerable demographics, without significantly exacerbating the welfare consequences of the shock for other agents, indicates that this program is particularly effective at providing insurance during these types of shocks.

Our work is related to three strands of the literature. The first strand focuses on the welfare consequences of the Great Recession. Most closely related to our work, Glover et al. (2012) and Hur (2013) who use a calibrated OLG model to quantify how welfare costs of severe recessions, such as the Great Recession, are distributed across different age groups. This paper advances this research agenda by not just focusing on the welfare effects of the shock but exploring how effective the Social Security program is at mitigating these effects across different cohorts.

The second strand tries to measure the long-run implications on welfare of a Social Security program. These works try to weigh the relative benefit from providing partial insurance against risks for which no market option exists against the welfare costs of distorting an individual's incentives to work and save. These studies, that largely focus on quantifying the benefit of providing intra-generational insurance for idiosyncratic earnings and mortality risks, include Auerbach and Kotlikoff (1987), Hubbard and Judd (1987), Hubbard (1988), Imrohoroglu et al. (1995), Storesletten et al. (1998), and Hong and Rìos-Rull (2007).[4] Moreover, Krueger and Kubler (2006) examine the welfare implications of Social Security in a steady-state model with both idiosyncratic risk and a moderate level of aggregate risk which allows them to quantify the benefits from Social Security of both inter-generational and intra-generational risk. By and large, these studies tend to find that the program is not welfare improving. They tend to find that the benefits from the Social Security system providing insurance against these risks are outweighed by the distortions that the the program

[4]For a theoretical discussion of the different types of risks that Social Security can provide insurance against see Shiller (1998).

imposes.[5] Similar to these papers, we aim to examine the welfare consequences of the current Social Security program. However, our study is different in that it focuses on the welfare implications of the Social Security program over the transitional period after a large shock, as opposed to focusing on the long-run welfare effects of the program.

The final strand of the literature examines the effect on the economy of reforming the current Social Security program. Examples of these studies include: Olovsson (2010), Imrohoroglu and Kitao (2012), Kitao (2012), Huggett and Parra (2010), and Huggett and Ventura (1999). Amongst these papers, Olovsson (2010) examines the welfare gains of a Social Security program that efficiently shares aggregate risks between generations. The author finds that although agents would prefer to be born into these more efficient programs, the welfare costs during the transition outweigh the benefits for living agents. In the spirit of Olovsson (2010), we solve and document the welfare effects on all the living individuals during a transitional period. However, instead of exploring the dynamics along the transitional path after a change in the Social Security program, this paper studies how the economy evolves during a particular business cycle episode.

This paper is organized as follows: Section 2 discusses the empirical data surrounding wealth and unemployment during the Great Recession while Section 3 introduces the computational model. Section 4 presents the competitive equilibrium. Section 5 describes the functional forms and calibration parameters. Section 6 reports the results of the computational experiment. Section 7 concludes.

2 Changes in Wealth and Unemployment during the Great Recession

This section examines two different channels by which the Great Recession affected households. In particular, we explore how wealth and unemployment evolved over this recent business cycle episode.

[5] One exception is Imrohoroglu et al. (2003), which find that if preferences are time-inconsistent then the benefits of Social Security outweigh the costs.

2.1 Changes in Household Wealth

In this section we examine the composition of the household balance sheet in 2007 and the change in households' wealth from 2007 to 2009 using both the 2007 wave and 2007-2009 panel in the Survey of Consumer Finance. Over the Great Recession, there was a large fall in both stock prices and home values. For example, the Dow Jones Industrial declined approximately thirty percent over 2007 and 2008. Over the same period, the Case-Shiller Nation Home Price Index declined a similar amount. Given the large fluctuations in the value of these assets, it is of interest to determine the exposure of households to the decreases in these assets' prices as of 2007.

As the second and third column of Table 1 illustrate, the exposures of household wealth to fluctuations in house prices and stock values was large and applied to households of all ages in the 2007 wave of the Survey of Consumer Finance (SCF). Over the life cycle, more than 45 percent of household net worth was invested either in stock or residential housing equity after the age of 25. Even though the percent invested in these asset classes was less for younger households, the amount in these asset classes still represented a large percent of the household's net worth.[6] Focusing on financial assets only (column I), the fraction of household financial assets directly held in stocks is even larger, fluctuating in a steady range between one half and two thirds over the life cycle.[7] Furthermore, similar portfolio allocation patterns are present when it comes to the liquid retirement wealth (column IV): between one half and two thirds of retirement funds are directly invested in the stock market. These findings, combined with the fact that, on average, over 90 percent of household retirement wealth is concentrated in private savings accounts (401K, IRA and Keogh) suggests that household funds explicitly allocated to post-retirement consumption were exposed to price declines associated with the Great Recession.

Next, we determine whether the large concentrations in these asset classes translated into widespread losses in wealth. We find that between 2007 and 2009 the median change

[6] We define net worth invested in residential housing as the total value of residential housing net of residential mortgage debt.

[7] When using housing values instead of housing equity, the fraction of net worth invested in housing or stock follows a more pronounced life cycle pattern, as young households hold large mortgage debt position – for discussion, see Glover et al. (2012).

Table 1: **Allocation of Wealth in Survey of Consumer Finance**

Age	Fraction of Financial Assets Invested in stocks	Fraction of Net Worth Invested In Stocks or in Residential Housing Equity	Fraction of Net Worth Invested in Stocks or in Housing Equity	Fraction of IRA/Thrift/Keogh Invested in Stocks	Fraction of Liquid Retirement Wealth Invested in IRA/Thrift/Keogh
< 20	0.21	0.16	0.16		
20-24	0.15	0.33	0.44	0.54	0.98
25-29	0.54	0.62	0.67	0.56	0.94
30-34	0.51	0.45	0.48	0.59	0.95
35-39	0.67	0.58	0.59	0.6	0.94
40-44	0.55	0.54	0.57	0.56	0.97
45-49	0.56	0.44	0.49	0.53	0.94
50-54	0.58	0.56	0.58	0.51	0.94
55-59	0.54	0.5	0.57	0.53	0.94
60-64	0.55	0.52	0.57	0.5	0.91
65-69	0.52	0.53	0.56	0.51	0.91
> 70	0.55	0.56	0.63	0.46	0.84

in wealth was a 21.5% decrease. Table 2 describes the median change in household wealth for different age, wealth, and income groups. Consistent with the findings in Bricker et al. (2011), we find that the losses are fairly consistent across these different groups.[8]

Table 2: **Median Change of Wealth in SCF Panel (2007-2009)**

Age of Head		Percentile of Wealth		Percentile of Total Income	
< 35	-34.2%	< 10	-65.5%	< 10	-24.6%
$35 - 45$	-28.2%	$10 - 25$	-42.2%	$10 - 25$	-26.6%
$45 - 55$	-21.8%	$25 - 50$	-18.1%	$25 - 50$	-25.2%
$55 - 65$	-16.4%	$50 - 75$	-17%	$50 - 75$	-20.7%
$65 - 75$	-15.4%	$75 - 90$	-21.6%	$75 - 90$	-19%
> 75	-22.3%	$90 - 100$	-23.8%	$90 - 100$	-18.1%

Given these findings, we choose to model the wealth channel of the Great Recession as a one-time unexpected 20% decrease in household wealth that affects all households in a similar manner. This approach has three implicit assumptions: the shock is uniform, causes a 20% depreciation, and is unexpected. The first two assumptions are supported by the findings in tables 1 and 2. We choose to make the last assumption, that the shock was unexpected, for two reasons. First, both popular press reports and survey evidence at the time of the shock point to the general public believing that house prices would not fall. For example, in surveys of home buyers in four metropolitan areas in 2003 Case and Shiller

[8]Although the shock that caused the Great Recession did not affect everyone in the same way, Bricker et al. (2011) find that almost two thirds of families experienced a loss of wealth between 2007 and 2009. Controlling for losses by income and age, the authors additionally document the median decline in wealth between 15% and 25%.

(2004) found that less then fifteen percent of respondents thought buying a home involved a great deal of risk. Furthermore, at the time of the survey, between 83 and 95 percent of respondents believed that house prices would increase over the next several years.[9] As Table 1 depicts, on average a large fraction of a household's balance sheet was invested in housing equity. Second, due to the Great Moderation, there was a belief that the risk of severe downturns was significantly reduced. For example, in his 2003 presidential address to the American Economic Association, Robert Lucas stated that the "central problem of depression-prevention has been solved."[10] These beliefs could have led many to believe that although investing in stocks still carried downside risk, there was minimal risk of a widespread sever decline in prices. Although we model the shock as unexpected, we do not take the stance that after the Great Moderation economists or the general public thought the business cycle was over. Instead, we believe these assumptions are consistent with a general belief that sever shocks, such as the one associated with the Great Recession, were generally outside the feasible set.[11]

2.2 Changes in Long-term Unemployment Risk

Next, we examine how unemployment changed over the Great Recession. We focus on the publicly available Current Population Survey (CPS) March Supplement files available through the IPUMS CPS website to document changes in unemployment during the Great Recession.[12] The Great Recession is associated with a large increase in unemployment and an extension of the average unemployment duration. As Figure 2.2 shows, the U.S. unemployment rate roughly doubled from 5 to 10 percent between March 2006 and March 2010.[13] At the same time, the fraction of the labor force that was unemployed 26 plus weeks

[9]For examples of popular press reports see "Housing Prices Always Rise" in the Washington Post's series on the worst ideas of the decade published on December 17th, 2009 by Greg Ip. The author notes that generally both home owners and investors were operating under the belief that home prices would never fall prior to the Great Recession.

[10]For more discussion of the state of economics prior to the Great Recession see Paul Krugman's Op-Ed piece in the New York Times entitled "How Did Economists Get It So Wrong?," in September 2nd, 2009.

[11]Another interpretation of our assumption is that households were not generally holding savings in order to buffer against large catastrophic shocks, instead their precautionary savings was primarily held to buffer against mild business cycle fluctuations and idiosyncratic earnings fluctuations.

[12]Appendix A describes how we compute these estimates in the CPS data.

[13]For official Bureau of Labor Statistics (BLS) estimates, see http://data.bls.gov/pdq/SurveyOutputServlet.

in a given year increased by 4 percentage points, respectively, while the median length of unemployment in a given year rose from 13 to 21 weeks over the same period. [14]

Figure 1: Unemployment Rates by Year

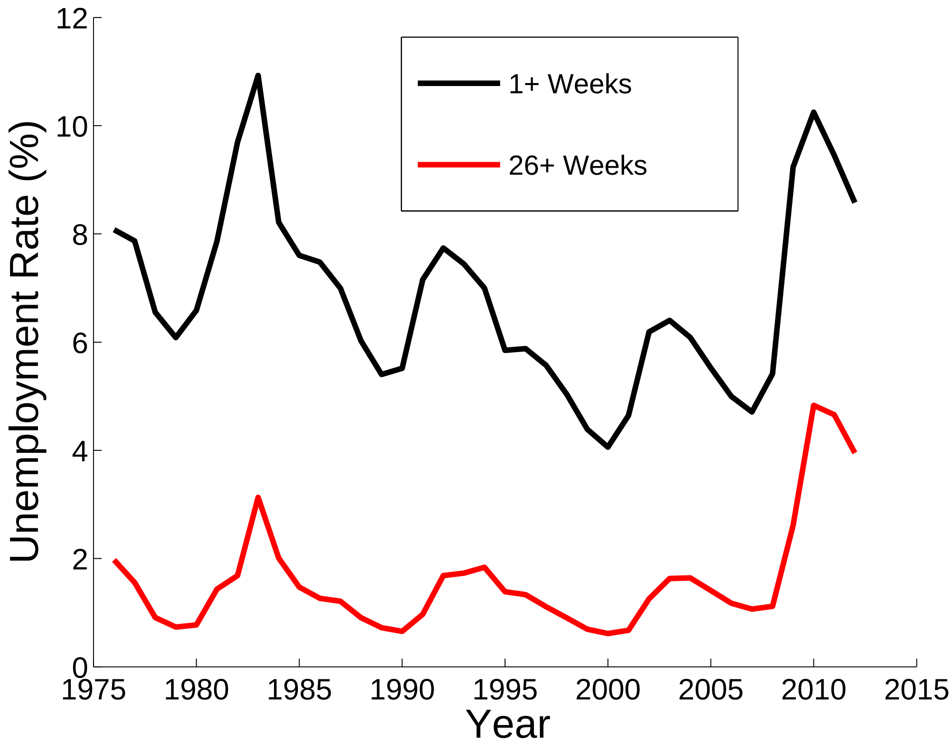


Table 3 and 4 depicts the average unemployment rates and duration by age and education in both 2005-2006 and 2009-2010. We define high educated individuals as those that have some additional education to high school. The table documents that both the level and the magnitude of the increase in the unemployment rate have varied with respondents' age and educational attainment, with young, low-education individuals experiencing the highest odds of unemployment and also observing the largest percentage point increase in unemployment rates. In contrast, observed increases in the average unemployment duration were relatively constant by age and education. The average unemployment duration in a given year increased by roughly 7 weeks across ages and education groups. Given these findings, we choose to model the second channel of the shock as an increase in both frequency and duration of

[14] Moreover, the fraction of unemployed U.S. workers unemployed for longer than 26 consecutive weeks rose from about 15 percent in 2006 to well over 40 percent by 2010 (see *The 2013 Long-Term Budget Outlook* (2013)).

the exogenous unemployment spells that mimic how these data evolved from 2007 through 2012.[15]

Table 3: **Percent Unemployed**

	2005-2006		2009-2010	
Age	**Low Education**	**High Education**	**Low Education**	**High Education**
20-45	8.06	3.70	15.95	7.05
> 45	4.46	2.78	10.04	5.82

Table 4: **Average Duration of Unemployment Spell (weeks)**

	2005-2006		2009-2010	
Age	**Low Education**	**High Education**	**Low Education**	**High Education**
20-45	18.7	17.9	25.2	24.2
> 45	23.2	24.2	31.1	31.6

Modeling the labor channel of the shock through unemployment spells may not capture all of the fluctuations in the labor market during the Great Recession. Figure 2.2 plots the evolution of the aggregate hours worked in the economy (defined here as the total hours worked normalized by the total population between ages 20 and 69) since 1976. As can be seen in the figure, despite a general downward trend after 2000, the average hours dropped considerably more starting in 2008. Theoretically, the observed decline in average hours could be attributed to (i) an increase in unemployment (either due to frequency or duration), (ii) a decrease in labor force participation, or (iii) workers working fewer hours (intensive margin). Since we only incorporate the first channel into our model, it is of interest to determine the relative size of each of these potential channels.

The first column of table 5 describes the percentage point deviation, accounting for the general trend, in aggregate hours after 2007.[16] Furthermore, the second through fourth columns of the table decomposes the deviations into the three possible sources. The table depicts that aggregate hours decreased a bit in 2008 and then declined much more from 2009

[15] Previous research demonstrates that there may exist a trend in unemployment duration over time. Therefore, we model the shock as the change in duration less the trend growth that was observed from 1997 through 2005.

[16] The trend growth of aggregate hours was calculated as the average growth rate from 1997 through 2005.

to 2011. Overall, the smaller change in aggregate hours in 2008 can be primarily explained by fluctuations on the intensive margin. Moreover, a majority of the larger declines in aggregate hours from 2009-2011 can be explained by changes in unemployment. Since our model only incorporates changes in unemployment, our model will have a difficult time matching the fluctuations in hours during periods when the other channels play a significant role.

Figure 2: Aggregates Hours Worked

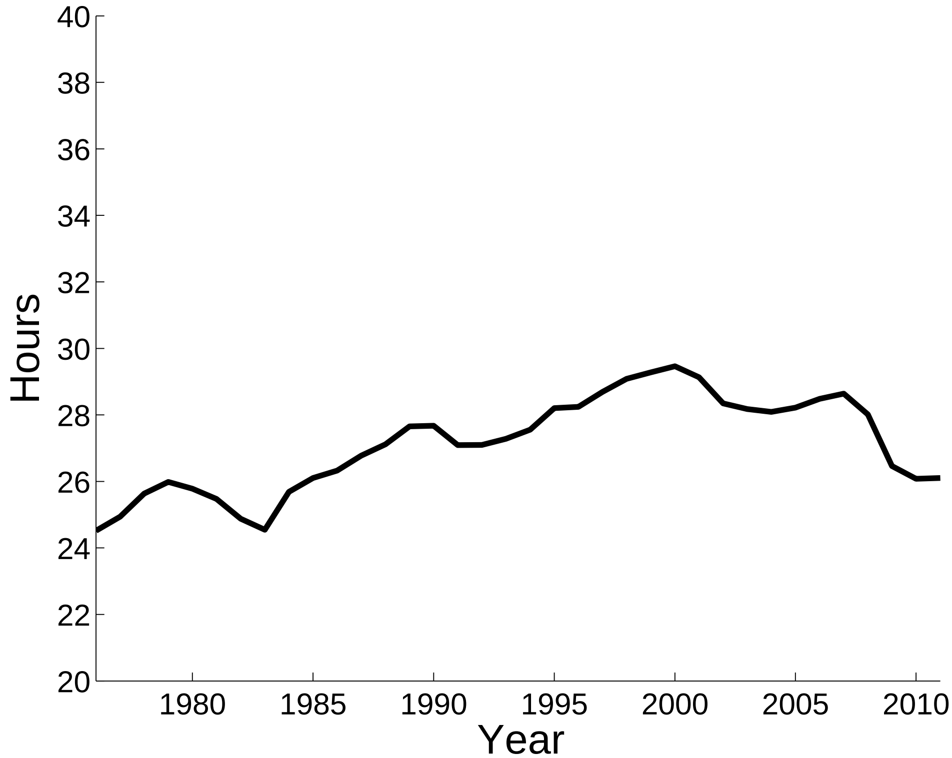


Table 5: **Changes in Aggregate Hours**

Year	P.P. Deviation in Agg. Hours	% due to Intensive	% due to Unemployment	% due to Participation
2008	-2.2	53%	31%	16%
2009	-7.6	29%	59%	12%
2010	-8.9	24%	62%	14%
2011	-8.8	21%	53%	26%

3 The model

Our framework is an Aiyagari-Bewley-Huggett style economy with overlapping generations of heterogenous households. Households derive utility from nondurable consumption and leisure. Households supply labor elastically and receive an idiosyncratic uninsurable stream of earnings that is governed by shocks to household productivity as well as by the dynamics of the market wage. Households make joint decisions about their consumption of nondurable goods, labor supply and savings. Idiosyncratic earnings shocks can be partially insured through precautionary holdings of a single asset in the economy and through labor supply decisions. Retired households receive payments from a PAY-GO Social Security system wherein retirees' benefits are paid for through income taxation of working-age individuals. The system of Social Security payments provides another margin of consumption insurance at old age. An important feature of this model is that households choose the age at which they retire, taking into consideration realistic features of the U.S. Social Security system such as the stylized system of Social Security payments that includes penalties for early retirement or credits for retiring past the normal retirement age.

3.1 Demographics

Time is assumed to be discrete, and the model period is equal to one year. In each period, the economy is populated by N overlapping generations of individuals of ages $j = 20, 21, ..., J$, with J being the maximum possible age an agent can live until. The size of each new cohort grows at a constant rate n. Lifetime length is uncertain with mortality risk rising varying over the lifetime. The conditional survival probability from age j to age $j+1$ is denoted Ψ_j where $\Psi_J = 0$. Annuity markets do not exits to insure life-span uncertainty and households are assumed to have no bequest motive. In spirit of Conesa et al. (2009), accidental bequests arising due to the presence of mortality risk are distributed equally amongst the living in the form of transfers Tr_t.

Agents work until their choose to retire at an endogenously determined age $j = R$. Endogenous retirement is an important extension of many existing models used to study the Social Security program. In the model, upon reaching the minimum retirement age $j = \underline{R}$, a household chooses every period whether to retire or not. We assume that the binary decision to retire (i.e., $I = \{0, 1\}$ where $I = 1$ denotes the event of retirement) is irreversible, making retirement a self-absorbing state.[17]

3.2 Endowments, Preferences and Unemployment Risk

Each period t, a household is endowed with one unit of time that can be used for leisure or market work. Household labor earnings are given by $y_t = w_t \omega_t h_t (1 - D_t)$, where w_t represents a wage rate per efficiency unit of labor, h_t is the fraction of the time endowment spent on labor market activities, D_t is the fraction of the time endowment in each period that the agent exogenously unemployed, and where the idiosyncratic labor productivity ω_t follows:

$$\log \omega_t = \theta_j + \alpha + \nu_t + \epsilon_t. \tag{1}$$

In this specification, based on the estimates in Kaplan (2012) from the Panel Study of Income Dynamics (PSID), θ_j governs the average age-profile of wages (or age-specific human capital), $\alpha \sim NID(0, \sigma_\alpha^2)$ is an individual-specific fixed effect (or ability) that is observed at birth and stays fixed for an agent over the life cycle, $\epsilon_t \sim NID(0, \sigma_\epsilon^2)$ is a transitory shock to productivity received every period, and ν_t is a persistent shock, also received each period, which follows a first-order autoregressive process:

$$\nu_t = \rho \nu_{t-1} + \psi_t \text{ with } \psi_t \sim NID(0, \sigma_\nu^2) \text{ and } \nu_1 = 0. \tag{2}$$

Additionally, agents face the possibility of an exogenous unemployment shock that displaces them from the labor market for a $D \in [0, 1]$ fraction of a time. This exogenous separation arrives with a probability $p^U(\alpha, j)$ that is a function of agent's ability α and age t.[18] When the unemployment spell hits, the worker loses the option to work during that fraction of her time endowment and receive an unemployment insurance benefit with a

[17] Cahill et al. (2011) demonstrate that few people who retire re-enter the labor force. Furthermore, Coile and Levine (2006) find that the boom and bust cycle of the stock market in 2001 did not have a statistically significant effect on the rate of re-entry of retirees back into the labor force.

[18] As documented in Section 2.2, both age and ability (which we use education attainment as a proxy) are important determinants of unemployment risk in the data.

replacement rate ι.

Household preferences over the stream of consumption, c, and labor supply, h, over the life cycle are governed by a time-separable utility function

$$E_0 \sum_{j=0}^{J} \beta^j U(c_j, h_j, D_j), \tag{3}$$

where β is the discount factor and where the expectation is taken with respect to the life-span uncertainty, the idiosyncratic labor productivity process, and the unemployment process. Furthermore, $U(c_j, h_j, D_j)$ is specified as:

$$U(c_j, h_j, D_j) = (1 - D_j)u(c_j, h_j) + D_j u(c_j, 0).^{19} \tag{4}$$

Modeling the period utility functions as the weighted average of the utility in the part of the period when the agent is unemployed and the part when they are employed allows us to pick a large enough model period (one year) that allows the model to be tractable but still incorporate unemployment spell that are shorter than the model period. We assume that consumption is constant across the period. Since we use a utility function that is separable in consumption and hours worked, the constant consumption is not binding as long as the agent realizes D_j at the beginning of the period.

3.3 Market structure

The markets are incomplete and households cannot fully insure against the idiosyncratic labor productivity, unemployment, and mortality risks by trading state-contingent assets. They can, however, partially self-insure these risks by accumulating precautionary asset holdings, a_t. The stock of assets earns a market return r_t. We assume that households enter the economy with no assets and are not allowed to borrow against future income, so that $a_0 = 0$ and $a_t \geq 0$ for all t.

[19] It is assumed that c_j, the flow of consumption, is equal throughout the perdiod.

3.4 Technology

Firms are perfectly competitive with constant returns to scale production technology. Aggregate technology is represented by a Cobb-Douglas production function of the form $Y = F(K, N) = K^{\zeta} N^{(1-\zeta)}$, where K and N are aggregate capital and labor (measured in efficiency units) and ζ is the capital share of output. Capital depreciates at a constant rate $\delta \in (0, 1)$. The firms rent capital and hire labor from households in competitive markets, where factor prices r_t and w_t are equated to their marginal productivity. The aggregate resource constraint is:

$$C_t + K_{t+1} - (1-\delta)K_t + G_t \leq K_t^{\zeta} N_t^{1-\zeta}, \tag{5}$$

where, in addition to the above described variables, C_t and G_t represent aggregate household and government consumption, respectively.

3.5 Government policy

The government partakes in four activities. First, the government distributes accidental bequests of the deceased agents in a form of lump-sum transfers, Tr_t, to the living.[20] Second, the government collects a proportional Social Security tax, τ_t^{ss}, on pre-tax labor income of working-age individuals (up to an allowable taxable maximum $\overline{y}$) to finance Social Security payments, b_t^{ss}, for retired workers (for details, see the section below). Third, the government distributes the unemployment benefits, b^{ui}, to agents who are exogenously separated. These benefits are a function of the average income across all agents in the economy and not related to an individuals specific earnings history. Fourth, government consumes in an unproductive sector. Following Conesa et al. (2009), Kitao (2012) and Imrohoroglu et al. (1995), the government consumption, G_t, is exogenously determined, and is modeled as proportional to the total output in the steady state economy, so that $G_t = \phi Y_t$. The government uses income tax revenue to finance its spending in the unproductive sector and on unemployment benefits. In the spirit of many studies including Conesa and Krueger (2006), the government

[20] By the timing convention, the transfers are received at the beginning of the period before agent's idiosyncratic labor productivity status is revealed.

taxes each individual's taxable income according to a progressive labor income tax schedule, $T(\tilde{y}_t)$, where the taxable income, $\tilde{y}_t$, is defined as:

$$\tilde{y}_t = y_t + r_t(Tr_t + a_t) - 0.5\tau_t^{ss} \min\{y_t, \overline{y_t}\}, \tag{6}$$

and where, as is the the case under current U.S. tax law, part of the pre-tax labor income, y_t, that is accounted for by the employer's contributions to Social Security, $0.5\tau_t^{ss} \min\{y_t, \overline{y_t}\}$, is not taxable.

3.6 Social security program

We model the system of Social Security payments, b^{ss}, to mimic the U.S. system in several key respects. In the U.S., Social Security benefits for retired workers (paid out at and after the endogenously determined retirement period R) are based on each worker's average level of earnings calculated over the highest 35 years of earnings.[21] A baseline benefit formula is then applied to each worker's average level of labor earnings to calculate the pre-adjustment Social Security benefit.[22] The benefit formula is designed to ensure that the Social Security system is progressive, with the replacement rate being inversely related to past earnings. The baseline benefit calculation is governed by two cut-off points (also known as "bend points") which jointly determine the degree of progressivity of the Social Security system. The third, implicit bend point is the cutoff on Social Security benefits and contributions. The cutoff limits the annual amount of earnings subject to taxation for a given year by determining $\overline{y_t}$, but also applies when those earnings are used in a benefit computation. Finally, the Social Security system makes various adjustments to the baseline benefit amount, such as permanent percentage reductions for early retirement and permanent percentage credits for retirement past the normal retirement age (NRA).[23]

[21] These earnings are expressed as workers' average indexed monthly earnings (AIME), indexed to present by wage growth. We abstract from wage indexation in the model and, for computational simplicity, base the Social Security payment b_{ss} on the average life cycle earnings with some adjustments described later in this section in Equation 9.

[22] The monthly Social Security benefit is called primary insurance amount (PIA). Once annualized, the PIA corresponds to the model baseline retirement benefit b_{ss}^{base}. In general, the PIA is the benefit a person would receive if she elects to begin receiving retirement benefits at her normal retirement age (NRA).

[23] Under the current law, the age at which a worker becomes eligible for full Social Security retirement benefits – the NRA – depends on the worker's year of birth. For people born before 1938, the NRA is 65.

To model the U.S. Social Security system, we proceed in three steps. First, following Huggett and Parra (2010) and Kitao (2012), we calculate the model analog of each worker's average level of labor earnings over the working life cycle. At every age, the total accumulated earnings follow the law of motion:

$$x_{j+1} = \begin{cases} \frac{\min\{y_j, \overline{y}\} + (j-1)x_j}{j} & \text{if} \quad j \leq 35, \\ \max\{x_j, \frac{\min\{y_j, \overline{y}\} + (t-j)x_j}{j}\} & \text{if} \quad 35 < j < R, \\ x_j & \text{if} \quad j \geq R, \end{cases} \tag{7}$$

where x_j is the accounting variable capturing the equally-weighted average of earnings before the retirement age R; and $\overline{y}$ is the maximum allowable level of labor earnings subject to the Social Security tax that corresponds to the benefit-contribution cap. Moreover, to infuse an additional degree of realism while maintaining the model's tractability, we extend on the specification in Huggett and Parra (2010) by introducing a rule to ensure that the total accumulated labor earnings, x_j, accrued over the working life cycle and used in the benefit calculation cannot fall below their previously realized level, x_{j-1}, after 35 working periods.[24] Finally, since agents are not allowed to work during their retirement, which is assumed to be a self-absorbing state, x_j becomes constant at $j = R$.

Second, the pre-adjustment Social Security benefit, b^{ss}_{base}, for each retiree is calculated using a convex, piecewise-linear function of average past earnings observed at retirement age, x_R, so that the marginal benefit rate varies over three levels of taxable income:

$$\begin{array}{lll} \tau_{r1} & \text{for} & 0 \leq x_R < b_1 \\ \tau_{r2} & \text{for} & b_1 \leq x_R < b_2 \\ \tau_{r3} & \text{for} & b_2 \leq x_R < b_3, \end{array} \tag{8}$$

where $\{b_1, b_2, b_3 = \overline{y}\}$ are the two bend points plus the benefit-contribution cut-off point, and where $\tau_{r1}, \tau_{r2}, \tau_{r3}$ represent the marginal replacement rates in the progressive Social Security

For slightly younger workers, it increases by two months per birth year, reaching 66 for people born in 1943. The NRA remains at 66 for workers born between 1944 and 1954 and then begins to increase in two-month increments again, reaching 67 for workers born in 1960 or later.

[24]Computing the Social Security benefit over the highest 35 years of earnings would render the model intractable, as it would require tracking each period's earnings as part of the model's state space.

payment schedule associated with the respective bend points.

Finally, adjustments for early and late retirement are calculated. In the U.S., workers can begin receiving permanently reduced monthly retirement benefits after reaching the early retirement age, $\underline{R}$.[25] The size of the reduction varies with the months out of labor force between the time at which worker retired and her NRA.[26] Conversely, when an individual retires after reaching the NRA, the Social Security benefit payments are increased by a fixed permanent proportion for every year spent working between the NRA and the maximum age cap $\overline{R}$ for which the credit is available.[27] As a result, the total Social Security benefit b_{ss} obtained by the retiree is defined as:

$$b^{ss} = \begin{cases} (1 - n\kappa_1(n))b^{ss}_{base} & \text{if} \quad \underline{R} \leq R < NRA \\ (1 - n\kappa_2(n))b^{ss}_{base} & \text{if} \quad NRA \leq R < \overline{R}, \end{cases} \tag{9}$$

where $n = (NRA - R)$ represents the years of early (delayed) retirement over which the penalty (credit) is accrued; and where $\kappa_1(n)$ and $\kappa_2(n)$ represent functions of yearly rates for early (delayed) retirement penalty (credit), respectively.

3.7 Timing convention

At the beginning of the period, uncertainty about early death is revealed to all agents. The living agents receive transfers from accidental bequests and observe their retirement status from the previous period. Households that previously retired receive the Social Security benefit and interest on their accumulated asset holdings, pay off their tax liabilities and make their consumption-saving decision. For households that have not retired in previous periods, the labor productivity status and the unemployment shock are revealed. Households

[25] In the U.S., the minimum retirement age at which Social Security benefits become available is set at 62. In the data, more than two-thirds of the workers began receiving Social Security retirement benefits before their normal retirement age. The majority of those early recipients began collecting benefits at age 62. Source: Social Security Administration, Annual Statistical Supplement, 2000, p. 240.

[26] A benefit is reduced 5/9 of one percent for each month before normal retirement age, up to 36 months. If the number of months exceeds 36, then the benefit is further reduced 5/12 of one percent per month.

[27] The delayed benefit retirement varies with year of birth, but reaches 2/3 of 1 percent of the benefit for every month delayed (or 8 percent annualized) for individuals born in 1943 or later. Source: Jonathan F. Pingle, Social Security's Delayed Retirement Credit and the Labor Supply of Older Men, 2006. No credit is given after age 69.

eligible for retirement then determine whether to retire or work. Working households supply labor and capital to the firm and production takes place. The working households next receive factor income, pay off their tax liabilities and make the consumption-saving decision. If the household chooses to retire then they receive their Social Security benefit.

3.8 Dynamic program of a of a previously working household

A household that was working in the previous period and is indexed by type $(a_t, x_t, \alpha, \epsilon_t, \nu_t, j, d)$ solves the dynamic program:

$$V_t(a, x, \alpha, \epsilon, \nu, j, d) = \begin{cases} \max_{c,a',x',h,d} U(c,h) + \beta s_j E V_{t+1}(a', x', \alpha, z', \nu', j+1, d') & \text{if} \quad j \leq \underline{R}, \\ \max_{c,a',x',h,I=\{0,1\}} U(c,h) + \beta s_j E V_{t+1}(a', x', \alpha, \epsilon', \nu', j+1, d') & \text{if} \quad \underline{R} < j \leq \overline{R}, \end{cases}$$

subject to

$$\begin{aligned} c + a' &= (1+r)(Tr + a) + y - T(\tilde{y}) - \tau^{ss} \min\{y, \overline{y}\} + d b^{\text{unemp}} & \text{if} \quad I = 0, \\ c + a' &= (1+r)(Tr + a) + y - T(\tilde{y}) - b^{ss} & \text{if} \quad I = 1. \end{aligned} \tag{10}$$

by choosing consumption, c, savings, a', and time spent working, h. The accounting variable x is the average lifetime labor earnings as of period t and follows the law of motion specified in equation 7. Households earn interest income $r(Tr + a)$ on the lump-sum transfer Tr from accidental bequests and on asset holdings from the previous period, a. y represents the pre-tax labor income of the working households and is described in Section 3.2. $\tilde{y}$ defines the taxable income on which the income tax, T, is paid, and follows the process in equation 6. d is the state variable for whether the individuals is exogenously unemployed and b^{unemp} is the exogenously determined unemployment benefits. Finally, τ_{ss} is the Social Security tax rate that is applied to the pre-tax labor income, y, up to an allowable taxable maximum, $\overline{y}$. As in the U.S. system, households of age $j < \underline{R}$ are not eligible for Social Security benefits and, as such, are not allowed the decision to permanently retire. Instead, households who decide not to participate in the labor market prior to reaching the minimum retirement age $j = \underline{R}$ can do so by choosing zero labor hours (i.e., $h = 0$). Upon reaching the minimum retirement age, households make a permanent decision to retire, with $I = 1$ describing the event of retirement ($I = 0$ otherwise). Finally, households are forced into a mandatory retirement after reaching age $\overline{R}$.

3.9 Dynamic program of a previously retired household

Upon reaching the minimum retirement age $\underline{R}$, households are allowed to retire permanently. Retired households receive a constant stream of Social Security payments whose size is determined by the level of the average life cycle labor earnings observed at the retirement period, x_R. Retired households are unaffected by labor productivity shocks observed post-retirement, as the option to work in retirement is not allowed in the model. As such, a retired household indexed by type $(a_t, x_R, \alpha, z_t, \nu_t, j)$ solves the dynamic program:

$$V_t(a, x_R, \alpha, \epsilon, \nu, j) = \max_{c,a'} U(c, h) + \beta s_j E V_{t+1}(a', x_R, \alpha, \epsilon', \nu', j + 1),$$

subject to

$$c + a' = (1 + r)(Tr + a) + b^{ss} - T(\tilde{y}), \tag{11}$$

by choosing consumption, c, and savings, a'. Similarly to non-retired households, retirees earn interest income $r(Tr + a)$ on the transfer, Tr, and their existing asset holdings, a, but also receive the Social Security payment, b^{ss}.

4 Equilibrium

Let $a \in R_+$, $x \in R_+$, $\mu \in E = \{\mu_1, \mu_2, ..., \mu_N\}$, $j \in J = \{1, 2, ..., J\}$, $D \in \mathfrak{D} = [0, 1]$, and let $S = R_+ \times R_+ \times E \times J$. Let $B(R_+)$ be the Borel $\sigma-$algebra of R_+ and $P(E)$, $P(J)$, and $P(\mathfrak{D})$ the power sets of E, J, and $\mathfrak{D}$, respectively. Let $\Theta = B(R_+) \times B(R_+) \times P(E) \times P(J) \times P(\mathfrak{D})$, and let M be the set of all finite measures over the measurable space (S, Θ).

Definition. Given a sequence of Social Security payment functions $\{SS_t\}_{t=1}^{\infty}$, and initial conditions capital, K_1, and the measure of agents of type (a_t, x_t, μ_t, j, D) at time t, Ω_1, a competitive equilibrium is a sequence of individual functions for the households $\{v_t, c_t, a'_t, l_t\}_{t=1}^{\infty}$, sequence of production plans for firms $\{N_t, K_t\}_{t=1}^{\infty}$, prices $\{w_t, r_t\}_{t=1}^{\infty}$, government policies for the Social Security system, $\{\tau_t^{ss}, b_t^{ss}\}_{t=1}^{\infty}$, government policy for the unemployment benefits,

$\{b^{\text{unemp}}\}$, and income taxation functions, $\{T_t\}_{t=1}^{\infty}$, a sequenc of transfers $\{Tr_t\}_{t=1}^{\infty}$, and a sequence of measures $\{\Omega_t\}_{t=1}^{\infty}$, $\Omega_t \in M$, such that for all t, the following hold.

1. Given prices, policies, transfers, and initial conditions, v_t is the solution to the dynamic programming problem in equations 9 - 11, with c_t, a'_t, and l_t as associated policy functions.

2. The prices w_t and r_t satisfy
$$r_t = \zeta(\frac{N_t}{K_t})^{1-\zeta} - \delta$$
$$w_t = (1-\zeta)(\frac{N_t}{K_t})^{\zeta}.$$

3. The Social Security policies satisfy:
$$\int \omega w h \tau_{ss}\ \Omega_t(i,a,\mu,j,D) = \int b^{ss}\ I\ \Omega_t(i,a,\mu,j,D).$$

4. Transfers are given by:
$$Tr = \int (1-\Psi_j)a\ \Omega(i,a,\mu,j,D).$$

5. Government budget balance:
$$G = \int T^y[r(a+Tr) + (1-.5\tau_{ss})w\omega h]\ \Omega_t(i,a,\mu,j,D) - \int (D)b^{\text{unemp}}\ \Omega_t(i,a,\mu,j,D).$$

6. Market clearing:
$$K = \int a\ \Omega_t(i,a,\mu,j),\ N = \int \omega h_j\ \Omega_t(i,a,\mu,j) \text{ and}$$
$$\int c\ \Omega_t(i,a,\mu,j) + \int a\ \Omega_t(i,a,\mu,j) + G = K^{\zeta}N^{1-\zeta} + (1-\delta)K.$$

Definition. We define a steady state equilibrium as a competitive equilibrium where Ω_t is constant and all aggregate variables grow at the same rate as population.

5 Calibration

The model is calibrated in two stages; all parameters are shown in Table 7. In the first stage, values are assigned to parameters that can be determined from the data without the need to solve the model. In the second stage, the remaining parameters are estimated by the simulated method of moments (SMM) to match key moments of the U.S. cross-sectional and aggregate data.

5.1 Demographics, endowments, unemployment risk and preferences

There are 80 overlapping generations of individuals of ages $j = 20, ..., 100$. We follow Conesa et al. (2009) and Kitao (2012) in setting population growth rate, n, to 1.1 percent to match the yearly population growth in the U.S. economy. The conditional survival probabilities, Ψ_j, are derived from the U.S. life tables (Bell and Miller (2002)).

Following Huggett and Parra (2010), the process for the idiosyncratic labor productivity, ω, is calibrated based on the estimates from the PSID data in Kaplan (2012).[28] The deterministic labor profile, $\exp^{\theta_j}$, is shown in Figure 5.1. The profile is (i) smoothed by fitting a quadratic function in age, normalized such that the value equal one when an agent enters the economy, and (ii) extended to cover ages 20 through 69 which we define as the last period in which households are assumed to participate in the labor activities ($\overline{R}$).[29] The permanent, persistent and transitory idiosyncratic shocks to individual's productivity are distributed normal with a mean of zero. The remaining parameters are also set in accordance with the estimates in Kaplan (2012): $\rho = 0.958$, $\sigma^2_\alpha = 0.065$, $\sigma^2_\nu = 0.017$ and $\sigma^2_\epsilon = 0.081$. We discretize all three of the shocks in order to solve the model, using two states to represent the transitory and permanent shocks and five states for the persistent shock. For expositional convenience, we refer to the two different states of the permanent shock as high and low ability types.

[28]For details on estimation of this process, see Appendix E in Kaplan (2012).
[29]The estimates in Kaplan (2012) are available for ages 25-65.

Figure 3: $\exp^{\theta_j}$

We model the preferences as additively separable between consumption and labor:

$$u(c_{it}, h_{it}) = \frac{c_{it}^{1-\gamma}}{1-\gamma} - \chi_1 \frac{h_{it}^{1+\frac{1}{\sigma}}}{1+\frac{1}{\sigma}} - \chi_2, \tag{12}$$

with $\gamma > 0$, $\sigma > 0$, $\chi_1 > 0$ and $\chi_2 > 0$.[30] The constant relative risk aversion preferences over consumption are standard and are characterized by the risk aversion coefficient, which determines household desire to smooth consumption across time and states. The existing estimates of γ typically ranging between 1 and 3; in this paper, we set $\gamma = 2$. The parameter σ represents the Frish labor supply elasticity on the intensive margin. Past microeconometric studies estimate the Frisch elasticity to be between 0 and 0.5 (see, for example, Kaplan (2012), Altonji (1986), MaCurdy (1981), Domeij and Floden (2006) or Browning et al. (1999)). However, more recent research shows that these estimates may be biased downward (see Imai and Keane (2004), Domeij and Floden (2006), Pistaferri (2003), Chetty (2009), and Contreras and Sinclair (2008)). As such, we calibrate σ at 0.5 – the upper range of the available estimates.[31] The scaling constant χ_1 is calibrated such that on average agents work one third of their endowment prior to the normal retirement age. Additionally, the fixed cost of working χ_2 is set such that seventy percent of individuals retire by the normal retirement

[30]We use this utility function that is additively separable in labor and consumption since Peterman (2013) and Conesa et al. (2009) demonstrate that when leisure, instead of labor, enters the utility function that the Frisch labor supply elasticity on the intensive margin is not constant over the lifetime and can affect the economy.

[31]We note that estimates of the Frisch elasticity from simulated data in this model would be larger than 0.5 due to changes in the wages affecting an individuals P.I.A. However, Peterman (2012) demonstrates that the increase in elasticity from endogenously determined Social Security benefits is small.

age which matches the data.[32] The fixed cost χ_2 implies that the disutility from working discontinuously increases when an agent goes from zero to positive hours worked.[33] Finally, in order to characterize the household preferences described in Equation 3, we calibrate the discount factor β to 0.990 to match the U.S. capital-to-output of 2.7.

In each period an individual receives an unemployment shock, D, which represents the fraction of the time endowment that period that they are unemployed. We discretize D to take two values, either zero or $d(\alpha, j)$ which is calibrated to match the unemployment durations described in 2007 listed Table 6. The probability that an agent receives a shock such that d is greater than zero is determined by $p_d(\alpha, j)$, which is set to match the values from 2007 (see Table 6).

Table 6: **Unemployment Parameters**

	$\mathbf{p_d}(\alpha, \mathbf{j})$		$\mathbf{d}(\alpha, \mathbf{j})$	
Age	**Low Education**	**High Education**	**Low Education**	**High Education**
20-45	7.5	3.1	18.2	15.5
> 45	4.4	2.7	20.6	22.6

Turning to the unemployment insurance, we define the replacement rate as a fraction of annualized unemployment income for the unemployed relative to the average annual earnings in the economy.[34] Using the Current Population Survey (CPS), the average replacement rate fluctuated between 32 and 37 percent between 2000 and 2006. We set the rate, ι, at 35 percent in the baseline model. The Department of Labor reports the average replacement rate relative to individual's pre-unemployment earnings at about 40 percent.[35]

[32] See http://www.ssa.gov/policy/docs/statcomps/supplement/2007/index.html (5a.pdf)

[33] An alternative formulation that would induce agents to make decisions on the extensive margin is to include a non-linear mapping between hours and productivity (for example see Rogerson and Wallenius (2009)). Although both modeling options create an active extensive margin, we found that solving for a steady state when using a fixed cost was more stable with respect to initial guesses.

[34] Earnings are defined as wage and salary income plus 2/3 (or the labor share) of the self-employment income.

[35] The Replacement Rate is the ratio of the claimants' weekly benefit amount to the claimants' average weekly wage. The replacement ratio is computed as the weighted average of the weekly benefit amount to the weighted average of normal hourly wage x 40 Hrs. Weekly wage is based on hourly wage of usual job of claimant, normalized to a 40-hour work week and may not equal the claimant's actual average weekly wage.

Table 7: **Calibration Parameters**

Parameter	Value	Source
Demographics:		
Normal Retirement Age: j_{nra}	66	By Assumption
Max Age: J	100	By Assumption
Surv. Prob: Ψ_j		Bell and Miller (2002)
Pop. Growth: n	1.1%	Conesa et al. (2009)
Firm Parameters:		
ζ	.36	Data
δ	8.33%	$\frac{I}{Y} = 25.5\%$
A	1	Normalization
Preference Parameters:		
Conditional Discount: β	0.990	$\frac{K}{Y} = 2.7$
Risk aversion: γ	2	Conesa et al. (2009)
Frisch Elasticity: σ	0.5	Intensive Frisch= $\frac{1}{2}$
Disutility to Labor: χ_1	44.4	Avg. $h_j = \frac{1}{3}$
Fixed Cost to Working: χ_2	1.07	70% retire by J_{nr}
Productivity Parameters:		
Persistence Shock: σ^2_ν	0.017	Kaplan (2012)
Persistence: ρ	0.958	Kaplan (2012)
Permanent Shock: σ^2_α	0.065	Kaplan (2012)
Transitory Shock: σ^2_ϵ	0.081	Kaplan (2012)
Government Parameters:		
Υ_0	.258	Gouveia and Strauss (1994)
Υ_1	.768	Gouveia and Strauss (1994)
ϕ	17%	Conesa et al. (2009)
ι	35%	Data
Social Security:		
κ_{1a}	6.7%	U.S. SS Program
κ_{1b}	5%	U.S. SS Program
κ_2	8%	U.S. SS Program
τ_{r1}	90%	U.S. SS Program
τ_{r2}	32%	U.S. SS Program
τ_{r3}	15%	U.S. SS Program
b_1	.21 x Avg Earnings	Huggett and Parra (2010)
b_2	1.29 x Avg Earnings	Huggett and Parra (2010)
b_3	2.42 x Avg Earnings	Huggett and Parra (2010)
τ_{ss}	10.0%	Mrkt Clearing

5.2 Social Security

For simplicity, we set the NRA at 66, irrespective of the calendar year in which an agent was born. Following the current U.S. Social Security system, the early retirement age $\underline{R}$ is set at 62 while the maximum age over which delay retirement credits can be accrued is set at 69. As discussed above, it is assumed that at age 70 no agent in the economy works. The early retirement percentage penalty parameters, κ_1 and κ_2, are based on the actual value in the U.S. Social Security system, and are set at 6.7 percent (κ_{1a}) for the first three years of early retirement and at 5 percent (κ_{1b}) for prior years. The delayed retirement credit, κ_2, is set at 8 percent per annum. The marginal replacement rates in the progressive Social Security payment schedule ($\tau_{r1}, \tau_{r2}, \tau_{r3}$) are also set at their actual respective values of 0.9, 0.32 and 0.15. Finally, we follow Huggett and Parra (2010) in setting the bend points and the maximum earnings $\overline{y}$ equal to the actual multiples of mean earnings used in the U.S. Social Security system so that the bend points b_1 and b_2 occur at 0.21 and 1.29 times average earnings in the economy. The third implicit bend point b_3 and the maximum taxable earnings by Social Security, $\overline{y}$ are equal to 2.42 times average earnings in the economy.

5.3 Government

We set the government spending in the unproductive sector to 17 percent of GDP in the steady state, so that $\phi = 0.17$. We follow a host of literature (two examples include Conesa et al. (2009) and Imrohoroglu and Kitao (2012)), in using the three parameter tax function from Gouveia and Strauss (1994) to calculate the income taxes over the taxable income for each individual.

$$T(\tilde{y}_t; \Upsilon_0, \Upsilon_1, \Upsilon_2) = \Upsilon_0(\tilde{y}_t - (\tilde{y}_t{}^{-\Upsilon_1} + \Upsilon_2)^{-\frac{1}{\Upsilon_1}}), \tag{13}$$

We set these parameters to the estimates in Gouveia and Strauss (1994), and similarly to Conesa et al. (2009), we solve for the scaling factor Υ_2 so that in the steady state the income taxes equals government spending. Finally, the Social Security tax, τ_{ss} is determined such that in steady state the program is balanced budget.[36]

[36]Currently instead of capping the labor income that is taxed at τ_{ss} at $\overline{y}$ we subject all labor income to the Social Security tax.

5.4 Shock

Consistent with the changes in the economy described in section 2, we model the shock as consisting of two channels. First, we include a one-time unexpected depreciation of assets at the beginning of the first period. Second, we model the increase in both frequency and of unemployment spells. We model these as unexpected in the first period, but after the initial unexpected shock we model the transition back to steady state employment as certain. Table 8 describes the percentage point changes in the probability of being unemployed during the shock. These changes are calculated as the deviation between the unemployment rate prior to the Great Recession in March 2007 and the observed unemployment rates by age and type.[37] After 2012, we project these rates forward using a similar pattern observed in CBO's projections in their long term outlook (see *The 2013 Long-Term Budget Outlook* (2013)). Similarly, table 9 describes the changes in the average weeks of an unemployment spell over the Great Recession.[38]

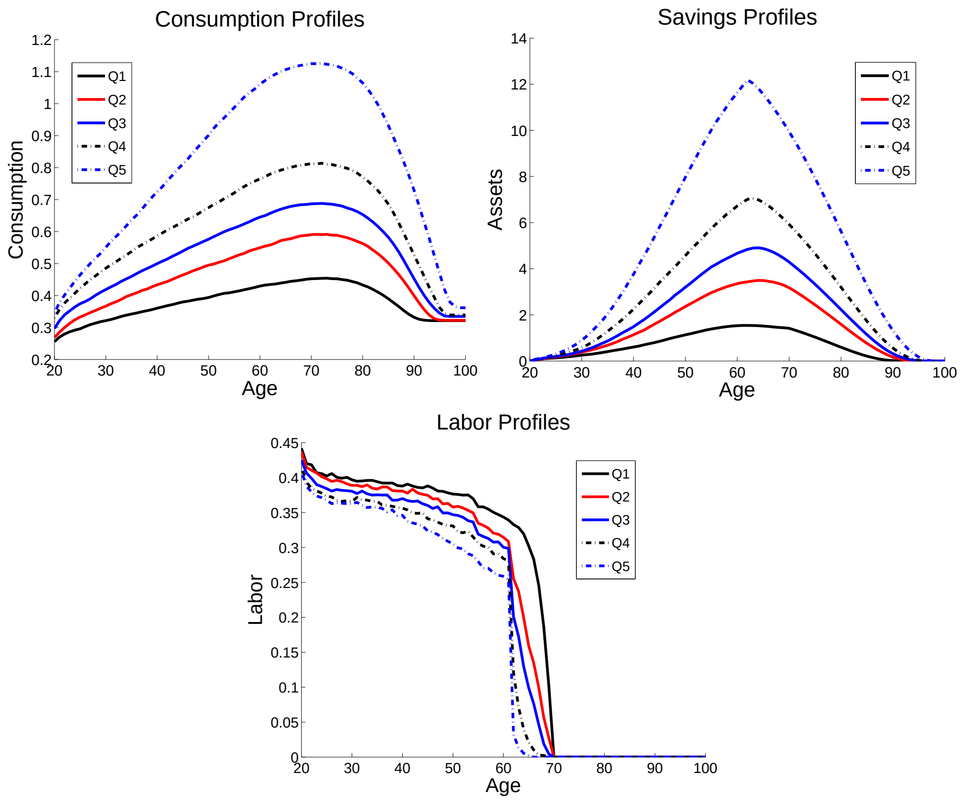
Table 8: **Shock to Unemployment Rate (pp)**

Year	Young Low	Young High	Old Low	Old High
2008	1.9	0.4	0.5	0.3
2009	7.6	3.5	4.9	2.9
2010	9.4	4.4	6.4	3.4
2011	8.3	3.9	5.3	3
2012	6.2	3.4	4.1	3
2013	6.2	3.4	4.1	3
2014	6.2	3.4	4.1	3
2015	4.1	2.3	2.7	2
2016	2.1	1.1	1.4	1
2017	0	0	0	0

Table 9: **Shock to Duration of Unemployment (weeks)**

Year	Young Low	Young High	Old Low	Old High
2008	-2.2	-1.1	-1.2	0.4
2009	1.6	1.9	2.9	1.6
2010	11.1	12.6	15.5	13.4
2011	14.5	15.9	17.2	18.6
2012	13.7	14.3	17.5	16.5
2013	13.7	14.3	17.5	16.5
2014	13.7	14.3	17.5	16.5
2015	9.1	9.5	11.7	11
2016	4.6	4.8	5.8	5.5
2017	0	0	0	0

Figure 4: **Steady State Life Cycle Profiles in Model with Social Security**



Note: These plots are the average values by age within a quintile of average lifetime wage.

6 Results

6.1 Baseline model with Social Security system

We begin by examining the benchmark model in the steady state economy with Social Security and comparing it to the data. Figure 4 shows the average baseline life cycle profiles across all households and for agents in different lifetime average wage quintiles.[39] The general shapes of the consumption and savings, in Panels A and B, follow expected hump shaped patterns with consumption peaking around age 70 and savings around age 65. Not surprisingly, the average consumption and savings for agents with higher wages, who tend to earn more labor income over their lifetime, large are superposed to those in lower income quintiles.

Panel C plots the average labor supply profile for the different quintiles. Generally, agents use about 40 percent of the total time endowment for labor at age 20. Early in their working the labor supply profile decreases rapidly because these young agents are liquidity constrained, thus, the positive wealth effect that labor supply has on household consumption and precautionary asset holdings more than offsets the disincentive to work associated with wages being relatively low at the beginning of the life cycle (for further discussion of this prediction, see Heathcote et al. (2010)). After age 25, the labor supply profile gradually decreases until agents reach retirement age. This general shape matches that of the average labor supply profiles in the PSID data shown in Figure **??** (black line).[40]

Turning to the labor supply by wage group, in the model the high wage agents spend less time in the labor market than their low wage counterparts. To compare this model prediction against empirical estimates, we use the PSID data to construct the age profile of labor hours for heads of households in the different quintiles of average lifetime wage. To assign each worker to a given quintile of the distribution, we compare the agents average

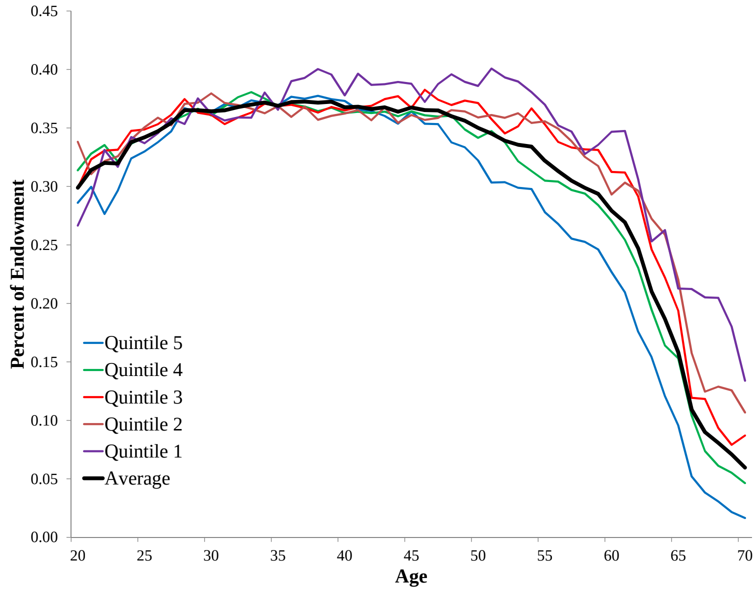
[37] High types are agents who receive the more productive α shock at birth. Young agents are agents from ages 20-46.

[38] These deviations account for the trend in duration over the last few decades.

[39] The wage used to differentiate agents is their total wage which is the product of the efficiency wage w and the agents idiosyncratic productivity $\theta\alpha\nu\epsilon$.

[40] To construct a head of households wage we use the reported labor earnings and labor hours across time to compute the average wage for the given household head in any given year of the working life cycle.

Figure 5: **Labor Profiles over the Lifecycle**



hourly wage over their lifetime to those of other households in the same cohort.[41] Figure 5 shows the estimated profiles for the different quintiles of the wage distribution. After the age of 45, similar to the model's predictions, the empirical estimates suggest that workers in the bottom two quintiles tend to spend more time working than the individuals in the top three quintiles after the age of 45.[42]

The endogenous nature of the retirement decision allows us to compare the model predictions against the empirical estimates. Figure 6 shows the fraction of households that are retired between ages 62 and 70 in both the benchmark model and in the PSID. The model matches the data well with two caveats. First, in the model, no agent is allowed to retire prior to age 62, although agents are allowed to supply zero labor hours prior to retirement. This is at odds with the PSID data where households are allowed to retire at any age (not pictured). Second, the model overstates the fraction of retirees for older agents, as all agents in the model are forced into a mandatory retirement at age 70 by assumption. Despite these

[41] When assigning households to a decile we are unable to compare households between cohorts because we do not observe the whole lifetime of each household. Therefore, we are restricted to comparing households within the same cohort for which we observe the same amount relevant working years.

[42] Using the same data source but assigning workers into educational groups instead of wage deciles, Erosa et al. (2011) estimate that the annual labor supply of workers with only a high school diploma is lower than the labor supply of workers with a college degree.

Figure 6: **Fraction of Population Retired**

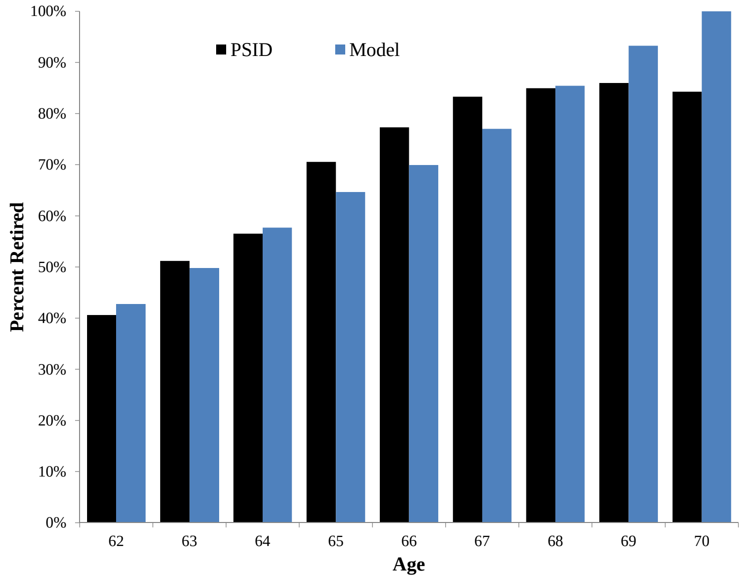


Table 10: **Average Retirement Age In Steady State With Social Security (by wage)**

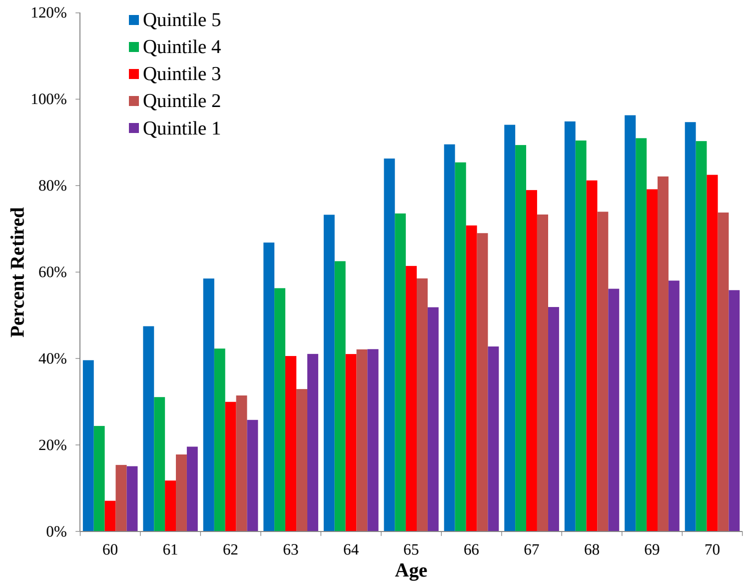
	With Social Security
All Households	64.7
Quintile 1	68.1
Quintile 2	65.5
Quintile 3	64.3
Quintile 4	62.8
Quintile 5	62.2

differences, the overall patterns of retirement are similar in the model and data.

Finally, Table 10 details the average retirement age in the baseline economy across all agents and within each of the wage quintiles. In the model, the lower wage workers tend to retire at older ages than their counterparts that experience higher wages. Figure 7 presents the fraction of households that are retired between ages 62 and 70 by wage quintiles. Similar to the predictions of the model, the general pattern in the data indicate that households falling in a lower quintile tend to retire later in life than households who are in a higher quintile.[43] Overall, our model seems to match some general labor supply predictions from

[43] This empirical finding is consistent with Shourideh and Troshkin (2011) who, using the same data source, confirm that the more productive workers on average retire significantly sooner than their low productivity

Figure 7: **Fraction of Population Retired (by Quintiles)**



the data.

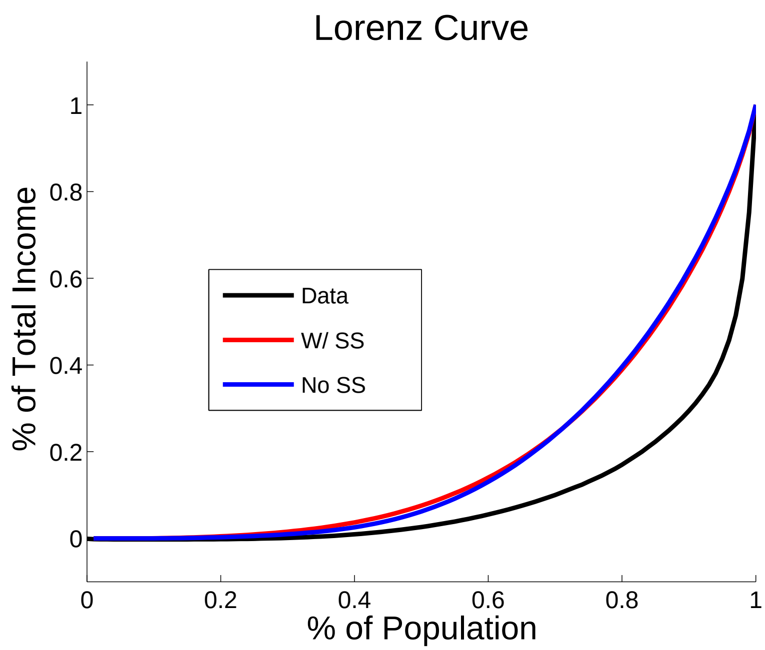
6.2 Counterfactual model with no Social Security

Next, we compare the baseline model with the Social Security program against a counterfactual economy in which government-provided consumption insurance at old age is absent. This comparison demonstrates some of the key effects that Social Security has in the steady

counterparts. Similarly, in the model, if we sort agents into high and low ability types based on α, then we find that low types tend to retire later.

Table 11: **Aggregates in Steady States**

Aggregate	Full S.S.	No S.S.
Y	0.93	1.06
K	2.51	3.6
N	0.53	0.53
w	1.12	1.27
r	0.05	0.02
Tr	0.04	0.06
τ_{ss}	0.1	0
Gini	.61	.60



state. Table 11 compares macroeconomic aggregates between the two models, while Figure 8 provides a comparison of average age-profiles of consumption, savings, and labor supply for high and low ability agents.[44]

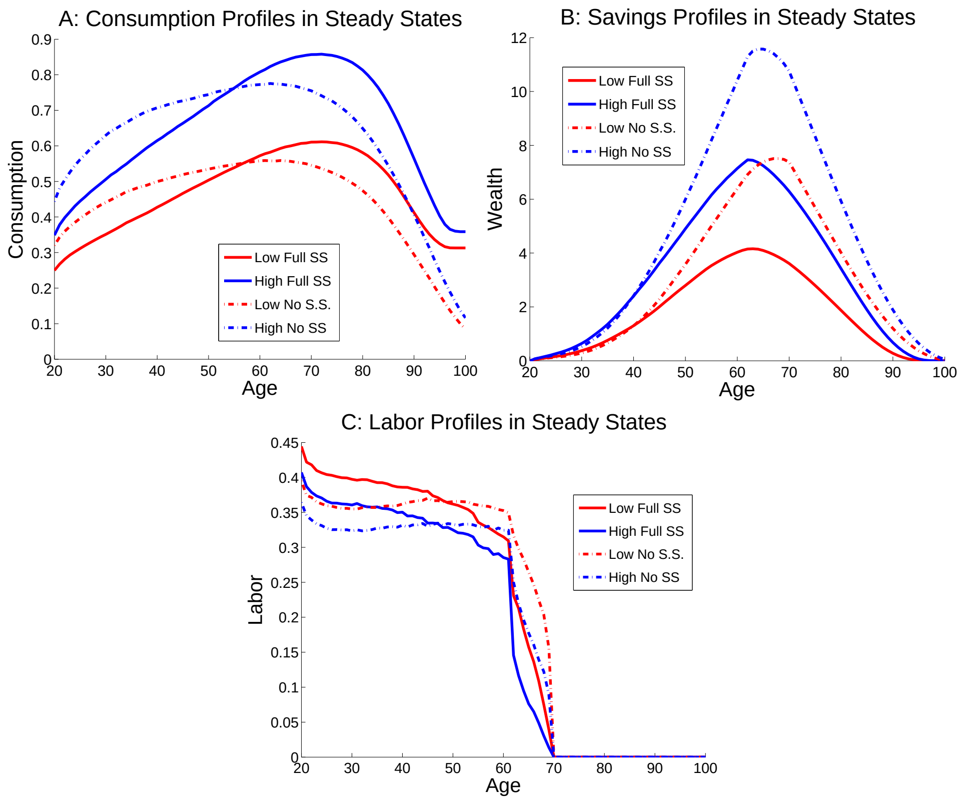
The economy with no Social Security is characterized by higher level of aggregate capital, as the Social Security program reduces the dependence of retirees on personal savings to fund their old-age consumption.[45] Since aggregate labor is similar in both models, the size of the economy is larger without Social Security because Social Security "crowds out" private productive savings. The higher aggregate level of capital in the counterfactual economy with no Social Security is thus characterized by a higher wage rate and a lower rental rate relative to the baseline model. We find that both models predict a similar value, 0.6, for the Gini coefficient of wealth inequality. Similar to previous studies, with the distribution of our idiosyncratic productivity shocks we are unable to match the fatter upper tails of the wealth distribution so the coefficient is below the empirically observed value of approximately 0.8 (see figure 6.2 for a plot of the Lorenz Curves).

Comparing the lifecycle profiles in the two models (Figure 8, the main difference stems from the higher rental rate of capital in the model with Social Security. Because of the higher

[44]We choose to present results with ability as opposed to wage quintiles for expositional clarity.

[45]This result is consistent with previous studies (see the introduction for a list).

Figure 8: **Life Cycle Profiles in Steady State**



Note: These plots are the average values by age and ability type in both models.

Table 12: **Average Retirement Age In Steady State (by wage)**

	Social Security	**No Social Security**
All Households	64.7	67.9
Quintile 1	68.1	69.7
Quintile 2	65.5	68.2
Quintile 3	64.3	67
Quintile 4	62.8	65.5
Quintile 5	62.2	62.8

rate, agents tend to value utility in the future relatively more leading them to delay both leisure and consumption compared to the model without Social Security.[46] Comparing the average retirement ages in Table 12, because agents value their leisure relatively less later in life in the model without Social Security, agents also tend to delay their retirement. Although agents delay their retirement in the model without Social Security, the same pattern of agents with lower lifetime average wages tending to retire later than agents with higher wages still exists. One other notable difference in the life cycle profiles is that in the model without Social Security agents must fund all of their post-retirement consumption with savings so agents tend to hold more savings than in the model with Social Security.

6.3 Welfare effects of Social Security in Steady Sate

Table 13 documents the consumption equivalent variation (CEV) for Social Security, or the uniform percent increase in each periods consumption necessary to make agents on average indifferent between being born into the economy with socials security versus the economy without Social Security. The average CEV is estimated at 7.5% meaning that on average agents would be willing to reduce their consumption by 7.5% each period in order to be born into the economy without Social Security as opposed to the economy with Social Security. This result confirms the findings in the existing studies (see, for example, Hong and Rìos-Rull

[46]Another way to view this relationship is through the intertemporal Euler equation controls the slope of consumption profile over an agent's lifetime. The relationship is

$$\left(\frac{c_{j+1}}{c_j}\right)^{\sigma_1} = \Psi_j \beta \widetilde{r}_t, \tag{14}$$

where $\widetilde{r}_t$ is the marginal after-tax return on capital.

Table 13: **Welfare Lost from Social Security**

Average	No G.E. Effects	Remainder
7.5%	5%	2.5%

Table 14: **Welfare Lost from Social Security (by income)**

Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
7.6%	7.8%	7.4%	7.1%	7.7%

(2007), Hubbard and Judd (1987), Imrohoroglu et al. (1995), and Storesletten et al. (1998)): in a steady-state, agents prefer to live in an economy where a Social Security system is largely absent. Although there are welfare benefits from the progressive nature of the Social Security replacement rate which provides insurance for the idiosyncratic productivity shocks, the welfare costs dominate. These welfare costs primarily come from the "crowding out" of private savings and the Social Security taxes which make it more difficult for agents to accumulate savings to help smooth consumption in times of lower idiosyncratic productivity shocks. The second column determines the average consumption an agent would be willing to give up to be born in an economy without Social Security even if there were not general equilibrium effects on prices from removing Social Security. Column three, the remainder, details the welfare lost due to the general equilibrium effects which are mainly comprised of the "crowd out". Overall, the effects from the general equilibrium price changes are about half as larger as the rest of the welfare effects of Social Security.

Table 14 examines the welfare consequences of Social Security for agents in different quintiles of the lifetime income distribution. Moreover, Table 15 documents a similar comparison but decomposes the sample into different quintiles of average lifetime wages. Both tables demonstrate a similar pattern, agents who are in the first, second and fifth quintile tend to dislike Social Security more than other agents. Agents with lower lifetime wages (income) particularly dislike Social Security because with lower wages (income) it is particularly hard for them amass savings and Social Security taxes compound this difficultly. The highest wage (income) agents tend to dislike social security more than others because they dislike the redistribution associated with the progressive benefit formula.

Table 15: **Welfare Lost from Social Security (by wage)**

Quintile 1	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**
8%	7.5%	7.3%	6.9%	7.7%

6.4 Transitional dynamics

Having discussed the steady state comparison of the baseline model and the counterfactual model with no Social Security, we next assess the effect of a shock that resembles the Great Recession. In particular, the shock is introduced as a 20 percent unexpected reduction in household wealth in the economy at time zero. Additionally, the probability and frequency of unemployment spells fluctuate over the transition according to Table 8 and 9.

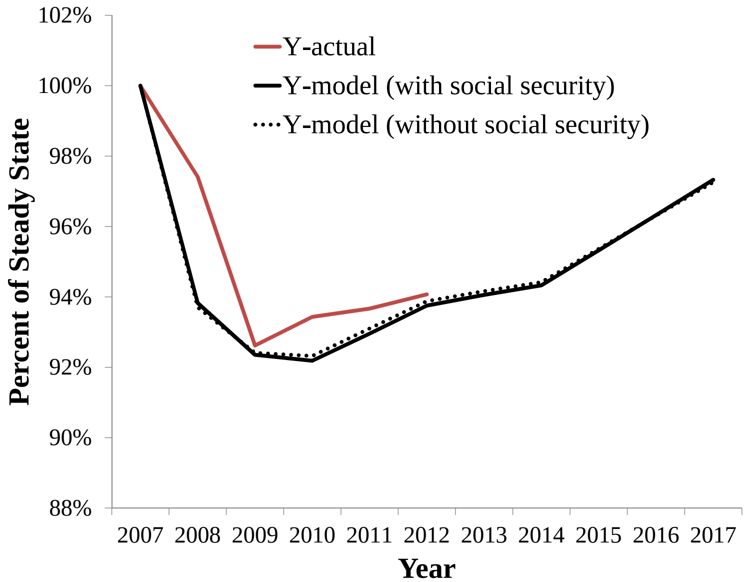
We begin by comparing the transition of various aggregates in the data to the model to see how well the model captures the transitional dynamics. First, Figure 9 compares the transition of output in the two models and the actual transition of GDP in the U.S. economy.[47] The drop in output after two years is approximately 8%, similar in the models and the data. Additionally, the slow recovery to pre-recession output levels in the models match the rate of recovery in the data. Figure 10 compares the transition in aggregate hours worked in the two models and the actual transition in hours in the U.S. economy.[48] Although the models do not match the initial decline in hours in the first year after the shock, they match the general shape of the transition of aggregate hours afterwards. The difference between the data and the models in the first period after the initial shock is not surprising, since as Table 5 describes, a majority of the change in that year was due to fluctuations on the intensive margin which the models do not capture. Finally, Figure 11 compares the transition in aggregate consumption to that predicted by the models.[49] Although the model slightly overpredicts the drop in consumption, the overall shape is fairly close to the actual transition. Overall, we employ parsimonious representation of the Great Recession. However, this representation appears to capture the salient aspects needed to replicate the aggregate

[47] We detrend GDP using potential output from the Congressional Budget Office.

[48] In order to detrend hours we use the linear trend from 1997 - 2005 which is considered to be a period of a fairly normal labor market.

[49] We use nominal Personal Consumption Expenditures produced by the Bureau of Economic Analysis as our measure of consumption. In order to account for the trend in consumption we use both the fluctuations in potential GDP and the linear trend in the residual from 1997 through 2005.

Figure 9: **Transition Of Output over Great Recession**



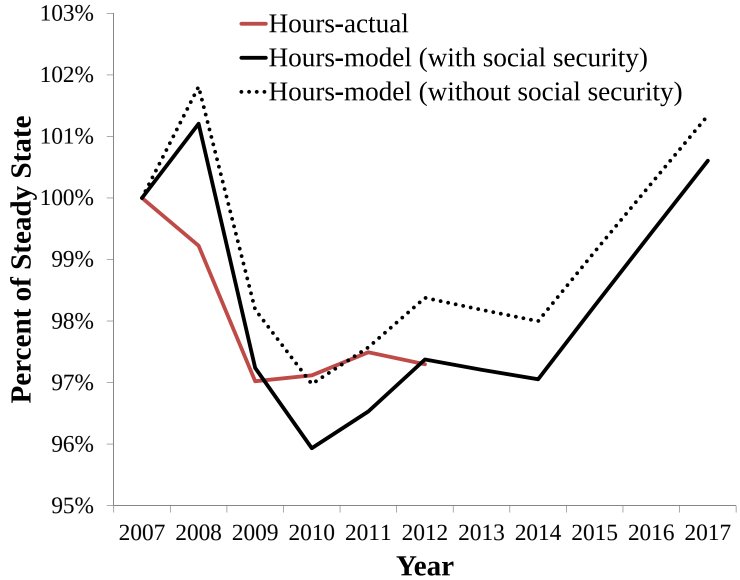
Note: Steady state output is Gross Domestic Product reported by the Bureau of Economic Analysis. In order to calculate Steady State the nominal value is detrended using the changes in potential output determined by the Congressional Budget Office. Additionally the series is normalized to the actual value of GDP in 2007 so there is no deviation from steady state.

fluctuations in output, consumption and hours.[50] Therefore we believe this representation of the Great Recession is useful in order to study the ability of Social Security to mitigate the adverse welfare effects of the Great Recession.

Turning to comparing the general fluctuation in the two models over the whole transition, Figure 12 plots these transitions as a percentage difference from the steady state in both models. Comparing the transitions in the model with Social Security (Panel A) and the model without Social Security (Panel B), the transitions look similar. Generally, at the time of the shock, by construction, aggregate capital decreases by 20%. Additionally, hours stay fairly constant over the transition leading to a large increase in the rental rate and a fall in the efficiency wage. One notable difference between the transition in the two models is that the change in the rental rate is somewhat larger in the model without Social Security because of the larger capital stock. In both models, over time, as the economy sets on the

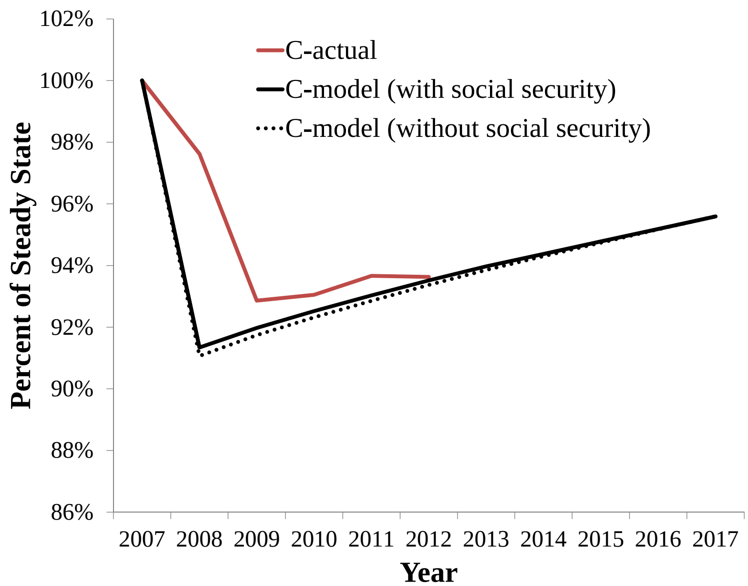
[50]Moreover, we find that if an agent held one unit of assets prior to the shock in the benchmark model it would take 3.6 years for the value of the asset to be equal to their pre-shock value. In comparison, after the trough in March of 2009 it took the Dow Jones Industrial average approximately 3 years to return to its pre-recession value. The fact that the benchmark model predicts a similar length of recovery for asset values provides further comfort.

Figure 10: **Transition Of Hours over Great Recession**



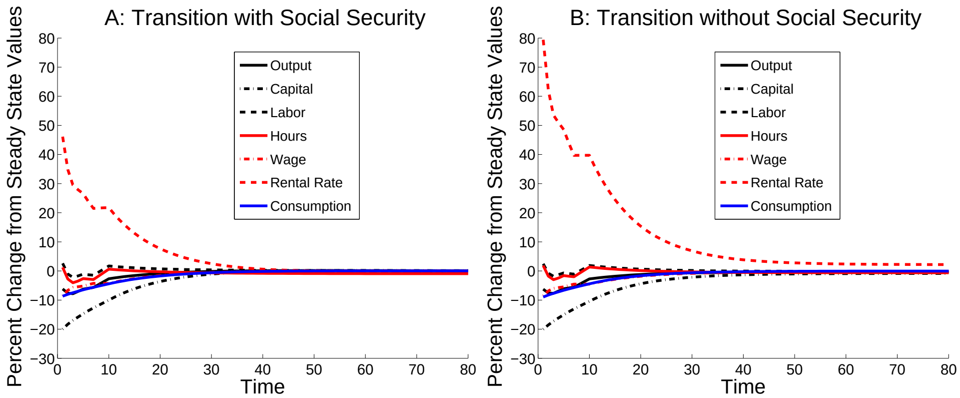
Note: The annual steady steady hours are determined by detrending the series using the linear trend from 1997-2005 and the then normalized to the value in 2007.

Figure 11: **Transition Of Consumption over Great Recession**



Note: The annual steady steady consumption are determined by detrended nominal Personal Consumption Expenditures from the Bureau of Economic Analysis using the trend in potential output determined by the Congressional Budget Office and also a linear trend from 1997-2005 and the then normalized to the value in 2007.

Figure 12: **Transition Of Aggregate Economic Variables**



transition path to the original steady state, the stock of capital gradually converges to its pre-shock level and the rental rate falls while the efficient wage rate rises.

6.5 Role of Social Security to Mitigate Welfare Losses

During the transition, we define the welfare loss as a constant percentage increase in per-period future consumption following the shock necessary to restore an individual's expected future utility to that in the steady state. Furthermore, we define the average welfare loss in each economy over the transition as the population-weighted mean of these values for each of the cohorts alive at the time of the shock. Table 16 describes the these welfare losses over the transitional path for each economy. The average overall welfare loss is 5.9 percent in the model with no Social Security and 4.3 percent in the baseline model with Social Security. The resulting difference in the welfare loss (1.6 percent) highlights the ability of the Social Security program to partly mitigate the adverse average effect of the shock. Moreover, this difference can be interpreted as on average living agents would be willing to forgo 1.6% of their future consumption in order to have Social Security, conditional on experiencing the shock.

In order to understand why Social Security helps mitigate the welfare consequences of the Great Recession it is necessary to examine the general welfare losses by age. Table 17 computes the welfare lost by age in both economies. On average, in both models, agents who are older than 65 at the time of the shock tend to lose more welfare due to the shock

Table 16: **Average Welfare Lost for Living Agents**

	Avg CEV
Full Social Security	4.3%
No Social Security	5.9%
Social Security Role	1.6%

Table 17: **Living Agents Welfare Loss (by age)**

	Avg.	**20-65**	**66-100**
Full Social Security	4.3%	4.1%	5.6%
No Social Security	5.9%	4.1%	14.3%
Social Security Role	1.6%	0%	8.7%

than younger agents. The larger welfare losses for the older agents are for two reasons. First, older agents generally have accumulated more wealth, therefore the 20% depreciation is associated with a larger level of lost wealth. Second, these agents have less time to work in order to offset their lost wealth and instead must absorb more of these losses with a decrease in consumption.

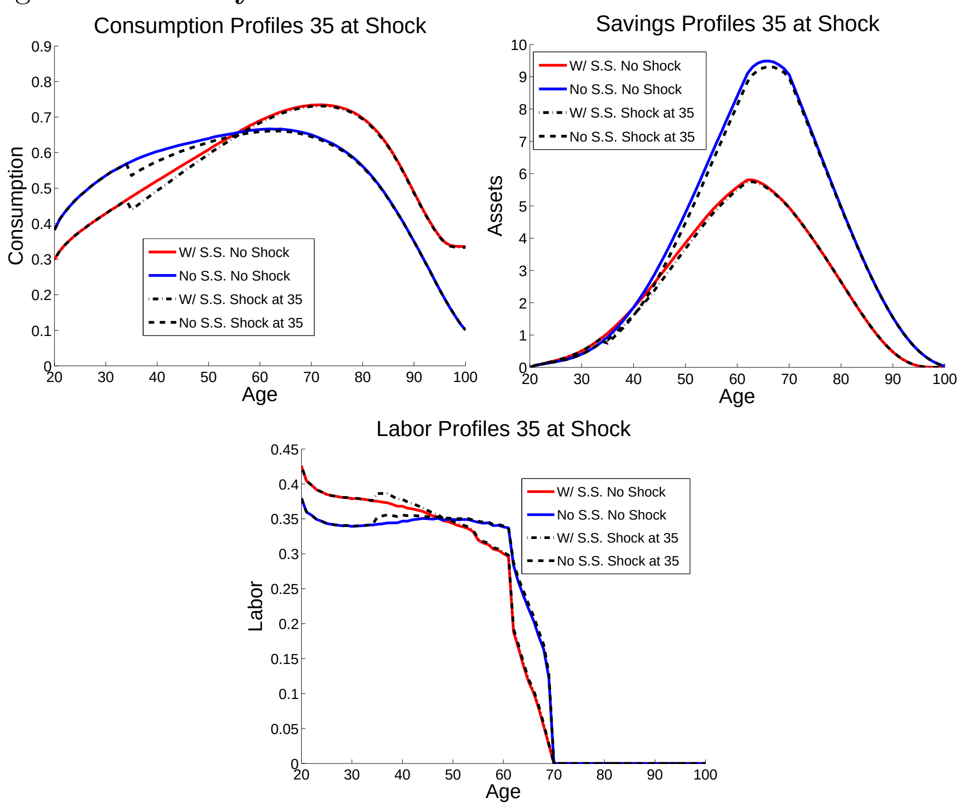
Comparing the average welfare losses for different aged agents at the time of the shock in the two economies, it is clear that Social Security plays a negligible role in mitigating the welfare losses for agents under the age of 65. The welfare lost due to the shock is 4.1% of expected future consumption in both models. In contrast, the welfare lost for older agents is 5.6% of expected future consumption in the economy with Social Security compared to 14.8% in the model without Social Security. The difference between these two values represents that, conditional on experiencing the shock, on average these older agents would be willing to give up 8.7% of the future expected consumption in order to live in the economy with Social Security as opposed to living in the economy without Social Security. In the economy without Social Security all of the agent's post-retirement consumption is financed by their savings. In contrast, in the model with Social Security, some of the post-retirement consumption is financed by the Social Security benefit. The Social Security benefit acts as partial insurance for a retired agent's consumption. Moreover, we found that the welfare implications of Social Security were almost identical when we excluded the unemployment shock leading to the conclusion that the wealth shock was the driving force behind these welfare results.

Figures 13-16 further highlight why Social Security plays a larger role mitigating the welfare losses for older agents. Panels A-C in the Figures 13-16 plots the average consumption, saving and labor profiles in both models over the transition for agents who were 35, 62, and 80 years of age at the time of the shock, respectively. Furthermore, the average profiles of agents in the steady state economy who never experienced the shock are plotted for reference (solid lines). In Figure 13, the dashed lines represent the average profiles for an agent who is 35 years of age at the time of the shock. The timing of the shock corresponds with a drop in consumption and an increase in labor hours, as agents who are not unemployed use the intensive labor margin to partially offset the effect of the shock. As Panel B demonstrate, young agents are able to re-accumulate their original asset positions relatively quickly. Comparing the red and blue lines to their dashed counterpart, the general responses to the shock for 35 year old agents are similar in both models.

Turning to middle-aged individuals, Figure 14 plots the average life cycle profiles for agents who were 62 at time of the shock. In both models, the effect of the shock on agents at the brink of retirement is much more persistent than the effect for agents who were younger at the time of the shock. The drop in the level of savings is much larger for these older agents because they have more wealth at the time of the shock. In response, these agents decrease their consumption and increase their labor supply to a varying degree in both models. However, the shock for agents who are 62 is associated with a smaller and less persistent decrease in both consumption and savings in the model with Social Security. The effects are smaller in the model without Social Security because the agent will enjoy a Social Security benefit once they retire that will partial fund post-retirement consumption. This benefit, unlike private savings which depreciated due to the shock, is unaffected by the shock.

When examining the labor supply responses in both models it is of interest how much is driven from changes on the intensive margin (changes in average hours worked) and changes on the extensive margin (changes in retirement age). Figure 15 demonstrates the effect of the shock on retirement decisions in both economies. Each line in Figure 15 shows the fraction of household who are retired when they reach the respective ages 62-70 over time. Panel A

Figure 13: **Life Cycle Profiles in Transition: 35 at time of shock**



Note: These plots are the average profiles for agents over the transition who were 35 at the time of the shock.

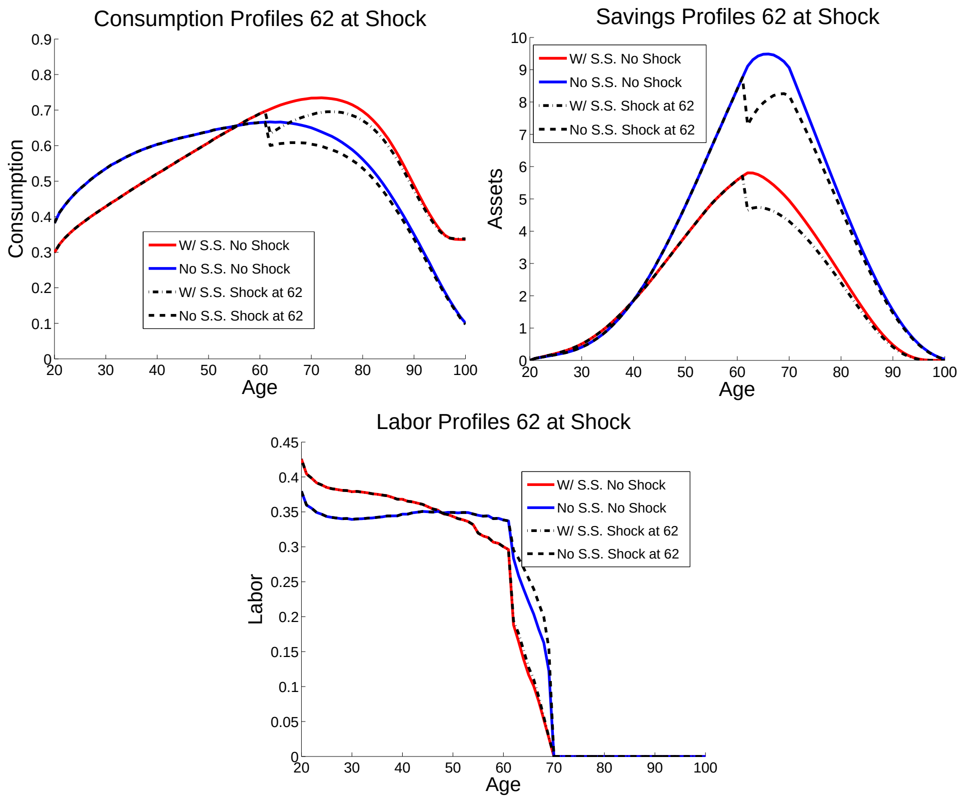
plots the percent retired in the economy with Social Security while Panel B focuses on the economy without Social Security. Focusing on Panel A, at steady state (time 0), about 43 percent of all agents who are 62 are retired in the model with Social Security. That said, 2 periods after the shock, only roughly 38 percent of all households who are age 62 at that point (or 60 at the time of the shock) are retired. The drop in the fraction of retired households in the economy following the shock demonstrates that pre-retirement households respond to the shock by delaying their planned retirement past the age of 62. In contrast, focusing on the percentage of households at age 66 that are retired, there is virtually no movement over the transition. Taken together, these two results demonstrate that in the model with Social Security the shock causes some agents who are near retirement, and who all else equal would retire prior to age 66, to delay retirement. However, agents do not generally delay their retirement past the age of 66 due to the shock.

Focusing on Panel B, there is a more stark reaction to retirement decisions due to the shock in the model without Social Security. Immediately after the shock the percent retired at each age drops more dramatically than in the model with Social Security. Additionally, there is a change in retirement behavior throughout all the ages 62 through 70. Additionally, the effect of the shock on retirement decisions is more persistent in the model without Social Security. The stronger reaction in the model without Social Security highlights the larger effect on welfare due to the fact that agents are more vulnerable to the shock since they do not enjoy Social Security benefits. In the model without Social Security, since agents will not receive Social Security benefits once they retire they are willing to pay a larger utility cost to continue to work to try to reaccumulate some of their lost wealth.

Finally, examining the average profiles for agents who are 80 at the time of the shock in Figure 16, agents respond to the shock with even larger decreases in consumption. At the age of 80 agents cannot offset some of their losses in wealth by working more. Moreover, the magnitude and the persistence of the responses in consumption are smaller in the model with Social Security because agents receive a Social Security benefit that helps finance post-retirement consumption and is unaffected by the shock. The smaller reaction in consumption represents the role Social Security plays in mitigating the effect of the shock for these agents.

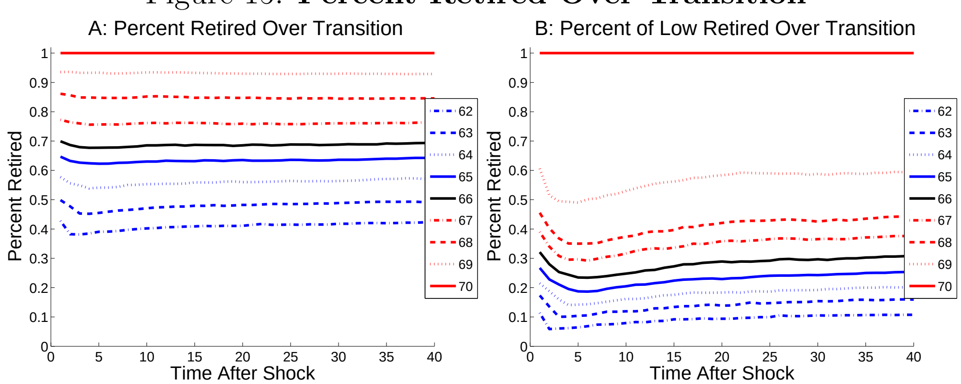
Taken as a whole, these results can be summed up in figure 17 which plots the average

Figure 14: **Life Cycle Profiles in Transition: 62 at time of shock**



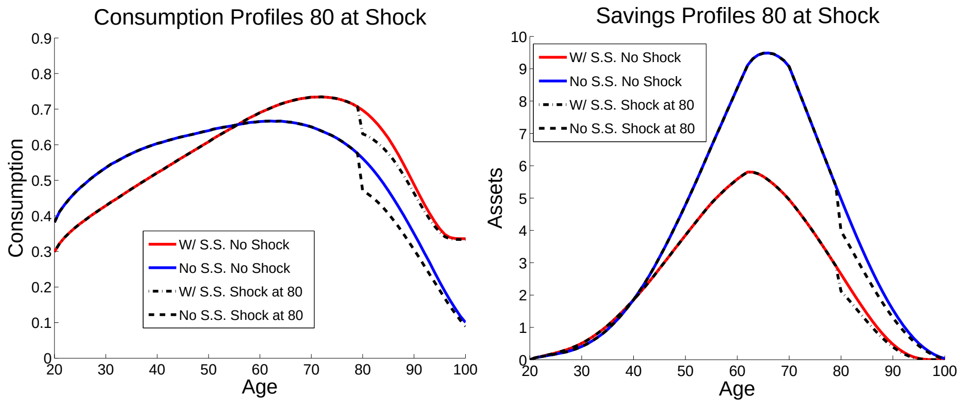
Note: These plots are the average profiles for agents over the transition who were 62 at the time of the shock.

Figure 15: **Percent Retired Over Transition**



Note: These plots are the percent of individuals retired at each age over the transition.

Figure 16: **Life Cycle Profiles in Transition: 80 at time of shock**



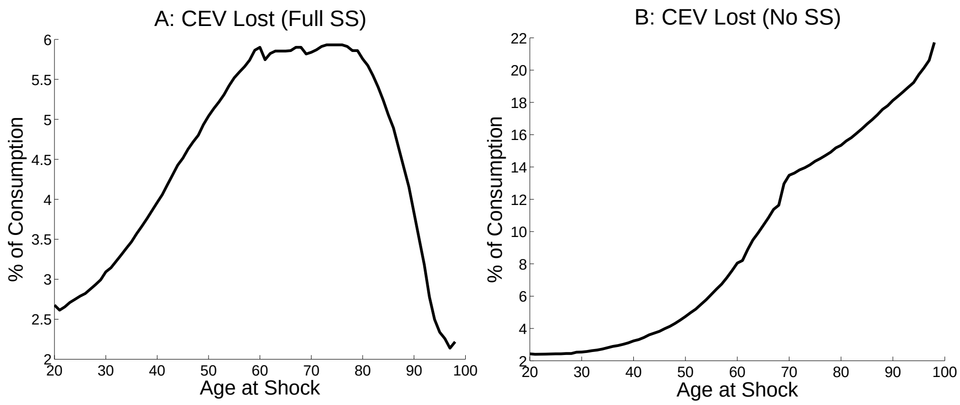
Note: These plots are the average profiles for agents over the transition who were 80 at the time of the shock.

welfare losses, by age at the time of the shock, in each model. Again, focusing on agents who are older at the time of the shock, the welfare losses monotonically increase with age at the time of the shock in the model without Social Security (Panel B). This monotonic increase is because the shock eliminates a similar percent of their future consumption which they have less time to smooth through. In contrast, in the model with Social Security, as agents age they rely more heavily on the Social Security benefit for their consumption so they are less vulnerable to the depreciation of wealth.

Next, we turn to how effective Social Security is at mitigating the welfare effects of the shock for particular ability and income groups of agents. Table 18 determines the average welfare losses for living agents by ability types. In both models, the higher ability agents tend to suffer more from the Great Recession than the lower ability agents because due to their higher productivity they tend to have more savings. The third row of Table 18 determines how effective Social Security is at mitigating the welfare effects of the shock in terms of average expected future consumption. Overall, Social Security is more effective at mitigating the losses for lower ability agents than for higher ability agents. Social Security is more effective for the lower ability agents because they tend to have less income so in the model with Social Security the benefit makes up a larger fraction of their post-retirement consumption.

Table 19 describes a similar decomposition of the welfare losses for agents in different

Figure 17: **Welfare Lost in Transition**



Note: These plots are the average welfare lost by type and age at the time of the shock smoothed over six ages.

Table 18: **Living Agents Welfare Loss (by type)**

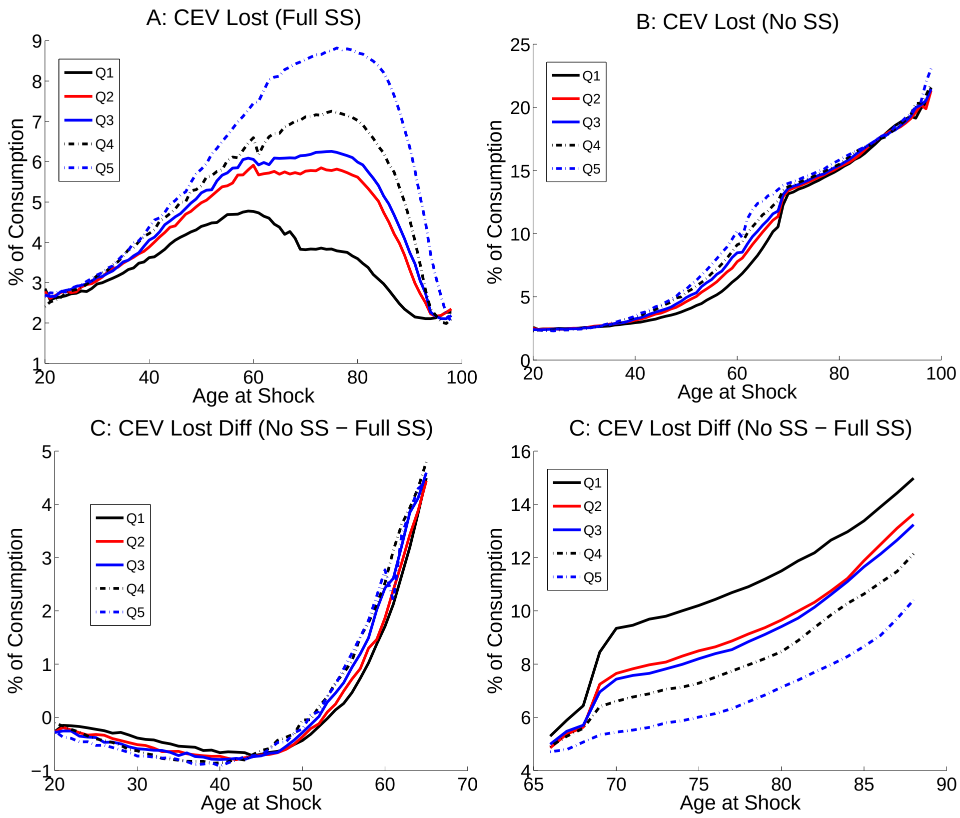
	Avg.	**Low**	**High**
Full Social Security	4.3%	4.2%	4.5%
No Social Security	5.9%	5.8%	6.0%
Social Security Role	1.6%	1.7%	1.4%

Table 19: **Living Agents Welfare Loss (by Income Quintile)**

	Avg.	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Full Social Security	4.3%	3.6%	4.3%	4.5%	4.7%	5.3%
No Social Security	5.9%	5.5%	5.8%	6%	6.2%	6.5%
Social Security Role	1.6%	1.8%	1.6%	1.6%	1.5%	1.2%

average lifetime income quintiles. In both models, agents who have higher lifetime income tend to suffer more from the shock because they tend to have more savings. However, Social Security is more effective at mitigating the welfare losses from the shock for agents in the lower lifetime income quintiles than in the higher income quintiles. Once again, Social Security is more effective at mitigating welfare losses for lower income agents because in the model with Social Security the benefit from the program makes up a larger share of their post-retirement consumption.

Turning to a more detailed examination of the welfare losses, Panel A and B of Figure 6.5 show the amounts of welfare lost by age at the time of the shock and lifetime income quintile. Furthermore Panel C and D show how effective Social Security is at mitigating the welfare losses by age and income quintile for agents who are younger and older at the time of the shock, respectively. Examining the figures produces similar themes as the previous tables. Overall, Social Security is more effective at mitigating welfare losses for agents who are older at the time of the shock. For example, in Panel C the effect of Social Security is only positive for agents older than 50 at the time of the shock. Moreover, for agents who are younger than 65 the effectiveness of Social Security at mitigating welfare losses is similar regardless of where the agents fall in the income distribution. Although Social Security is generally effective at mitigating welfare losses for agents who are older than 70 at the time of the shock, it is more effective for agents who experience lower incomes over their lifetime. The program is particularly effective at mitigating welfare losses for agents who are old at the time of the shock and experience lower incomes for two reasons. First, in the benchmark model the Social Security benefit makes up a larger portion of these agents consumption. Second, these agents are unable to offset any of the effect of the shock by working since they have already retired.

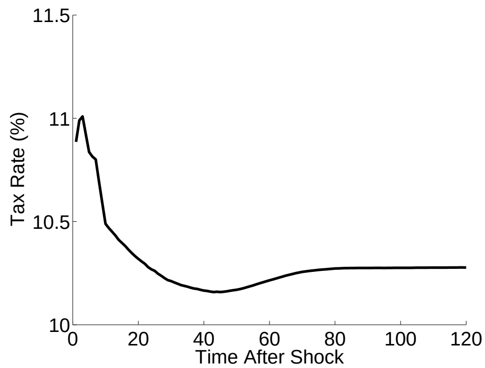


Given the particular effectiveness of Social Security to mitigate the welfare losses for these older lower income agents, it is of interest to determine whether the effect is at the cost of another group of living agents or agents who do not experience the effect of the shock. Table 20 decomposes the welfare losses and the role Social Security plays in mitigating these losses into finer age groups at the time of the shock. Although the welfare losses for agents who are under 50 at the time of the shock are slightly exacerbated by Social Security, the program does not significantly exacerbate the welfare losses for any of these groups. The younger agents losses are exacerbated because during the transition total income in the economy is depressed leading Social Security tax rates to increase in order to ensure that the program's budget is balanced. Figure 18 plots the tax rate over the transition and the small increase right after the shock is responsible for Social Security slightly exacerbating the welfare losses from the shock for the younger agents. Nevertheless, even though Social Security significantly reduces the welfare losses for living agents who are older, lower income, and less productive at the time of the shock, it generally does not cause much harm to the

Table 20: **Living Agents Welfare Loss (by age)**

	20-29	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**
Full SS	2.8%	3.4%	4.4%	5.4%	5.9%	5.9%	5.2%	3.1%
No SS	2.4%	2.8%	3.8%	6%	10.1%	14.2%	16.3%	18.9%
SS Role	-0.3%	-0.7%	-0.7%	0.5%	4.2%	8.3%	11.1%	15.8%

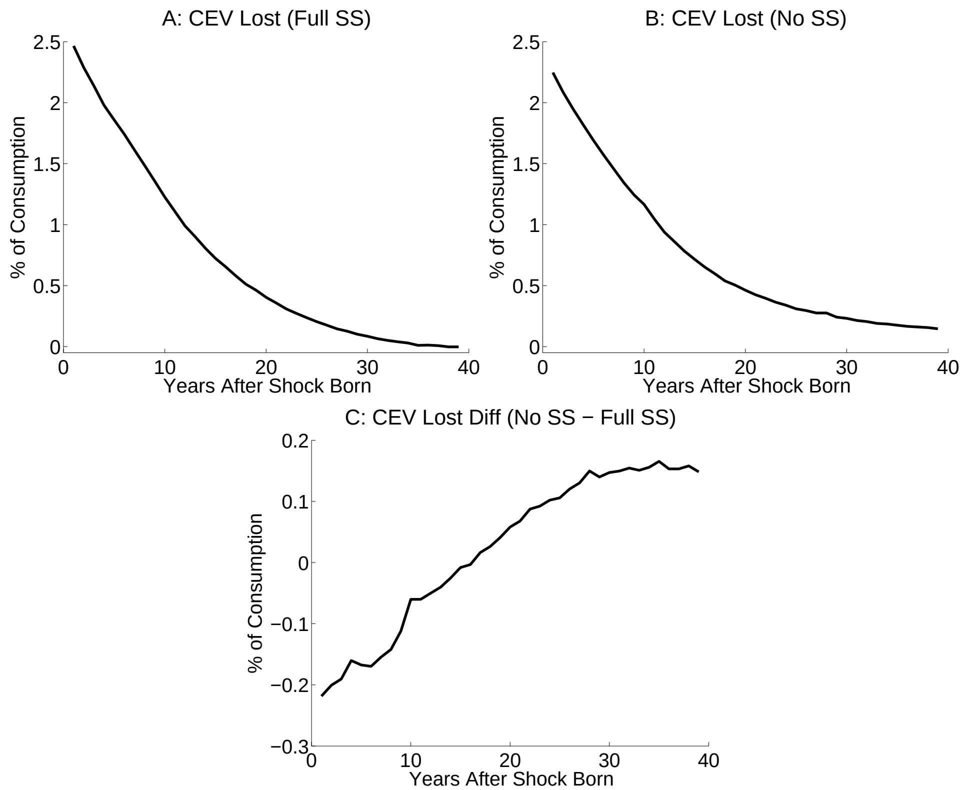
Figure 18: **Social Security Tax Rate over Transition**



other living agents.

Finally, we examine the welfare losses for agents who enter the model after the shock. Panel A and B in Figure 6.5 plot the welfare losses for cohorts born after the shock in the model with and without Social Security, respectively. Overall, agents who enter the models after the shock tend to suffer smaller welfare losses than agents who are alive at the time of the shock. Moreover, agents who enter the model immediately after the shock are most adversely effected by the shock with the impact trailing off over time. These agents are adversely effected even though they are not alive at the time of the shock because wages stay depressed as the economy transitions back to the steady state. Comparing Panels A and B, the shape of the welfare losses for different cohorts looks similar in the two models with the effect of the shock being slightly more persistent in the model without Social Security. Panel C takes the difference between the first two panels and reveals the role for Social Security to mitigate the shock for these future cohorts. Overall, the effect of Social Security is minimal with the effect being between .25% and .2% of expected lifetime consumption. In particular, because of the temporarily increased Social Security taxes, Social Security

Figure 19: Welfare Loses for Future Cohorts



slightly exacerbates the effects of the shocks for cohorts that enter the model within 15 years of the shock. Moreover, because of the quicker transition back to steady state, the welfare losses are slightly smaller for agents who start working more than 15 years after the shock in the model with Social Security than in the model without Social Security.

Although Social Security slightly exacerbates the welfare losses during the Great Recession for younger agents alive at the time of the shock and agents who enter the model within 15 years of the shock, we do not find any specific age, income or ability group for which Social Security substantially exacerbates the welfare consequences of the shock. Instead the role that Social Security plays in significantly mitigating the welfare consequences of the shock for older, lower income, and lower ability agents comes from the general welfare losses in the steady state. The ability of Social Security to mitigate the welfare losses for some of the demographics groups considered most vulnerable to shocks, without significantly exacerbating the welfare consequences of the shock for other agents, indicates that this program is a particularly effective at providing insurance for these types of shocks.

7 Conclusion

This paper quantitatively assesses the ability of Social Security to lessen the welfare losses due to a shock that, similar to the Great Recession, causes both a large decrease in wealth and an increase in unemployment. Generally, we find that Social Security mitigates the average overall welfare losses for agents living at the time of the shock by the equivalent of 1.6% of expected future lifetime consumption. We find that the program is particularly effective at mitigating welfare losses for agents who are older at the time of the shock and agents who experience lower lifetime income. Social security is valuable for the agents who are older at the time of the shock because they have less time to offset losses to their wealth by increasing their labor supply and must absorb more of the shock through a reduction in their consumption. Moreover, Social Security is more effective at mitigating welfare losses for lower income agents because the Social Security benefit represents a larger portion of their post-retirement consumption.

Overall, examining agents who are alive at the time of the shock or enter the model after the shock, we do not find any specific age, income, or ability group for which Social Security substantially exacerbates the welfare consequences of the Great Recession. Instead the role that Social Security plays in mitigating the welfare consequences of the shock is due to a more general welfare tradeoff with agents who live during the steady state. Although the welfare consequences of Social Security in the steady state are larger than the benefits during the business cycle episode, the ability of Social Security to mitigate welfare losses for some of the most vulnerable demographics, without significantly exacerbating the welfare consequences of the shock for other agents, indicates that this program is a particularly effective at providing insurance for these types of shocks.

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