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

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Abstract

Using a computational life cycle model, this paper assesses how Social Security affects the welfare of different types of individuals during the Great Recession. Overall, we find that Social Security reduces the average welfare losses for agents alive at the time of the Great Recession by the equivalent of 1.4 percent of expected future lifetime consumption. Moreover, we show that although the program mitigates some of the welfare losses for most agents, it is particularly effective at mitigating the losses for agents who are poorer and/or older at the time of the shock.

JEL: E21, D91, H55
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1 Introduction

Designed in part to alleviate old-age poverty in the wake of the Great Depression, Social Security aims to provide inter- and intra-generational consumption insurance for older-age

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individuals.[2] However, the insurance is not without costs: retirement benefits and payroll taxes distort agents' labor and savings decisions. Generally, previous studies found that the economic costs of the distortions dominate in the long run, leading Social Security to be, on average, welfare reducing in the steady state.[3] Despite this well-documented result, little is known about the welfare implications of Social Security for agents of different ages, incomes, wealth and abilities, especially at times of large adverse swings in economic activity. These periods are of particular interest because the need for the insurance, as well as the effects of the distortions, may be amplified. Moreover, the change in these effects may not be uniform across all agents. To help fill this gap, and motivated by the historically large losses in household wealth and income during the Great Recession, this paper examines the role that Social Security plays in mitigating or exacerbating the welfare consequences of large and broad-based shocks to wealth and unemployment for agents of different ages and economic backgrounds.

The paper documents two salient features of the Great Recession: a sudden, large and broad-based decline in household wealth; and persistent increases in the rate and duration of unemployment spells. First, using the 2007-2009 panel of the Survey of Consumer Finances (SCF), we show that between 2007 and 2009, the median level of household wealth declined by approximately 20 percent. Moreover, the percent wealth losses were relatively larger for households who were relatively younger and older at the time of the shocks. Second, using the

[2]In addition to insuring old-age consumption, Social Security provides disability insurance. This paper abstracts from the disability insurance aspect of the program and focuses only on the part of the program that insures post-retirement consumption.

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

Current Population Survey (CPS) micro data, we document that the recession was associated with large increases in the unemployment rate and average duration of unemployment spells, with the increases being particularly large for younger and less-educated households. These empirical facts motivate our choice to model the Great Recession as one-time unexpected age-dependent depreciation shocks to household wealth, combined with increases in the likelihood and duration of unemployment spells that, similar to the data, persist over numerous years.

Next, we quantify Social Security's role in mitigating or exacerbating the adverse effects of the Great Recession using a computational experiment conducted in four main steps. First, we build a benchmark Aiyagari-Bewley-Huggett-Imrohoroglu overlapping generations (OLG) life cycle model that is augmented to include idiosyncratic productivity shocks, unemployment risk, endogenous labor supply, endogenous retirement decision, and a realistically modeled U.S. Social Security program. Second, we build a counterfactual economy that excludes the Social Security program. Third, in each model, we calculate the welfare lost (relative to their respective steady states) due to the exogenous wealth and unemployment shocks for agents alive at time of the shocks. Finally, in the spirit of differences-in-differences (DiD) estimation, we calculate the difference in welfare losses between the two economies for agents of varying ages, wealth, income, and abilities. Comparing the welfare losses due to the wealth and unemployment shocks between the two economies identifies the role that Social Security plays in either mitigating or exacerbating the adverse effects of these shocks for agents of different ages and economic backgrounds.

Before examining the effect of Social Security on the welfare implications of the Great Recession, it is useful to revisit the welfare effects of the program in the steady state absent the wealth and unemployment shocks. Social Security increases welfare primarily by providing intra-generational insurance. Conversely, the program reduces welfare, because the payroll tax makes it harder for younger and low-wage agents to earn enough after-tax income to both smooth consumption over their lifetime and to accumulate precautionary savings. Additionally, the program "crowds out" private savings, thereby reducing the stock of aggregate capital available for production.[4] Similar to previous studies, we find that the economic costs outweigh the insurance benefits in the steady state. We estimate that the program reduces ex-ante welfare by the equivalent of 12.4 percent of expected lifetime consumption (CEV).

Turning to the average effects of the program during the Great Recession, we find that, on balance, Social Security mitigates a notable portion of the welfare losses induced by the wealth and unemployment shocks. In particular, we find that Social Security reduces the average welfare losses for agents alive at the time of the shock by the equivalent of 1.4 percent of expected future lifetime consumption. On average, Social Security mitigates some of the welfare losses due to the Great Recession primarily because it reduces the exposure of agents to the wealth shock. In the counterfactual model without Social Security, agents are completely exposed to this shock because all of their post-retirement consumption is financed with private savings. In contrast, in the benchmark economy agents are less vulnerable to this shock because their post-retirement consumption is partially financed with Social Security benefits which, unlike private savings, are unaffected by the shock. We also find that the program generally mitigates a similar portion of welfare losses from the Great Recession when households' expectations include the potential for the aggregate shock.

[4] In rational-expectations models, the program redirects what would otherwise be private savings in capital into retirement transfers. This result has been well documented in other studies discussed below.

Zooming in on the implications of Social Security on the welfare losses due to the Great Recession for agents of different ages, we find that Social Security is particularly effective at mitigating the welfare losses for agents who are older at the time of the shock. Older agents who are still working at the time of the shock have less time to rebuild their wealth by increasing their labor supply prior to retirement, leading them to be more vulnerable to the shocks. This effect is enhanced even further for agents who are retired at the time of the shock and cannot offset any of the losses by working more. Therefore, the insurance from Social Security is more valuable for these agents. Moreover, due to the presence of increasing mortality risk, Social Security benefits comprise a growing portion of consumption for these retired agents as they age.[5] Therefore, the Social Security benefits play an increasingly important role providing insurance for older agents during the Great Recession.

In contrast, we find that Social Security slightly exacerbates the welfare losses for agents who are younger at time of the shock. The negligibly larger welfare losses for these younger agents arise from the presence of the payroll tax that is particularly painful for these agents during the economic downturn when incomes are depressed, budget constraints are tighter and unemployment risk rises.

Slicing the welfare effects by wealth, income, and labor productivity, we find that Social Security mitigates welfare losses due the recession somewhat more for agents with lower lifetime incomes, wealth, and labor productivity because Social Security makes up a relatively larger portion of their post-retirement consumption.[6] Moreover, we do not find any specific

[5]Optimizing, rational agents rely more heavily on the benefit as they age, and their expected probability of survival decreases.

[6]This finding is particularly interesting since the program has been associated with a large reduction in

age, income, wealth, or labor productivity group for which Social Security substantially exacerbates the welfare consequences of the Great Recession.

The ability of Social Security to mitigate welfare losses for some of the most vulnerable demographic groups during this type of a business cycle episode, without significantly exacerbating the welfare consequences of the shock for other agents, indicates that this program is particularly effective at providing insurance against these episodes. Nevertheless, welfare losses attributed to the program in the steady state are large. Therefore, we explore the ability of a scaled-down program, with a potentially lower steady state welfare cost, to mitigate the welfare losses due to the Great Recession. In particular, we examine a counterfactual program (in the spirit of the Supplemental Security Income (SSI) program) that provides a smaller benefit than Social Security and is means tested. Although we find that this smaller-scale program only mitigates the equivalent of 0.7 percent of expected future lifetime consumption for agents alive at the time of the shock (relative to 1.4 percent for the Social Security), the ex-ante welfare costs in the steady state are significantly reduced (1 versus 12.4 percent CEV).

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. (2017) and Hur (2018) 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 Great Recession but also by exploring how effective the Social Security program is at mitigating

elderly poverty rates over the last century (see Engelhardt and Gruber (2004)).

these losses across different cohorts.

The second strand tries to measure the long-run implications on welfare of a Social Security program. These works weigh the expected relative benefit to newborns from providing partial insurance against expected future risks for which no market option exists against the welfare costs of distorting these individuals' incentives to work and save. Among these studies, a large body of literature focuses on quantifying the benefit of providing *intra-generational* insurance for idiosyncratic earnings and mortality risks (see, for example, Auerbach and Kotlikoff (1987), Hubbard and Judd (1987), Hubbard (1988), Imrohoroglu et al. (1995), Fuster et al. (2007), Storesletten et al. (1999), and Hong and Rìos-Rull (2007)).[7]

Other research has explored the role of Social Security in insuring *inter-generational* risk (i.e., insuring aggregate business cycle risk across generations). In particular, in their influential paper, Krueger and Kubler (2006) examine the welfare implications of Social Security in a two-period economy with aggregate (but not idiosyncratic) risk. The authors find that in expectation, the benefit from the inter-generational insurance is generally smaller than the adverse effects of capital crowd-out. Harenberg and Ludwig (forthcoming) examine the potential interaction of both types of risk (idiosyncratic as well as aggregate) in a model with a simplified Social Security program. They find that this interaction can significantly enhance the role for insurance from Social Security, leading the insurance benefit to outweigh the adverse effects of capital crowd-out in the long run. In keeping with this preceding line of work on the insurance role of Social Security in the presence of aggregate economic shocks, we find that the insurance benefit of Social Security with respect to aggregate shocks is

[7]For a theoretical discussion of the different types of risks that Social Security can provide insurance against, see Shiller (1999).

non-trivial, as the program is able to mitigate a considerable amount of welfare losses from deep recessions. However, our paper's main focus is on the distribution of the welfare effects of Social Security by age, lifetime income, and productivity over a transitional period after a large aggregate shock, as opposed to focusing on the expected average long-run welfare effects of the program across cohorts. Moreover, compared to the existing studies, of particular relevance is our finding that a smaller program similar to SSI would mitigate a meaningful amount of welfare losses from a large recession for the most vulnerable agents while posing significantly lower long-run welfare costs than the current U.S. program.

In a related study, Sommer and Peterman (2015) quantify the welfare effects of enacting Social Security on cohorts of agents who were alive at the time the original program was adopted. While Sommer and Peterman (2015) and this paper both study the interaction of Social Security and a large-scale recession, the questions and conclusions differ in important ways. Specifically, in this paper, we explore the ability of a Social Security program that is already in place to mitigate welfare losses caused by a large recession. We show that even though today's Social Security program is generally welfare-reducing, the *established* program can meaningfully mitigate welfare losses from large economic downturns. In contrast, Sommer and Peterman (2015) explore the implications of the *introduction* of the original Social Security program on the welfare of cohorts who experience the program's roll out. That paper shows that the introduction of the original Social Security program was generally welfare improving for agents who experienced the program's enactment. However, the paper also shows that introducing it during a severe recession reduced these welfare gains from the program's roll out for the original cohorts relative to a counterfactual implementation, wherein the program is enacted in normal economic conditions.

The final strand of the literature examines the effect on the economy of reforming the current Social Security program. Examples of these studies include: Conesa and Krueger (1999), Huggett and Ventura (1999), Huggett and Parra (2010), Olovsson (2010), Imrohoroglu and Kitao (2012), and Kitao (2014). 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 reform to the Social Security program, this paper studies how the economy evolves during a particular business cycle episode.

This paper is organized as follows: In Section 2, we introduce the computational model. Section 3 describes the functional forms and calibration parameters. In Section 4, we discuss the empirical data surrounding wealth and earnings shocks during the Great Recession and how we introduce them into the model. In Section 5, we report the results of the baseline computational experiment. Section 6 presents an additional set of findings for alternative social insurance programs; namely, Social Security with a payroll tax cut during the Great Recession, and a smaller insurance program in the spirit of the Supplemental Security Income (SSI) program. In Section 7, we test the sensitivity of our results to alternative ways of modeling the Great Recession. These experiments entail introducing within-cohort heterogeneity in wealth shocks experienced by households during the Great Recession, and including the risk of the Great Recession in households' expectations. Section 8 concludes.

2 Model

Our framework is an Aiyagari–Bewley–Huggett–Imrohoroglu economy with overlapping generations of heterogeneous agents, augmented to include unemployment risk and a stylized U.S. Social Security program. Agents derive utility from consumption and leisure. Agents supply labor elastically and receive an idiosyncratic, uninsurable stream of earnings that is governed by their labor decisions, labor productivity, unemployment shocks, and the market efficiency wage. Idiosyncratic labor productivity and unemployment shocks can be partially insured through precautionary holdings of a single asset in the economy and through labor supply decisions. Retired agents receive retirement benefits payments from a PAYGO Social Security system that is funded through income taxation of working-age individuals. Social Security payments provide another margin of consumption insurance for older agents. An important feature of this model is that agents choose the age at which they retire, taking into consideration realistic features of the U.S. Social Security program, such as progressive benefit payments that are tied to an agent's past earnings history, early retirement penalties, and delayed retirement credits.

2.1 Demographics, Endowments, Preferences, and Unemployment

We assume time is discrete and the model is annual. In each period, the economy is populated by J overlapping generations of individuals of ages $j = 20, 21, ..., J$, with J being the maximum possible age an agent can live. The size of each new cohort grows at a constant rate n. Lifetime length is uncertain with mortality risk rising with age. The conditional survival probability from age j to age $j+1$ is denoted Ψ_j where $\Psi_J = 0$. Annuity markets do not exist to insure life-span uncertainty, and agents are assumed to have no bequest motive. In the spirit of Conesa et al. (2009), accidental bequests, which arise from the presence of mortality risk, are distributed equally amongst the living in the form of transfers Tr.

Agents work until they choose to retire at an endogenously determined age $j = R \geq \underline{R}$, where $\underline{R}$ is the minimum retirement.[8] The endogenous retirement decision, $I' = \{0, 1\}$, is irreversible, with $I' = 1$ indicating that an agent is retired this period. Consequently, the state indicator variable $I = 1$ denotes an agent who has already retired in a previous period.[9] Endogenous retirement is an important extension of many existing models used to study the Social Security program.

Each period, an agent is endowed with one unit of time. D defines the fraction of the time endowment in each period that the agent is exogenously unemployed. Accordingly, $(1 - D)$ thus represents the remaining time allocation that can be apportioned to leisure or market work, with h denoting the fraction of this time spent providing labor market services. An agent's labor earnings are thus given by $y = w\omega h(1 - D)$, where w represents a wage rate per efficiency unit of labor and ω is the idiosyncratic labor productivity which follows:

$$\log \omega = \theta_j + \alpha + \nu + \epsilon. \tag{1}$$

In this specification, based on the estimates in Kaplan (2012) from the Panel Study of

[8]Prior to $\underline{R}$, agents can decide not to participate in the labor market by setting their labor hours to zero. However, such agents are not eligible for Social Security payments.

[9]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 reentry of retirees back into the labor force.

Income Dynamics (PSID), θ_j governs age-specific human capital (or the average age-profile of wages) and is the same for all agents of the same age. The rest of the income process is idiosyncratic and gives rise to within-cohort heterogeneity. Specifically, $\alpha \sim NID(0, \sigma_\alpha^2)$ is an individual-specific fixed effect (or ability) that is observed at birth and stays fixed for an agent over the life cycle, $\epsilon \sim NID(0, \sigma_\epsilon^2)$ is a transitory shock to productivity received every period, and ν is a persistent shock, also received each period, which follows a first-order autoregressive process $\nu' = \rho\nu + \psi'$ with $\psi \sim NID(0, \sigma_\nu^2)$ and $\nu = 0$ during an agents first period in the economy. Additionally, the exogenous unemployment shock, D, is discretized to two values: $D \in \{0, d(\alpha, j)\}$ with $d(\alpha, j) \in (0, 1]$. The positive value $D = d(\alpha, j)$ arrives with a probability $p^U(\alpha, j)$; both are a function of an agent's ability α and age j.[10] When the unemployment spell hits, the worker loses the option to work during $D = d(\alpha, j)$ fraction of their one-unit time endowment and receives an unemployment insurance benefit with a replacement rate ι.

Following Kaplan (2012), an agent's preferences over the stream of consumption, c, and supplied labor, h, over the life cycle are governed by a time-separable utility function:

$$E_0 \sum_{j=0}^{J} \beta^j (u(c) + v(h, D)), \tag{2}$$

where β is the discount factor. Expectations are taken with respect to the life-span uncertainty, the idiosyncratic labor productivity process, and the unemployment process.

[10]As documented in Section 4, both age and ability (for which we use education attainment as a proxy) are important determinants of unemployment risk in the data.

2.2 Technology and Market Structure

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, N, and ζ are aggregate capital, aggregate labor (measured in efficiency units), and the capital share of output. Capital depreciates at the rate $\delta \in (0, 1)$. The firms rent capital and hire labor from agents in competitive markets, where factor prices r and w are equated to their marginal productivities. The aggregate resource constraint is:

$$C + K' - (1 - \delta)K + G \leq K^{\zeta} N^{1-\zeta}, \tag{3}$$

where, in addition to the above described variables, C and G represent aggregate individual and government consumption, respectively.

The markets are incomplete and agents cannot fully insure against the idiosyncratic labor productivity, unemployment, and mortality risks by trading state-contingent assets. However, they can partially self-insure against these risks by accumulating savings, a, which earn a market return r. We assume that agents enter the economy with no assets and are not allowed to borrow.[11]

[11] In Appendix A.5, we relax this assumption and allow agents to borrow. As the appendix illustrates, relaxing the borrowing constraint has little effect of our qualitative and quantitative findings. The appendix also shows that the average age-profile of wealth produced by the model roughly matches an empirical profile constructed from the 2007 SCF data.

2.3 Government Policy

The government partakes in four activities. First, at the beginning of the period the government distributes accidental bequests of the deceased agents to the living in the form of lump-sum transfers (Tr). Second, the government collects a proportional Social Security tax, τ^{ss}, on the pre-tax labor income of working-age individuals (up to an allowable taxable maximum $\overline{y}$) to finance Social Security payments, b^{ss}, for retired workers (for details, see Section 2.4). Third, the government distributes the unemployment benefits, b^{ui}, to unemployed agents. Fourth, the government consumes in an unproductive sector. Following Conesa et al. (2009), Kitao (2014) and Imrohoroglu et al. (1995), the government consumption, G, is endogenously determined as a fraction of the total output in the steady state economy (i.e., $G = \phi Y$). The government uses income tax revenue to finance its consumption in the unproductive sector and unemployment benefits. Moreover, the government taxes each individual's taxable income according to a progressive income tax schedule. The taxable income, $T(\tilde{y})$, is defined as:

$$\tilde{y} = y + r(Tr + a) - 0.5\tau^{ss} \min\{y, \overline{y}\}, \tag{4}$$

where, consistent with U.S. tax law, the part of the pre-tax labor income (y) that is from the employer's contributions to Social Security ($0.5\tau^{ss} \min\{y, \overline{y}\}$) is not taxable.

2.4 Social Security

We model the Social Security system to mimic the U.S. system. In the U.S., Social Security benefits for retired workers are based on each worker's average level of earnings over the highest 35 years of earnings.[12] A baseline benefit formula is then applied to each worker's average level of labor earnings to calculate the pre-adjustment Social Security benefit.[13] The benefit formula is designed to ensure that the Social Security system is progressive, with the replacement rate being inversely related to past earnings. In particular, the marginal replacement rate changes when earnings reach two different bend points, which jointly determine the degree of progressivity of the Social Security benefits. The third (implicit) bend point is the cutoff on Social Security benefits and contributions. The cutoff limits not only the annual amount of earnings subject to payroll taxation but also the maximum earnings used to calculate the Social Security benefits. Finally, the Social Security system makes various adjustments to the baseline benefit amount depending on the retirement age, such as permanent percentage reductions for early retirement and permanent percentage credits for retirement past the normal retirement age (NRA).

To model these features of the U.S. Social Security system, we proceed in three steps. First, following Huggett and Parra (2010) and Kitao (2014), we calculate the model analog of each worker's average level of labor earnings over the working life cycle. At every age, the average accumulated earnings follow the law of motion:

$$x_{j+1} = \begin{cases} \frac{\min\{y_j,\overline{y}\}+(j-1)x_j}{j} & \text{if} \quad j \leq 35, \\ \max\{x_j, \frac{\min\{y_j,\overline{y}\}+(j-1)x_j}{j}\} & \text{if} \quad 35 < j < R, \\ x_j & \text{if} \quad j \geq R, \end{cases} \tag{5}$$

[12]These earnings are expressed as workers' average indexed monthly earnings (AIME).

[13]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 they begin receiving retirement benefits at the NRA.

where x_j is the accounting variable capturing the 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. To infuse an additional degree of realism while maintaining the model's tractability, we follow Kitao (2014) and introduce a rule to ensure that the average accumulated labor earnings, x_j, cannot fall below their previously realized level, x_{j-1}, after 35 working periods.[14] Moreover, since agents are not allowed to work during their retirement, which is assumed to be an absorbing state, x_j is 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:

$$\begin{aligned} &\tau_{r1} \quad \text{for} \quad 0 \leq x_R < b_1 \\ &\tau_{r2} \quad \text{for} \quad b_1 \leq x_R < b_2 \\ &\tau_{r3} \quad \text{for} \quad b_2 \leq x_R < b_3, \end{aligned} \tag{6}$$

where $\{b_1, b_2, b_3 = \overline{y}\}$ are the two bend points plus the benefit-contribution cutoff point, and where $\tau_{r1}, \tau_{r2}, \tau_{r3}$ represent the marginal replacement rates in the progressive Social Security payment schedule associated with the respective bend points.

Third, adjustments for early and late retirement are calculated. In the U.S., workers can begin receiving permanently reduced monthly retirement benefits after reaching the minimum retirement age, $\underline{R}$. The size of the reduction varies with the amount of time before

[14] 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.

the NRA an individual retires. 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 retirement age for which the credit is available ($\overline{R}$). As a result, the total Social Security benefit b^{ss} obtained by the retiree is defined as:

$$b^{ss} = \begin{cases} (1 - n\kappa_1(n))b^{ss}_{base} & \text{if} \quad \underline{R} \leq R < NRA \\ (1 + n\kappa_2(n))b^{ss}_{base} & \text{if} \quad NRA \leq R < \overline{R}, \end{cases} \tag{7}$$

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.

2.5 Dynamic Programming Problem

An agent who is yet to retire ($I = 0$) and is indexed by type $(a, x, \alpha, \epsilon, \nu, j, D, I = 0)$ solves the dynamic program:

(8)

$$V_t(a, x, \alpha, \epsilon, \nu, j, D, I = 0) = \begin{cases} \max\limits_{c,a',h}(u(c) + v(h, D)) + \beta\Psi_j EV'(a', x', \alpha, \epsilon', \nu', j+1, D', I') & \text{if} \quad j \leq \underline{R}, \\ \max\limits_{c,a',h,I'}(u(c) + v(h, D)) + \beta\Psi_j EV'(a', x', \alpha, \epsilon', \nu', j+1, D', I') & \text{if} \quad \underline{R} < j \leq \overline{R}, \end{cases}$$

subject to

$$\begin{aligned} c + a' &= (1 + r)(Tr + a) + y - T(\tilde{y}) - \tau^{ss}\min\{y, \overline{y}\} + Db^{\text{ui}} && \text{if} \quad I' = 0, \\ c + a' &= (1 + r)(Tr + a) - T(\tilde{y}) + b^{ss} && \text{if} \quad I' = 1, \end{aligned} \tag{9}$$

by choosing consumption, c, savings, a', time spent working, h, and whether to retire, $I' \in \{0, 1\}$. The accounting variable x follows the law of motion specified in equation 5. Agents 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 agents and is described in Section 2.1. $\tilde{y}$ defines the taxable income on which the income tax, T, is paid, and follows the process in equation 4. D is the state variable for the fraction of the period an agent is exogenously unemployed, while b^{ui} represents 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, $\overline{y}$.

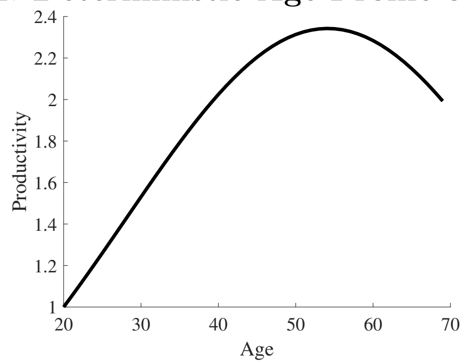
Retiring agents receive a constant stream of Social Security payments, b^{ss}, whose size is determined by the level of the average life cycle labor earnings observed at the retirement period, x_R, and the age they choose to retire. As in the U.S. system, agents of age $j < \underline{R}$ are not eligible for Social Security benefits and, as such, are not allowed to permanently retire.[15] For tractability, agents are forced into a mandatory retirement after reaching age $\overline{R}$.

The dynamic programming problem of already retired agents ($I = 1$) simplifies because these agents are no longer affected by labor productivity shocks since they do not work. As such, retired agents indexed by type $(a, x_R, j, I = 1)$ solves the dynamic program:

$$V(a, x_R, j, I = 1) = \max_{c,a'} u(c) + \beta s_j EV'(a', x_R, j + 1, I' = 1), \tag{10}$$

[15]Instead, agents can decide not to participate in the labor market prior to reaching the minimum retirement age $j = \underline{R}$ by choosing zero labor hours (i.e., $h = 0$).

Figure 1: **Deterministic Age Profile of Wages**



subject to

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

by choosing consumption, c, and savings, a'. These agents no longer choose h or I'.

2.6 Equilibrium

We define a stationary steady state competitive equilibrium as a collection of policy functions for agents, which are functions of the vector of states Ξ, such that decision rules are optimal, budgets are balanced, market clear, and the distribution $\mu(\Xi)$ is stationary. A formal definition of the equilibrium is presented in Appendix A.1.

3 Calibration

The model is calibrated in two stages. First, values are assigned to parameters that can be determined from the data without the need to solve the model. Second, the remaining parameters are estimated by simulated method of moments (SMM), matching key moments of the U.S. cross-sectional and aggregate data. The parameters are summarized in Table 20 in Appendix A.2.

3.1 Demographics, Endowments, Unemployment, and Preferences

There are 80 overlapping generations of individuals of ages $j = 20, ..., 100$. We follow Conesa et al. (2009) and Kitao (2014) in setting population growth rate, n, to 1.1 percent to match the annual 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).[16] The deterministic labor productivity profile, $\exp^{\theta_j}$, is shown in Figure 1. The profile is (i) smoothed by fitting a quadratic function in age, (ii) normalized such that the value equals unity when an agent enters the economy, and (iii) extended to cover ages 20 through 69, which we define as the last period in which agents are assumed to be able to participate in the labor activities ($\overline{R}$).[17] The permanent, persistent, and transitory idiosyncratic shocks to individuals' productivity are distributed normal with a mean of zero. The remaining parameters are also set in accordance with the estimates in Kaplan (2012): $\rho = 0.958$, $\sigma_\alpha^2 = 0.065$, $\sigma_\nu^2 = 0.017$ and $\sigma_\epsilon^2 = 0.081$. We discretize all three of the shocks in order to solve the model, representing the transitory shock with two states, the permanent shock with two states, and the persistent shock with five states. For expositional convenience, we refer to the two different states of the permanent shock as high and low ability types.

[16]See Appendix E in Kaplan (2012) for details on estimation of this process.

[17]The estimates in Kaplan (2012) are available for ages 25–65.

Table 1: **Unemployment Parameters in the Benchmark Model**

	$p^U(\alpha, j)$		$d_{\alpha,j}$	
Age	Low α	High α	Low α	High α
20-45	7.5%	3.1%	18.2%	15.5%
> 45	4.4%	2.7%	20.6%	22.6%

Note: Based on the March Supplement CPS data. α proxies for attained education in the CPS calculations. Duration is expressed as the percent of the period that an agent spends unemployed.

The unemployment shock, D, which represents the fraction of a given period which an agent is unemployed, is discretized to take on two values so that $D \in \{0, d(\alpha, j)\}$. $d(\alpha, j)$ and its arrival probability, $p_d(\alpha, j)$, vary with agents' age and ability, and are calibrated to match their corresponding 2007 CPS values listed in Table 1. The unemployment insurance payments, b^{ui}, is determined as a fraction of the average annual earnings in the economy. The average replacement rate fluctuated between 32 and 37 percent in the 2000–2006 CPS data. We therefore set this rate, ι, at 35 percent.

Following Kaplan (2012), household preferences are modeled as:

$$u(c_j) + v(h_j, D_j) = \frac{c_{it}^{1-\gamma}}{1-\gamma} - \chi_1 \frac{((1-D_{it})^{\xi} h_{it})^{1+\frac{1}{\sigma}}}{1+\frac{1}{\sigma}} - \chi_2(1-I'), \tag{12}$$

with the binary indicator $I' = 1$ denoting whether an agent is retired in the current period. To parameterize the deep preference parameters γ, σ, and ξ, we adopt the estimates from Kaplan (2012), setting the risk aversion coefficient, γ, and the Frisch labor supply elasticity on the intensive margin, σ, to 2.2 and 0.41, respectively.[18] The parameter ξ—also estimated in Kaplan (2012)—determines how much utility from leisure an agent receives during unemployment spells. In particular, when $\xi = 1$, then an agent derives leisure from the entire

[18] All preference parameters are based on Column 3 in Table 2 of Kaplan's paper.

unemployment spell. Moreover, when $\xi < 1$, then, at most, only a part of an unemployment spell is equivalent to leisure. Consistent with estimates in Kaplan (2012), we set $\xi = 0$, meaning that unemployment spells are associated with some disutility.[19]

The remaining parameters are calibrated endogenously to match external data moments. In particular, the scaling constant χ_1 is calibrated such that, on average, agents work one-third of their time endowment prior to the normal retirement age. Similarly, the fixed cost of not being retired, χ_2,[20] is calibrated so that 70 percent of individuals retire by the normal retirement age.[21] Finally, the discount factor, β, is calibrated to 0.99 to match the U.S. capital-to-output ratio of 2.7.[22]

3.2 Social Security

For simplicity, we set the NRA at 66, irrespective of the calendar year in which an agent was born.[23] Following the current U.S. Social Security system, the minimum retirement age, $\underline{R}$,

[19]Kaplan (2012) estimates $\xi = -0.08$ but not statistically different from zero.

[20]Including a fixed utility cost of working non-zero hours (or, alternatively, including a nonlinear mapping between hours and productivity) is a standard modeling approach in macro labor literature in order to produce an active extensive margin with reasonable utility parameters; for further discussion, see Rogerson and Wallenius (2013). An example of something that this utility cost proxies for are the resources used to commute to work. We expand on this treatment by assuming that the utility cost is also incurred by non-retired agents who do not work. Examples consistent with these costs include the resources used to keep work skills up to date or to apply for jobs.

[21]See Annual Statistical Supplement to the Social Security Bulletin, 2007, 5a.pdf.

[22]Although this target is commonly used in other studies (e.g. Conesa and Krueger (1999) and Conesa et al. (2009)), the empirical value has fluctuated somewhat over time. A smaller target would tend to lead to a lower value of β which could reduce the insurance value from future Social Security payments.

[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.

is set at 62, while the maximum age over which delayed retirement credits can be accrued, $\overline{R}$, is set at 69.[24] As discussed above, it is assumed that at age 70, no agent in the economy works. The early retirement penalty parameters, κ_1 and κ_2, are set at the values in the U.S. Social Security system, 6.7 percent (κ_{1a}) for the first three years of early retirement and at 5 percent (κ_{1b}) for years four and five. The delayed retirement credit, κ_2, is set at 8 percent per annum.[25] The marginal replacement rates in the progressive Social Security payment schedule ($\tau_{r1}, \tau_{r2}, \tau_{r3}$) are set at the values of 0.9, 0.32 and 0.15, respectively. Finally, we follow Huggett and Parra (2010) and set the bend points (b_1, b_2, b_3) and the maximum earnings ($\overline{y}$) so that b_1, b_2 and $b_3 = \overline{y}$ occur at 0.21, 1.29 and 2.42 times average earnings in the model, consistent with the U.S. economy.

3.3 Technology and Market Structure

We assume the aggregate production function is Cobb–Douglas. The capital share parameter, ζ, is set at .36. The depreciation rate is set to target the observed investment-to-output ratio of 0.26.

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] 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. Source: Social Security Administration, Annual Statistical Supplement, 2000, p. 240.

[25] See Pingle (2006) for more details.

3.4 Government

We set the government spending in the unproductive sector equal to 17 percent of GDP in the steady state ($\phi = 0.17$). We follow a host of literature (two examples include Conesa et al. (2009) and Imrohoroglu and Kitao (2012)) and use the three-parameter tax function from Gouveia and Strauss (1994) to capture the progressivity of the U.S. income tax function:

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

In this tax function, Υ_0 primarily controls the average tax rate, Υ_1 primarily controls the progressivity of the tax policy, and Υ_2 is a scaling factor. We use the estimates from Gouveia and Strauss (1994) for Υ_0 and Υ_1, and calibrate Υ_2 such that, in the steady state, the income tax revenue equals government spending. Finally, the Social Security tax, τ^{ss}, is determined so that in the steady state the Social Security program's budget is balanced.

4 The Great Recession

4.1 General Modeling Approach

The Great Recession was the largest business cycle episode since the Great Depression. De Nardi et al. (2011) document that households responded to this severe business cycle episode with significant reductions in consumption. Moreover, in a stylized model, the authors demonstrate that two channels can account for the majority of the large changes in consumption. In particular, their simple model can reproduce the decline in aggregate consumption over the Great Recession by incorporating observed declines in household wealth and decreases in expected future income. Motivated by these findings, we incorporate the Great Recession through shocks that affect households' net worth and future earnings dynamics, the primary determinants of households' resources available for consumption and savings.

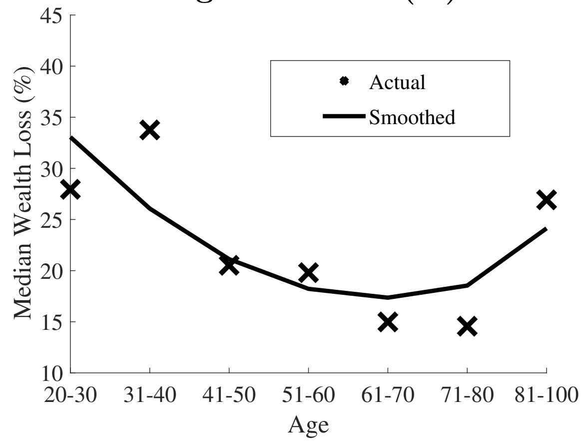
Specifically, we model the Great Recession as one-time unexpected heterogeneous depreciation shocks to household wealth, combined with increases in both the likelihood and duration of unemployment spells that persist for several years following the onset of the Great Recession. After the initial surprise, the evolution of aggregates, as well as the increased likelihood and duration of unemployment spells, are perfectly known and therefore there is no additional aggregate uncertainty during the perfect-foresight transition back to the steady state.[26]

We choose to model the onset of the shocks as unexpected for two reasons. First, both popular press reports and survey evidence at the time of the shocks point to a general belief that real estate prices—one asset whose value declined significantly during the Great Recession—would not fall. For example, in surveys of home buyers in four metropolitan areas in 2003, Case and Shiller (2003) find that less than 15 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.[27] Second, we choose to model the shocks as unexpected because, due to the

[26]However, idiosyncratic uncertainty still exists. For example, while agents are aware that the likelihood of realizing an unemployment spell has increased, they do not know if they will realize one or not.

[27]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, prior to the Great Recession, generally both homeowners and investors were operating under the belief that

Figure 2: **Median 2007–2009 Change in Wealth (%) in SCF Panel, by Age in 2007**



Note: Based on the SCF 2007-2009 panel. Households with negative net worth in 2007 are excluded.

Great Moderation, there was a belief that the risk of severe economic 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."[28] These beliefs could have led many to believe that although there was still a risk of mild business cycle episodes, there was minimal risk of a widespread, severe downturn such as the Great Recession. That said, in Section 7.2, we demonstrate that relaxing the assumption of the unexpected nature of the shock by introducing the risk of the aggregate shock into households' expectations does not notably change our quantitative findings.

4.2 Calibration of the Shocks

The rest of this section details the heterogeneous nature of the wealth and unemployment shocks in the 2007–2009 SCF panel and the CPS micro files, and discusses the calibration

home prices would never fall.

[28]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?," on September 2nd, 2009.

of these shocks in the model.

Figure 2 summarizes the median change in household wealth between 2007 and 2009 (computed from the SCF panel) by age.[29] As the figure illustrates, the Great Recession was associated with substantial losses of household wealth across all age groups, with the median decline in the weighted sample of approximately 20 percent. Moreover, in percentage point terms, the losses in wealth were relatively larger for households who were young or old in 2007. In the baseline calibration, we model the wealth losses over the Great Recession as age dependent. In particular, we fit the age profile of wealth losses (black cross marks) in Figure 2 with a second-order polynomial (solid black line) and use these values to determine the size of the wealth shock for agents at any given age. However, even after controlling for age-dependent losses, there is still a significant amount of residual within-cohort heterogeneity. Thus, in Section 7.1 we test the sensitivity of our main results once additional within-cohort heterogeneity is introduced into the model.

Next, we examine how unemployment changed over the Great Recession in order to calibrate the unemployment shocks. The Great Recession is associated with a large increase in unemployment and an extension of the average unemployment duration. The U.S. unemployment rate roughly doubled from 5 to 10 percent between March 2006 and March 2010.[30] Table 2 depicts the average unemployment rates and duration by age and education in both 2005–2006 and 2009–2010 CPS data.[31] The table documents that both the level of the un-

[29]We exclude households with zero or negative net worth in 2007 in this calculation. This restriction excludes about 8 percent of the weighted sample in the SCF.

[30]For the official BLS estimates, see http://data.bls.gov/pdq/SurveyOutputServlet.

[31]We define high-education individuals as those who have at least some education in addition to high school.

Table 2: **Unemployment Rate and Duration, by Age and Education**

	2005-2006		2009-2010	
Age	**Low Education**	**High Education**	**Low Education**	**High Education**
		Unemployment Rate (%)		
20-45	8.06	3.70	15.95	7.05
> 45	4.46	2.78	10.04	5.82
		Average Unemployment Duration (Weeks)		
20-45	18.7	17.9	25.2	24.2
> 45	23.2	24.2	31.1	31.6

Note: Based on the March Supplement CPS data. High education individuals have at least some college.

employment rate and the magnitude of the increase in the unemployment rate vary by age and education. In particular, young, low-education individuals experienced the highest odds of unemployment in the pre-recession data, and they also observed the largest percentage point increase in unemployment rates during the Great Recession. In contrast, the 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.

Table 3 describes the changes in the probability and duration of being unemployed that we incorporate in the model along the perfect-foresight transitional path. The 2008–2012 increases in the unemployment rate and duration by age and ability groups are calculated as percentage point deviations from their respective pre-crisis benchmark levels. After 2012, we project the deviations using the contour of the CBO long-term unemployment rate projections (see Mancheste (2013)).

Table 3: **Exogenous Evolution of the Unemployment Shocks Along the Transition**

	Rate (pp)				**Duration (weeks)**			
Year	**Young Low**	**Young High**	**Old Low**	**Old High**	**Young Low**	**Young High**	**Old Low**	**Old High**
2008	1.9	0.4	0.5	0.3	-2.2	-1.1	-1.2	0.4
2009	7.6	3.5	4.9	2.9	1.6	1.9	2.9	1.6
2010	9.4	4.4	6.4	3.4	11.1	12.6	15.5	13.4
2011	8.3	3.9	5.3	3	14.5	15.9	17.2	18.6
2012	6.2	3.4	4.1	3	13.7	14.3	17.5	16.5
2013	6.2	3.4	4.1	3	13.7	14.3	17.5	16.5
2014	6.2	3.4	4.1	3	13.7	14.3	17.5	16.5
2015	4.1	2.3	2.7	2	9.1	9.5	11.7	11
2016	2.1	1.1	1.4	1	4.6	4.8	5.8	5.5
2017	0	0	0	0	0	0	0	0

Note: Estimates are based on the March Supplement CPS data. Young agents are agents between ages 20–46. High types are agents who receive the more productive ability (α) at birth. The 2008–2012 increases in the are calculated as percentage point deviations from their respective pre-crisis benchmark levels. After 2012, we project the deviations using the contour of the CBO long-term unemployment projections.

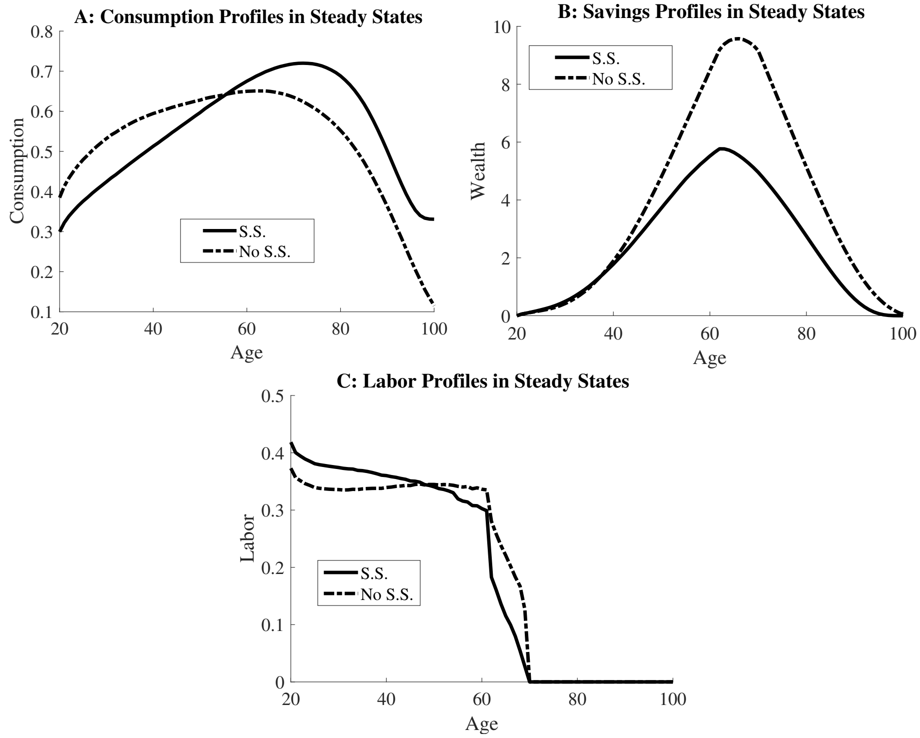
5 Baseline Results

5.1 Steady State Predictions

This section compares the benchmark and counterfactual economies in the steady state. Figure 3 depicts the life-cycle profiles, while Table 4 shows the aggregate variables in each economy. Consistent with previous studies, Social Security crowds out capital: the average savings profile (shown in Figure 3) as well as the level of aggregate capital K (shown in Table 4) are relatively higher in the counterfactual economy.[32] The lower K with Social Security, paired with the aggregate labor supply N that is roughly identical between the two economies, translates into a higher return to capital r and lower market wage w, which

[32]This is because, in the counterfactual economy, agents finance all of their post-retirement consumption from private funds, as opposed to part of their old-age consumption being funded with Social Security benefits.

Figure 3: **Life Cycle Profiles in Steady State**



Note: "S.S." denotes the benchmark economy with the U.S. Social Security program. "No S.S." denotes the counterfactual economy with no Social Security.

in turn affect the inter-temporal allocation of consumption and leisure.[33] In particular, as illustrated in Figure 3, the lower r induces agents to both consume more and enjoy more leisure early in life. Moreover, on the extensive margin, since the lower r reduces the relative importance of leisure later in life, agents tend to retire at a later age in the counterfactual economy without Social Security.

Turning to the steady state welfare effects of Social Security, we find that agents would be willing to give up 12.4 percent of their per-period expected consumption in order to

[33]The removal of Social Security mostly affects how agents fund their post-retirement consumption. Thus, Social Security does not have a large effect on an agents incentives to work, and therefore the effects on aggregate labor are second order.

be born into the counterfactual economy without a program.[34] Although Social Security provides intra-generational insurance, it reduces average steady state welfare for standard reasons. Namely, the payroll tax makes it harder for younger and low-wage agents to smooth consumption over their lifetime and to accumulate precautionary savings, and the progressive contribution-to-benefits formula further distorts agents' labor supply decisions. Moreover, the program "crowds out" private savings, thereby affecting the marginal products of capital and labor in general equilibrium. Overall, we find that roughly half of the total estimated welfare loss can be explained by the direct effects of Social Security on agents' decisions, while the other half is due to general equilibrium effects.[35]

Table 5 depicts the welfare losses due to Social Security for agents in various quintiles of the lifetime labor income, productivity, and wealth distributions.[36] As can be seen in the table, the ex-ante welfare losses due to Social Security range between 11.9 to 13.3 percent across the distribution, with the reduction in ex-ante welfare being the largest for the bottom

[34]Our estimates are on the upper end of the range estimated by other studies (see Hong and Rìos-Rull (2007), Storesletten et al. (1999), and Imrohoroglu et al. (2003)) who report ex-ante welfare losses from the program between 3.7 percent and 12.9 percent. Our model estimates tend to be larger because, to our knowledge, our model is the first to simultaneously incorporate endogenous labor, endogenous retirement, idiosyncratic labor productivity, unemployment, and mortality risks. With all of these features, the welfare costs of the program are enhanced.

[35]To isolate the effect of the direct distortions on agents' consumption-saving decisions, we conduct a partial equilibrium experiment in which we remove Social Security but hold prices at the levels of the baseline model with Social Security. We find that the welfare gained from removing the direct distortions from Social Security is 5.8 percent CEV, while the remaining 6.6 percent represents the additional welfare losses from Social Security due to the general equilibrium effects.

[36]Productivity is measured as the lifetime average idiosyncratic productivity, and is comparable to a agent's average wage.

Table 4: **Aggregates in the Steady States**

Aggregate	S.S.	No S.S.
Y	0.91	1.05
K	2.47	3.64
N	0.52	0.53
w	1.12	1.28
r	0.05	0.02
Tr	0.04	0.06
τ_{ss}	0.1	0
Avg. Retirement Age	64.6	66.7

Note: "S.S." denotes the benchmark economy with the U.S. Social Security program. "No S.S." denotes the counterfactual economy with no Social Security.

Table 5: **Steady State Welfare Lost from Social Security**

	Quint 1	Quint 2	Quint 3	Quint 4	Quint 5
Income	11.9%	13.2%	12.2%	11.6%	13.3%
Productivity	12.4%	12.6%	12.3%	11.5%	13.2%
Wealth	12.3%	12.8%	12.1%	11.8%	12.9%

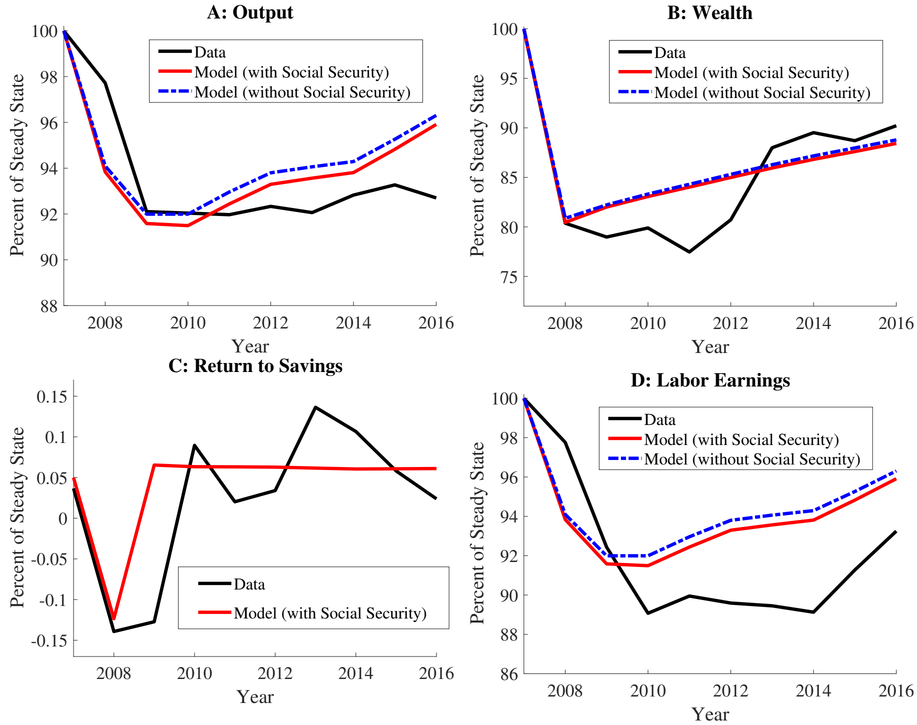
Note: Average, steady state welfare losses due to Social Security by quintiles of agents' lifetime income, lifetime wealth, and lifetime productivity.

two and the top quintiles. The bottom two quintiles of the distributions are particularly adversely affected by the payroll taxes. In contrast, agents in the upper end of the labor income, productivity, and wealth distributions are particularly adversely affected by the progressive scheme of the Social Security program, which redistributes resources away from the top to the rest of the distribution.

5.2 Recessional Dynamics of Aggregates

This section studies the evolution of economic aggregates in the benchmark and counterfactual model and compares them to the data along the transitional path. As described in Section 4, we model the Great Recession as one-time, unexpected age-dependent depreciation shocks to household wealth, combined with persistent increase in the likelihood and

Figure 4: **Evolution of Aggregate Output, Wealth and Labor Earnings over the Transition**



Note: The data represent the deviations after 2007 from each series' long-run trend. Data sources: Output (BEA), Earnings (CPS), and Wealth (Flow of Funds); series are detrended using a 3rd degree polynomial. The construction of the total return to saving is described in the text. All the series are normalized to 100 percent in 2007.

duration of unemployment spells that vary by agents' age and ability.

In order to confirm that these shocks filter though our model in a way that is broadly consistent with the data, we compare the dynamics of economic aggregates over the Great Recession. As shown in Panel A of Figure 4, output drops initially by about 8 percent in both the model and the data in the first two years of the recession. It recovers modestly through the early stages of the economic recovery, but remains depressed for many years.[37,38]

[37]In the data, output, wealth, and labor earnings grow over time; we therefore base the comparisons on the data that is detrended using a third-order polynomial.

[38]Appendix A.3 shows the transitional dynamics of the aggregate variables in both the benchmark and counterfactual economies.

Next, in order to further determine whether our approach to modeling the Great Recession is appropriate to study the welfare effects on households, we examine the dynamics of key factors that affect the resources available for household consumption and savings; namely, labor earnings, returns to savings, and wealth (Panels B–D). As the panels illustrate, the model generally matches the evolution of these key aggregates compared to the data. Turning first to the evolution of aggregate wealth (Panel B), at the onset of the recession household net worth falls by approximately 20 percent in the model and the data.[39] After the initial shock, aggregate wealth in the model grows at a similar rate as in the data and after 8 years is at approximately 90 percent of its pre-crisis level.[40]

Turning next to the return to savings, in our model, household only have access to one asset, which we take to parsimoniously represent a value-weighted portfolio of assets in the data. This is important because housing and equities were the key drivers of changes in household wealth over the Great Recession in the data, and so returns from these assets should be included when calculating the total asset return to compare with the model. To create a measure of the total return to savings in the data, we build on Glover et al. (2017) and Hur (2018) and construct a value-weighted index of asset returns. The index combines returns across risky asset classes (derived from fluctuations in prices of stocks and housing) with returns to 10-year Treasury bonds.[41] Turning to the model, we capture the

[39]Household wealth is calculated from the Federal Reserve's Flow of Funds data. See Table Z.1 at http://www.federalreserve.gov/releases/z1/current/accessible/b100.htm.

[40]These figures are adjusted for the trend growth in aggregate wealth.

[41]To construct such composite return in the data, we follow Glover et al. (2017) and Hur (2018) and compute the yearly return to risky assets (i.e., housing and stock) from annual real changes in the Case-Shiller House Price Index and the Wilshire 5000 Index, weighted in equal proportions. Returns to safe assets are measured as nominal interest rates on 10-year Treasuries minus CPI inflation. Following Glover et al.

sharp devaluation of equities and housing over the Great Recession with the initial one-time depreciation shock. Since the return to savings in our model is captured by the interest rate net depreciation, the initial depreciation shock directly enters the calculations of this return in the model.[42] As Panel C in Figure 4 illustrates, the measures of per-period total returns to household savings in the model and data generally follow a similar pattern with similarly large, outsized declines at the beginning of the recession. Subsequently, although more volatile in the data, the returns over the recovery are quite similar, on average, providing a degree of comfort that the Great Recession's effect on the household return to savings is similar in the model to the effect in the data.

Next, the evolution of labor income in the model matches the data quite well (Panel D); labor earnings drop approximately 10 percent in both the model and the data, though the trough in a bit deeper in the data and lags the model slightly. That said, despite the close match of labor earnings, the composition of factors underlying the change differs somewhat between the model and the data. In the model and the data, both wages and hours fall, but in somewhat different proportions. Accounting for composition bias, Elsby et al. (2016) estimate that a concept of wages that is consistent with the efficiency wage in the model fell 3.7 percent during the recession, less than the nearly 8 percent decrease

(2017), we use a weight of approximately 92 percent and 8 percent for risky and safe assets, respectively, to create a single composite index over the risky and riskless asset classes.

[42]The one-time recessionary depreciation shock occurs at the beginning of the first period of the transition, prior to production taking place. Since the depreciation shock directly reduces the amount of capital available for agents to rent to firms in this first period of the transition, it affects the net return to savings in this period through its effects on both the marginal product of capital and the depreciation rate. This one-time recessionary depreciation shock occurs in the period in addition to the standard depreciation of capital that takes place during production.

in the model. Meanwhile, aggregate hours fell by nearly 10 percent in the data, more than the approximately 4 percent decline in the model, likely reflecting that the model does not account for involuntary part-time unemployment or discouraged workers dropping out of labor force. The difference in labor hours (which enter directly into the household's utility function and affect welfare) could cause our model to somewhat understate the welfare costs of the Great Recession. However, as long as the over-predictions for labor hours from the model are similar across the economies with and without Social Security, then our DiD approach should limit their effect on the main welfare findings.

Overall, although we model the Great Recession in a fairly parsimonious manner, the model is able to broadly match the evolution of output, wealth, the total return to savings, and labor earnings in the data. Thus, we conclude that our model captures the main effects of the Great Recession observed in the data, including the effects on households' available resources for savings and consumption.

5.3 Welfare Effects of Social Security Due to the Great Recession

Next, we assess the role that Social Security plays in mitigating the welfare consequences of the Great Recession on average and also for agents of different ages, incomes, wealth and abilities. The experiment is conducted in two steps. First, in each model, we calculate the welfare lost (relative to the steady state) due to the exogenous wealth and unemployment shocks. We define the welfare lost due to the shocks as the constant fraction of per-period future expected consumption that an agent would be willing to give up in order to not to live through the Great Recession (CEV). Second, in the spirit of a DiD estimation, we calculate

Table 6: **Avg. Welfare Loss from the Great Recession for Living Agents**

	Avg. CEV
S.S.	4.6%
No S.S.	5.9%
S.S. Welfare Effects	1.4%

Note: "S.S. Welfare Effect" is the difference between the welfare losses due to the Great Recession in the benchmark (S.S.) and counterfactual (No S.S.) economies. A positive value implies a mitigation while a negative value implies an exacerbation of the losses. Differences between the S.S. and No S.S. may not equal the S.S. welfare effect due to rounding.

the difference in welfare losses due to the shocks between the two economies. The difference in the welfare losses due to the Great Recession in each of the economies identifies the role that Social Security plays in either mitigating or exacerbating the effects of the shocks.

5.3.1 Average Welfare Effects of Social Security

Table 6 compares the average welfare losses due to the Great Recession for agents living at the time of the shocks in the benchmark and counterfactual economies. As shown, in the benchmark model, the Great Recession reduces average welfare for agents alive at the time of the shocks by an equivalent of 4.6 percent of their expected future consumption. In the counterfactual economy, the reduction in average welfare is much larger, estimated as the equivalent of 5.9 percent of expected future consumption. The resulting difference (1.4 percent) in average welfare losses from the Great Recession between the two economies suggests that Social Security mitigated a non-trivial amount of these welfare losses.

Social Security affects the welfare consequences of the Great Recession through two competing channels. On one hand, Social Security mitigates some of the average welfare losses from the Great Recession by reducing agents' exposure to potential consumption losses caused by the declines in wealth and labor earnings. In the counterfactual model without

Table 7: **Welfare Loss for Living Agents, by Age**

Age	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**
S.S.	3.5%	4.3%	4.9%	5.1%	4.9%	5.4%	5.8 %	3.8%
No S.S.	2.9%	3.4%	4.2%	5.5%	8.5%	12.8%	17.9 %	24%
S.S. Welfare Effects	-0.6%	-0.9%	-0.8%	0.5%	3.6%	7.5%	12.1 %	20.2%

Note: Repeats analysis in Table 6 by agents' age.

Social Security, agents must fund all of their post-retirement consumption with savings that are exposed to the shock. In contrast, in the benchmark model, agents are less vulnerable to this shock because their post-retirement consumption is partially financed with Social Security benefits which, unlike private savings and labor earnings, are unaffected by the shock. On the other hand, Social Security exacerbates welfare losses because the effects of payroll tax τ^{ss} on household budget constraints are particularly painful in an environment where household wealth and earnings unexpectedly erode. On average, the positive welfare effect of the program dominates, meaning that Social Security mitigates the welfare losses due to the Great Recession. With this finding in mind, we next focus on two other questions of interest. First, we examine which age, income, wealth, and labor productivity groups benefit the most from the mitigating effects of Social Security during the Great Recession. Second, we ask whether the program exacerbates the welfare losses for any particular group.

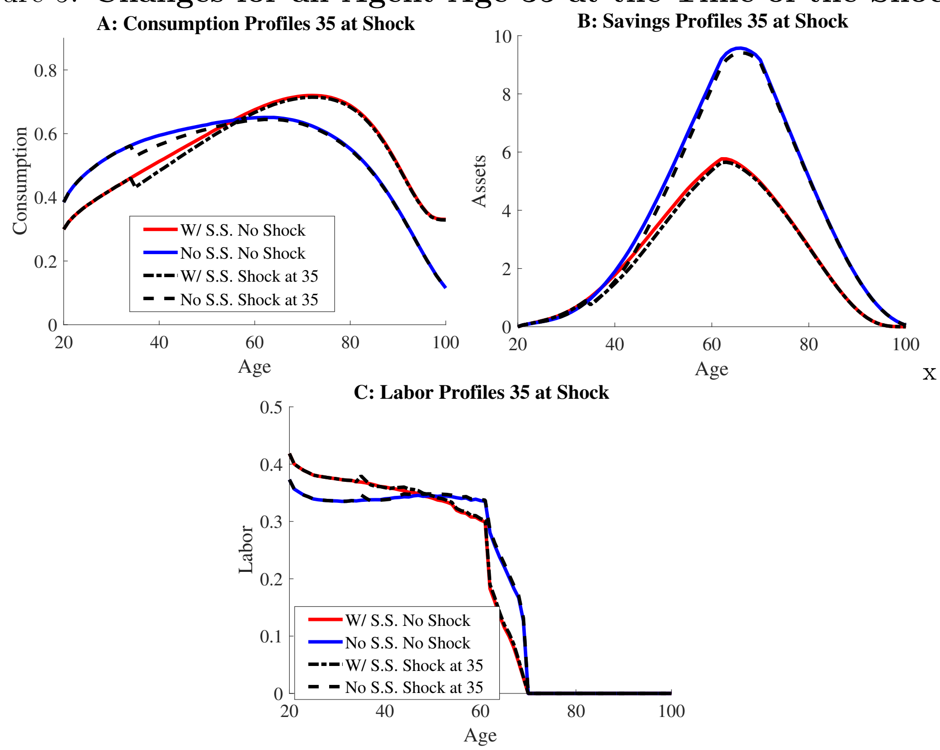
5.3.2 Welfare Effects of Social Security by Age

Table 7 summarizes the effect of Social Security on welfare losses from the Great Recession on agents of different ages at the time of the shock. The estimated effects can be discussed in the context of three broad age categories: (i) agents who are in their prime working ages at the time of the shock (ages 20 to 50), (ii) agents who are nearing retirement at the time of the shock (ages 50 to 70), and (iii) agents who are retired at the time of the shock (ages 70+). As can be seen in the table, Social Security exacerbates the adverse welfare effect of the Great Recession for younger agents between ages 20 and 50. However, the overall effect is relatively small. At the same time, Social Security mitigates a large amount of the welfare losses for older agents who are either near retirement or who have already retired.

Turning first to agents who are younger at time of the shock, Figure 5 compares the average consumption, savings, and labor profiles in the benchmark and counterfactual economies for agents who never experience the Great Recession against the average profiles of agents who are 35 at the onset of the economic downturn. As can be seen in the figure, younger agents respond by increasing their labor supply very slightly upon impact but reduce their consumption for numerous periods following the shocks. However, the changes in the consumption, savings, and labor profiles in each model are similar, suggesting that Social Security plays only a minor role in affecting the welfare consequences of the Great Recession for younger agents.

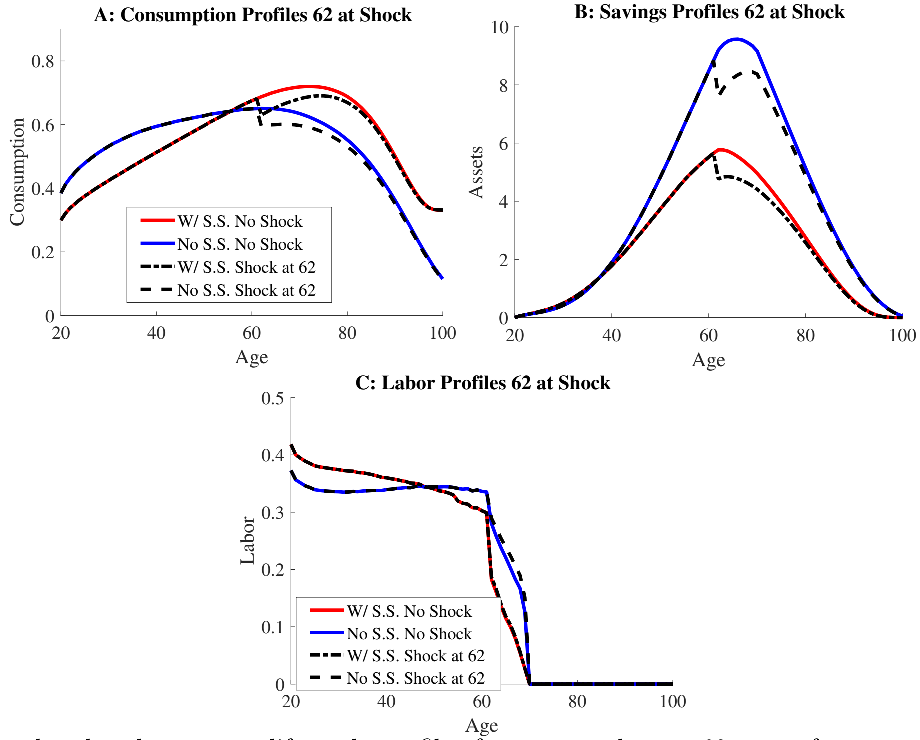
The small amount of additional welfare lost on average by younger agents during the Great Recession due to Social Security arises because the negative effect of payroll tax on agents' welfare during the Great Recession outweighs the positive insurance benefit that Social Security provides. In particular, the presence of payroll tax tightens budget constraints, making it more difficult for younger agents to smooth consumption and to partially self-insure against idiosyncratic productivity and unemployment shocks. At the same time, younger agents are less vulnerable to the wealth shock because they have not yet accumulated as large a fraction of their lifetime savings at the time of the shock and have many periods before retirement to offset the losses by working more. As such, the insurance provided by

Figure 5: **Changes for an Agent Age 35 at the Time of the Shocks**



Note: The graphs plot the average life cycle profiles for agents who are 35 year of age at the time of the shock, and compare them to the average profiles of agents who never experience the shock in the benchmark (W/ S.S.) and the counterfactual (No S.S.) economies.

Figure 6: **Changes for an Agent Age 62 at the Time of the Shocks**



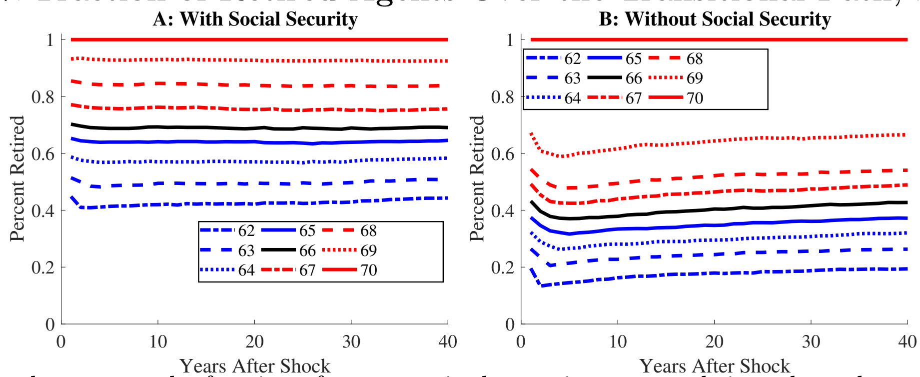
Note: The graphs plot the average life cycle profiles for agents who are 62 year of age at the time of the shock, and compare them to the average profiles of agents who never experience the shock in the benchmark (W/ S.S.) and the counterfactual (No S.S.) economies.

the Social Security benefit, which is unaffected by the shock, is relatively less important.

Figure 6 repeats the analysis in Figure 5 for older agents who are age 62 at the time of the shock. In both models, agents respond to the shock with a large decrease in consumption, which persists for numerous years; however, the effect of shock is relatively larger in the counterfactual model. Moreover, the age profile of labor supply shifts up between ages 62 and 70 in the counterfactual economy, indicating that older agents respond to the shocks by postponing retirement. Taken together, the larger response of consumption and labor in the counterfactual model suggests that Social Security effectively mitigates a large amount of the welfare losses from the Great Recession for agents between ages 50 and 70.

Social Security mitigates welfare losses for these agents because the insurance benefit

Figure 7: **Fraction of Retired Agents Over the Transitional Path, by Age**

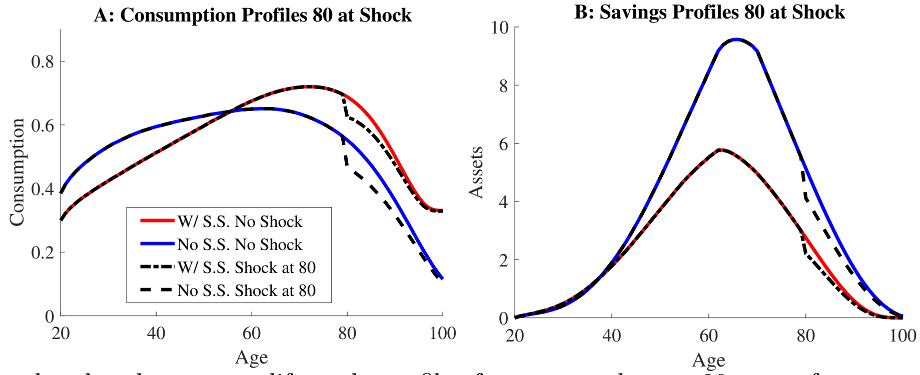


Note: The graphs capture the fraction of agents retired at a given age and time along the transitional path in the benchmark and counterfactual economies. For example, in Panel A, about 44 percent of all agents age 62 are retired in the steady state (time 0).

provided by Social Security outweighs the negative effects of payroll taxation. The stream of post-retirement payments from Social Security, which is unaffected by the shocks, is more valuable for older agents relative to their younger counterparts for two reasons. First, older agents close to retirement have less time prior to their retirement to rebuild their wealth by increasing their labor supply. Second, since these older agents are closer to retirement, they hold a larger fraction of their total lifetime wealth (intended to finance post-retirement consumption) at the time of the shocks. As such, these agents are more vulnerable to the effects of the shocks. Moreover, the adverse effect of tighter budget constraints due to the payroll tax is relatively smaller for these agents since they tend to hold a large amount of wealth.

Panels A and B in Figure 7 detail the varying magnitudes of the retirement decision responses in models with and without Social Security, respectively. In particular, the panels capture the fraction of agents retired at a given age in each steady state and also track how the fraction changes over time during and after the Great Recession. In the model, there are two opposing forces affecting the retirement decisions of households. On the one hand, households

Figure 8: **Changes for an Agent Age 80 at the Time of the Shocks**



Note: The graphs plot the average life cycle profiles for agents who are 80 year of age at the time of the shock, and compare them to the average profiles of agents who never experience the shock in the benchmark (W/ S.S.) and the counterfactual (No S.S.) economies.

may delay retirement due to the wealth shock. On the other hand, households may be prompted into earlier retirement by unemployment shocks. In our economy with Social Security, and consistent with empirical evidence from Coile and Levine (2011), the effects of these two forces on the retirement flows are weak and largely offsetting, suggesting a limited role of the Great Recession in determining households' retirement decisions.[43] In contrast, in the model without Social Security (Panel B), the wealth shock channel dominates, causing the fraction of retired agents across the spectrum of retirement ages to drop noticeably and to remain depressed for many periods.

Finally, Figure 8 plots the average consumption and savings decisions for agents who are 80 at the time of the shock. While in both models old agents respond to the shocks by cutting consumptions sharply, the much larger drop in consumption in the model without Social Security highlights the important role played by Social Security in mitigating

[43] At the onset of the shock the unemployment channel dominates and the flow of households newly retiring in the model increase by roughly 1.5 percent, similar to the 2 percent increase estimated in Coile and Levine (2011). This increase isolates the effect of the Great Recession, net of the usual flows into retirement due to population aging.

Table 8: **Welfare Loss for Living Agents, by Lifetime Wealth, Productivity, and Income**

Lifetime Wealth:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4.4%	4.4%	4.5%	4.8%	4.7%
No S.S.	5.9%	5.9%	5.9%	6%	6%
S.S. Welfare Effect	1.5%	1.4%	1.4%	1.3%	1.3%
Lifetime Productivity:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	3.9%	4.5%	4.7%	5.1%	5.4%
No S.S.	5.5%	5.9%	6%	6.3%	6.6%
S.S. Welfare Effect	1.6%	1.4%	1.3%	1.2%	1.1%
Lifetime Income:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4%	4.5%	4.7%	4.9%	5.4%
No S.S.	5.6%	5.9%	6%	6.2%	6.5%
S.S. Welfare Effect	1.6%	1.3%	1.4%	1.3%	1.1%

Note: Repeats analysis in Table 6 by agents' lifetime wealth, productivity, and income.

the welfare losses of the Great Recession for retired agents. In addition to the mitigating reasons discussed above, retired agents face an increasing mortality probability as they age. Therefore, in the benchmark model, Social Security benefits comprise a larger portion of consumption as agents age. Hence, Social Security plays an even larger role mitigating the welfare effects of the Great Recession for retired agents the older they are at the time of the shocks.

5.3.3 Welfare Effects of Social Security by Income, Wealth, and Productivity

Table 8 show the welfare losses due to the Great Recession in the benchmark and counterfactual economies by average lifetime wealth, average lifetime productivity, and average lifetime labor income, respectively. As before, the differences in the welfare losses across the groups identify the role that Social Security plays in either mitigating or exacerbating the welfare losses caused by the Great Recession.

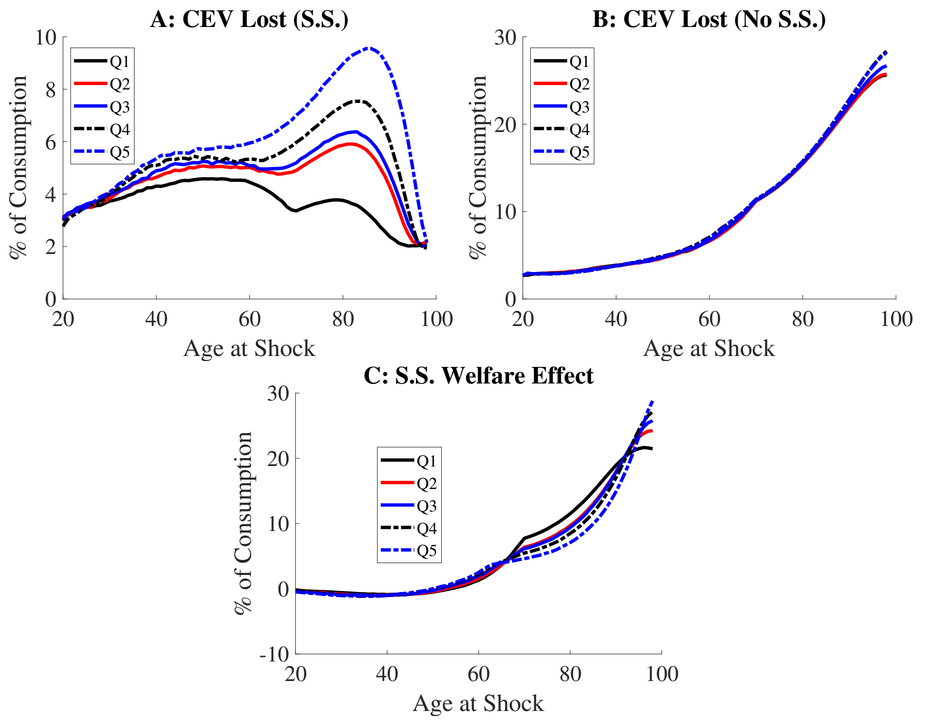
Overall, the results are similar for each of the distributions. While agents with greater lifetime wealth, incomes or productivity generally suffer relatively larger welfare losses due to the shocks in both models, Social Security generally mitigates a larger *share* of the welfare losses for poorer, lower-income, and lower-productivity agents.[44] The program is more effective at mitigating welfare losses for these agents because, similar to older retired agents, Social Security benefits make up a larger portion of these agents' post-retirement consumption. Additionally, Social Security does not exacerbate the average welfare losses for any of these groups; it only mitigates. Overall, our results highlight the effectiveness of Social Security in mitigating welfare losses due to the shocks for some of the most vulnerable segments of the population without significantly exacerbating the losses for other, potentially less vulnerable groups.

For completeness, Figure 9 examines the welfare losses by both age at the time of the shock and lifetime income. Panels A and B plot these welfare losses in the benchmark and counterfactual models, respectively. Panel C shows the effect of Social Security on welfare losses due to the Great Recession.[45] As before, Panel C demonstrates that (i) Social Security slightly exacerbates the average welfare losses for agents who are younger at the time of the shocks, (ii) moderately mitigates the average welfare losses for agents who are near retirement at the time of the shocks, and (iii) strongly mitigates for retirement-age agents. Moreover,

[44]The high income, wealth and productivity agents suffer larger losses for a few reasons. First, because these agents tend to have more savings the wealth shock results in larger losses. Moreover, due to the progressive nature of the income taxation, re-accumulating these larger amounts of lost wealth would require relatively larger increases in labor.

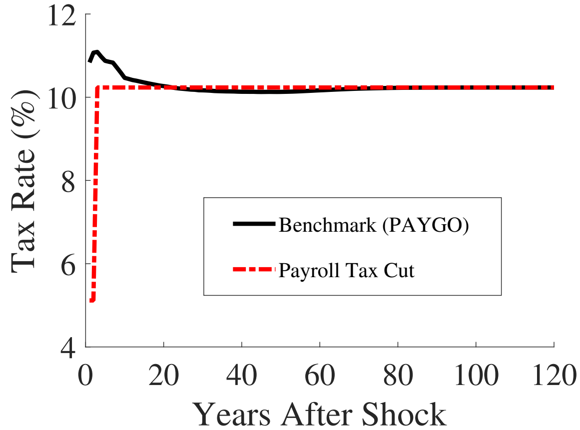
[45]The effect of Social Security is determined by differencing the welfare losses due to the shocks in the benchmark and counterfactual economies (shown in Panels A and B).

Figure 9: **Welfare Loss for Living Agents, by Age and Income**



Note: Repeats analysis in Table 6 by both agents' age and lifetime income. Panel A captures welfare losses due to the Great Recession in the benchmark economy while Panel B captures the losses in the counterfactual economy. Panel C captures the welfare effect of Social Security.

Figure 10: **Evolution of the Payroll Tax over the Transitional Path**



while the size of the mitigating or exacerbating effects is roughly the same irrespective of agents' income for younger agents, Social Security mitigates a bit more of the welfare losses for older agents who are at the bottom of the lifetime income distribution.

6 Alternative Social Security Specifications

6.1 Payroll Tax Cut

Up to this point, our analysis has maintained the assumption that payroll tax rate τ^{ss} follows a strict PAYGO rule so that the program's budget is balanced both in the steady state and in every period along the transitional path. In the spirit of the U.S. experience, in this section we relax this assumption and examine the effects of Social Security in an economy where the payroll tax is cut in half for the first few years after the recession begins. Figure 10 plots the evolution of the payroll tax over the transitional path in the baseline model and the alternative path under the payroll tax cut.

Table 9 illustrates that Social Security mitigates the welfare losses from the Great Reces-

Table 9: **Welfare Effect of Social Security by Payroll Tax Scheme, by Age**

Tax Scheme	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**	**All Ages**
Balanced Budget	-0.6%	-0.9%	-0.8%	0.5%	3.6%	7.5%	12.1 %	20.2%	
Payroll Tax Cut	0.4%	0%	0.1%	1.1%	3.6%	7.2%	12 %	20.2%	

Note: "S.S. Welfare Effect" captures the differences between the welfare losses due to the Great Recession in the benchmark (S.S.) and counterfactual (No S.S.) economies.

Table 10: **Welfare Effect of Social Security by Payroll Tax Scheme, by Lifetime Income**

Tax Scheme	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Balanced Budget	1.6%	1.3%	1.4%	1.3%	1.1%
Payroll Tax Cut	2.3%	1.9%	1.9%	1.8%	1.6%

Note: "S.S. Welfare Effect" captures the differences between the welfare losses due to the Great Recession in the benchmark (S.S.) and counterfactual (No S.S.) economies.

sion for older agents (age 50+) by roughly the same amount irrespective of the payroll tax scenario. However, for younger agents, the exacerbating effect of Social Security varies with the payroll tax scenario. In the baseline PAYGO setting where τ^{ss} rises in response to the business cycle, Social Security exacerbates welfare losses from the Great Recession along the transition, largely because the adverse effect of payroll taxation on the welfare of younger individuals is amplified by the increase in the payroll tax during the Great Recession. In contrast, when τ^{ss} is cut in half in response to the shocks, Social Security has virtually no exacerbating effect on the welfare losses from the Great Recession, due to the attenuating effect of lower τ^{ss} relative to the benchmark model. Table 10 repeats the analysis by quintiles of the lifetime productivity distribution, and shows similar result. Taken together, our results suggest that payroll tax policies adopted during economic downturns can either enhance or diminish the effectiveness of Social Security in mitigating or exacerbating effects from business cycle episodes.

6.2 Smaller Insurance Program

Overall, we find that the stylized U.S. Social Security program mitigates an economically significant amount of the welfare losses due to the Great Recession. Moreover, it is effective at mitigating these losses for groups that may be particularly vulnerable, such as older and poorer agents. However, the program does have some undesirable consequences. In particular, it causes a substantial reduction in welfare in the steady state, and also slightly exacerbates the welfare losses due to the Great Recession for agents who are younger at the time of the shocks. Therefore, we study the effectiveness of a smaller scale program in mitigating welfare losses due to the shocks, and weigh it against the long-term welfare implications of such a program. In the spirit of the Supplemental Security Income (SSI) program, we replace the benchmark Social Security with an alternative old-age income insurance program that is means tested. In this alternative program, instead of benefits being linked to an agent's labor earnings history, benefits are set at 15 percent of the average economy-wide labor income.[46] Additionally, the SSI program is means tested; retired agents only receive these benefits if they hold no assets.[47] Similar to the model with Social Security, the payroll tax used to fund SSI is determined such that the budget for SSI is balanced in each period.

We begin by determining the ex-ante welfare effects of SSI in the steady state. We find that the average welfare lost from SSI in the steady state is the equivalent of 1 percent of expected lifetime consumption. Because SSI is a smaller program that is more targeted

[46] These replacement rates generally line up with the estimated rates in Braun et al. (2017) and Kopecky and Koreshkova (2014). For comparison, Social Security replaces approximately 40 percent of average earnings in the U.S. economy (see Rettenmaier and Saving (2006)).

[47] In the U.S., the means-testing is somewhat less restrictive; however, setting the wealth cutoff at zero captures the nature of a means tested program.

Table 11: **Welfare Loss for Living Agents, by Size of Social Security Program**

	Avg CEV
S.S.	4.6%
S.S.I.	5.2%
No S.S.	5.9%
S.S. Welfare Effect	1.4%
S.S.I. Welfare Effect	0.7%

Note: "S.S. Welfare Effect" captures the differences between the welfare losses due to the Great Recession in the benchmark (S.S.) and counterfactual (No S.S.) economies. "SSI Welfare Effect" captures the differences between the welfare losses in the economy with SSI and the counterfactual economy (No S.S.). A positive value implies a mitigation while a negative value implies an exacerbation of the losses.

towards lower-income agents, the ex-ante welfare losses in steady state from SSI are less than one-tenth as large as those from Social Security (12.4 percent).

Turning to the effect of the program on welfare losses due to the Great Recession, the first three rows of Table 11 presents the average welfare losses for agents living at the time of the shocks in the models with Social Security, SSI, and no retirement insurance program, respectively. The fourth and fifth rows describe the role that each Social Security and SSI play in mitigating the welfare losses due to the Great Recession. We find that, on average for living agents, SSI mitigates welfare losses due to the Great Recession by the equivalent of 0.7 percent of expected future consumption. Compared to Social Security, we find that even though SSI causes less than one-tenth of the welfare losses in the steady state, it is still approximately one-half as effective at mitigating the welfare losses from the Great Recession as Social Security. Therefore, the more targeted SSI program is relatively more effective at mitigating the effects of the Great Recession while minimizing long-run, steady state welfare losses.

Next, we compare the welfare effects of both programs for agents of different lifetime income levels and ages at the time of the shock (see Tables 12 and 13). Focusing on Table

Table 12: **Welfare Loss for Living Agents, by Age**

	20-29	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**
S.S.	3.5%	4.3%	4.9%	5.1%	4.9%	5.4%	5.8 %	3.8%
S.S.I.	2.9%	3.4%	4.1%	5.3%	7.8%	10.6%	11.1 %	7.9%
No S.S.	2.9%	3.4%	4.2%	5.5%	8.5%	12.8%	17.9 %	24%
S.S. Welfare Effect	-0.6%	-0.9%	-0.8%	0.5%	3.6%	7.5%	12.1 %	20.2%
S.S.I. Welfare Effect	0%	0%	0.1%	0.2%	0.7%	2.2%	6.8 %	16.1%

Note: Repeats analysis in Table 11 by agents' age.

Table 13: **Welfare Loss for Living Agents, by Lifetime Productivity**

	Q1	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	3.9%	4.5%	4.7%	5.1%	5.4%
S.S.I.	4.4%	5.1%	5.5%	5.9%	6.3%
No S.S.	5.5%	5.9%	6%	6.3%	6.6%
S.S. Welfare Effect	1.6%	1.4%	1.3%	1.2%	1.1%
S.S.I. Welfare Effect	1.1%	0.7%	0.5%	0.4%	0.3%

Note: Repeats analysis in Table 11 by agents' lifetime income.

12, similar to Social Security, SSI on average mitigates a large amount of the welfare losses due to the Great Recession for agents who are retired at the time of the shock. However, SSI has virtually no welfare effects on agents who are under age 70 at the time of the shock. The smaller effects on these agents are caused by SSI being a scaled-down, more targeted program. Table 13 presents the welfare effects of each of the programs by lifetime productivity. Similar to Social Security, SSI tends to mitigate a larger amount of the welfare losses for lower-productivity agents. However, the mitigating effects of SSI are even more skewed toward lower-productivity agents because agents only receive SSI benefits if they have no savings.[48] Taken as a whole, these results indicate since SSI is a smaller, more focused program, the costs are smaller but the benefits are more concentrated on older and lower-productivity agents.

[48]A similar qualitative pattern exists if the welfare effects are examined by labor productivity or wealth.

7 Alternative Ways of Modeling the Great Recession

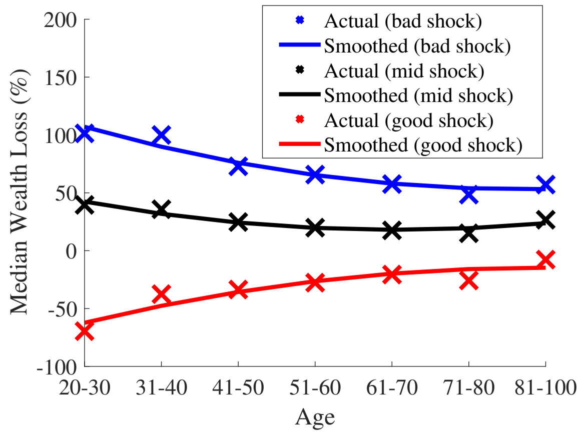
7.1 Heterogeneous Wealth Losses

Until this point, our approach to modeling the Great Recession has focused on capturing the correlation between household age and median wealth changes. Although other observables, such as household wealth, income, and riskiness of portfolio, can explain some of the variation in wealth losses, even after controlling for these observables there remains considerable amount of unexplained residual heterogeneity in the data.[49] Given the substantial idiosyncratic variation in wealth changes in the data, in this section, we examine how including within-cohort heterogeneity in wealth changes of the Great Recession affects our welfare findings.

In order to introduce this within-cohort heterogeneity in wealth changes in a tractable manner, we feed into the model an age-dependent discretized distribution of shocks to wealth calculated from the SCF 2007-09 panel. Specifically, for each age group, we split households into tertiles ordered by the size of the percent wealth change from 2007 to 2009. For each age group, within each of the tertiles, we find the median percent change in wealth (Figure 11). We refer to the median wealth change for the bottom tercile of wealth changes as the "bad shock", the median change for the top tercile as the "good shock", and the median wealth

[49] For example, regressing the 2007-09 wealth change on age, 2007 income and wealth, and the share of risky assets in households' portfolio, the R^2 from these regressions is very low (below 0.02). Furthermore, there is considerable variance in household wealth changes between 2007 and 2009 in the data. Whereas in the baseline model, all of the households experience a wealth decline, in the data about a third of households had seen their wealth increase over the recession.

Figure 11: **Median 2007-2009 Change in Wealth (%) in SCF Panel, by Age and wealth level in 2007**



Note: Based on the SCF 2007-2009 panel. Households with negative net worth in 2007 are excluded.

change for the middle tercile as "mid-shock".[50] As Figure 11 illustrates, the wealth changes vary considerably within each age bin. Whereas both the bad and mid shocks are associated with large wealth *losses* of 15 to about 100 percent (depending on the age bin), the good shock is associated with a notable wealth *gain* of 8 to 70 percent. Although we find that variation in the percent change in wealth decreases with age, there still remains considerable divergence between the good and bad shocks throughout the life cycle.

Table 14 shows that the average welfare losses during the Great Recession with and without Social Security in the models with and without heterogeneous wealth shocks. In both economies with and without Social Security, the average welfare losses are notably higher when within-cohort heterogeneity of wealth losses is added to the model (compare columns 1 and 2). To illustrate the main drivers of this result, the table shows the welfare effects of the recession by the type of the wealth shocks that agents received (columns 3-5).

[50]We use a quadratic regression to fit the median wealth losses for the age bins in each tertiles across different ages. Moreover, since we do not allow borrowing in our benchmark results we limit the wealth losses to 100 percent.

Table 14: **Welfare Loss from the Great Recession for Living Agents: Heterogeneous Wealth Losses**

	Baseline	**Heterogeneous Losses**			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Average	**Average**	**Bad**	**Mid**	**Good**
S.S.	4.6%	5.8%	15.9%	5%	-3.4%
No S.S.	5.9%	9%	25.6%	6.4%	-5.1%
S.S. Welfare Effect	1.4%	3.2%	9.6%	1.4%	-1.7%

Note: "S.S. Welfare Effect" is the difference between the welfare losses due to the Great Recession in the benchmark (S.S.) and counterfactual (No S.S.) economies. A positive value implies a mitigation while a negative value implies an exacerbation of the losses.

Agents who received the mid-shock experience a similar wealth change as in the baseline model with homogenous age-dependent wealth shocks.[51] Thus, we find that the welfare losses for the agents who receive the mid-shock (column 4) are very similar to the welfare losses in the baseline (column 1). In contrast, even though the percentage point deviation of the size of the good and bad wealth shocks from the mid-shock are roughly identical (Figure 11), the diminishing marginal utility of consumption causes the additional welfare losses for agents who experience the bad shock (column 3 minus column 4) to significantly outweigh the additional welfare gains for agents who experience the good shock (column 5 minus column 4). As a result, including within-cohort heterogeneity in the wealth shocks causes the average welfare losses from the Great Recession to rise, on net, both with and without Social Security. These relatively larger welfare losses in an economy that includes within-cohort wealth loss heterogeneity enhance the insurance benefit of Social Security during the Great Recession relative to the baseline model. As a result, the mitigating effect of Social Security during the Great Recession more than doubles, with the average CEV difference between economies with and without Social Security increasing to 3.2 percent in

[51]To see this, compare Figures 2 and 11.

Table 15: **Welfare Loss for Living Agents, by Age—Heterogeneous Wealth Losses**

Age	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**
S.S.	3.6%	4.6%	5.8%	7.1%	8.2%	8%	7 %	4%
No S.S.	3.1%	3.6%	4.8%	7.7%	16.8%	25.6%	26.9 %	29.1%
S.S. Welfare Effect	-0.5%	-1%	-1%	0.7%	8.6%	17.6%	19.9 %	25.1%

Note: Repeats analysis in Table 7 in the model with within-cohort heterogeneous wealth losses.

the economy that includes within-cohort heterogeneity (column 2) from 1.4 percent in the baseline experiment (column 1).

Table 15 revisits the welfare findings by age. Relative to the baseline model, the welfare findings are largely qualitatively and quantitatively unchanged for agents between ages 20 and 60.[52] However, in the model with within-cohort heterogeneity of wealth losses, the ability of Social Security to buffer the adverse welfare effects of the Great Recession is somewhat enhanced for older agents. This is because experiencing the bad shock without Social Security is particularly devastating for older agents who are on a steeper part of their utility curve and cannot partially offset the wealth loss by working more. In contrast, the welfare effects are more muted for agents experiencing a good shock, as the wealth shock moves these agents' consumption along the flatter part of their utility curve.

Turning to the effects of Social Security by lifetime wealth, income and productivity, Table 16 shows that, similar to the benchmark model, Social Security is particular beneficial for agents with low levels of lifetime wealth, income, or productivity. However, unlike in the baseline model, Social Security is also quite effective at mitigating the welfare losses for agents with high levels of lifetime wealth, income, or productivity when heterogeneous wealth changes are included. For these generally wealth agents, a bad wealth shock leads to a

[52]To see this, compare the table to Table 7.

Table 16: **Welfare Loss for Living Agents, by Lifetime Wealth, Productivity and Income—Heterogeneous Wealth Losses**

Lifetime Wealth:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	5.3%	5.9%	5.7%	5.7%	6.4%
No S.S.	8.4%	9.2%	9.1%	8.7%	9.5%
S.S. Welfare Effect	3.1%	3.3%	3.4%	2.9%	3.1%
Lifetime Productivity:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4.5%	5.5%	6%	6.4%	8.4%
No S.S.	7.8%	8.7%	9.1%	9.2%	12.1%
S.S. Welfare Effect	3.3%	3.2%	3.1%	2.7%	3.7%
Lifetime Income:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4%	5.3%	5.9%	6.6%	10%
No S.S.	7.3%	8.5%	8.6%	9.4%	14.5%
S.S. Welfare Effect	3.2%	3.2%	2.7%	2.8%	4.5%

Note: Repeats analysis in Table 8 in the model with within-cohort heterogeneous wealth losses.

large reduction in welfare due to massive wealth losses during the recession. Conversely, the welfare gains for these high wealth agents who experience the good wealth shock are quite small since the added wealth moves their consumption up on a fairly flat part of their utility curve. Given the unequal magnitude of the welfare effects from the good and bad shocks, the insurance value from Social Security increases, on net, for the high wealth, income, and productivity agents with the economy with heterogeneous wealth losses.

7.2 Aggregate Risk

Up to this point, we have modeled the Great Recession as an unexpected aggregate shock. One implication of this approach is that households do not adjust their savings and labor supply behavior to the possibility of the large aggregate shock. If including this aggregate risk in households' expectations were to lead to different responses of household savings and labor supply across the economies with and without Social Security, this modeling choice could affect our quantitative welfare findings. In this section, we relax the assumption of the unexpected nature of the Great Recession and include the potential for the shock in households' expectations.

In order to include the aggregate risk in a tractable manner, we model the Great Recession as a one-time binary disaster shock. In the initial stochastic steady state, agents recognize that the Great Recession can occur tomorrow and incorporate the potential for the shock into their expectations with a fixed probability p. Once the shock is realized, aggregate uncertainty is resolved, and the economy sets off on a deterministic transitional path to the final deterministic steady state without the risk of the aggregate shock. By varying the internalized recessionary probability p, we are able to gauge the importance of the anticipation of the aggregate shock and the precautionary savings effect on our results.

This analysis does not account for potential welfare effects from endogenous portfolio choice and endogenous asset price responses. Incorporating a portfolio choice in presence of aggregate risk may affect the welfare implications of the Great Recession. Specifically, in a model with endogenous portfolio choice and endogenous asset prices, older agents may hold safer portfolios than younger agents. This change in the portfolio allocation over the life cycle could weaken the role that Social Security plays in mitigating the welfare losses for older agents relative to younger agents. However, solving the transitional path of an annual model with several asset classes that were an integral part of the Great Recession (i.e., housing, as well as safe and risky financial assets), while maintaining a realistic Social Security system with benefits tied to past earnings, endogenous retirement, and endogenous labor, is computationally prohibitive. See Glover et al. (2017) for an analysis of the welfare implications of the Great Recession in presence of portfolio choice and asset price adjustments in a model that is less rich in cross-sectional heterogeneity.

Let vector s represent the current state space and let $GR = 1$ represent the event of the Great Recession occurring in a given period; zero, otherwise. Conditional on the recession not yet occurring ($GR = 0$), the household optimization problem in the initial stochastic steady state is:

$$(14)\quad V(s, GR = 0) = \max u(c) + v(h, D) + \beta(pEV'(s', GR' = 1) + (1-p)EV'(s', GR' = 0)),$$

where $EV'(s', GR' = 1)$ is the expected continuation value, conditional on the Great Recession occurring next period and where $EV'(s', GR' = 0)$ represents the expected continuation value conditional on the aggregate shock not occurring next period. Once the aggregate shock is realized (i.e., $GR = 1$), the aggregate risk dissipates forever (i.e., $GR' = 1$ at all future times), and the value function over the transitional path is calculated in the same manner as in a model without the aggregate risk. Computationally, we are able to iterate on a guess for the initial risky steady state and the transitional path to the final, post-recession deterministic steady state where the aggregate risk is resolved until we find a fixed point for both.[53] The key advantage of introducing aggregate risk in this stylized manner is that it allows us to test the sensitivity of our results to the scenario where agents internalize some probability of the Great Recession without the need to use the computationally intensive Krussell-Smith setup. One downside to including aggregate risk in this manner is that the initial steady state is not the same as the final steady state because the potential for the

[53]Given the deterministic nature of the final steady state we are able to determine this steady state in isolation.

Table 17: **Welfare Loss for Living Agents by Recessionary Probability** p— **Stochastic Economy**

Recession Probability (p)	10%	5%	2.5%	1%
Steady State Welfare Loss from S.S.	13.1%	12.9%	12.7%	12.6%
Mitigating Role of S.S.				
S.S.	4.7%	4.7%	4.6%	4.6%
No S.S.	6.6%	6.4%	6.2%	6%
S.S. Welfare Effects	1.9%	1.7%	1.6%	1.5%

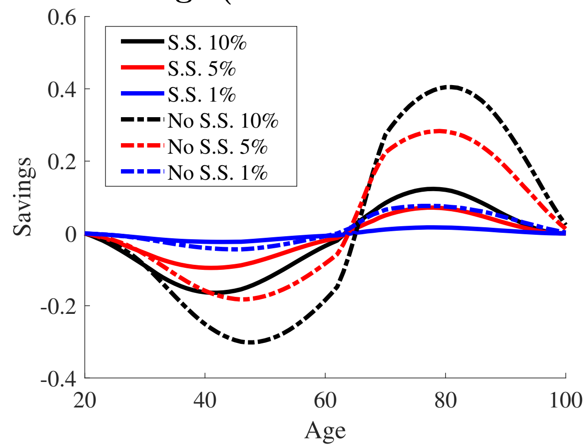
Note: Repeats analysis in Section 5.1 and Table 6 by stochastic probability.

Great Recession is included in the initial steady state but not in the final steady state.

Table 17 summarizes our findings across a range of recession probabilities, p. For all intents and purposes, our main findings are qualitatively unchanged. First, Social Security is associated with sizable welfare losses in the stochastic steady state. Across the range of probabilities considered, agents would be willing to give up between 12.6 and 13.1 percent of their expected lifetime consumption to live in the steady state without the program. The losses are a touch larger in the stochastic steady state than in the deterministic steady state, increasing slightly with p. Second, Social Security continues to mitigate welfare losses of the Great Recession, especially for older and poorer agents (Tables 18 and 19). As the tables illustrate, the ability of Social Security to mitigate these losses also increases a bit with the probability p.

The small increases, in both the steady state losses and in the value of Social Security during the Great Recession when agents internalize the potential for the aggregate shock, are primarily caused by adjustments in savings patterns due to the agents internalizing the potential for this shock. In particular, there are opposing savings adjustments for agents when they are working versus when they are retired. There are two channels through working-age households can insure against the aggregate shock: (i) savings more in anticipation of the

Figure 12: **Difference in Savings (Stochastic - Deterministic Steady States)**



Note: The change in savings, by age, between the stochastic steady state where agents internalize the potential for the Great Recession and the deterministic steady state where agents do not internalize the potential for the aggregate shock. The solid lines depict the differences in savings in an economy with Social Security and the dashed lines are for an economy without Social Security.

shock, and (ii) working more once the shock is realized. For working-age households, saving more in anticipation of the shock is not effective at providing consumption insurance, as the aggregate shock leads to a large one-time proportional depreciation of assets. Rather, working-age agents respond to the aggregate risk by saving less in the anticipation of the shock and by working more in the event that the shock realizes.[54] In contrast, retired agents who internalize the potential for the Great Recession save more, as they can no longer use labor to respond to the shock.

To quantify the anticipatory effect of risk on savings, Figure 12 shows the deviation in average savings by age in the stochastic steady state where agents internalize the potential for the aggregate shock relative to the deterministic steady state in which they do not anticipate the potential shock. The figure shows that the intensity of the savings response

[54] Probabilistically younger agents are also more likely to experience a recession in their lifetimes. Specifically, a 5 percent probability of a recession implies that the recession is more likely than not to occur within the next 14 years.

Table 18: **S.S. Welfare Effect for Living Agents, by Age**

Age	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**
Stochastic 10%	0%	-0.4%	-0.2%	0.9%	4.1%	7.9%	12.5 %	20.7%
Stochastic 5%	-0.2%	-0.6%	-0.4%	0.8%	4%	7.9%	12.4 %	20.5%
Stochastic 2.5%	-0.4%	-0.8%	-0.6%	0.6%	3.8%	7.7%	12.3 %	20.3%
Stochastic 1%	-0.5%	-0.9%	-0.7%	0.5%	3.7%	7.6%	12.2 %	20.1%
Deterministic	-0.6%	-0.9%	-0.8%	0.5%	3.6%	7.5%	12.1 %	20.2%

Note: Repeats analysis in Table 7 in the economy with the aggregate risk.

by both working and retired households increases with the rise in the recessionary probability p. Moreover, the reduction in savings by younger households always more than offsets the increase in savings by retirement-age agents and results in somewhat lower levels of aggregate capital and output relative to the economy where agents do not internalize the potential for the aggregate shock. With levels of aggregate capital and output modestly lower in the initial stochastic steady state, liquidity constraints are increasingly more binding with the rise in p, exacerbating the adverse welfare effects of the payroll tax and causing the welfare losses from the program to increase slightly relative to the deterministic steady state. Moreover, once the shock is realized, the somewhat lower levels of capital and output also make the welfare losses from the recession a bit larger relative to the baseline model, thereby increasing the value of Social Security insurance. As a result, the mitigating effect of Social Security on welfare losses from the Great Recession edges up, and does it more so with the rise in the probability of a recession, p.

8 Conclusion

This paper quantifies the ability of Social Security to mitigate the welfare losses due to the Great Recession. There are two competing channels by which Social Security primarily

Table 19: **S.S. Welfare Effect for Living Agents, by Lifetime Wealth, Productivity and Income**

Lifetime Wealth:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Stochastic 10%	2.1%	2%	1.9%	1.7%	1.7%
Stochastic 5%	1.9%	1.8%	1.7%	1.5%	1.5%
Stochastic 2.5%	1.7%	1.7%	1.6%	1.4%	1.4%
Stochastic 1%	1.5%	1.5%	1.5%	1.3%	1.3%
Lifetime Productivity:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Stochastic 10%	2.4%	1.9%	1.7%	1.5%	1.3%
Stochastic 5%	2.2%	1.7%	1.6%	1.4%	1.3%
Stochastic 2.5%	1.9%	1.6%	1.5%	1.3%	1.2%
Stochastic 1%	1.8%	1.5%	1.4%	1.3%	1.2%
Lifetime Income:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Stochastic 10%	2.3%	2%	1.7%	1.7%	1.3%
Stochastic 5%	2.1%	1.8%	1.6%	1.5%	1.2%
Stochastic 2.5%	1.9%	1.6%	1.5%	1.4%	1.1%
Stochastic 1%	1.7%	1.5%	1.4%	1.3%	1.1%

Note: Repeats analysis in Table 8 by stochastic probability.

affects the welfare implications of the Great Recession. On one hand, Social Security lessens the welfare losses by reducing agents' exposure to the wealth shock. On the other hand, the welfare cost of the payroll tax (used to fund Social Security) is enhanced during the Great Recession because agents tend to face tighter budgets constraints. We find that, on balance, the former channel dominates. In particular, Social Security mitigates the average welfare losses for agents alive at the time of the Great Recession by the equivalent of 1.4 percent of expected future lifetime consumption.

Given that the relative strengths of these two channels may vary across agents, we also examine the welfare losses by age, income, wealth, and labor productivity groups. We find that Social Security is particularly effective at mitigating the welfare effects of the Great Recession for agents who are poorer, less productive, or older at the time of the shock. Moreover, we find that younger agents are the only group for which Social Security exacerbates the welfare losses due to the Great Recession. However, the exacerbating effect on these agents is small and a majority of it is eliminated if payroll taxes are cut, as opposed to endogenously increasing. The ability of Social Security to mitigate welfare losses for some of the most vulnerable demographic groups, without significantly exacerbating the welfare consequences of the shock for other agents, indicates that this program is particularly effective at providing insurance for these types of shocks.

Despite the fact that Social Security effectively mitigates the welfare effects of the Great Recession for many potentially vulnerable agents, the welfare consequences of Social Security in the steady state are quite large compared to the mitigating benefits provided by the program during this type of a business cycle episode. Therefore, we also explore the welfare implications of a more targeted program. In particular, we examine the welfare implications of a means tested program, such as SSI, in which the benefits that agents receive are both smaller and unrelated to their individual lifetime income. Although we find that this smaller-scale program only mitigates the equivalent of 0.7 percent of expected future lifetime consumption for agents alive at the time of the shock (relative to 1.4 percent for the full-fledged Social Security program), the ex-ante welfare costs in the steady state are significantly reduced (1 percent versus 12.4 percent CEV). These results indicate that there is some scope for an adjustment of the Social Security program so that it effectively mitigates the welfare effects of large, adverse swing in economic activity for vulnerable agents, with much lower average long-run welfare costs. However, generally, when developing such programs, policy makers will still face a tradeoff between the coverage of the population for which the program mitigates the welfare effects of an adverse business cycle episode and the long-run welfare costs of such program.

A For Online Publication: Appendix

A.1 Definition of Equilibrium

We define a stationary steady state competitive equilibrium. An agent's state variables, Ξ are assets (a), average past earnings (x), age (j), ability (α), persistent shock (ν), idiosyncratic shock (ϵ), unemployment shock (D), retirement status (I). For a given set of exogenous demographic parameters (n, Ψ_j), a sequence of exogenous age-specific human capital ($\{\theta_j\}_{j=1}^{\overline{R}}$), government tax function ($T : \mathbb{R}_+ \to \mathbb{R}_+$), Social Security tax rate τ^{ss}, Social Security benefits formula ($B^{ss} : \mathbb{R}_+ \times j \to \mathbb{R}_+$), a production plan for the firm (N,K), and a utility function ($U : \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$), a steady state competitive equilibrium consists of agent's decision rules for c, h, a, and I for each state variable, factor prices (w, r), transfers (Tr), and the distribution of individuals $\mu(\Xi)$ such that the following holds:

1. Given prices, policies, transfers, and initial conditions, the agent solves the dynamic programming problem in equations 8 - 11, with c, h,a', and I as associated policy functions.

2. The prices w and r satisfy

$$r = \zeta(\frac{N}{K})^{1-\zeta} - \delta$$

$$w = (1-\zeta)(\frac{N}{K})^{\zeta}.$$

3. The Social Security policies satisfy:

$$\sum \min\{wD\omega h, \overline{y}\}\tau^{ss}\ \mu(\Xi) = \sum b^{ss}\ I\ \mu(\Xi).$$

4. Transfers are given by:

$$Tr = \sum (1-\Psi_j) a\ \mu(\Xi).$$

5. Government budget balance:

$$G = \sum T^y[r(a+Tr) + wD\omega h - .5\tau^{ss}\min\{wD\omega h, \overline{y}\}]\ \mu(\Xi) - \sum (D) b^{\text{ui}}\ \mu(\Xi).$$

6. Market clearing:

$$K = \sum a\ \mu(\Xi),\ N = \sum \omega h\ \mu(\Xi) \text{ and}$$

$$\sum c\ \mu(\Xi) + \sum a\ \mu(\Xi) + G = K^{\zeta}N^{1-\zeta} + (1-\delta)K.$$

7. The distribution of $\mu(x)$ is stationary, that is, the law of motion for the distribution of individuals over the state space satisfies $\mu(x) = Q_\mu \mu(x)$, where Q_μ is a one-period recursive operator on the distribution.

A.2 Calibration

The calibration parameters are summarized in Table 20.

A.3 Transitional Dynamics

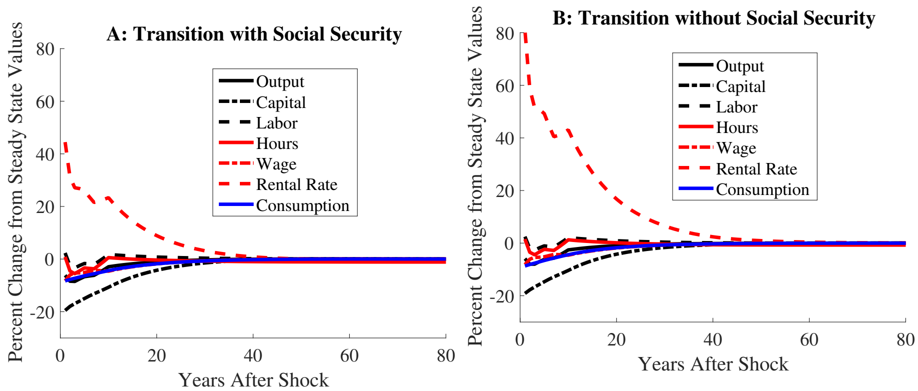
Figure 13 compares the percent changes in economic aggregates in the benchmark and counterfactual models over the transitional path. Capital initially decreases by approximately 20 percent in both models by construction, and then gradually returns to the steady state values over 30 years. Consumption, wages, and output drop by approximately 10 percent in both models and take approximately 25 years to converge back to the original steady state levels. Notably, the return to capital increases more in response to the shock in the counterfactual model where, due to the absence of Social Security, the relative size of the

Table 20: **Calibration Parameters**

Parameter	**Value**	**Source/Target**
Demographics:		
Normal Retirement Age: NRA	66	By Assumption
Minimum Retirement Age: $\underline{R}$	62	U.S. SS Program
Maximum Retirement Age: $\overline{R}$	69	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^{***}	0.992	$\frac{K}{Y} = 2.7$
Risk aversion: γ	2.2	Kaplan (2012)
Frisch Elasticity: σ	0.41	Kaplan (2012)
Disutility to Labor: χ_1^{***}	80.4	Avg. $h_j = \frac{1}{3}$
Fixed Cost to Working: χ_2^{***}	1.3	70% retire by NRA
Productivity Parameters:		
Persistence Shock: σ_ν^2	0.017	Kaplan (2012)
Persistence: ρ	0.958	Kaplan (2012)
Permanent Shock: σ_α^2	0.065	Kaplan (2012)
Transitory Shock: σ_ϵ^2	0.081	Kaplan (2012)
Government Parameters:		
Υ_0	.258	Gouveia and Strauss (1994)
Υ_1	.768	Gouveia and Strauss (1994)
Υ_2^{***}	5.16	Market Clearing
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***}	10.2%	Mrkt Clearing

Note: *** denotes parameters either calibrated through the Method of Simulated Moments or were determined in equilibrium through market clearing.

Figure 13: **Transitional Dynamics in Models**



Note: Captures changes (percent) in economic aggregates relative to the respective steady states along the transitional path in the benchmark and counterfactual economies.

capital stock is larger.

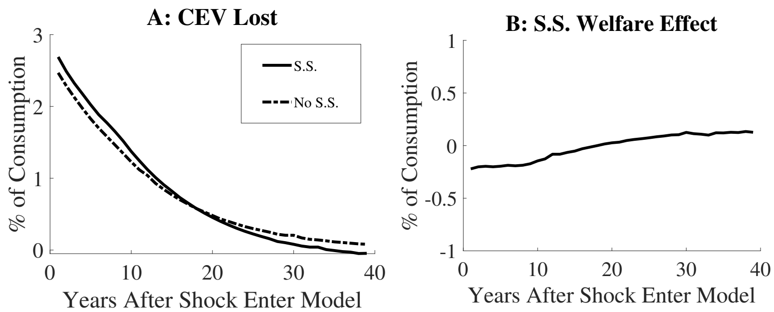
A.4 Welfare Effects of Social Security for Future Generations

Figure 14 examines the impact of Social Security on the welfare of agents who enter the economy after the shock. Panel A plots the welfare lost due to the Great Recession for these agents in the model with and without Social Security. Panel B captures the differences between the welfare losses due to the Great Recession between the two economies. Generally, the welfare losses are very similar, signifying that Social Security plays a minor role in either mitigating or exacerbating the effects of the Great Recession for future generations, with the small differences due to general equilibrium effects.

A.5 Borrowing Constraints

In the baseline analysis, we do not allow households to borrow. As Figure 15 illustrates, the baseline model matches well the comparable average age-profile of household wealth

Figure 14: **Welfare Loss for Future Generations**



Note: Repeats analysis in Table 6 for future generations. Panel A captures the welfare loss to the Great Recession in the benchmark (S.S.) and counterfactual (No S.S.) economies. Panel B captures the differences between the welfare losses due to the Great Recession between the two economies.

constructed in the SCF 2007 data for households with non-negative net worth in 2007. However, not allowing households to borrow could have quantitative implications for our findings. In this section, we thus relax this assumption and introduce a borrowing constraint $a \geq \underline{a}$. The parameter $\underline{a}$ is calibrated so that, consistent with the SCF panel, 12 percent of households between ages 20 and 60 have negative or zero wealth in the steady state.[55] We find that $\underline{a}$ consistent with approximately 7 percent of average savings in the economy lets the model match the 12 percent target.

Tables 21 and 22 indicate that the welfare losses from the Great Recession are little changed when borrowing is allowed in the economies with and without Social Security. This is because in both of the economies most agents have sufficient savings prior to the shock such that they do not borrow in response to the shock. Young agents are an exceptions; allowing borrowing somewhat exacerbates the welfare losses for these agents on net, due to two competing effects. On the one hand, young agents can smooth through the Great

[55]Since we do not allow agents to borrow once they retire and no longer have labor income, we calibrate the model to match this selective age range.

Figure 15: **Average Savings Profile in Model versus Data**

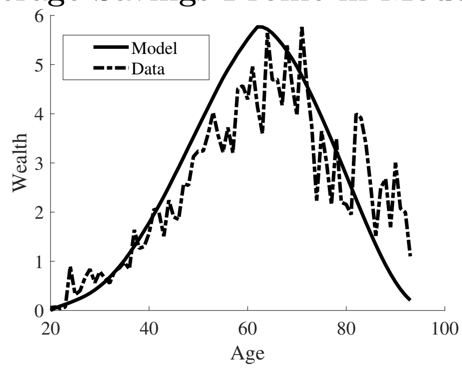


Table 21: **Welfare Loss for Living Agents, by Age—Borrowing Allowed**

Age	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-98**	**Average**
S.S.	3.6%	4.4%	4.9%	5.1%	4.9%	5.4%	5.9 %	4%	4.6%
No S.S.	3%	3.4%	4.2%	5.5%	8.5%	12.8%	17.9 %	24%	6%
S.S. Welfare Effect	-0.6%	-1%	-0.8%	0.5%	3.6%	7.4%	12 %	20%	1.4%

Note: Repeats analysis in Table 6 by agents' age.

Recession using borrowing, which serves to mitigate the welfare losses. On the other hand, when borrowing is allowed, many young agents are in debt prior to the recession (not knowing that the shock could happen). Once the shock unexpectedly hits, their initial negative asset positions exacerbate the welfare losses from the recession, because the shock lowers these agents' expected future lifetime income that can be used to repay these debts and consequently makes accumulating enough saving for retirement more difficult relative to the baseline model where borrowing is not allowed. Generally, we find that the latter channel tends to dominate for these younger cohorts, and the welfare losses from the Great Recession are a bit larger when borrowing is allowed. However, the small increase in welfare losses are similar with or without Social Security, and thus allowing borrowing has very little effect on the ability of Social Security to mitigate the welfare losses from the Great Recession.

Table 22: **Welfare Loss for Living Agents, by Lifetime Wealth, Productivity and Income—Borrowing Allowed**

Lifetime Wealth:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4.5%	4.5%	4.6%	4.8%	4.7%
No S.S.	5.9%	5.9%	5.9%	6%	6%
S.S. Welfare Effect	1.5%	1.4%	1.4%	1.2%	1.2%
Lifetime Productivity:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4%	4.5%	4.7%	5.1%	5.4%
No S.S.	5.6%	5.9%	6%	6.3%	6.6%
S.S. Welfare Effect	1.6%	1.3%	1.3%	1.2%	1.1%
Lifetime Income:	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
S.S.	4%	4.5%	4.7%	5%	5.4%
No S.S.	5.6%	5.9%	6%	6.2%	6.5%
S.S. Welfare Effect	1.6%	1.4%	1.3%	1.3%	1.1%

Note: Repeats analysis in Table 22 by agents' lifetime wealth, productivity, and income.

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