Social Health Insurance: A Quantitative Exploration*

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Abstract

We quantitatively explore the welfare benefits of health insurance over the lifecycle in a dynamic general equilibrium model with health risk and a health care sector. We consider three distinct approaches to designing a health insurance system: (*i*) a mixed private and public health insurance system similar to the US system, (*ii*) private health insurance (PHI), and (*iii*) universal public health insurance (UPHI). Our results indicate that the introduction of the US system into an economy without any health insurance results in large welfare gains, but does not produce the best welfare outcome. The PHI system with some government regulation on premiums is viable and produces welfare gains comparable to the welfare gains generated by the US system. The UPHI system with a high enough coinsurance rate produces better overall welfare outcomes than the other two systems. There exists an optional coinsurance rate that maximizes the welfare benefits of the UPHI system. A structural reform that replaces the US system with the UPHI system—i.e., Medicare for all—is welfare improving, but would face political headwinds due to opposing welfare effects across income groups.

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1 Introduction

Health shocks are an important source of risk over the lifecycle. A common view in the health insurance literature is that health risk is not easily insurable via private health insurance due to moral hazard and adverse selection issues caused by information asymmetries in health insurance markets as well as other factors specific to health risk (highly auto-correlated health shocks, age dependent shock magnitudes, etc.) that impede insurance markets from functioning well for a large group of individuals. These issues provide a rationale for government regulation in insurance markets as well as calls for the provision of some kind of social health insurance (e.g., see Rothschild and Stiglitz (1976)).[1] While we do observe some differences in the health insurance systems across OECD countries (Carrin and James (2005)), most of them do provide public health insurance for a large share of their population, while private health insurance is voluntary and relegated to provide supplementary insurance to higher income groups. Figure 1 provides a breakdown of health expenditures by funding source—public insurance, private insurance and out-of-pocket—for select OECD countries. The one notable exception in this group is the US. The US has a hybrid system in which private health insurance plays a more prominent role as it covers most of the working population, while public health insurance focuses on retirees and low income individuals. As shown in Figure 2, this different approach has led to much different insurance coverage rates, health expenditures and cost sharing in the US.

Pressing issues surrounding the health insurance system in the US, including lack of health insurance and high health care cost, continue to draw attention from both policy-makers and academics. There is a large literature examining the effects of health insurance reforms in the US. However, relatively little effort has been devoted to assessing the overall welfare benefits of the US health insurance system in comparison with other approaches to providing health insurance. This paper uses a dynamic general equilibrium model with a health care sector to quantitatively analyze three distinct approaches to designing a health insurance system: (*i*) a mixed private and public health insurance (US) system, (*ii*) a private health insurance (PHI) system, and (*iii*) a universal public health insurance (UPHI) system. The PHI and UPHI systems in consideration are two counter factual systems, but essential for comparing the benefits of the US system.

In an environment where individuals are subject to idiosyncratic health shocks but have limited access to private insurance markets, the public provision of health insurance can significantly improve welfare. However, these welfare benefits may decrease sharply once we factor in the financing cost of public health insurance systems. The overall welfare benefit of a health insurance system depends on how these insurance and incentive trade-offs play out. We first illustrate how these effects determine the optimal amount of social (public) insurance in a simple two period model with health risk. We then formulate a more realistic quantitative framework—a dynamic general equilibrium model with income and health risks and a healthcare sector calibrated to

[1] Introducing social health insurance can also be justified on other grounds including high administrative costs of private health insurance systems, altruism, free riding issues, optimal taxation problems, equity reasons including redistribution of wealth and health capital across and within age cohorts (e.g., see Blomqvist and Horn (1984*a*), Besley (1988), Culyer and Wagstaff (1993), Cremer and Pestieau (1996), Zweifel and Manning (2000) as well as Nyman (2003)).

US data in 2009— and quantitatively analyze the welfare outcomes of the three approaches to providing health insurance.

Our quantitative model has two key features: health capital accumulation over the lifecycle similar to Grossman (1972*b*) and agent heterogeneity due to idiosyncratic risks and incomplete markets similar to Bewley (1986). In the model health affects utility and labor productivity and serves as a consumption and as an investment good. Individuals are exposed to idiosyncratic health shocks in addition to labor productivity shocks. They can buy health insurance and invest in their health via the consumption of medical services. Health care and health insurance choices are jointly determined with consumption, savings and labor supply. In the presence of idiosyncratic earnings and health shocks individuals use savings and health insurance to smooth their consumption and health over the lifecycle. Individuals know their individual-specific health capital and insurance status at the time they make their decision on medical consumption and health insurance. This feature introduces incentives for individuals to purchase health insurance and medical services. Thus, elements of adverse selection and ex-post moral hazard are present in our framework.[2]

To discipline our quantitative analysis we require our benchmark model to match the lifecycle patterns of income and health, labor supply, asset holdings and health expenditures in the US before Affordable Care Act (ACA) in 2010. Our model is able to capture the lifecycle structure of health risk in conjunction with income risk as observed in the data. Health expenditures are low early in life because of low health risk for young individuals, and subsequently rise as the probability of negative health shocks increases and health capital depreciates. On average, health expenditures rise exponentially later in life because individuals are exposed to more frequent and larger health shocks. In addition, our model reproduces the hump-shaped lifecycle profile of insurance take-up rates in the US. Finally, our model replicates the income distribution from the Panel of Income Dynamics (PSID) as well as macroeconomic aggregates from national income accounts (NIPA).

In order to measure the size of the welfare effects of the three different systems, we construct a hypothetical economy where all private and public health insurance arrangements are removed. In this no-insurance economy all individuals are forced to self-finance all health expenditures. The two types of idiosyncratic risks (wage income shocks and health shocks) are not fully insurable in this economy. The lack of insurance options against health risk interacts with the limited set of market instruments against income risk (i.e., essentially constrained household savings and adjustments of the labor supply) and amplifies the welfare cost of amplified consumption variance viz-a-viz a standard Bewley model without health risk. The overall welfare cost is the sum of the cost of missing insurance against income risk and the cost of incomplete health insurance against health risk. The former is well documented in a large literature (e.g., Deaton (1991), Huggett

[2]Ex-ante moral hazard is absent in our framework since agents are not able to influence the probability distribution of health shocks. Ex-post moral hazard, on the other hand, describes the situation where the individual is assumed to have a choice about the extent of treatment once an illness has occurred. The insurer is not able to observe how ill the individual is and can therefore not condition the insurance contract on this information, so that a moral hazard issue arises. See Pauly (1968) and Zeckhauser (1970) for a formal model of ex-post moral hazard.

(1993), Aiyagari (1994) and Levine and Zame (2002)), while the latter only appears in incomplete market models with health risk (e.g., Jeske and Kitao (2009), Nardi (2010), Capatina (2015), Jung and Tran (2016)).

With the introduction of the US system into the baseline economy without health insurance, retirees and poor individuals benefit from public insurance through Medicare and Medicaid, while working individuals have options to buy private health insurance policies. Even though this hybrid system is quite segmented and fails to insure everybody, many individuals do benefit from health insurance. On the other hand, GDP drops by roughly 7 percent due to the adverse incentive effects. Nevertheless large welfare gains across all income groups can be observed. The overall welfare gain of a US style health insurance system—relative to an economy with economic fundamentals similar to the US economy but with a complete lack of insurance contracts—is large at about 5.2 percent of compensating equivalent consumption variation (CEV).[3]

We next analyze the welfare effects of introducing a private health insurance (PHI) system into the no-insurance economy. In particular, we consider two designs of the PHI system: (*i*) without government regulation in insurance and healthcare markets and (*ii*) with government regulation in both markets. The PHI system without government regulation provides only individual health insurance (IHI) plans similar to the ones in the benchmark US system. Insurance companies that offer IHI plans are free to adjust and charge premiums according to the risk type of the household. Our results show that this pure market-based approach is not feasible due to an adverse selection spiral that completely unravels the insurance markets. The pure private health insurance system collapses and the economy is identical to the no-insurance economy. That is, adverse selection restricts the type of insurance contracts available through markets, which creates a potential role for government regulation. In an extension, we allow the government to impose certain regulations on insurance premiums and medical prices in addition to provisions in the tax code that make premiums tax deductible (similar to group health insurance plans (GHI) in the current US system). Under these regulations, the PHI system with government regulations becomes viable and insurance take-up rates reach close to 69.8 percent of the active working population. Welfare gains, compared to the no-insurance economy, are again realized. The welfare benefit of the PHI system with government regulations is slightly smaller than that of the US system. The main reason is that the insurance take-up rate is smaller under the PHI system.

Finally, we assess the welfare effects of a universal public health insurance (UPHI) system. Not surprisingly, compulsory public health insurance significantly reduces savings (i.e., self insurance) due to crowding-out effects and tax distortions. This subsequently leads to a 12 percent decline in the long-run capital stock, compared to the economy with no health insurance. The share of GDP spent on health care increases significantly due to an ex-post moral hazard effect.[4] However, under the UPHI system, adverse selection effects are completely eliminated as the entire population is automatically enrolled in the health insurance program which leads to improvements

[3] CEV is measured as percent of lifetime consumption of a newborn individual. This is an aggregate measure of welfare benefit.

[4] Ex-ante moral hazard effects are not modeled as consumers cannot affect the probability of a health shock in our model.

in risk sharing and subsequent welfare gains. Moreover, the UPHI system financed by flat taxes implicitly redistributes wealth and income in favor of the high-risk low-income cohorts. Overall the insurance/redistribution effects dominate the distortionary effects so that welfare gains are realized compared to the economy with no health insurance.

The levels of the welfare gains of the UPHI system depend strongly on the coinsurance rate of public health insurance.[5] The coinsurance rate affects the incentive to purchase medical services and thus the degree of ex-post moral hazard, which subsequently determines the amount of cost sharing between government and households in the economy. That is, there is a trade-off between two conflicting objectives: providing risk coverage while incentivizing the insured individuals to moderate their health expenses. By varying the coinsurance rate, the government is able to determine the degree of ex-post moral hazard in the economy. We observe a hump-shaped pattern of welfare gains as we increase the coinsurance rate. There exists an optional coinsurance rate that maximizes the overall welfare benefits of the UPHI system. Interestingly, we can also identify a range of coinsurance rates where the welfare benefits of the UPHI system dominate the welfare gains of the US system over the no insurance case. The logic is as follows. The UPHI system eliminates all adverse selection effects but results in larger ex-post moral hazard effects and tax distortions.[6] Conversely, the US system—a mix of public and private health insurance—suffers from adverse selection effects, which lead to lower insurance take-up rates among low income individuals in bad health. On the plus side, the US system triggers smaller tax distortions due to the smaller size of the public health insurance component. Our results indicate that the UPHI system with sufficiently large coinsurance rates delivers better welfare outcomes than the US system as it better balances the insurance and incentive effects, while controlling for moral hazard and not being negatively affected by adverse selection.

Thus, a structural reform that replaces the US system with a UPHI system can result in large welfare gains. However, such a radical reform would face political headwinds due to opposing welfare effects across income groups. Low income groups experience large welfare gains and prefer to switch to the UPHI system, while middle and high income groups experience welfare losses and would prefer the US system. This finding highlights political challenges associated with radically reforming the US system into the UPHI system.

Related literature. Our paper contributes to a large macroeconomics literature analyzing the welfare benefits of public transfer programs in quantitative dynamic general equilibrium models. Auerbach and Kotlikoff (1987), İmrohoroğlu, İmrohoroğlu and Joines (1995), Conesa and Krueger (1999) and Fuster, Imrohoroglu and Imrohoroglu (2007) study the welfare effects of social security. Hansen and Imrohoroglu (1992) evaluate the welfare benefit of unemployment insurance. More recently, Braun, Kopecky and Koreshkova (2017) assess the welfare effects of means-tested social insurance for the older population. We instead focus on the social insurance role of public

[5]Linear coinsurance under ex post moral hazard, where insurers pay the same fraction of the health care cost whatever the individuals expenses, has been studied in the health insurance literature (e.g., see Zeckhauser (1970) and Feldstein (1973)).

[6]Compare Spence and Zeckhauser (1971), Pauly (1974), Blomqvist and Horn (1984*b*), Besley (1988), Besley (1989), Manning and Marquis (1996), Nyman (1999) and Petretto (1999).

health insurance.

Our paper is closely related to the broader literature on incomplete markets macroeconomic models with heterogeneous agents as pioneered by Bewley (1986) and extended by Huggett (1993) and Aiyagari (1994). This model has been applied widely to quantify the welfare cost of public insurance for idiosyncratic income and longevity risks (e.g., Hubbard and Judd (1987), Golosov and Tsyvinski (2006), Heathcote, Storesletten and Violante (2008), Conesa, Kitao and Krueger (2009), Huggett and Parra (2010), and Krueger and Perri (2011)). This literature shows that if the ability of risk sharing in private markets is limited, then publicly provided risk sharing mechanisms can improve the allocation of risk, smooth non-medical consumption and increase welfare. Labor income shocks are the source of risk and consumption variation in the Bewley type model. We introduce medical consumption and health shocks as another source of risk into the Bewley framework.

A number of studies address health risk and precautionary savings (e.g., Kotlikoff (1988), Levin (1995), Hubbard, Skinner and Zeldes (1995) and Palumbo (1999)). These studies commonly assume exogenous health expenditure shocks. More recent contributions to this literature have incorporated exogenous health expenditure shocks into large-scale dynamic general equilibrium models which are then used to evaluate the macroeconomic effects of health insurance reforms (e.g., Jeske and Kitao (2009), Pashchenko and Porapakkarm (2013) and Hansen, Hsu and Lee (2014)). In their models, incomplete markets and adverse selection restrict the type of insurance policies available and creates a potential role for health insurance reforms. Unlike these studies we introduce the micro-foundations of health capital accumulation and endogenize both health care and health insurance decisions. In our incomplete markets model, adverse selection and ex-post moral hazard are both present. We account for the two-way interaction between insurance status and health expenditures, which is a key element in explaining the effects of ex-post moral hazard arising from health insurance reforms.

Our work can be viewed as a quantitative extension of the Grossman model of health capital. The roots of the health accumulation process in our model are established in the Grossman literature on health capital (Grossman (1972*b*) and Grossman (1972*a*)). However, the Grossman literature abstracts from matching the models directly to the stylized facts of health related lifecycle behaviors as they tend to be rather parsimonious. Studies in health economics mainly concentrate on the theoretical and empirical micro-foundations of medical spending (see Grossman (2000) for a review of this literature). We extend the Grossman model to a dynamic general equilibrium model where we account for health shocks, insurance choice, supply side of medical service and institutional features. We demonstrate that our generalized Grossman model can match the lifecycle patterns of health expenditures and the take-up rates of health insurance in US data.

More recent studies, including Suen (2006), Hall and Jones (2007), Jung and Tran (2008), Nardi (2010), Feng (2010), Hugonnier, Pelgrin and St-Amour (2013), Fonseca et al. (2013), Scholz and Seshadri (2013), Zhao (2014), Capatina (2015), Yogo (2016), Jung and Tran (2016) and Ozkan (2017) use lifecycle models of medical and non-medical consumption to study implications of health and healthcare reform. Jung and Tran (2016) in particular analyze the long-run effects of the Affordable Care Act in the US. We deviate from focusing on the US health insurance system and explore the welfare effects of different approaches to providing social health insurance in an incomplete markets model.

Our paper is connected to the literature on optimal insurance and government redistribution (e.g., Blomqvist and Horn (1984*b*), Rochet (1991) and Cremer and Pestieau (1996)) as well as the literature on mixed public-private health insurance systems (e.g., Besley (1989), Selden (1997), Blomqvist and Johansson (1997), Petretto (1999) and Chetty and Saez (2010)). These studies analytically investigate the optimal structure of mixed insurance systems in terms of efficiency and equity in highly stylized models. Differently, we provide a quantitative analysis using a more realistic model.

The paper is structured as follows. Section 2 describes the insurance and incentive trade off in a two-period model. Section 3 presents the full dynamic model. Section 4 describes our calibration strategy. Section 5 describes our experiments and quantitative results. Section 6 concludes. The Appendix presents all calibration tables figures.

2 A two period model with health risk

We start by demonstrating how the public provision of health insurance can improve welfare when health risks are present and markets are incomplete.

Environment. We consider a two period overlapping generations model. Young individuals in period 1 work and earn labor income. They subsequently retire in period 2 and live on their savings. Each cohort has measure one. The health state h_2 of retired individuals is a random variable with density $f(h_2)$. The health state subsequently determines the level of health care expenditures $m(h_2)$ in the second period. Insurance markets are assumed to be incomplete so that agents are not able to share health risk across households and generations. They rely on their precautionary savings as self-insurance device.

Health risk and demand for insurance. A young individual knows the distribution of future health states, $f(h_2)$, but not the specific health state that she will end up in when old. At the beginning of period 1, the individual decides on consumption, labor supply and savings to maximize expected utility, while forming an expectation about her future health h_2. The optimization problem can be written as

$$V(\Gamma_1) = \max_{c_1,n_1,s_1,c_2} \left\{ \begin{array}{c} u(c_1) - \theta v(n_1) + Eu(c_2,h_2) \;\; s.t. \\ c_1 + s_1 = n_1 w_1 \text{ and } c_2 + m_2 = R s_1, \end{array} \right\}$$

where $Eu(c_2,h_2) = \int u(c_2,h_2) f(h_2) dh_2$ is expected utility derived from health and consumption, w_1 and R are the market wage and interest rates, respectively, c_1 is consumption and n_1 is labor supply when young, s_1 is saving, c_2 is consumption when old, $m_2 = m(h_2) \geq 0$ is the health expenditure in the second period as a function of health status. Note that, it is assumed that the utility functions $u(c)$, $v(n)$ and $u(c,h)$ have standard properties: $u_c > 0$, $v_n > 0$,

$u_h > 0$, and $u_{cc} < 0$. The F.O.Cs for the household problem are: $u_{c_1}(c_1) = \frac{\theta}{w_1} v_{n_1}(n_1)$ and $u_{c_1}(c_1) = R\beta E u_{c_2}(c_2, h_2)$. Let Γ_1 denote the state variable vector. The individual's optimal decision rules are $c_1^* = g^c(\Gamma_1)$, $n_1^* = g^n(\Gamma_1)$ and $s_1^* = g^s(\Gamma_1)$ and the value function with no health insurance is $V(\Gamma_1)$.

In our setting agents are risk averse. Since no health insurance option is available they are forced to self-insure against health risk by "oversaving." Young agents are therefore willing to pay more than the actuarially fair premium for an insurance contract that eliminates future health expenditure risk which creates demand for health insurance.

Social health insurance. In the absence of well functioning health insurance markets, the presence of health risk gives rise to government intervention through tax-transfer programs that provide alternative mechanisms for pooling health risk across households. We consider a government-run health insurance program for retirees where the government sets coinsurance rate (γ) which determines the fraction of total health expenditure that individuals end up paying out-of-pocket. In order to finance the program the government imposes a tax rate (τ) on labor income in period 1 so that $\tau n_1 w_1 = \int (1-\gamma) m(h_2) f(h_2) dh_2$. Let Γ_2 denote the state variable vector with social health insurance. The optimization problem can be written as

$$V(\Gamma_2) = \max_{c_1, n_1, s_1, c_2} \left\{ \begin{array}{c} u(c_1) - \theta v(n_1) + Eu(h_2, c_2) \;\; s.t. \\ c_1 + s_1 = (1-\tau) n_1 w_1 \text{ and } c_2 + \gamma m_2 = R s_1. \end{array} \right\}$$

The optimal decision rules are $c_1^* = g^c(\Gamma_2)$, $n_1^* = g^n(\Gamma_2)$ and $s_1^* = g^s(\Gamma_2)$ and the value function with a public health insurance program is $V(\Gamma_2)$.

In our second-best setting the provision of public health insurance institutes more equitable risk sharing across retirees which results in welfare gains. We refer to this as the *insurance effect*. On the other hand, the public health insurance program needs to be financed by taxes which distort household incentives to work and save in period 1 which tends to cause welfare losses. We refer to these distortions as the *incentive effect*. The introduction of a public health insurance program is often justified based on the classic trade-off between insurance and incentive effects. If the insurance effect is dominant, welfare gains are realized, $V(\Gamma_2) > V(\Gamma_1)$.

An optimal design of a public health insurance program is obtained when the system efficiently trades-off between insurance and incentive effects. We next consider an optimal policy problem in which the government chooses the coinsurance rate of the public health insurance system γ and the tax rate τ to maximize a social welfare function that weighs every individual equally subject to (i) balancing the government budget constraint and (ii) solving household optimization problems. In our framework, each agent has a known and common wage income when young but face uncertain future health states. Old agents are thus heterogeneous in their health status and their second period utilities. The government's objective function takes this distribution into account and chooses a coinsurance rate γ and a tax rate τ so that the aggregate expected lifetime welfare is maximized. The government problem can be written as

$$W=\max_{\gamma,\tau}\left\{\begin{array}{c}u\left(c_1\right)-\theta v\left(n_1\right)+\int u\left(h_2,c_2\right)f\left(h_2\right)dh_2\ s.t.\\ \tau n_1 w_1=\int(1-\gamma)m_2 f\left(h_2\right)dh_2,\\ c_1=g^c\left(\Gamma_2\right),\ n_1=g^n\left(\Gamma_2\right)\ \text{ and }\ s_1=g^s\left(\Gamma_2\right).\end{array}\right\}$$

Evaluating the government's F.O.Cs yields the optimal coinsurance rate as

$$\gamma^*=1-\frac{\beta R\int\left(u_{c_2}m_2 f\left(h_2\right)\right)dh_2-u_{c_1}\mu}{u_{c_1}\times\mu\times\frac{n_1'}{n_1}},$$

where $\mu=\int m\left(h_2\right)f\left(h_2\right)dh_2$ is the average health expenditure and $n_1'=\frac{\partial n_1}{\partial\tau}$.

This expression illustrates the classic trade-off that determines how much social insurance should be provided through a public health insurance program. How the trade-off plays out depends on economy-based fundamentals such as preferences, endowments including income and health risks, the evolution of health capital over the lifecycle, the insurance market structure and institutional settings. In the next section, we therefore formulate a more realistic model where some of these factors are modeled. We then quantitatively explore the welfare implications of different approaches to designing a health insurance system.

3 A full model with income and health risk

3.1 Demographics

The economy is populated with overlapping generations of individuals who live to a maximum of J periods. Individuals work for J_1 periods and then retire for $J-J_1$ periods. In each period individuals of age j face an exogenous survival probability π_j.[7] Deceased agents leave an accidental bequest that is taxed and redistributed equally to all working-age agents alive. The population grows exogenously at an annual net rate n. We assume stable demographic patterns, so that age j agents make up a constant fraction μ_j of the entire population at any point in time. The relative sizes of the cohorts alive μ_j and the mass of individuals dying $\tilde{\mu}_j$ in each period (conditional on survival up to the previous period) can be recursively defined as $\mu_j=\frac{\pi_j}{(1+n)^{years}}\mu_{j-1}$ and $\tilde{\mu}_j=\frac{1-\pi_j}{(1+n)^{years}}\mu_{j-1}$, where *years* denotes the number of years per model period.

[7] We abstract from the link between health, health expenditures and mortality due to computational constraints and the empirical issues with the value of life calculations that would require further assumptions (see Hall and Jones (2007)). While there are studies that support our assumption of exogenous mortality such as Finkelstein and McKnight (2008) who find evidence that the introduction of Medicare had no discernible impact on elderly mortality in its first 10 years, there are also studies such as Scholz and Seshadri (2013a) and Ozkan (2017) that do find links between large public health insurance programs and mortality, especially for lower income groups. We therefore do acknowledge that the assumption of exogenous mortality can potentially affect the welfare numbers in our study.

3.2 Endowments and preferences

In each period individuals are endowed with one unit of time that can be used for work l or leisure. Individual utility is denoted by function $u(c,l,h)$ where $u : R^3_{++} \to R$ is C^2, increases in consumption c and health h, and decreases in labor l. Individuals are born with a specific skill type ϑ that cannot be changed over their lifecycle and that together with their health state h_j and an idiosyncratic labor productivity shock ϵ^l_j determines their age-specific labor efficiency $e\left(\vartheta, h_j, \epsilon^l_j\right)$. The transition probabilities for the idiosyncratic productivity shock ϵ^l_j follow an age-dependent Markov process with transition probability matrix Π^l. An element of this transition matrix is defined as the conditional probability $\Pr\left(\epsilon^l_{i,j+1}|\epsilon^l_{i,j}\right)$, where the probability of next period's labor productivity $\epsilon^l_{i,j+1}$ depends on today's productivity shock $\epsilon^l_{i,j}$.

3.3 Health capital

Health capital depreciates at rate δ^h_j. In addition, individuals face idiosyncratic health shocks ϵ^h_j. Individuals can buy medical services m_j at price p_m to improve their health capital as in Grossman (1972*b*). Health capital therefore evolves according to

$$h_j = i\left(m_j, h_{j-1}, \delta^h_j, \epsilon^h_j\right), \tag{1}$$

where h_j denotes current health capital and h_{j-1} denotes health capital of the previous period. The exogenous health shock ϵ^h_j follows a Markov process with age dependent transition probability matrix Π^h_j. Transition probabilities to next period's health shock ϵ^h_{j+1} depend on the current health shock ϵ^h_j so that an element of transition matrix Π^h_j is defined as the conditional probability $\Pr\left(\epsilon^h_{j+1}|\epsilon^h_j\right)$.

3.4 Technologies and firms

The economy consists of two production sectors. The two sectors are assumed to grow at a constant rate g. In sector one, there is a representative firm that uses physical capital K and effective labor services L to produce non-medical consumption goods c with a normalized price of one. The firm in the non-medical sector are perfectly competitive and solve the following maximization problem

$$\max_{\{K,\ L\}} \left\{F(K,L) - qK - wL\right\}, \tag{2}$$

taking the rental rate of capital q and the wage rate w as given. Capital depreciates at rate δ in each period. Sector two, the medical sector, is also populated by a continuum of identical firms that use capital K_m and labor L_m to produce medical services m at a price of p_m. The representative firm in the medical sector chooses capital K_m and effective labor L_m in order to maximize its profit according to

$$\max_{\{K_m,\ L_m\}} \left\{p_m F_m(K_m, L_m) - qK_m - wL_m\right\}. \tag{3}$$

3.5 Government

The government engages in a number of activities via various government programs: social security program, social insurance programs, a general consumption program and an accidental bequest redistribution program. The social security program operates on the basis of the Pay-As-You-Go (PAYG) principle in which the government collects a payroll tax τ^{SS} from the working population to finance social security benefits of t^{SS} per retired household. The PAYG program is self-financed.

In addition, the government provides a social transfer program (T^{SI}) that guarantees a minimum consumption level. The government also operates a government spending program (G) that is exogenous and unproductive. The government collects consumption tax revenue at a flat rate, τ^{C}, and income tax revenue at a progressive rate to balance its budget every period. Finally, the government collects and redistributes accidental bequests t_j^{Beq} in a lump-sum fashion to each working-age household.

3.6 Household problem

Agents with age $j \leq J_1$ are workers and thus exposed to labor shocks. Old agents, $j > J_1$, are retired ($l_j = 1$) and receive pension payments. They do not face labor market shocks anymore. The agent state vector at age j is given by

$$x_j \in D_j \equiv \begin{cases} \left(a_j, h_{j-1}, \vartheta, \epsilon_j^l, \epsilon_j^h\right) \in R_+ \times R_+ \times R_+ \times R_+ \times R_- & \text{if } j \leq J_1, \\ \left(a_j, h_{j-1}, \vartheta, \epsilon_j^h\right) \in R_+ \times R_+ \times R_+ \times R_- & \text{if } j > J_1, \end{cases} \tag{4}$$

where a_j is the capital stock at the beginning of the period, h_{j-1} is the health state at the beginning of the period, ϑ is the skill type, ϵ_j^l is the positive labor productivity shock, ϵ_j^h is a negative health shock. After the realization of the state variables, agents simultaneously chose from their choice set

$$\mathcal{C}_j \equiv \begin{cases} (c_j, l_j, m_j, a_{j+1}) \in R_+ \times [0,1] \times R_+ \times R_+ & \text{if } j \leq J_1, \\ (c_j, m_j, a_{j+1}) \in R_+ \times R_+ \times R_+ & \text{if } j > J_1, \end{cases}$$

where c_j is consumption, l_j is labor supply, m_j are health care services, and a_{j+1} are asset holdings for the next period in order to maximize their lifetime utility. All choice variables in the household problem depend on state vector x_j. We suppress this dependence in the notation to improve readability. The household optimization problem is

$$V(x_j) = \max_{\{\mathcal{C}_j\}} \left\{ u(c_j, h_j, l_j) + \beta \pi_j E\left[V(x_{j+1}) \mid x_j\right] \right\} \ s.t. \tag{5}$$

$$\left(1 + \tau^C\right) c_j + (1+g)\, a_{j+1} + p_m \times m_j = y_j - tax_j - tax_j^{SS},$$

$$0 \leq a_{j+1},\ 0 \leq l_j \leq 1,\ \text{and } (1),$$

where $p_m \times m_j$ is out-of-pocket medical spending, y_j is the sum of all income including labor, assets and bequests, tax_j is total income taxes paid and tax_j^{SS} is the social security tax. Household income and tax payments are defined as

$$
\begin{aligned}
y_j &= \begin{cases} e\left(\vartheta, h_j, \epsilon_j^l\right) \times l_j \times w + R\left(a_j + t^{\text{Beq}}\right) + t_j^{\text{SI}} & \text{if } j \leq J_1, \\ t_j^{\text{SS}} + R\left(a_j + t^{\text{Beq}}\right) \;\; + t_j^{\text{SI}} & \text{if } j > J_1, \end{cases} \quad (6) \\
tax_j &= \tilde{\tau}\left(\tilde{y}_j\right), \\
\tilde{y}_j &= y_j - a_j - t^{\text{Beq}} - 0.5 \times tax_j^{SS}, \quad (7) \\
tax_j^{SS} &= \tau^{\text{SS}} \times \min\left(\bar{y}_{ss},\ e\left(\vartheta, h_j, \epsilon_j^l\right) \times l_j \times w\right), \\
t_j^{\text{SI}} &= \max\left[0,\ \underline{c} + p_m \times \underline{m} + tax_j - y_j\right].
\end{aligned}
$$

Variable w is the market wage rate and R is the gross interest rate. Variable $\tilde{y}_j$ is taxable income, $\tilde{\tau}\left(\tilde{y}_j\right)$ is the progressive income tax payment and tax_j^{SS} is the social security tax with marginal rate τ^{SS} that finances the social security payments t_j^{SS}. The maximum contribution to social security is $\bar{y}_{ss}$. The social insurance payment t_j^{SI} guarantees a minimum consumption level $\underline{c}$ and a minimum level of health spending $\underline{m}$. The latter is set so that individuals do not fall below the lowest health capital grid point but also to prevent individual from using social insurance to build up their health capital to the maximum level. Also, if social insurance is paid out, then automatically $a_{j+1} = 0$ so that social insurance cannot be used to finance savings. For each $x_j \in D_j$ let $\Lambda\left(x_j\right)$ denote the measure of age j agents with $x_j \in D_j$. Then expression $\mu_j \Lambda\left(x_j\right)$ becomes the population measure of age-j agents with state vector $x_j \in D_j$ that is used for aggregation.

3.7 Recursive equilibrium

Given transition probability matrices $\left\{\Pi_j^l\right\}_{j=1}^{J_1}$ and $\left\{\Pi_j^h\right\}_{j=1}^{J}$, survival probabilities $\left\{\pi_j\right\}_{j=1}^{J}$ and exogenous government policies $\left\{tax\left(x_j\right), \tau^C, \tau^{SS}, \underline{c}, \bar{y}_{ss}\right\}_{j=1}^{J}$, a competitive equilibrium is a collection of sequences of distributions $\left\{\mu_j, \Lambda_j\left(x_j\right)\right\}_{j=1}^{J}$ of individual household decisions $\left\{c_j\left(x_j\right), l_j\left(x_j\right), a_{j+1}\left(x_j\right), m_j\left(x_j\right)\right\}_{j=1}^{J}$, aggregate stocks of physical capital and effective labor services $\left\{K, L, K_m, L_m\right\}$, and factor prices $\left\{w, q, R, p_m\right\}$ such that

(a) $\left\{c_j\left(x_j\right), l_j\left(x_j\right), a_{j+1}\left(x_j\right), m_j\left(x_j\right)\right\}_{j=1}^{J}$ solves the consumer problem (5),

(b) the firm first order conditions hold in both sectors

$$
\begin{aligned}
w &= F_L\left(K, L\right) = p_m F_{m,L}\left(K_m, L_m\right), \\
q &= F_K\left(K, L\right) = p_m F_{m,K}\left(K_m, L_m\right), \\
R &= q + 1 - \delta,
\end{aligned}
$$

(c) markets clear

$$
\begin{aligned}
K + K_m &= \sum_{j=1}^{J} \mu_j \int \left(a\left(x_j\right)\right) d\Lambda\left(x_j\right) + \sum_{j=1}^{J} \int \tilde{\mu}_j a_j\left(x_j\right) d\Lambda\left(x_j\right), \\
L + L_m &= \sum_{j=1}^{J_1} \mu_j \int e_j(x_j) l_j\left(x_j\right) d\Lambda\left(x_j\right),
\end{aligned}
$$

(d) the aggregate resource constraint holds

$$
G + (1+g) S + \sum_{j=1}^{J} \mu_j \int \left(c\left(x_j\right) + p_m m\left(x_j\right)\right) d\Lambda\left(x_j\right) = Y + p_m Y_m + (1-\delta) K,
$$

(e) the government programs clear

$$
\sum_{j=J_1+1}^{J} \mu_j \int t_j^{\mathrm{SS}}\left(x_j\right) d\Lambda\left(x_j\right) = \sum_{j=1}^{J_1} \mu_j \int tax^{\mathrm{SS}}\left(x_j\right) d\Lambda\left(x_j\right),
$$

$$
\overbrace{\sum_{j=1}^{J} \mu_j \int t_j^{\mathrm{SI}}\left(x_j\right) d\Lambda\left(x_j\right)}^{T^{SI}} + G = \sum_{j=1}^{J} \mu_j \int \left[\tau^C c\left(x_j\right) + tax_j\left(x_j\right)\right] d\Lambda\left(x_j\right), \tag{8}
$$

(f) the accidental bequest redistribution program clears

$$
\sum_{j=1}^{J_1} \mu_j \int t_j^{\mathrm{Beq}}\left(x_j\right) d\Lambda\left(x_j\right) = \sum_{j=1}^{J} \int \tilde{\mu}_j a_j\left(x_j\right) d\Lambda\left(x_j\right),
$$

(g) the insurance system is self-financed so that insurance payouts over all participants equal premium contributions and/or ear marked tax collections and[8]

(h) the distribution is stationary $\mu_{j+1}, \Lambda\left(x_{j+1}\right) = T_{\mu,\Lambda}\left(\mu_j, \Lambda\left(x_j\right)\right)$ where $T_{\mu,\Lambda}$ is a one period transition operator on the distribution.

3.8 Health insurance system and household optimization

In this section we describe how individuals fund their medical expenditures. In an economy with no health insurance, individuals have to pay all medical expenditures out-of-pocket. When a health insurance system is introduced, the amount individuals end up paying out-of-pocket for medical services is a direct function of their insurance status, the coinsurance rate of their health insurance, the price of medical services and the quantity that the individual buys. We consider three alternative health insurance systems: (i) a hybrid system of mixed private and public health

[8] We discuss the specifics of the insurance system in the following sections.

insurance (US system), (*ii*) a private health insurance system (PHI), and (*iii*) a universal public health insurance system (UPHI).

3.8.1 System 1: A mixed public and private insurance (US) system

This system consists of private health insurance provided by insurance companies for workers and public health insurance provided by the government for retirees and poor individuals.

Health insurance. Insurance companies offer two types of health insurance policies for workers: a group health insurance plan (GHI) via the employer or an individual health insurance plan (IHI). Individuals are required to buy insurance one period prior to the realization of their health shock in order to be insured in the following period. The insurance policy needs to be renewed each period. By construction, agents in their first period are thus not covered by any insurance. GHI can only be bought by workers who receive a GHI offer from their employer. Let ϵ^{GHI} be a binary random variable that indicates the state of the GHI offer from the employer. The GHI offer follows a Markov process which is a function of the permanent skill type ϑ and age j of an individual. Let $\Pr\left(\epsilon_{j+1}^{\mathrm{GHI}}|\epsilon_{j}^{\mathrm{GHI}},\vartheta\right)$ be the conditional probability that an agent has GHI status $\epsilon_{j+1}^{\mathrm{GHI}}$ at age $j+1$ given that she had group insurance status $\epsilon_{j}^{\mathrm{GHI}}$ at age j. The 2×2 transition probability matrix $\Pi_{j,\vartheta}^{\mathrm{GHI}}$ collects all conditional probabilities for group insurance status. The insurance premium, $\mathrm{prem}^{\mathrm{GHI}}$, is tax deductible and group rated so that insurance companies are not allowed to screen workers by health or age. If a worker is not offered group insurance from the employer, i.e., $\epsilon^{\mathrm{GHI}}=0$, the worker can still buy IHI. In this case the insurance premium is not tax deductible and the insurance company screens the worker by age and health status, $\mathrm{prem}^{\mathrm{IHI}}(j,h)$.

The government runs two public health insurance programs: Medicaid for the poor and Medicare for retirees. To be eligible for Medicaid, individuals are required to pass an income and asset test.

The health insurance state in_j for workers can therefore take on the following values:

$$in_j=\begin{cases}0 & \text{if not insured,}\\ 1 & \text{if individualhealthinsurance(IHI),}\\ 2 & \text{if group health insurance (GHI),}\\ 3 & \text{if Medicaid.}\end{cases}$$

After retirement ($j>J_1$) all agents are covered by public health insurance which is a combination of Medicare and Medicaid for which they pay a premium, prem^{R}. The government collects a payroll tax to finance Medicare and Medicaid.

Medical prices. An agent's total health expenditure in any given period is $p_m^{in_j}\times m_j$, where the price of medical services $p_m^{in_j}$ depends on insurance state $in_j\in$ {no Insurance, IHI, GHI, Medicaid, Medicare}. We accomplish this in the form of insurance specific price mark-ups over a base price p_m of medical services so that insurance specific premiums can be written as

$$\left[p_m^{\mathrm{noIns}},p_m^{\mathrm{IHI}},p_m^{\mathrm{GHI}},p_m^{\mathrm{Maid}},p_m^{\mathrm{Mcare}}\right]=\left[f_{\mathrm{noIns}}\ ,f_{\mathrm{IHI}},f_{\mathrm{GHI}},f_{\mathrm{Maid}},f_{\mathrm{Mcare}}\right]\times p_m.$$

These exogenously imposed markups generate profits, profits^M, for medical providers that we redistribute to all surviving households. The out-of-pocket (OOP) health expenditure of a working-age agent is given by

$$o\left(m_j\right)=\begin{cases} p_m^{in_j} m_j, & \text{if } in_j=0, \\ \gamma^{in_j}\times\left(p_m^{in_j} m_j\right), & \text{if } in_j>0, \end{cases} \tag{9}$$

where $0 \leq \gamma_j^{in_j} \leq 1$ are the insurance state specific coinsurance rates.[9] A retiree's OOP expenditure is $o\left(m_j\right)=\gamma^R \times\left(p_m^R \times m_j\right)$, where γ^R is the coinsurance rate of Medicare and p_m^R is the price that a retiree pays for medical services.

Insurance provider. For simplicity we abstain from modeling insurance companies as profit maximizing firms and simply allow for a premium markup ω. Since insurance companies in the individual market screen customers by age and health, we impose separate clearing conditions for each age-health type, so that premium, $\text{prem}^{\text{IHI}}\left(j,h\right)$, adjusts to balance

$$\left(1+\omega_{j,h}^{\text{IHI}}\right)\mu_j \int\left[1_{\left[in_j\left(x_j,h\right)=1\right]}\left(1-\gamma_j^{\text{IHI}}\right) p_m^{\text{IHI}} m_{j,h}\left(x_{j,h}\right)\right] d\Lambda\left(x_{j,-h}\right) \tag{10}$$

$$= \quad R\mu_{j-1}\int\left(1_{\left[in_{j-1,h}\left(x_{j-1,h}\right)=1\right]}\text{prem}^{\text{IHI}}\left(j-1,h\right)\right) d\Lambda\left(x_{j-1,-h}\right),$$

where $x_{j,-h}$ is the state vector for cohort age j not containing h since we do not want to aggregate over the health state vector h in this case. The clearing condition for the group health insurances is simpler as only one price, prem^{GHI}, adjusts to balance

$$\left(1+\omega^{\text{GHI}}\right)\sum_{j=2}^{J_1}\mu_j \int\left[1_{\left[in_j\left(x_j\right)=2\right]}\left(1-\gamma_j^{\text{GHI}}\right) p_m^{\text{GHI}} m_j\left(x_j\right)\right] d\Lambda\left(x_j\right) \tag{11}$$

$$= \quad R\sum_{j=1}^{J_1-1}\mu_j\int\left(1_{\left[in_j\left(x_j\right)=2\right]}\text{prem}^{\text{GHI}}\right) d\Lambda\left(x_j\right),$$

where $\omega_{j,h}^{\text{IHI}}$ and ω^{GHI} are markup factors that determine loading costs (fixed costs or profits), γ_j^{IHI} and γ_j^{GHI} are the age dependent coinsurance rates, and p_m^{IHI} and p_m^{GHI} are the prices for health care services of the two insurance types. The respective left-hand-sides in the above expressions summarize aggregate payments made by insurance companies whereas the right-hand-sides aggregate the premium collections one period prior. Since premiums are invested for one period, they enter the capital stock and we therefore multiply the term with the after tax gross interest rate R. The premium markups generate profits that are redistributed in equal (per-capita) amounts, denoted $\text{profit}^{\text{In}}$, to all surviving agents.[10]

[9] The coinsurance rate denotes the fraction of the medical bill that the patient has to pay out-of-pocket. For simplicity we include deductibles and co-pays into the coinsurance rate.

[10] Notice that ex-post moral hazard and adverse selection issues arise naturally in the model due to information asymmetry. Insurance companies cannot directly observe the idiosyncratic health shocks and have to reimburse agents based on the actual observed levels of health care spending. Adverse selection arises because insurance companies cannot observe the risk type of agents and therefore cannot price insurance premiums accordingly. They instead have to charge an average premium that clears the insurance companies' profit conditions. Individual

Medicare is financed by a Medicare tax and premium payments and together with Medicaid enter the government budget in the following way:

$$
\begin{aligned}
& G+T^{SI}+\sum_{j=2}^{J_1}\mu_j\int 1_{[in_j(x_j)=3]}\left(1-\gamma^{\text{MAid}}\right)p_m^{\text{MAid}}m_j\left(x_j\right)d\Lambda\left(x_j\right) \qquad (12)\\
& +\sum_{j=J_1+1}^{J}\mu_j\int\left(1-\gamma^{R}\right)p_m^{R}m_j\left(x_j\right)d\Lambda\left(x_j\right)\\
= & \sum_{j=1}^{J}\mu_j\int\left[\tau_C c\left(x_j\right)+tax_j\left(x_j\right)\right]d\Lambda\left(x_j\right)+\sum_{j=J_1+1}^{J}\mu_j\int\text{prem}^{R}\left(x_j\right)d\Lambda\left(x_j\right)+\sum_{j=1}^{J_1}\mu_j\int tax_j^{\text{Med}}d\Lambda\left(x_j\right),
\end{aligned}
$$

where γ^{MAid} and γ^{R} are the coinsurance rate of Medicaid and of the combined Medicare/Medicaid program for the old, respectively.

Household optimization. The state vector for the household optimization problem includes one additional dimension for workers due to the employer matching shock ϵ_j^{GHI}:

$$
x_j\in D_j\equiv\begin{cases}\left(a_j,h_{j-1},\vartheta,\epsilon_j^{l},\epsilon_j^{h},\epsilon_j^{\text{GHI}},in_j\right)\in R_+\times R_+\times R_+\times R_+\times R_-\times\{0,1\}\times\{0,1,2,3\} & \text{if } j\leq J_1,\\ \left(a_j,h_{j-1},\vartheta,\epsilon_j^{h},in_j\right)\in R_+\times R_+\times R_+\times R_-\times\{1\} & \text{if } j>J_1.\end{cases}
$$

The household choice set is defined as

$$
\mathcal{C}_j\equiv\begin{cases}\left(c_j,l_j,m_{j,}a_{j+1},\text{in}_{j+1}\right)\in R_+\times[0,1]\times R_+\times R_+\times\{0,1,2,3\} & \text{if } j\leq J_1,\\ \left(c_j,m_{j,}a_{j+1}\right)\in R_+\times R_+\times R_+ & \text{if } j>J_1.\end{cases}
$$

The insurance system component that enters the household budget constraint on the left hand side is

$$
i\left(\text{in}_{j+1}\right)=\begin{cases}1_{\{in_{j+1}=1\}}\text{prem}^{\text{IHI}}\left(j,h\right)+1_{\{in_{j+1}=2\}}\text{prem}^{\text{GHI}}+tax_j^{\text{Med}}-\left(\text{profits}^{M}+\text{profits}^{\text{In}}\right) & \text{if } j\leq J_1,\\ \text{prem}_j^{\text{Med}}-\left(\text{profits}^{M}+\text{profits}^{\text{In}}\right) & \text{if } j>J_1,\end{cases}
$$

where $1_{\{in_{j+1}=1\}}$ and $1_{\{in_{j+1}=2\}}$ are indicator variables that are equal to one if the individual chooses the respective insurance state and zero otherwise. Medicare is financed by a payroll tax $\text{tax}_j^{\text{Med}}$ and premium payments $\text{prem}_j^{\text{Med}}$. Per capita provider profits are denoted profits^{M} and per capita insurance company profits are denoted profits^{In}. Taxable income $\tilde{y}_j$ now includes provider profits, GHI premium deductions and payroll tax deductions from Medicaid payments:

$$
\begin{aligned}
\tilde{y}_j &= y_j+\text{profits}^{M}+\text{profits}^{\text{In}}-a_j-t^{\text{Beq}}-1_{[in_{j+1}=2]}\text{prem}^{\text{GHI}}-0.5\left(tax_j^{SS}+tax_j^{\text{Med}}\right),\\
tax_j^{SS} &= \tau^{\text{SS}}\times\min\left(\bar{y}_{ss},\ e\left(\vartheta,h_j,\epsilon_j^{l}\right)\times l_j\times w-1_{[in_{j+1}=2]}\text{prem}^{\text{GHI}}\right),\\
tax_j^{\text{Med}} &= \tau^{\text{Med}}\times\left(e\left(\vartheta,h_j,\epsilon_j^{l}\right)\times l_j\times w-1_{[in_{j+1}=2]}\text{prem}^{\text{GHI}}\right),
\end{aligned}
$$

insurance contracts do distinguish agents by age and health status but not by their health shock.

where τ^{Med} is a payroll tax financing Medicare.

3.8.2 System 2: A private health insurance (PHI) system

We next introduce a private health insurance (PHI) system where only private health insurance is available and all public health insurance programs such as Medicaid and Medicare are removed. Specifically, we analyze two cases: a PHI system without government regulation in health insurance and health care markets and a PHI system with government regulation in health insurance and health care market. In the unregulated PHI system insurance companies are free to set premiums according to the health state and age of an individual similar to individual health insurance (IHI) markets in the US system (i.e., age and health discrimination is possible). Differently, in the regulated PHI system the government introduces regulations that prevents premium price discrimination by insurance companies based on health status, and also provides tax credits to individuals who buy private insurance, which is similar to group health insurance (GHI) markets in the US system.

Health insurance. The health insurance state in_j for individuals can therefore take on the following values:

$$in_j = \begin{cases} 0 & \text{if not insured,} \\ 1 & \text{if privately insured (either IHI or GHI).} \end{cases}$$

The premiums for private insurance are again denoted by $\text{prem}^{\text{IHI}}(j,h)$ or prem^{GHI}, respectively. The out-of-pocket health expenditures depend on the insurance state

$$o(m_j) = \begin{cases} p_m^{in_j} m_j & \text{if } in_j = 0, \\ \gamma^{in_j} \times \left(p_m^{in_j} m_j\right) & \text{if } in_j > 0, \end{cases} \tag{13}$$

where $0 \leq \gamma^{in_j} \leq 1$ are the insurance type specific coinsurance rates.

Insurance provider. The respective IHI and GHI sectors are set up similarly to the US case in expressions (10) or (11) with the exception that private insurance is extended to include the retired population. IHI companies again screen customers by age and health so that we impose separate clearing conditions for each age-health type with premiums, $\text{prem}^{\text{IHI}}(j,h)$, adjusting to balance expression (10) for all age groups j where $x_{j,-h}$ is the state vector for cohort age j not containing h since we do not want to aggregate over the health state vector h in this case. The clearing condition for the group health insurances is simpler as only one price, prem^{GHI}, adjusts to balance expression (11) for the working age population and a separate constraint for the retired population:

$$\begin{aligned} & \left(1+\omega^{\text{GHI}}\right) \sum_{j=J_1+1}^{J} \mu_j \int \left[1_{[in_j(x_j)=1]} \left(1-\gamma^{\text{GHI}}\right) p_m^{\text{GHI}} m_j(x_j)\right] d\Lambda(x_j) \\ = \quad & R \sum_{j=J_1}^{J-1} \mu_j \int \left(1_{[in_j(x_j)=1]} \text{prem}^{\text{GHI}}\right) d\Lambda(x_j). \end{aligned} \tag{14}$$

Household optimization. The state vector for the household optimization problem is

$$x_j \in D_j \equiv \begin{cases} \left(a_j, h_{j-1}, \vartheta, \epsilon_j^l, \epsilon_j^h, in_j\right) \in R_+ \times R_+ \times R_+ \times R_+ \times R_- \times \{0,1\} & \text{if } j \leq J_1, \\ \left(a_j, h_{j-1}, \vartheta, \epsilon_j^h, in_j\right) \in R_+ \times R_+ \times R_+ \times R_- \times \{1\} & \text{if } j > J_1, \end{cases}$$

the household choice set is

$$\mathcal{C}_j \equiv \begin{cases} (c_j, l_j, m_j, a_{j+1}, \mathrm{in}_{j+1}) \in R_+ \times [0,1] \times R_+ \times R_+ \times \{0,1\} & \text{if } j \leq J_1, \\ (c_j, m_j, a_{j+1}, \mathrm{in}_{j+1}) \in R_+ \times R_+ \times R_+ \times \{0,1\} & \text{if } j > J_1, \end{cases}$$

and the insurance system component that enters the household budget constraint on the left hand side is

$$i\left(\mathrm{in}_{j+1}\right) = \begin{cases} 1_{\{in_{j+1}=1\}}\mathrm{prem}^{\mathrm{PI}}(j,h) - \left(\mathrm{profits}^{\mathrm{M}} + \mathrm{profits}^{\mathrm{In}}\right) & \text{if } j \leq J_1 \ , \\ 1_{\{in_{j+1}=1\}}\mathrm{prem}^{\mathrm{PI}}(j,h) - \left(\mathrm{profits}^{\mathrm{M}} + \mathrm{profits}^{\mathrm{In}}\right) & \text{if } j > J_1, \end{cases}$$

with

$$\mathrm{prem}^{\mathrm{PI}}(j,h) = \begin{cases} \mathrm{prem}^{\mathrm{IHI}}(j,h) & \text{if IHI case,} \\ \mathrm{prem}^{\mathrm{GHI}} & \text{if GHI case,} \end{cases}$$

where $1_{\{in_{j+1}=1\}}$ is an indicator variable that is equal to one if the individual chooses to buy private health insurance and zero otherwise. Per capita provider profits are denoted $\mathrm{profits}^{\mathrm{M}}$ and per capita insurance company profits are denoted $\mathrm{profits}^{\mathrm{In}}$. Taxable income $\tilde{y}_j$ now includes provider profits, GHI premium deductions for the case with GHI and payroll tax deductions from Social Security payments:

$$\begin{aligned} \tilde{y}_j &= y_j + \mathrm{profits}^{\mathrm{M}} + \mathrm{profits}^{\mathrm{In}} - a_j - t^{\mathrm{Beq}} - 1_{[in_{j+1}=1]}\mathrm{prem}^{\mathrm{GHI}} - 0.5 \times tax_j^{\mathrm{SS}}, \\ tax_j^{SS} &= \tau^{\mathrm{SS}} \times \min\left(\bar{y}_{ss},\ e\left(\vartheta, h_j, \epsilon_j^l\right) \times l_j \times w - 1_{[in_{j+1}=1]}\mathrm{prem}^{\mathrm{GHI}}\right). \end{aligned}$$

3.8.3 System 3: A universal public health insurance (UPHI) system

We finally consider a universal public health insurance (UPHI) system where the government provides a Medicare type program for all workers and retirees and the private health insurance markets are not available in the model.

Health insurance. The UPHI is mandatory, covers everybody and is financed by taxes. The OOP health expenditures of the household are given by

$$o\left(m_j\right) = \gamma^{\mathrm{UPHI}} \times \left(p_m^{\mathrm{UPHI}} m_j\right),$$

where γ^{UPHI} is the coinsurance rate of the UPHI program and p_m^{UPHI} is the price that providers charge uniformly.

Insurance provider. The government is the sole provider of insurance. Aggregate insurance payments are defined as

$$\text{InsPay}^{\text{UPHI}} = \sum_{j=1}^{J} \mu_j \int \left[\left(1 - \gamma^{\text{UPHI}} \right) p_m^{\text{UPHI}} m_j \left(x_j \right) \right] d\Lambda \left(x_j \right).$$

We consider two financing options. First, a payroll tax τ^V finances the UPHI system so that

$$\text{InsPay}^{\text{UPHI}} = \sum_{j=1}^{J_1} \mu_j \int \left[\tau^{\text{V}} \times e_j \left(x_j \right) l_j \left(x_j \right) w \right] d\Lambda \left(x_j \right) \tag{15}$$

has to hold in addition to the government budget constraint in expression (8). Alternatively, we also solve for the case where a consumption tax τ^C finances the UPHI system. In this case the government budget constraint changes to

$$\text{InsPay}^{\text{UPHI}} + G + T^{\text{SI}} = \sum_{j=1}^{J} \mu_j \int \left[\tau^C c \left(x_j \right) + tax_j \left(x_j \right) \right] d\Lambda \left(x_j \right).$$

Household optimization. The state vector for the household optimization problem is

$$x_j \in D_j \equiv \begin{cases} \left(a_j, h_{j-1}, \vartheta, \epsilon_j^l, \epsilon_j^h, in_j \right) \in R_+ \times R_+ \times R_+ \times R_+ \times R_- \times \{1\} & \text{if } j \leq J_1, \\ \left(a_j, h_{j-1}, \vartheta, \epsilon_j^h, in_j \right) \in R_+ \times R_+ \times R_+ \times R_- \times \{1\} & \text{if } j > J_1, \end{cases}$$

the household choice set is

$$\mathcal{C}_j \equiv \begin{cases} \left(c_j, l_j, m_{j,} a_{j+1} \right) \in R_+ \times [0,1] \times R_+ \times R_+ & \text{if } j \leq J_1, \\ \left(c_j, m_{j,} a_{j+1} \right) \in R_+ \times R_+ \times R_+ & \text{if } j > J_1, \end{cases}$$

and the insurance system component that enters the household budget constraint is either

$$i \left(in_j = \text{UPHI} \right) = \tau_V \times e \left(\vartheta, h_j, \epsilon_j^l \right) l_j w - \text{profits}^M$$

if a payroll tax τ_V is used to finance the system or

$$i \left(in_j = \text{UPHI} \right) = \tau_C \times c_j \ - \text{profits}^M$$

if a consumption τ_C is used. Taxable income $\tilde{y}_j$ now includes provider profits:

$$\tilde{y}_j = y_j + \text{profits}^{\text{M}} - a_j - t^{\text{Beq}} - 0.5 \times tax_j^{\text{SS}}.$$

4 Benchmark calibration

In order to calibrate the structural parameters of our benchmark model we use the US-version of the model from Section 3.8.1. We match moments generated by the model to moments from

US data before the implementation of the Affordable Care Act in 2010. We use a standard numeric algorithm to solve the model and determine parameter values.[11] We use data from the Medical Expenditure Panel Survey from 1999–2009 augmented with data from CMS, the Panel Study of Income Dynamics (PSID) from 1984–2005 as well as data from the National Income Accounts (NIPA). In our calibration, there are two sets of parameters: *external* and *internal* parameters. *External* parameters are estimated independently from MEPS and CMS or borrowed from previous studies. We list these external parameters in the Appendix, Table 8. *Internal* parameters are calibrated within the model so that model-generated data moments match a given set of targets from US data. We present these parameters in the Appendix, Table 9. We next discuss how we choose the parameters, followed by a discussion of how well the US-model fits the data. More details about the data and the calibration strategy are provided inJung and Tran (2016).

4.1 Demographics

One period is defined as 5 years. We model households from age 20 to age 95 which results in $J = 15$ periods. The annual conditional survival probabilities are taken from US life-tables in 2010 and adjusted for period length. The population growth rate for the US was 1.2 percent on average from 1950 to 1997 according to the Council of Economic Advisors (1998). In the model the total population over the age of 65 is 17.7 percent which is very close to the 17.4 percent as fraction of the 20+ year olds in the census.

4.2 Preferences and endowments

Preferences. We choose a Cobb-Douglas type utility function of the form

$$u(c,l,h) = \frac{\left(\left(c^{\eta} \times \left(1 - l - 1_{[l>0]}\bar{l}_j\right)^{1-\eta}\right)^{\kappa} \times h^{1-\kappa}\right)^{1-\sigma}}{1-\sigma},$$

where c is consumption, l is labor supply, $\bar{l}_j$ is the age dependent fixed cost of working as in French (2005), η is the intensity parameter of consumption relative to leisure, κ is the intensity parameter of health services relative to consumption and leisure and σ is the inverse of the intertemporal rate of substitution (or relative risk aversion parameter). Cobb–Douglas preferences are widely used in the macroeconomic literature (e.g., see Heathcote, Storesletten and Violante (2008)), as they are consistent with a balanced growth path, irrespective of the choice for σ.[12]

The fixed cost of working parameters are set to match labor hours per age group. Parameter σ is set to 3.0 and the time preference parameter β is set to 1.001 to match the capital output

[11] We use a variant of the Gauss-Seidl algorithm and first guess a price vector, then backward solve the household problem using these prices, then aggregate the economy and finally solve for a new price vector using firm first order conditions. We then update the price vector and repeat all the steps until the price vector converges.

[12] Palumbo (1999), French (2005), Nardi (2010) and French and Jones (2011) use similar setups where health status serves as preference shifter.

ratio and the interest rate.[13] We set the intensity parameter $\eta = 0.43$ to match the aggregate labor supply and $\kappa = 0.75$ to match the ratio between final goods consumption and medical consumption. In conjunction with the health productivity parameters ϕ_j and ξ from the health production function in expression (17) these preference weights also ensure that the model matches total health spending and the health insurance take-up rate for each age group.

Labor productivity. The effective quality of labor supplied by workers is

$$e_j\left(\vartheta, h_j, \epsilon^l\right) = \left(\overline{wage}_{j,\vartheta}\right)^{\chi} \times \left(\exp\left(\frac{h_j - \bar{h}_{j,\vartheta}}{\bar{h}_{j,\vartheta}}\right)\right)^{1-\chi} \times \epsilon^l \text{ for } \; j = \{1, ..., J_1\}, \tag{16}$$

and has three components. First, we model the work efficiencies of four skill types, denoted ϑ. Skill types are assumed to be predetermined and permanent and are formed by wage quartile. The work efficiencies of the skill types are hump-shaped over the lifecycle and are estimated using average hourly wage estimates $\overline{wage}_{j,\vartheta}$ by wage quartile (i.e., the permanent skill group ϑ) and age j from MEPS data.

Second, the quality of labor can be influenced by health. Since $\overline{wage}_{j,\vartheta}$ already reflects the productivity for average health capital of an (j, ϑ) type, the idiosyncratic health effect is measured as percent deviation from the average health capital $\bar{h}_{j,\vartheta}$ of each skill and age group. In order to avoid negative numbers we use the exponent function. Parameter $\chi = 0.85$ measures the relative weight of the average productivity vs. the individual health effect.

The third component is an idiosyncratic labor productivity shock ϵ^l and is based on Storesletten, Telmer and Yaron (2004). We discretize this process into a five state Markov process following Tauchen (1986) with labor shocks $\epsilon^l \in \{4.41;\ 3.51;\ 2.88;\ 2.37;\ 1.89\}$.

4.3 Health capital

Health production technology. The law of motion of health capital consists of three components:

$$h_j = h\left(m_j, h_{j-1}, \delta_j^h, \epsilon_j^h\right) = \overbrace{\phi_j m_j^{\xi}}^{\text{Investment}} + \overbrace{\left(1 - \delta_j^h\right) h_{j-1}}^{\text{Trend}} + \overbrace{\epsilon_j^h}^{\text{Disturbance}}. \tag{17}$$

The first component is a health production function that uses health services m as inputs to produce new quantities of health capital. The second component measures the natural health deterioration over time with age-dependent depreciation rate δ_j^h. The third component represents a random and age dependent health shock. Grossman (1972*a*) and Stratmann (1999) estimate positive effects of medical services on measures of health outcomes. However, we are not aware of any precise estimates for parameters ϕ_j and ξ in expression (17). A recent empirical contribution by Galama et al. (2012) finds weak evidence for decreasing returns to scale which would imply that $\xi < 0$. In our paper we let ϕ_j be age-dependent and let ξ and ϕ_j endogenously adjust to match aggregate health expenditures and the medical expenditure profile over age.

[13] It is understood that in a general equilibrium model every parameter affects the equilibrium value of all endogenous variables to some extent. Here we associate parameters with those equilibrium variables that are the most directly affected (quantitatively).

Health capital space. MEPS contains two possible sources of information on health status that could serve as a measure of health capital: self-reported health status and the health index Short-Form 12 Version 2 ($SF-12v2$).[14] Since the $SF-12v2$ index is more objective and comparable over the lifecycle, we use this index as measure for health capital in our model. In order to construct a health capital space we assume a maximum health capital level $h_m^{max} = 3.5$. All other health shock and health production parameters are then re-scaled using this value. We allow for 15 states on the health grid. The lower bound of the health grid $h_m^{\min}$ is treated as an internal parameter that is chosen in conjunction with the health production parameters ϕ_j and ξ.

Health depreciation rate. We next approximate the natural rate of health depreciation δ_j^h per age group. We calculate the average health capital $\bar{h}_j$ per age group of individuals with group insurance and zero health spending in any given year. We then postulate that such individuals did not incur a negative health shock in this period as they could easily afford to buy medical services m to replenish their health due to their insurance status. This means that for those individuals the smoothing and shock component in expression (17) disappear as $\epsilon_j^h = 0$ and $m_j = 0$. The average law of motion of health capital then reduces to $\bar{h}_j = \left(1 - \delta_j^h\right) \bar{h}_{j-1}$, from which we can recover the age dependent natural rate of health depreciation δ_j^h. The depreciation rates are increasing in age and fall between 0.6 and 2.13 percent per period. Note that these values are rather small because they do not contain the negative health shocks that are modeled separately.

Heath shock. For each age cohort j we separate individuals into four risk groups: group 1, whose health capital levels fall into the 25^{th} percentile of age j individuals, group 2 whose health capital levels fall between the 25^{th} and the 50^{th} percentile, group 3 falls between the 50^{th} and the 75^{th} percentile, and group 4 whose health capital is in the top quartile. We assume that group 4 experiences no health shock, so that this group's average health capital defines the maximum health capital $\bar{h}_{j,d}^{max}$ (where subscript d indicates that this variable is calculated from MEPS data). Group 3 experiences a "small" health shock, group 2 experiences a "moderate" health shock, and group 1 suffers from a "large" health shock. The averages of health capital per age group are denoted $\left\{\bar{h}_{j,d}^{\max} > \bar{h}_{j,d}^3 > \bar{h}_{j,d}^2 > \bar{h}_{j,d}^1\right\}$. We next express the shock magnitudes as percentage deviations from the maximum health state in the data, so that the shock vector is: $\epsilon_j^{h\%} = \left\{0, \frac{\bar{h}_{j,d}^3 - \bar{h}_{j,d}^{\max}}{\bar{h}_{j,d}^{\max}}, \frac{\bar{h}_{j,d}^2 - \bar{h}_{j,d}^{\max}}{\bar{h}_{j,d}^{\max}}, \frac{\bar{h}_{j,d}^1 - \bar{h}_{j,d}^{\max}}{\bar{h}_{j,d}^{\max}}\right\}$. This vector is then multiplied with the maximum health capital level in the model $h_m^{\max}$ to calculate the shock levels in the model. The transition probability matrix of health shocks Π^h is calculated by counting how many individuals move across risk groups between two consecutive years in MEPS data. We smooth the transition probabilities and adjust for period length.

[14] The $SF-12v2$ includes twelve health measures of physical and mental health. There are two versions of this index available, one for physical health and the other for mental health. Both measures use the same health measures to construct the index but the physical health index puts more weight on variables measuring physical health components (compare Ware, Kosinski and Keller (1996) for further details about this health index). For this study we use the physical health index.

4.4 Technologies and firms

We impose a standard Cobb-Douglas production technology that uses physical capital and labor as inputs to produce a final consumption good according to $F(K,L) = AK^{\alpha}L^{1-\alpha}$. The medical sector uses $F_m(K_m, L_m) = A_m K_m^{\alpha_m} L_m^{1-\alpha_m}$. We set the capital share of production α to 0.33 and the annual capital depreciation rate at $\delta = 0.1$, which are both standard values in the calibration literature (e.g., Kydland and Prescott (1982)). The capital share in production in the health care sector is set lower at $\alpha_m = 0.26$ (based on Donahoe (2000) and our own calculations).

4.5 Government

Pensions. In the model, social security transfers are defined as a function of average labor income per skill type $w\bar{L}(\vartheta)$ where $\bar{L}(\vartheta)$ denotes the average effective human capital of type ϑ. Let $t^{\mathrm{SS}}(\vartheta) = \Psi \times w\bar{L}(\vartheta)$ be type specific pension payments where Ψ is a scaling factor that determines the size of the pension payment. Total pension payments amount to 4.1 percent of GDP. This is close to the number reported in the budget tables of the Office of Management and Budget (OMB) for 2008 which is close to 5 percent.

Taxes. We use the formula from Gouveia and Strauss (1994) to calculate the progressive income tax as

$$\tilde{\tau}(\tilde{y}) = a_0 \left[\tilde{y} - \left(\tilde{y}^{-a_1} + a_2\right)^{-1/a_1}\right],$$

where $\tilde{y}$ is taxable income. The parameter estimates for this tax polynomial are $a_0 = 0.258$, $a_1 = 0.768$ and $a_2 = 0.031$. The social security system is self-financed via a payroll tax of $\tau^{SS} = 9.4$ percent which is similar to the 10.6 percent used in Jeske and Kitao (2009). The payroll tax is collected on labor income up to a maximum of \$97.500. The consumption tax rate is set to 5.0 percent (Mendoza, Razin and Tesar (1994) report 5.67 percent). The model results in total tax revenue of 21.8 percent of GDP and residual (unproductive) government consumption of 12 percent.

4.6 US health insurance system

Medicare. We use data from CMS (Keehan et al. (2011)) and calculate that the share of total Medicaid spending that is spent on individuals older than 65 is about 36 percent. Adding this amount to the total size of Medicare results in a combined total of 4.16 percent of GDP of public health insurance reimbursements for the old. Since MEPS only accounts for about 65-70 percent of health care spending in the national accounts (see Sing et al. (2006) and Bernard et al. (2012)) we target a size of 3.0 percent of GDP. Given a coinsurance rate of $\gamma^R = 0.20$, the size of the combined Medicare/Medicaid program in the model is 3.1 percent of GDP. We fix the premium for Medicare at 2.11 percent of per-capita GDP as in Jeske and Kitao (2009). The Medicare tax τ^{Mcare} is set to 2.9 percent.[15]

[15] Medicare payroll taxes are 2×1.45 percent on all earnings split in employer and employee contributions (see SSA (2007)).

Medicaid. According to Kaiser (2013), 16 states have Medicaid eligibility thresholds below 50 percent of the FPL, 17 states have eligibility levels between 50 and 99 percent, and 18 states have eligibility levels that exceed 100 percent of the FPL. In addition, state regulations vary greatly with respect to the asset test of Medicaid. According to MEPS data, 9.2 percent of working age individuals have some form of public health insurance. In the model we therefore calibrate the Medicaid eligibility level to 70 percent of the FPL ($FPL_{\text{Maid}} = 0.7 \times \text{FPL}$) and calibrate the asset test level, $\bar{a}_{Maid}$, so that 9.2 percent of the working age population become eligible for Medicaid. For the reasons explained above, using the FPL directly would grossly overstate the Medicaid population. The size of Medicaid for workers is about 1.46 percent of GDP according to national accounts data but Medicaid spending in MEPS only accounts for about 0.95 to 1.02 percent of GDP (see Sing et al. (2006), Keehan et al. (2011) and Bernard et al. (2012)). The Medicaid coinsurance rate is based on MEPS estimates and depends on age so that $\gamma_j^{Maid} \in [0.11, 0.21]$. The resulting size of Medicaid for workers is 0.5 percent of GDP in the model.

Group insurance offer. We estimate a Markov process that governs the group insurance offer probability from MEPS which contains information about whether agents have received a group health insurance offer from their employer i.e. offer shock $\epsilon^{\text{GHI}} = \{0, 1\}$ where 0 indicates no offer and 1 indicates a group insurance offer. Since the probability of a GHI offer $\Pr\left(\epsilon_{j+1}^{\text{GHI}} | \epsilon_j^{\text{GHI}}, \vartheta\right)$ is highly correlated with income, we construct the group offer transition matrix $\Pi_{j,\vartheta}^{\text{GHI}}$ by skill type ϑ. That is, for each skill type we count the fraction of individuals with a GHI offer in year j that is still offered group insurance in $j+1$. We smooth the transition probabilities and adjust for the five-year period length.

Coinsurance rates and insurance premiums. Age and health dependent markup profits $\omega_{j,h}^{\text{IHI}}$ in expression (10) are calibrated to match the IHI take-up rate over the lifecycle. The GHI markup profit ω^{GHI} in expression (11) is calibrated to match the insurance take-up rate of GHI.[16] We define the coinsurance rate as the fraction of out-of-pocket health expenditures over total health expenditures, so that our coinsurance rates include deductibles and copayments. We again use MEPS data to estimate the age dependent coinsurance rates of both types of insurances to be $\gamma_j^{\text{IHI}} \in [0.22, 0.52]$ and $\gamma_j^{\text{GHI}} \in [0.33, 0.5]$, respectively. The insurance premiums are endogenously adjusted to solve the insurance companies' problems.

Price of medical services. The base price of medical services p_m is endogenous. Shatto and Clemens (2011) report that the reimbursement rates of Medicare and Medicaid are close to 70 percent of the price that private health insurances pay for comparable health care services. Furthermore, various studies have found that uninsured individuals pay over 50 percent higher prices for prescription drugs as well as hospital services than insured individuals (see Anderson (2007), Gruber and Rodriguez (2007)). According to Brown (2006) the national average is a markup of around 60 percent. Large group insurance companies are able to operate at lower average fixed costs and will also be able to negotiate lower prices for health care services (see

[16]In the GHI we allow for lower premiums for the two youngest age cohorts in order to match the relatively high take-up rates despite the very low probability of adverse health shocks. Without this "minor" discrimination, GHI premiums would be too high and not enough young low risk types would buy GHI to match the take-up rate in the data.

Phelps (2003)). Based on this information and assuming that Medicaid reimbursement levels result in zero provider profits, we pick the following markup factors for p_m :

$$\left[p_m^{\text{noIns}}, p_m^{\text{IHI}}, p_m^{\text{GHI}}, p_m^{\text{Maid}}, p_m^{\text{Mcare}}\right] = [1.70, 1.20, 1.10, 1.0, 0.90] \times p_m.$$

When the experiments are run, this relative pricing structure is held constant so that Medicaid and Medicare remain the programs that pay the lowest prices for medical services. Thus, providers are assumed to not being able to renegotiate reimbursement rates.[17]

4.7 Properties of the benchmark model

Our calibrated benchmark model is capable of producing lifecycle trends of average medical expenditures that match US data. Table 10 report simulated data moments and target moments from US data. Figures 3 and 4 and Tables 10 and 11 summarize the model output.

Medical expenditures. Panel 1 of Figure 3 compares health expenditure profiles as fraction of income with MEPS data for heads of households. Health expenditures are low early in life because of high initial health capital and low health risk, and then rise as health capital depreciates. Health expenditures rise exponentially later in life because agents are exposed to more health risk. Our model also produces a hump-shaped lifecycle profile of insurance take-up rate in the US.

Our model generates total medical expenditures of 17.7 percent of gross household income which matches data provided by CMS. In addition, we show that our model reproduces the distribution of health expenditures as seen in panel 2 of Figure 3.

Insurance take-up ratio. Panels 3, 4 and 5 of Figure 3 plot the lifecycle profiles of insurance take-up rates for individual health insurance (IHI), group health insurance (GHI) and Medicaid of the working age population. Young agents with low income are less likely to buy private health insurance compared to middle aged agents at the peak of their lifecycle earnings ability. Young individuals face lower health risk and are less willing to buy private health insurance than older individuals who are both, more willing (i.e., they face higher expected negative health shocks) and more able to buy health insurance. The model slightly overstates the take-up rate of Medicaid among young agents.

Assets and labor supply. The model reproduces the hump-shaped patterns of lifecycle asset holdings from the PSID. However, the model does not match the peak age of asset holdings in the data. Our model slightly overstates the hours worked of the youngest cohort.

Aggregates. The model can reproduce important macroeconomic aggregates in the US data. Table 10 compares model moments with moments from MEPS, CMS, and National Income data.

Income distribution. Table 11 provides a summary of the income distribution compared to data from MEPS. Our benchmark model matches the lower and upper tails of the income distribution with around 14.8 percent of individuals having income below the FPL vs. 16.4 percent in MEPS.

[17] We are not able to formally model the bargaining process between medical care providers and the insurance companies due to computational constraints.

5 Quantitative analysis

In this section we study the potential welfare benefits of introducing health insurance into an economy without any health insurance. We start by constructing a hypothetical economy in which all health insurance arrangements are removed, but all structural parameters and fiscal policies remained unchanged. This economy has economic fundamentals similar to the US economy but lacks all forms of health insurance. Individuals rely on their income and savings to cover their health care expenditures. In this economy, the lack of insurance options against health risk interacts with the limited set of market instruments against income risk (i.e., household savings with borrowing constraints) and amplifies consumption variance. This generates a welfare cost that is the sum of (*i*) welfare losses due to missing insurance options against income risk, (*ii*) losses due to incomplete health insurance against health risk and (*iii*) the dynamic interaction between the two.[18]

We next introduce different health insurance systems and quantify the welfare implications compared to the no-insurance economy. As pointed out in the discussion of the small model in Section 2, the rich interactions between welfare gains from risk sharing and welfare losses due to distorted incentives when implementing health insurance can now be factored in. These experiments allow us to isolate quantitatively the welfare benefits of the different designs of a health insurance system relative to the economy without any health insurance.

5.1 System 1: Mixed private and public insurance

We start with calculating the potential welfare benefit of introducing the US system with private and public health insurance into the economy without any insurance. We report steady state results in Table 1. To facilitate model comparison we normalize the values of the No-Health-Insurance case to either 0 or 100 depending on the context. As seen in column [0], no one has access to health insurance in the baseline system. The value differences between columns [0] and [1] are interpreted as the long-run effects of introducing a US health insurance system into an incomplete markets economy where individuals are exposed to health and income risks, but subjected to a no borrowing constraint and no health insurance contracts.

[18]There are several other social insurance programs including social security, minimum consumption and progressive income taxes in the model. However, since we focus on the social insurance role of the health insurance system, we keep these other programs identical to the US model in all simulations.

	[0] No Health Insurance	[1] US System
Premium discrimination	N/A	YES
Medical price markup	70	$0-70$
Insured workers (%)	0	77.23
• IHI (%)	-	6.44
• GHI (%)	-	61.01
• Medicaid (%)	-	9.78
Insured retirees (%)	0	100
•Medicare(%	-	100
Med. consumption (M)	100	107.86
Med. spending ($p_m M$)	100	88.55
Capital (K_c)	100	81.14
Output (Y_c)	100	85.90
Welfare (CEV - %):	0	+5.21
• Income Group 1-Low (%)	0	+6.54
• Income Group 2 (%)	0	+6.79
• Income Group 3 (%)	0	+2.63
• Income Group 4-High (%)	0	+1.51

Table 1: **The Mixed Private and Public Health Insurance (US) System.**
This table presents steady state results comparing the counterfactual baseline economy without any health insurance (Column **[0] No Health-Insurance**) to an economy with the US health insurance system that provides private insurance for the working age population and public insurance for the old or poor (Column **[1] US System**). The No-Health-Insurance economy is identical to the US-System economy but lacks all health insurance contracts. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the No-Health-Insurance case. Each column presents steady-state results. CEV values are reported as percentage changes of lifetime consumption of a newborn individual.

There are several important features of the US health insurance system which potentially result in welfare gains. First, individuals have access to a number of health risk sharing mechanisms: individual health insurance (IHI) for workers, group health insurance (GHI) for workers through employers, Medicare for retirees and Medicaid for the poor. Second, the insured now have access to cheaper medical services at relatively lower medical prices, compared to the no insurance case as health insurance providers can negotiate lower prices for otherwise identical medical services. This "negotiation" is implemented through exogenous price markups as described in Section 3.8.1. Third, some individuals benefit from tax deductions when buying group health insurance (GHI) policies. Final, low income individuals benefit from redistribution via Medicaid.

As seen in column [1] of Table 1, under the US system retirees and low income workers have access to Medicare and Medicaid, respectively while working individuals have access to private health insurance policies (IHI and GHI). Overall, the insurance take-up rate of the working population is about 77 percent.

Aggregates. The introduction of the US health insurance system introduces distortions that result in reduced aggregate output. In the No-Health-Insurance economy, individuals rely on their own investments to self-insure against health and income risk by either accumulating a risk-free asset, investing in health capital or working longer hours to generate higher per period incomes. Conversely, with the introduction of the US health insurance system physical capital accumulation drops by about 12 percent from the no-insurance steady state. Individuals move from self-insurance via savings into buying insurance contracts or signing up for Medicaid if they fulfill the eligibility criteria. As a result, the production of non-medical goods Y_c is 14 percent lower in the US system.

On the other hand, the medical sector production in the US system is 7.8 percent larger due to increases in demand triggered by the wide availability of insurance. This is a typical ex-post moral hazard effect. Insurance decreases the effective price of health care via two channels: (*i*) health insurance picks up a share of the medical bill so that households only pay a fraction of the price and (*ii*) health insurance reduces the sticker price charged for medical services by providers because insurance companies have market power and can negotiate lower prices on behalf of their clients.[19] Overall medical spending under the US system is lower despite the increase in medical consumption. This is mainly driven by the decrease in the price of medical services.

Welfare. In a conventional Bewley model, idiosyncratic income shocks and missing consumption insurance impose a welfare cost caused by consumption uncertainty. In our extended Bewley model, the presence of health shocks introduces an additional source of spending and income risk which affects consumption, savings and the stock of health capital. Risk-averse individuals benefit, at least in expectation, from health insurance contracts against health risk as these contracts facilitate consumption smoothing. In order to quantify the welfare gains from having access to health insurance we construct a welfare measure expressed in terms of permanent consumption compensation. More specifically, we compute the consumption equivalent variation (CEV) which is the percentage increase in lifetime consumption required to make a newborn individual indifferent between the No-Health-Insurance system and the US system. A negative CEV denotes a welfare loss from introducing the US system into the No-Health-Insurance economy and a positive CEV denotes a welfare gain of the US system over the No-Health-Insurance case.

There are two opposing welfare effects in our setting. Insurance causes incentive distortions (i.e., ex-post moral hazard) and decreases aggregate income which lowers overall welfare due to a negative income effect. On other hand, some of the insurance policies redistribute income and reduce the exposure to health risk which results in welfare gains. When these two effects are evaluated together, the positive welfare effects outweigh the negative welfare effects. These welfare gains are observed across all four permanent income (or skill) groups. The low income groups benefit relatively more from health insurance. The lowest income group experiences welfare gains of about 6.5 percent of CEV compared to the more moderate welfare gains of 1.5 percent for the highest income group. This outcome is mainly due to the redistribution effect of Medicare and, more importantly, Medicaid which targets low income groups. Overall, the US system generates a significant welfare gain of about 5.2 percent. Other things equal, all income groups prefer to live in an economy with the US health insurance system over an economy without any health insurance.

[19] As discussed in Section 4.6 we do not model this bargaining process explicitly. We exogenously impose markups over a base price for medical services so that the price difference between an uninsured and insured individual matches price differences observed in the data.

The welfare benefit of the US health insurance system reported in our paper is larger than the welfare benefits of other social insurance programs reported in previous studies, including unemployment insurance program in Hansen and Imrohoroglu (1992), social security program in İmrohoroğlu, İmrohoroğlu and Joines (1995) and Fuster, Imrohoroglu and Imrohoroglu (2007), and means-tested social insurance programs in Braun, Kopecky and Koreshkova (2017).

5.2 System 2: Private health insurance

In this section, we explore the welfare and output effects of a private health insurance system in a dynamic general equilibrium economy with a health risk structure similar to the US economy. We consider two private health insurance (PHI) systems which differ in terms of government regulations of insurance premiums and medical prices as described in Section 3.8.2.

	[0] No Health Ins.	**[2] Private Health Insurance (PHI)**	
		[2A] Unregulated	**[2B] Regulated**
Premium discrimination	N/A	YES	NO
Premium tax deduct.	N/A	NO	YES
Medical price markup	70%	70% if not insured 20% if insured	70% if not insured 20% if insured
Insured Workers (%)	0	0	69.85
• IHI (%)	-	0	-
• GHI (%)	-	-	69.85
Insured Retirees (%)	0	0	29.83
• IHI (%)	-	-	-
• GHI (%)	-	0	29.83
Med. consumption (M)	100	100	103.64
Med. spending ($p_m M$)	100	100	87.45
Capital (K_c)	100	100	98.76
Output (Y_c)	100	100	100.44
Welfare (CEV-%)	0	0	+5.01
• Income Group 1 (%)	0	0	+1.92
• Income Group 2 (%)	0	0	+4.60
• Income Group 3 (%)	0	0	+7.23
• Income Group 4 (%)	0	0	+10.34

Table 2: **Private Health Insurance (PHI) System.**
This table presents steady state results after introducing a market-based system of private health insurance into an economy with no health insurance. We model two different versions. First, an unregulated economy with individual health insurance (IHI) and premium price discrimination and second, a regulated economy with group health insurance (GHI). Government regulation prevents price discrimination in GHI markets and allows premium payments to be tax deductible. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the No-Health-Insurance case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

Unregulated PHI System. We start with an unregulated PHI system without government regulations on insurance premiums and medical prices. Insurance companies are allowed to price discriminate and charge premiums according to health status and age, while healthcare providers can charge markups on medical prices. Under this unregulated PHI system, health insurance policies are similar to individual health insurance (IHI) policies in the US model. We report the results in column [2A] of Table 2.

The unregulated PHI system is not viable in an economy with a health risk structure similar to the US economy. The main reason is an adverse selection spiral caused by information asymmetry in our setting. Individuals know their past and current health shocks when they form expectations about future health shocks which determines their willingness to pay for health insurance. Insurance companies, on the other hand, have only limited information about the history of individual-specific health shocks as they only observe the current age and the current health state before the new health shocks arrive. Insurance companies are therefore unable to work out the actuarially fair price for each age and health risk type, which consequently causes adverse selection in the PHI markets. The viability of PHI markets depends crucially on who chooses to enroll. If relatively healthy individuals exit from the pool, premiums of PHI contracts rise and more individuals will exit. In our model this adverse selection problem eliminates unregulated PHI markets completely so that all individuals are left without insurance. The equilibrium outcome with the unregulated PHI system is identical to the no-insurance benchmark. This complete market failure in our model is consistent with classic results documented in the insurance literature on adverse selection spirals (e.g., Pauly (1974) and Rothschild and Stiglitz (1976)).[20]

Regulated PHI System. In our calibrated model, incomplete markets and adverse selection restrict the type of private insurance contracts available in equilibrium, which creates a potential role for government regulation. We therefore consider a regulated PHI system next. In this system the government does not allow insurance companies to price discriminate by health status and age. In addition, the government allows for tax deductibility of premium payments from income taxes. Under this regulated PHI system, health insurance policies are similar to group health insurance (GHI) policies in the US system. We report the results of this system in column [2B] of Table 2.

We find that these regulations make the PHI market viable. As reported in column [2B] of Table 2, with 20 percent negotiated price markup (down from 70 percent in the no-insurance case) the PHI take-up rates are 70 percent and 30 percent for the working population and the retired population, respectively.[21] When insurance companies are able to secure lower prices from providers, they can offer more affordable insurance premium to individuals. However, the market-based system, even with government subsidies and premium regulation, fail to eliminate the adverse selection issue and therefore does not result in universal insurance take-up. Many young and healthy individuals who face very low health risk opt out of PHI as do low income groups who cannot afford the premiums.

Regulated PHI markets provide a mechanism to pool health risk so that households are able to defray some of the healthcare cost. This improves the allocation of health risk and redistributes income toward unhealthy individuals. Although the government does not provide health insurance

[20] Welfare costs of adverse selection have been estimated in Cutler and Reber (1998).

[21] If PHI companies are not able to negotiate lower price markups with providers, then regulated PHI markets are also not viable and an adverse selection spiral sets in that completely unravels the insurance market.

directly, it implicitly provides social health insurance via subsidizing PHI premiums and regulating premium pricing policies. On other hand, similar to our earlier experiments individuals with health insurance reduce their savings. The stock of aggregate capital decreases slightly by about 1.2 percent, while human capital increases due to increases in labor supply. There is a small increase in non-medical goods production and an expansion of 3.6 percent in medical goods production. Overall, even though this market-based approach to sharing health risk does not result in universal coverage, welfare gains are realized for all income groups as reported in the lower part of Table 2 in column [2B]. High income individuals benefit the most as they are the most likely to buy PHI. The tax deductibility introduces a regressive element that further benefits high income groups.

The PHI system with government regulation exhibits a lower degree of risk pooling and a lower degree of redistribution of wealth compared to the US system. However, the efficiency losses in terms of reduced capital accumulation and output are less pronounced under the regulated PHI system because of the lower tax burden. Overall, the PHI system with government regulation produces slightly smaller overall welfare gains than the US system.

5.3 System 3: Universal public health insurance

In this section we analyze the effects of a universal public health insurance (UPHI) system as described in Section 3.8.3. Specifically, the government sets the coinsurance rate $\gamma^{\text{UPHI}} = 0.2$, which is identical to the calibrated value of Medicare in the benchmark model. The government uses either a consumption tax or a payroll tax to finance the UPHI system. The government also eliminates all markups on medical prices in the UPHI system.[22]

The results for the UPHI system financed by a consumption tax and a payroll tax are reported in columns [3A] and [3B] of Table 3, respectively.

[22] We later provide results for 20 percent and 70 percent medical price markups in the UPHI system to demonstrate the role of medical price markups.

	[0] No Health Ins.	[3] UPHI ($\gamma^{\text{UPHI}} = 0.2$)	
		[3A] with τ_C	**[3B] with τ_V**
Medical price markup	70%	0%	0%
Insured via UPHI (%)	0	100	100
Cons. tax - τ_C (%)	4.31	19.87	2.86
Payroll tax - τ_V(%)	0	0	14.11
Med. consumption (M)	100	117.44	111.43
Med. spending ($p_m M$)	100	90.34	85.38
Capital (K_c)	100	90.07	81.85
Output (Y_c)	100	92.70	87.53
Welfare (CEV - %):	0	+4.86	+5.38
• Income Group 1-Low (%)	0	+18.62	+26.27
• Income Group 2 (%)	0	+7.30	+6.83
• Income Group 3 (%)	0	−6.96	−10.46
• Income Group 4-High (%)	0	−12.53	−15.62

Table 3: **Universal Public Health Insurance (UPHI) System.**
This table presents the effects of introducing a UPHI system into an economy with no health insurance. The UPHI system is either financed by a consumption tax in column [2A] or a payroll tax on wage income in column [2B]. The coinsurance rate is set at 20%, i.e., $\gamma^{UPHI} = 0.2$. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the No-Health-Insurance case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

Aggregates. The introduction of the UPHI system reduces individuals' dependence on self-insurance. This subsequently leads to significant decreases in capital accumulation and output. In particular, aggregate capital stock decreases by 8.3 percent and subsequently output decreases by 10 percent (column [3A]) compared to the No-Health-Insurance case. The decline in capital accumulation is due to disincentives to save as well as negative income effects triggered by higher taxes that are needed to finance the UPHI system. Notice that the introduction of UPHI completely eliminates the adverse selection problem as participation in the health insurance program through the tax system is compulsory. In order to finance the large increase in demand for medical services after the UPHI is introduced, the government has to increase the consumption tax τ^C from 4.3 percent to 19.87 percent. This increase represents a direct measure of the cost of full health insurance coverage. If the UPHI system is financed by a payroll tax on wage income then a 14.1 percent tax is required.

Welfare. The introduction of the UPHI system pools the health risk of all individuals which is welfare improving (insurance effect). On the other hand, the UPHI system creates incentive problems as it introduces large tax distortions, discourages individuals to save for self-insurance and encourages increased health spending (ex-post moral hazard) which potentially leads to efficiency and welfare losses (incentive effect). The welfare benefit of a UPHI system depends on the trade-off between the insurance and the incentive effect.

In our heterogeneous agent framework, the welfare effects vary across income groups. First, low income groups experience welfare gains while higher income groups experience welfare losses compared to the No-Health-Insurance economy. The welfare gain is 18.6 percent for the lowest income group as opposed to a welfare loss of 12.5 percent for highest income group. These opposing welfare effects are driven by redistribution. The UPHI system redistributes income towards "unlucky" individuals that experience large health shocks. Overall, the UPHI system creates a welfare gain of about 4.9 percent in terms of CEV. This finding indicates that the welfare gains associated with the insurance effect dominate the welfare losses associated with the adverse incentive effects.

The insurance and incentive effects are also influenced by the specific tax policy that the government implements to finance the UPHI system. The payroll tax on wage income is slightly progressive as low income individuals are tax exempt. As reported in column [2B] of Table 3, the positive welfare effects experienced by low income groups are much larger while high income groups suffer from larger welfare losses. The overall welfare effect is larger with a payroll tax as a financing instrument.

The role of coinsurance rates. In our endogenous health model, the coinsurance rate affects household's incentives to consume medical services. By changing the coinsurance rate the government is able to vary the degree of ex-post moral hazard in medical consumption. Smaller coinsurance rates shift the financial burden of medical care toward the government. On the other hand, larger coinsurance rates require households to contribute more out-of-pocket to finance their health expenditures.

In the baseline analysis, the coinsurance rate is set at 20 percent which is the level of Medicare in the US benchmark calibration. We next allow the government to set different coinsurance rates according to $\gamma^{\text{UPHI}} = [0.1, 0.2, 0.3, 0.4, 0.5]$. We report the results in Table 4.

	[3A] UPHI with τ_C				
Coinsurance rate -γ^{UPHI}	0.1	0.2	0.3	0.4	0.5
Medical price markup	0%	0%	0%	0%	0%
Cons. tax - τ_C (%)	31.0	19.9	16.6	14.1	12.1
Output (Y_c)	88.3	92.7	93.7	95.2	96.4
Welfare (CEV):	−7.0	+4.8	+7.3	+7.1	+6.4
• Income Group 1 (%)	+10.1	+18.6	+20.2	+18.0	+15.3
• Income Group 2 (%)	−5.1	+7.30	+9.4	+9.3	+8.2
• Income Group 3 (%)	−20.6	−6.96	−4.0	−2.4	−1.6
• Income Group 4 (%)	−26.5	−12.5	−6.7	−6.7	−5.2

Table 4: **UPHI System with Different Coinsurance Rates.**
This table presents steady state results comparing the No-Health-Insurance regime to the equilibrium outcomes with UPHI financed by a consumption tax. We allow for different levels of generosity of UPHI as presented by variations in the coinsurance rate. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the No-Health-Insurance case. Each column presents steady-state results solved with a different co-insurance rate for UPHI. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

The coinsurance rate affects the incentive to purchase medical services and thus the degree of ex-post moral hazard, which subsequently affects the trade-off between the insurance and incentive effects.[23] In our model, the improved risk sharing and redistributional measures embedded in the UPHI system result in welfare gains for low income individuals in poor health and welfare losses for high income individuals in good health. The final welfare outcome depends on the strength of the negative effects triggered by ex-post moral hazard and fiscal distortions. In our framework, the size of these negative effects depends on the magnitude of the coinsurance rate. When the coinsurance rate is small, individuals pay for a smaller share of total health expenditure out-of-pocket. This implies a larger ex-post moral hazard effect which leads to larger tax distortions as the government has to impose higher taxes to finance a higher level of medical spending.

More specifically, our results indicate that with a small coinsurance rate of $\gamma^{\text{UPHI}} = 0.1$ the welfare losses caused by the ex-post moral hazard effect (i.e., it increases medical consumption by 49 percent) and fiscal distortions of high consumption tax rate (i.e., $\tau_C = 31$ percent) dominate the welfare gains from improved risk sharing and income redistribution. The net welfare effect is negative and households are worse off with this UPHI system than if there was no insurance available at all. A higher coinsurance rate reduces the degree of ex-post moral hazard in the economy. With coinsurance rates of $\gamma^{\text{UPHI}} \geq 0.2$ positive welfare outcomes are realized as moral hazard is reduced. As the coinsurance rate increases further the welfare gains increase. However, for coinsurance rates larger than 30 percent, the exposure to health spending risk increases and the welfare gains start to decrease. Overall, we observe a hump-shaped pattern of welfare gains over the range of coinsurance rates reported in Table 4.

In order to characterize the optimal coinsurance rate where the UPHI system optimally balances the insurance against the incentive effect we follow the approach in Conesa, Kitao and Krueger (2009) and assume that the government maximizes the ex-ante lifetime utility of an individual born into the stationary equilibrium implied by the chosen coinsurance rate. More formally, the government's objective is defined as

$$\gamma_{max}^{\text{UPHI}} = \underset{\gamma^{\text{UPHI}} \in [0,1]}{\operatorname{argmax}} \int V\left(x_{j=1}; \gamma^{\text{UPHI}}\right) d\Lambda\left(x_{j=1}\right).$$

Notice that the government maximizes the social welfare function over the coinsurance rate only and keeps all other fiscal policy variables unchanged. We assume that the government uses a consumption tax to finance the UPHI system in this optimization.

Our results indicate that a coinsurance rate of 38.5 percent efficiently trades off the positive insurance/redistribution effects with the negative incentive effects and results in the largest welfare of a newborn individual. When the government uses a payroll tax the optimal coinsurance rate is slightly larger at 39 percent. This estimate is in the range of studies by Blomqvist (1997) who finds optimal coinsurance rates in the mid 20 percent range and studies by Feldstein and Friedman (1977) and Manning and Marquis (1996) who find higher values up to 60 percent.

Our positive welfare outcome of a UPHI system is somewhat different from the classic result in the literature analyzing the welfare implications of social security in stochastic dynamic

[23] The effects of linear coinsurance under ex post moral hazard, where insurers pay the same fraction of the health care cost whatever the individuals expenses, have been analyzed in partial equilibrium models (e.g., see Zeckhauser (1970) and Feldstein (1973)).

general equilibrium frameworks (e.g., Auerbach and Kotlikoff (1987), İmrohoroğlu, İmrohoroğlu and Joines (1995), Conesa and Krueger (1999) and Fuster, Imrohoroglu and Imrohoroglu (2007)). This literature shows that the general equilibrium channels amplify the fiscal distortions caused by social security so that the introduction of a pay-as-you-go social security program generates welfare losses. Hansen and Imrohoroglu (1992) report welfare gains after the introduction of an unemployment insurance program. More recently, Braun, Kopecky and Koreshkova (2017) demonstrate the welfare benefits of means-tested social insurance programs. Our results indicates a similar welfare outcome for a public health insurance program such as the UPHI system.

The role of medical price markups. In the benchmark calibration we stipulated that price markups for medical services are the result of price negotiations between health care providers and insurance companies or individuals without insurance. We did not explicitly model the formation of these markups but rather imposed exogenous markups that were calibrated to data. In this section we postulate that the government can regulate these markups directly in order to influence the price of medical services and the level of medical consumption.

Since medical prices affect household's incentives to consume medical services, the government is able to affect the degree of ex-post moral hazard in medical consumption via this channel. By changing the medical price markups, the government also changes the lump-sum dispersion of provider profits which by itself provides a redistribution channel from households with high medical expenses to households with good health and low medical spending.

In the baseline analysis, the medical price markup is set to zero which is the markup for Medicare in the US calibration. In order to better understand the effects of this channel we analyze two alternative cases where the government allows higher markups on medical prices of 20 percent and 70 percent, respectively. Note that in these experiments all other fiscal policy variables are identical to the ones in the baseline analysis, including the 20 percent coinsurance rate. We report the results of this exercise in Table 5.

	[0] No HI	[3] UPHI ($\gamma^{\text{UPHI}} = 0.2$)						
		[3A] with τ_C				[3B] with τ_V		
Med. price markup	70%	70%	20%	0%		70%	20%	0%
Insured via UPHI (%)	0	100	100	100		100	100	100
Cons. tax - τ_C (%)	4.31	31.26	22.54	19.87		1.50	2.57	2.86
Payroll tax - τ_V(%)	0	0	0	0		26.29	17.13	14.11
Med. consumption (M)	100	106.51	112.23	117.44		102.59	107.85	111.43
Med. spending ($p_m M$)	100	139.58	103.71	90.34		133.63	99.18	85.38
Capital (K_c)	100	85.33	89.52	90.07		70.01	79.13	87.53
Output (Y_c)	100	86.09	91.24	92.70		74.90	84.49	81.85
Welfare (CEV-%):	0	+11.73	+7.70	+4.86		+6.93	+7.02	+5.38
• Income Group 1 (%)	0	+49.04	+27.79	+18.62		+59.61	+36.62	+26.27
• Income Group 2 (%)	0	+12.48	+9.89	+7.30		+4.49	+7.76	+6.83
• Income Group 3 (%)	0	−14.22	−8.10	−6.96		−26.41	−13.95	−10.46
• Income Group 4 (%)	0	−25.21	−15.44	−12.53		−36.87	−20.98	−15.62

Table 5: **Universal Public Health Insurance (UPHI).**
This table presents steady state results comparing the economy without health insurance to economies with UPHI and different price markups for medical services. The UPHI program is either financed by a consumption tax in column [3A] or payroll tax in column [3B]. The coinsurance rate is set at 20%, i.e., $\gamma^{UPHI} = 0.2$. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the No-Health-Insurance case. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

Our results show that higher markup rates reduce the quantity of medical services (M) consumed, but increase the total medical spending costs ($p_m \times M$) due to higher medical prices. This implies that the government can mitigate the adverse effects of moral hazard by raising the markup. However, this policy amplifies the adverse effects of tax distortions caused by the need for higher taxes to finance relatively larger UPHI systems. Overall, we still observe positive welfare outcomes for all cases. Interestingly, the welfare gains from introducing UPHI in an economy without insurance are larger for cases with higher markup rates than the case with a zero markup.

It is important to note that the lump-sum redistribution of provider profits that are generated by the price markups plays a crucial role in generating overall positive welfare effects. If profits would be redistributed to a subset of households (say high income households only), then overall welfare gains from higher markups are less likely.

5.4 Switching from the US system to the UPHI system

Our previous analysis shows that the UPHI system can outperform the US system in terms of welfare if the coinsurance rate is appropriately chosen. In this section, we consider a structural reform proposal that replaces the US system with a UPHI system. Technically, the proposal is synonymous with the expansion of Medicare to all workers.[24] We consider a number of different coinsurance rates: $\gamma^{\text{UPHI}} = [0.2,\ 0.3,\ 0.4,\ 0.5]$ and let the consumption tax adjust to finance

[24]A policy reform that would allow younger workers to purchase Medicare coverage from the government has been discussed in the US since the Clinton administration. Hansen, Hsu and Lee (2014) study the welfare effects of Medicare buy-in for older workers aged 55-64.

the UPHI system. We report the results in Table 6. The economy with the US system now serves as benchmark with level variables normalized to 100 or 0.

	[1] US System	**[3A] UPHI with τ_C**			
		$\gamma^{\text{UPHI}} = 0.2$	0.3	0.4	0.5
Cons. tax - τ_C (%)	5.0	19.9	16.6	14.1	12.1
Med. consumption (M)	100	108.71	100.58	96.82	95.17
Med. spending ($p_m M$)	100	98.52	94.33	90.87	89.37
GDP	100	99.08	100.68	101.99	103.18
Welfare (CEV):	0.00	-1.90	$+1.58$	$+1.80$	$+1.33$
• Income Group 1 (low)	0.00	$+10.23$	$+12.72$	$+10.92$	$+8.83$
• Income Group 2	0.00	-1.30	$+2.25$	$+2.33$	$+1.60$
• Income Group 3	0.00	-10.73	-6.60	-4.89	-3.97
• Income Group 4	0.00	-14.42	-10.44	-7.97	-6.43

Table 6: **A Switch from the US-System to a UPHI System Financed by Consumption Tax.**

This table presents steady state results comparing the US health insurance system to the equilibrium outcomes with UPHI financed by a consumption tax. We allow for different levels of generosity of UPHI as presented by variations in the coinsurance rates. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the US-benchmark case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

The UPHI system with a coinsurance rate of $\gamma^{\text{UPHI}} = 0.2$ results in a 1 percent drop of GDP compared to the steady state outcome under the US system. The same experiments with slightly less generous UPHI, i.e. $\gamma^{\text{UPHI}} \geq 0.3$, lead to GDP growth. This implies that higher coinsurance rates can mitigate the adverse effects from moral hazard and tax distortions. This risk pooling and redistribution mechanism indeed lead to increases in capital accumulation and output.

The welfare outcomes are non-linear. There is overall welfare loss when switching from the US system to the UPHI system with $\gamma^{\text{UPHI}} = 0.2$. However, there are large welfare gains when switching to the UPHI system with $\gamma^{\text{UPHI}} \geq 0.3$. The intuition is as follows. The UPHI system pools risk more efficiently across the different groups and redistributes wealth more equitable. The overall welfare gains are mainly driven by welfare gains of the low income groups who now can access medical services at a lower price. High income groups are better off under the US system. As can be seen in Figures (5) and (6) the variation of out-of-pocket health expenditures and health capital is lowest over the entire lifecycle under the UPHI system (red line in the figures). Figure (7) shows relative variation normalized with the mean value of health capital per age group over the lifecycle. [25]

Payroll tax as financing tool. We next assume that the government uses a payroll tax to finance the reform proposal. We report the results in Table 7.

[25] We assume that all markups on the price of medical care are removed when switching to the UPHI system. Changing the price of medical services is another redistribution mechanism that affects the final welfare outcome. After the reform, the working population can consume medical services at a lower price; meanwhile, the retiring population has to pay a higher price. We compare the reforms with and without markups and find that the effects from this channel does not change our main result.

This payroll tax is more progressive as it redistributes funds from high income individuals to low income and less healthy individuals. The positive welfare effects experienced by low income groups are now much larger while high income groups suffer from larger welfare losses. Surprisingly, the aggregate welfare effect is similar across the two financing regimes.

	[1] US System	**[3B] UPHI with τ_V**			
		$\gamma^{\text{UPHI}} = 0.2$	0.3	0.4	0.5
Payroll tax - τ_V (%)	0.00	14.1	11.2	9.1	7.2
Med. consumption (M)	100	103.58	97.86	95.75	94.86
Med. spending ($p_m M$)	100	93.37	91.50	89.65	88.90
GDP	100	93.82	96.33	98.61	100.58
Welfare (CEV):	0.00	-2.47	$+0.78$	$+0.93$	$+0.51$
• Income Group 1 (low)	0.00	$+15.17$	$+15.97$	$+12.94$	$+10.03$
• Income Group 2	0.00	-2.57	$+0.93$	$+1.11$	$+0.50$
• Income Group 3	0.00	-14.51	-9.74	-7.46	-5.99
• Income Group 4	0.00	-17.67	-13.18	-10.15	-8.00

Table 7: **A Switch from the US-System to a UPHI System Financed by Payroll Tax.** This table presents steady state results comparing the US health insurance system to the equilibrium outcomes with universal public health insurance (UPHI) financed by a payroll tax on wage income greater than $200,000. We allow for different levels of generosity of UPHI as presented by variations in the coinsurance rates. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are indexed to normalized values of the US-benchmark case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

Taxing labor income to finance the UPHI system reduces labor supply and therefore GDP by more than in the earlier case with consumption tax financing. However, the overall pattern of the welfare effects are quite similar and vary significantly across income groups. Interestingly, the optimal coinsurance rate is higher when using a payroll tax as financing source. The intuition is that the higher coinsurance rate reduces the degree of moral hazard and mitigates the fiscal burden and adverse effects on work incentives.

Hence, our findings indicate that switching from the UPHI system to he US system results in overall welfare gains if the coinsurance rate is large enough at around 30 percent in order to keep the negative effects of ex-post moral hazard in check. However, such radical reform faces political impediments because of opposing welfare effects across different income groups. Low income households prefer to switch to the UPHI system while high income households oppose the change and prefer to keep the US system.

6 Conclusion

In this paper we investigate the welfare implications of different health insurance systems and their effectiveness in insuring health risk over the lifecycle. We develop a generalized Bewley-Grossman model that matches the lifecycle structure of earnings and health risks in US data. We use the model to evaluate the potential welfare benefits of three different health insurance systems that differ in the degree of government involvement. We specifically consider: (i) a mixed public and private insurance system similar to the pre-ACA US system, (*ii*) a private health insurance system with/without government regulation, and (*iii*) a universal public health insurance system.

Our results indicate that the introduction of the US system into an economy with no health insurance results in large welfare gains. This implies that the positive insurance/redistribution effects strongly dominate the negative incentive effects caused by tax distortions and ex-post moral hazard effects. However, the US system does not deliver the best welfare outcome. A UPHI system with appropriately chosen coinsurance rates can outperform the US system in terms of overall welfare gains. The coinsurance rate plays an important role in determining the welfare benefit of the UPHI system. There is an optimal coinsurance rate that balances the trade-off between positive insurance and negative incentive effects and maximizes welfare.

More importantly, we find that these three distinct approaches to providing health insurance lead to opposing welfare outcomes for different income groups. Low income households benefit more from the UPHI system whereas high income households benefit more from the US system or the PHI system. There are significant welfare gains when switching from the US system to the UPHI system with coinsurance rates of 30 percent and higher. However, this radical reform faces political challenges as middle and high income groups would experience welfare losses and will therefore oppose such reform proposals.

Other elements in the model—such as high administrative costs, price markups due to inefficiencies of private insurance markets, concerns about equity in health outcomes, and other forms of social insurance provided through social security, minimum consumption floors and progressive taxes—could potentially interact with the social insurance role of a health insurance programs. We leave a detailed analysis of these further issues for future research.

There are also several modeling extensions possible in future work. The optimality of insurance contracts is currently restricted to the analysis of a single policy instrument – coinsurance rates with a linear tax adjusting to balance the public insurance program or a base premium adjusting to balance the private health insurance contract. More general policy instruments (i.e., progressive taxes, differential premiums, etc.) can be investigated to describe optimal equilibrium outcomes. The large state space of the model and computational constraints prevent us from providing a description of the transition dynamics. Solutions for transitions between different health insurance systems would be required to answer the question of reform implementability that we hinted at in the welfare discussions. The lack of a bequest motive and the imposed independence of survival from health states lead to lower than observed assets holdings of the retired cohorts and affect the level of self-insurance via savings.

References

Aiyagari, Rao S. 1994. "Uninsured Idiosyncratic Risk and Aggregate Saving." *The Quarterly Journal of Economics* pp. 659–684.

Anderson, Gerard. 2007. "From 'Soak The Rich' To 'Soak The Poor': Recent Trends In Hospital Pricing." *Health Affairs* 26(3):780–789.

Auerbach, J. Alan and Laurence J. Kotlikoff. 1987. *Dynamic Fiscal Policy.* Cambridge: Cambridge University Press.

Bernard, Didem, Cathy Cowan, Thomas Selden, Lining Cai, Aaron Catling and Stephen Heffler. 2012. "Reconciling Medical Expenditure Estimates from the MEPS and NHEA, 2007." *Medicare & Medicaid Research Review* 2(4):1–19.

Besley, Timothy. 1989. "Publicly Provided Disaster Insurance for Health and the Control of Moral Hazard." *Journal of Public Economics* 39(2):141–156.

Besley, Timothy J. 1988. "Optimal Reimbursement Health Insurance and the Theory of Ramsey Taxation." *Journal of Health Economics* 7(4):321–336.

Bewley, Truman. 1986. Stationary Monetary Equilibrium with a Continuum of Independently Fluctuating Consumers. In *Werner Hildenbrand, Andreu Mas-Colell (Eds.), Contributions to Mathematical Economics in Honor of Gerard Debreu.* North-Holland.

Blomqvist, Åke. 1997. "Optimal Non-Linear Health Insurance." *Journal of Health Economics* 16(3):303–321.

Blomqvist, Ake and Henrik Horn. 1984*a*. "Public Health Insurance and Optimal Income Taxation." *Journal of Public Economics* 24(3):353–371.

Blomqvist, Åke and Henrik Horn. 1984*b*. "Public Health Insurance and Optimal Income Taxation." *Journal of Public Economics* 24(3):353–371.

Blomqvist, Åke and Per-Olov Johansson. 1997. "Economic Efficiency and Mixed Public/Private Insurance." *Journal of Public Economics* 66(3):505–516.

Braun, Anton, Karen Kopecky and Tatyana Koreshkova. 2017. "Old, Sick, Alone, and Poor: A Welfare Analysis of Old-Age Social Insurance Programmes." *Review of Economics Studies* 84:580–612.

Brown, Paul. 2006. *Paying the Price: The High Cost of Prescription Drugs for Uninsured Californians.* CALPIRG Education Fund.

Capatina, Elena. 2015. "Life-Cycle Effects of Health Risk." *Journal of Monetary Economics* 74:67–88.

Carrin, Guy and Chris James. 2005. "Social Health Insurance: Key Factors Affecting the Transition Towards Universal Coverage." *International Social Security Review* 58(1):45–64.

Chetty, Raj and Emmanuel Saez. 2010. "Optimal Taxation and Social Insurance with Endogenous Private Insurance." *American Economic Journal: Economic Policy* 2:85–114.

Conesa, Juan Carlos, Sagiri Kitao and Dirk Krueger. 2009. "Taxing Capital? Not a Bad Idea after All." *American Economic Review* 99(1):25–48.

Conesa, Juan and Dirk Krueger. 1999. “Social Security Reform with Heterogeneous Agents.” *Review of Economics Dynamics* 2:757–795.

Council of Economic Advisors. 1998. Economic Report of the President, United States Government Printing Office.

Cremer, Helmuth and Pierre Pestieau. 1996. “Redistributive Taxation and Social Insurance.” *International Tax and Public Finance* 3(3):281–295.

Culyer, Anthony J. and Adam Wagstaff. 1993. “Equity and Equality in Health and Health Care.” *Journal of Health Economics* 12(4):431–457.

Cutler, David M. and Sarah J. Reber. 1998. “Paying for Health Insurance: The Trade-off between Competition and Adverse Selection.” *The Quarterly Journal of Economics* 113(2):433–466.

Deaton, A. 1991. “Saving and Liquidity Constraints.” *Econometrica* 59(5):1221ï¿½1248.

Donahoe, Gerald F. 2000. “Capital in the National Health Accounts.” Health Care Financing Administration, Sept. 28, 2000.

Feldstein, Martin. 1973. “The Welfare Loss of Excess Health Insurance.” *Journal of Political Economy* 81:251–280.

Feldstein, Martin and Bernard Friedman. 1977. “Tax Subsidies, the Rational Demand for Insurance and the Health Care Crisis.” *Journal of Public Economics* 7(2):155–178.

Feng, Zhigang. 2010. Macroeconomic Analysis of Universal Coverage in the U.S. In *Social Computing, Behavioral Modeling and Prediction*, ed. S. K. Chai, J. J. Salemo and P. L. Mabry. Springer pp. 87–96.

Finkelstein, Amy and Robin McKnight. 2008. “What Did Medicare Do (And Was It Worth It)?” *Journal of Public Economics* 92(7):1644–1668.

Fonseca, Raquel, Pierre-Carl Michaud, Titus Galama and Arie Kapteyn. 2013. “Accounting for the Rise of Health Spending and Longevity.” IZA DP No. 7622.

French, Eric. 2005. “The Effects of Health, Wealth, and Wages on Labor Supply and Reitrement-Behaviour.” *Review of Economic Studies* 72:395–427.

French, Eric and John B. Jones. 2011. “The Effects of Health Insurance and Self-Insurance on Retirement Behavior.” *Econometrica* (79):693–732.

Fuster, Luisa, Ayse Imrohoroglu and Selahattin Imrohoroglu. 2007. “Elimination of Social Security in a Dynastic Framework.” *Review of Economic Studies* 74 (1):113–145.

Galama, Titus J., Patrick Hullegie, Erik Meijer and Sarah Outcault. 2012. “Empirical Evidence for Decreasing Returns to Scale in a Health Capital Model.” Working Paper, Health, Econometrics and Data Group at the University of York.

Golosov, Mikhail and Aleh Tsyvinski. 2006. "Designing Optimal Disability Insurance: A Case for Asset Testing." *Journal of Political Economy* 114 (No 2):257–279.

Gouveia, Miguel and Robert P. Strauss. 1994. "Effective Federal Individual Income Tax Functions: An Exploratory Empirical Analysis." *National Tax Journal* 47:317–339.

Grossman, Michael. 1972*a*. "The Demand for Health: A Theoretical and Empirical Investigation." Columbia University Press for the National Bureau of Economic Research, New York.

Grossman, Michael. 1972*b*. "On the Concept of Health Capital and the Demand for Health." *Journal of Political Economy* 80(2):223–255.

Grossman, Michael. 2000. *Handbook of Health Economics*. Elsevier North Holland chapter The Human Capital Model, pp. 347–408.

Gruber, Jonathan and David Rodriguez. 2007. "How Much Uncompensated Care Do Doctors Provide?" *Journal of Health Economics* 26(6):1151–1169.

Hall, Robert E. and Charles I. Jones. 2007. "The Value of Life and the Rise in Health Spending." *Quarterly Journal of Economics* 122(1):39–72.

Hansen, Gary D. and Ayse Imrohoroglu. 1992. "The Role of Unemployment Insurance in an Economy with Liquidity Constraints and Moral Hazard." *Journal of Political Economy* 100(1):118–142.

Hansen, Gary D, Minchung Hsu and Junsang Lee. 2014. "Health insurance reform: The impact of a medicare buy-in." *Journal of Economic Dynamics and Control* 45:315–329.

Heathcote, Jonathan, Kjetil Storesletten and Giovanni L. Violante. 2008. "Insurance and Opportunities: A Welfare Analysis of Labor Market Risk." *Journal of Monetary Economics* 55(3):501–525.

Hubbard, Glenn R., Jonathan Skinner and Stephen P. Zeldes. 1995. "Precautionary Saving and Social Insurance." *The Journal of Political Economy* 103(2):369–399.

Hubbard, R. Glenn and Kenneth Judd. 1987. "Social Security and Individual Welfare." *American Economic Review* 77(4):630–646.

Huggett, Mark. 1993. "The Risk-Free Rate in Heterogeneous-Agent Incomplete-Insurance Economies." *The Journal of Economic Dynamics and Control* 17(5-6):953–969.

Huggett, Mark and Juan Carlos Parra. 2010. "How Well Does the U.S. Social Insurance System Provide Social Insurance?" *Journal of Political Economy* 118(1):76–112.

Hugonnier, Julien, Florian Pelgrin and Pascal St-Amour. 2013. "Health and (Other) Asset Holdings." *Review of Economic Studies* 80(2):663–710.

İmrohoroğlu, Ayşe, Selahattin İmrohoroğlu and Douglas Joines. 1995. "A Life Cycle Analysis of Social Security." *Economic Theory* 6(1):83–114.

Jeske, Karsten and Sagiri Kitao. 2009. "U.S. Tax Policy and Health Insurance Demand: Can a Regressive Policy Improve Welfare?" *Journal of Monetary Economics* 56(2):210–221.

Jung, Juergen and Chung Tran. 2008. "Transfers and Labor Market Behavior of the Elderly in Developing Countries: Theory and Evidence from Vietnam." Working Paper.

Jung, Juergen and Chung Tran. 2016. "Market Inefficiency, Insurance Mandate and Welfare: U.S. Health Care Reform 2010." *Review of Economic Dynamics* 20:132–159.

Kaiser. 2013. "Where Are States Today? Medicaid and CHIP Eligibility Levels for Children and Non-Disabled Adults." Kaiser Family Foundation Fact Sheet.

Keehan, Sean P., Andrea M. Sisko, Christopher J. Truffer, John A. Poisal, Gigi A. Cuckler, Andrew J. Madison, Joseph M. Lizonitz and Sheila D. Smith. 2011. "National Health Spending Projections Through 2020: Economic Recovery And Reform Drive Faster Spending Growth." *Health Affairs* 30(8):1594–1605.

Kotlikoff, Laurence J. 1988. Health Expenditures and Precautionary Savings. In *What Determines Saving?* Cambridge MIT Press chapter 6.

Krueger, Dirk and Fabrizio Perri. 2011. "Public Versus Private Risk Sharing." *Journal of Economic Theory* 146(3):920–956.

Kydland, Finn E. and Edward C. Prescott. 1982. "Time to Build and Aggregate Fluctuations." *Econometrica* 50(6):1345–1370.

Levin, Laurence. 1995. "Demand for Health Insurance and Precautionary Motive for Savings among the Elderly." *Journal of Public Economics* 57:337–367.

Levine, David K. and W.R. Zame. 2002. "Does Market Incompleteness Matter?" *Econometrica* 70(5):1805–1839.

Manning, Willard G. and M. Susan Marquis. 1996. "Health Insurance: The Tradeoff between Risk Pooling and Moral Hazard." *Journal of Health Economics* 15(5):609–639.

Mendoza, Enrique, G., Assaf Razin and Linda L. Tesar. 1994. "Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Ratees on Factor Incomes and Consumption." *Journal of Monetary Economics* 34(3):297–323.

Nardi. 2010. "Why Do the Elderly Save? The Role of Medical Expenses." *Journal of Political Economy* 118(1):39–75.

Nyman, John A. 1999. "The Economics of Moral Hazard Revisited." *Journal of Health Economics* 18:811–824.

Nyman, John A. 2003. *The Theory of Demand for Health Insurance*. Stanford University Press.

Ozkan, Serdar. 2017. "Preventive vs. Curative Medicine: A Macroeconomic Analysis of Health Care over the Life Cycle." Working Paper, University of Toronto.

Palumbo, Michael G. 1999. "Uncertain Medical Expenses and Precautionary Saving Near the End of the Life Cycle." *Review of Economic Studies* 66(2):395–421.

Pashchenko, Svetlana and Ponpoje Porapakkarm. 2013. "Quantitative Analysis of Health Insurance Reform: Separating Regulation from Redistribution." *Review of Economic Dynamics* 16 (3):383–404.

Pauly, Mark V. 1968. "The Economics of Moral Hazard: Comment." *The American Economic Review* 58(3):531–537.

Pauly, Mark V. 1974. "Overinsurance and Public Provision of Insurance: The Roles of Moral Hazard and Adverse Selection." *The Quarterly Journal of Economics* 88(1):44–62.

Petretto, Alessandro. 1999. "Optimal Social Health Insurance with Supplementary Private Insurance." *Journal of Health Economics* 18:727–745.

Phelps, Charles E. 2003. *Health Economics*. Upper Saddle River, New Jersey: Pearson Education Inc.

Rochet, Jean-Charles. 1991. "Incentives, Redistribution and Social Insurance." *The Geneva Papers on Risk and Insurance Theory* 16(2):143–165.

Rothschild, Michael and Joseph Stiglitz. 1976. "Equilibrium in Competitive Insurance Markets: An Essay on the Economicsof Imperfect Information." *The Quarterly Journal of Economics* 90(4):630–649.

Scholz, John Karl and Ananth Seshadri. 2013. "Health and Wealth in a Life Cycle Model." *Working Paper* .

Scholz, Karl J. and Ananth Seshadri. 2013a. "Health and Wealth in a Lifecycle Model." Working Paper.

Selden, Thomas M. 1997. "More on the Economic Efficiency of Mixed Public/Private Insurance." *Journal of Public Economics* 66(3):517–523.

Shatto, John D. and Kent M. Clemens. 2011. "Projected Medicare Expenditures Under An Illustrative Scenario with Alternative Payment Updates to Medicare Providers." Centers for Medicare and Medicaid Services, Office of the Actuary (May).

Sing, Merrile, Jessica Banthing, Thomas Selden, Cathy Cowan and Sean Keehan. 2006. "Reconciling Medical Expenditure Estimates from the MEPS and NHEA, 2002." *Health Care Financing Review* 28(1):25–40.

Spence, Michael and Richard Zeckhauser. 1971. "Insurance, Information and Individual Action." *The American Economic Review* 61(2):380–387.

SSA. 2007. "Social Security Update 2007." SSA Publication No. 05-10003.

Storesletten, Kjetil, Christopher I. Telmer and Amir Yaron. 2004. "Consumption and Risk Sharing Over the Life Cycle." *Journal of Monetary Economics* 51(3):609–633.

Stratmann, Thomas. 1999. "What Do Medical Services Buy? Effects of Doctor Visits on Work Day Loss." *Eastern Economic Journal* pp. 1–16.

Suen, Richard M. H. 2006. "Technological Advance and the Growth in Health Care Spending." Economie D'Avant Garde, Research Report No. 13. University of Rochester.

Tauchen, George. 1986. "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions." *Ecomomics Letters* 20:177–181.

Ware, John E., Mark Kosinski and Susan D. Keller. 1996. "A 12-Item Short-Form Health Survey: Construction of Scales and Preliminary Tests of Reliability and Validity." *Medical Care* 34(3):220–233.

Yogo, Motohiro. 2016. "Portfolio Choice in Retirement: Health Risk and the Demand for Annuities, Housing and Risky Assets." 80:17–34.

Zeckhauser, Richard J. 1970. "Medical Insurance: A Case Study of the Tradeoff Between Risk Spreading and Appropriate Incentives." *Journal of Economic Theory* 2(1):10–26.

Zhao, Kai. 2014. "Social Security and the Rise in Health Spending." *Journal of Monetary Economics* 64:21–37.

Zweifel, P. and W.G. Manning. 2000. *Handbook of Health Economics, Volume 1*. Elsevier Science chapter Moral Harzard and Consumer Incentives in Health Care, pp. 410–455.

7 Appendix

7.1 Appendix A: Calibration tables

Parameters:		Explanation/Source:
- Periods working	$J_1 = 9$	
- Periods retired	$J_2 = 6$	
- Population growth rate	$n = 1.2\%$	CMS 2010
- Years modeled	$years = 75$	from age 20 to 95
- Total factor productivity	$A = 1$	Normalization
- Growth rate	$g = 2\%$	NIPA
- Capital share in production	$\alpha = 0.33$	Kydland and Prescott (1982)
- Capital in medical services prod.	$\alpha_m = 0.26$	Donahoe (2000)
- Capital depreciation	$\delta = 10\%$	Kydland and Prescott (1982)
- Health depreciation	$\delta_{h,j} = [0.6\% - 2.13\%]$	MEPS 1999/2009
- Survival probabilities	π_j	CMS 2010
- Health Shocks	Technical Appendix	MEPS 1999/2009
- Health transition prob.	Technical Appendix	MEPS 1999/2009
- Productivity shocks	see Section 4	MEPS 1999/2009
- Productivity transition prob.	Technical Appendix	MEPS 1999/2009
- Group ins. transition prob.	Technical Appendix	MEPS 1999/2009
- Price for medical care for uninsured	$\nu^{\text{noIns}} = 0.7$	MEPS 1999/2009
- M price markup for IHI insured	$\nu^{\text{IHI}} = 0.25$	Shatto and Clemens (2011)
- M price markup for GHI insured	$\nu^{\text{GHI}} = 0.1$	Shatto and Clemens (2011)
- M price markup for Medicaid	$\nu^{\text{Maid}} = 0.0$	Shatto and Clemens (2011)
- M price markup for Medicare	$\nu^{\text{Mcare}} = -0.1$	Shatto and Clemens (2011)
- Coinsurance rate: IHI in %	$\gamma_j^{\text{IHI}} \in [22, 46, 48, 49, 50, 53, 52, 50]$	MEPS 1999/2009
- Coinsurance rate: GHI in %	$\gamma_j^{\text{GHI}} \in [33, 33, 33, 34, 36, 36, 45, 50]$	MEPS 1999/2009
- Medicare premiums/GDP	2.11%	Jeske and Kitao (2009)
- Medicaid coinsurance rate in %	$\gamma_j^{\text{Maid}} \in [11, 14, 17, 16, 17, 18, 20, 22]$	Center for Medicare and Medicaid Services (2005)
- Public coinsurance rate retired in %	$\gamma^{\text{R}} = 20$	Center for Medicare and Medicaid Services (2005)

Table 8: **External Parameters.**

These parameters are based on our own estimates from MEPS and CMS data as well as other studies.

Parameters:		**Target Moment:**	**Nr.M.**
- Relative risk aversion	$\sigma = 3.0$	$\frac{K}{Y}$ and R	1
- Preference on consumption vs. leisure:	$\eta = 0.43$	labor supply and $\frac{p \times M}{Y}$	1
- Preference on c and l vs. health	$\kappa = 0.75$	labor supply and $\frac{p \times M}{Y}$	1
- Discount factor	$\beta = 1.0$	$\frac{K}{Y}$ and R	1
- IHI markup profits	$\omega_{j,h} \in [0.6 - 1.5]$	spending profile	8
- Health production productivity	$\phi_j \in [0.2 - 0.45]$	spending profile	15
- TFP in medical production	$A_m = 0.4$	$\frac{p \times M}{Y}$	1
- Production parameter of health	$\xi = 0.26$	$\frac{p \times M}{Y}$	1
- effective labor services production	$\chi = 0.85$	labor supply	1
- Health productivity	$\theta = 1.0$	used for sensitivity analysis	1
- Pension replacement rate	$\Psi = 40\%$	τ^{soc}	1
- Residual Government spending	$\Delta_C = 12.0\%$	size of tax revenue	1
- Minimum health state	$h_{\min} = 0.01$	health spending	1
-Total number of internal parameters:			34

Table 9: **Internal Parameters**.
We choose these parameters in order to match a set of target moments in the data.

Moments	**Model**	**Data**	**Source**	**Nr.M.**
- Medical expenses HH income	17.6%	17.07%	CMS communication	1
- Workers IHI	5.6%	7.2%	MEPS 1999/2009	1
- Workers GHI	61.1%	62.2%	MEPS 1999/2009	1
- Workers Medicaid	9.6%	9.2%	MEPS 1999/2009	1
- Capital output ratio: K/Y	2.7	$2.6 - 3$	NIPA	1
- Interest rate: R	4.2%	4%	NIPA	1
- Size of Social Security/Y	5.9%	5%	OMB 2008	1
- Size of Medicare/Y	3.1%	$2.5 - 3.1\%$	U.S. Department of Health (2007)	1
- Payroll tax Social Security: τ^{Soc}	9.4%	$10 - 12\%$	IRS	1
- Consumption tax: τ^{C}	5.0%	5.7%	Mendoza et al. (1994)	1
- Payroll tax Medicare: τ^{Med}	2.9%	$1.5 - 2.9\%$	Social Security Update (2007)	1
- Medical spend. profile	Figure 3	Figure 3	MEPS 1999/2009	15
- IHI insurance take-up profile	Figure 3	Figure 3	MEPS 1999/2009	8
Total number of moments				34

Table 10: **Matched Data Moments**.
We choose internal parameters so that model generated data match data from MEPS, CMS and NIPA.

Quantiles	**MEPS Data** (in \$1,000)	**Model** (in \$1,000)
10%	11.02	8.12
20%	18.17	15.86
30%	24.88	23.39
40%	31.14	31.05
50%	37.98	38.00
60%	45.75	48.05
80%	68.82	78.21
100%	391.18	323.52

Table 11: **Select Quantiles of the Income Distribution.**
We compare model generated income quantiles to income quantiles from MEPS. These quantiles were not targeted in the calibration.

7.2 Appendix B: Figures

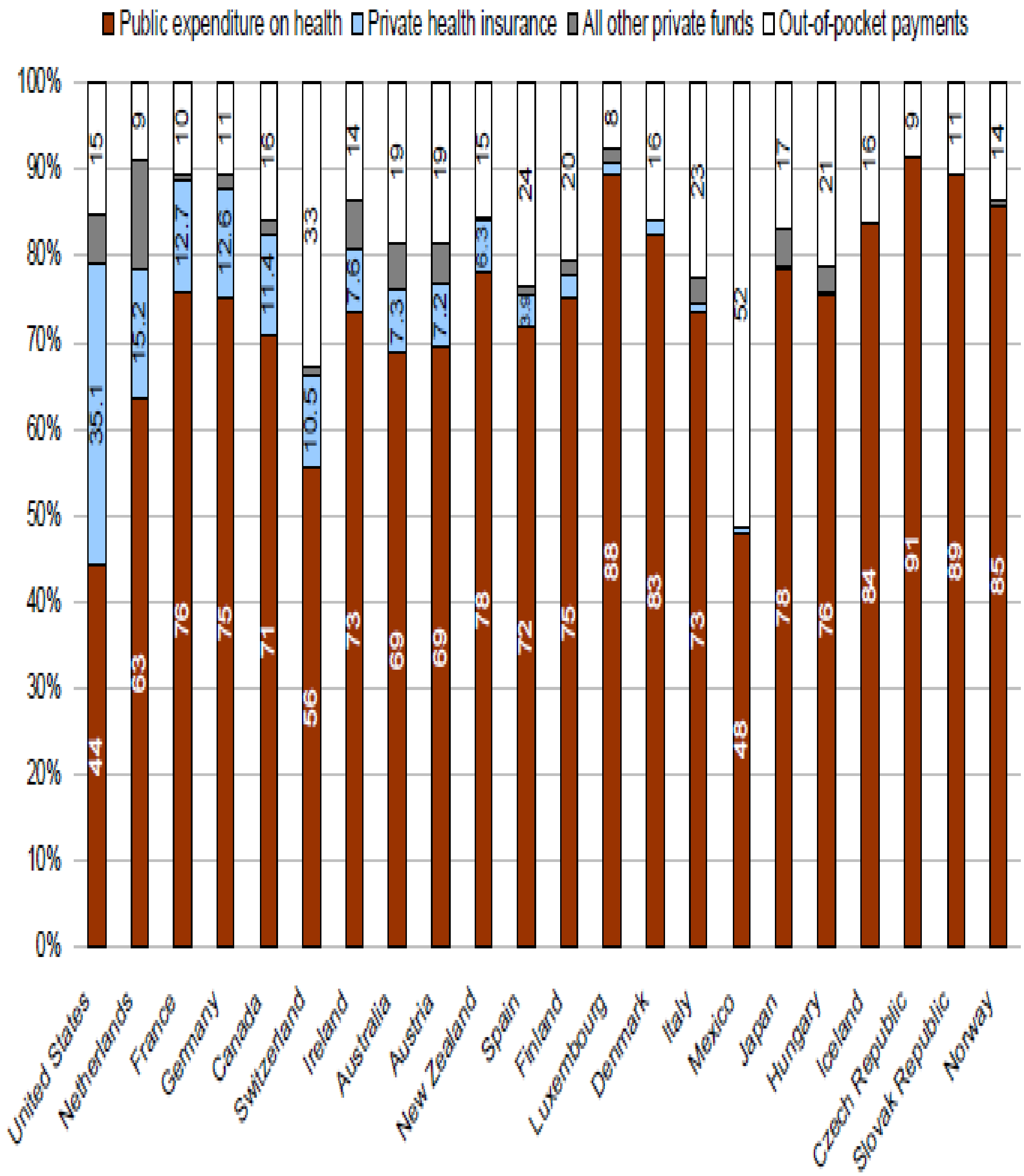

Figure 1: **Health Expenditures by Sources in OECD Economies** (OECD, 2004).

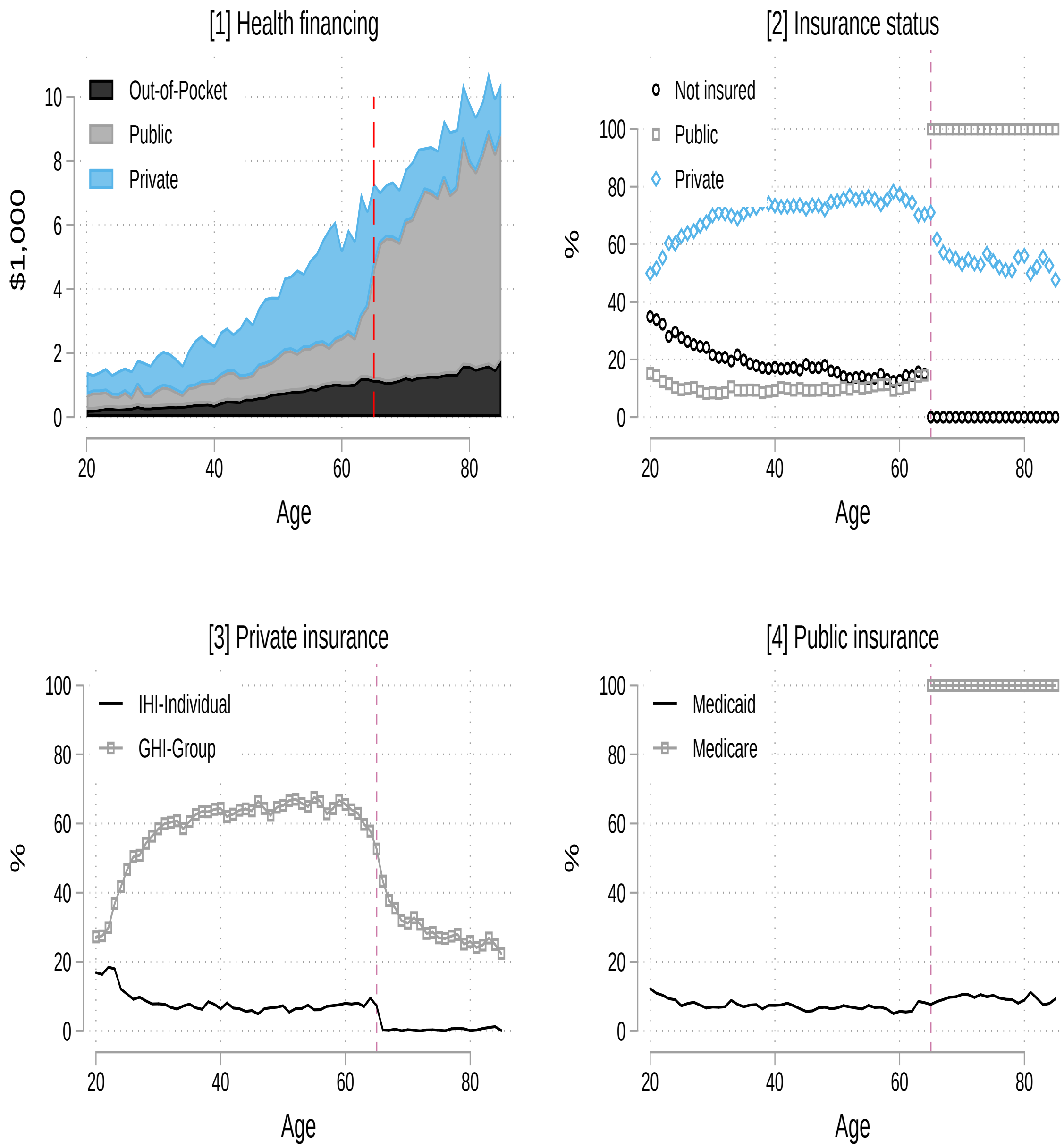

Figure 2: **Health Spending over the Lifecycle by Financing Source.**
We present average health spending per 5-year age cohort based on MEPS 1999-2009. We break down health spending by spending source. Spending values are inflation adjusted to 2009-dollar values.

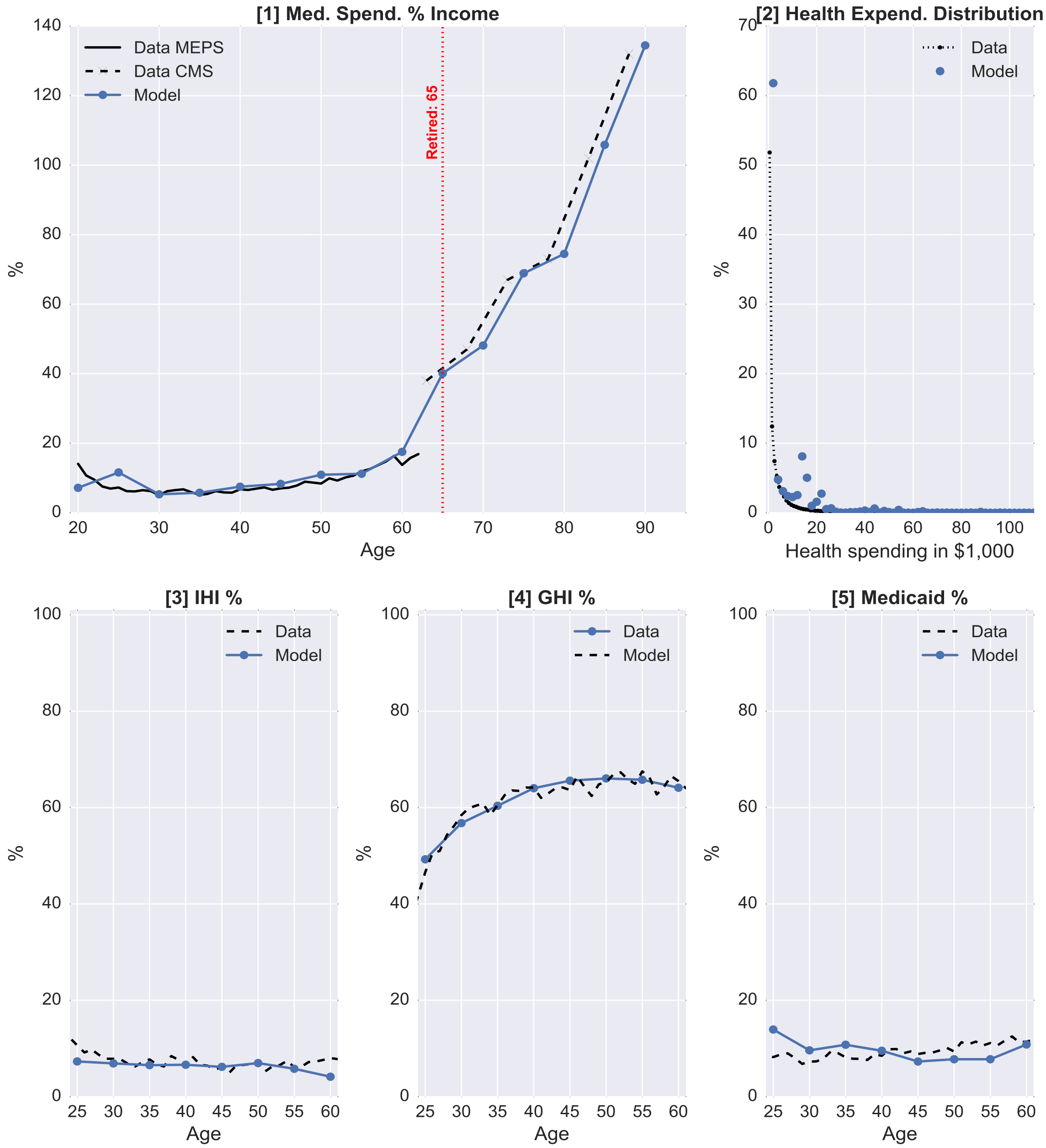

Figure 3: **Moment Matching using MEPS Data 2000-2009.**
Blue lines are model generated data moments and black dotted lines are MEPS data. Panel [1] depicts the percentage of average medical spending as percent of total household income of a 5-year age-cohort. Panel [2] shows the health expenditure distribution of heads of households from MEPS vs. model generated health spending. Panels [3-4] show the fraction of individual, group and Medicaid insurance for the working age population.

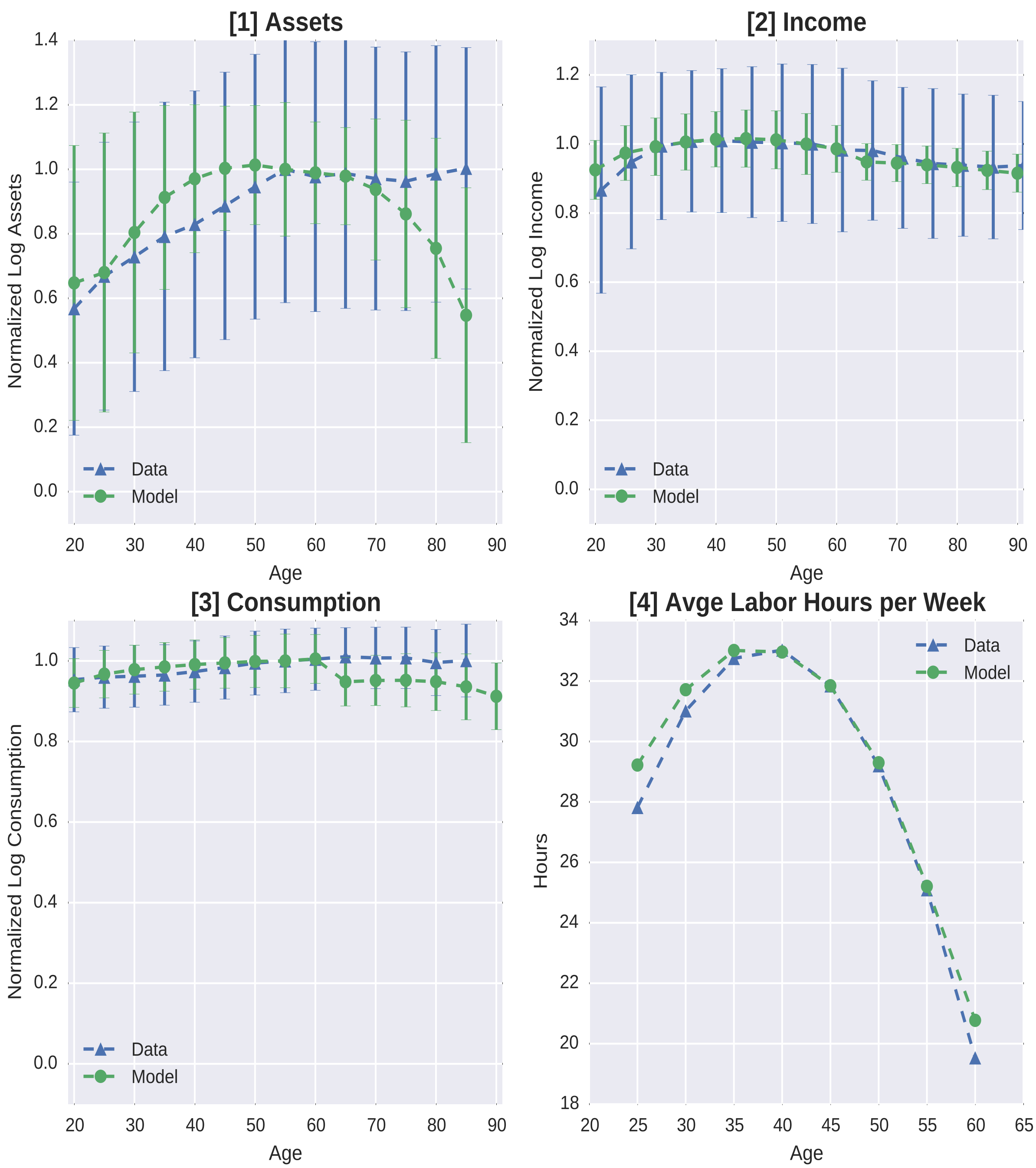

Figure 4: **Model vs. Data.**

Average lifecycle profiles normalized to values from the age 55 cohort. The vertical lines in panels [1]-[3] are standard deviations of log-values. Asset data in Panel [1] is from PSID 1984-2007. Income data for panel [2] is from MEPS 2000-2009. Consumption data in panel [3] is from CEX 1980-2007. Data on weekly work-hours by age-cohort in panel [4] is from CPS 1999-2007.

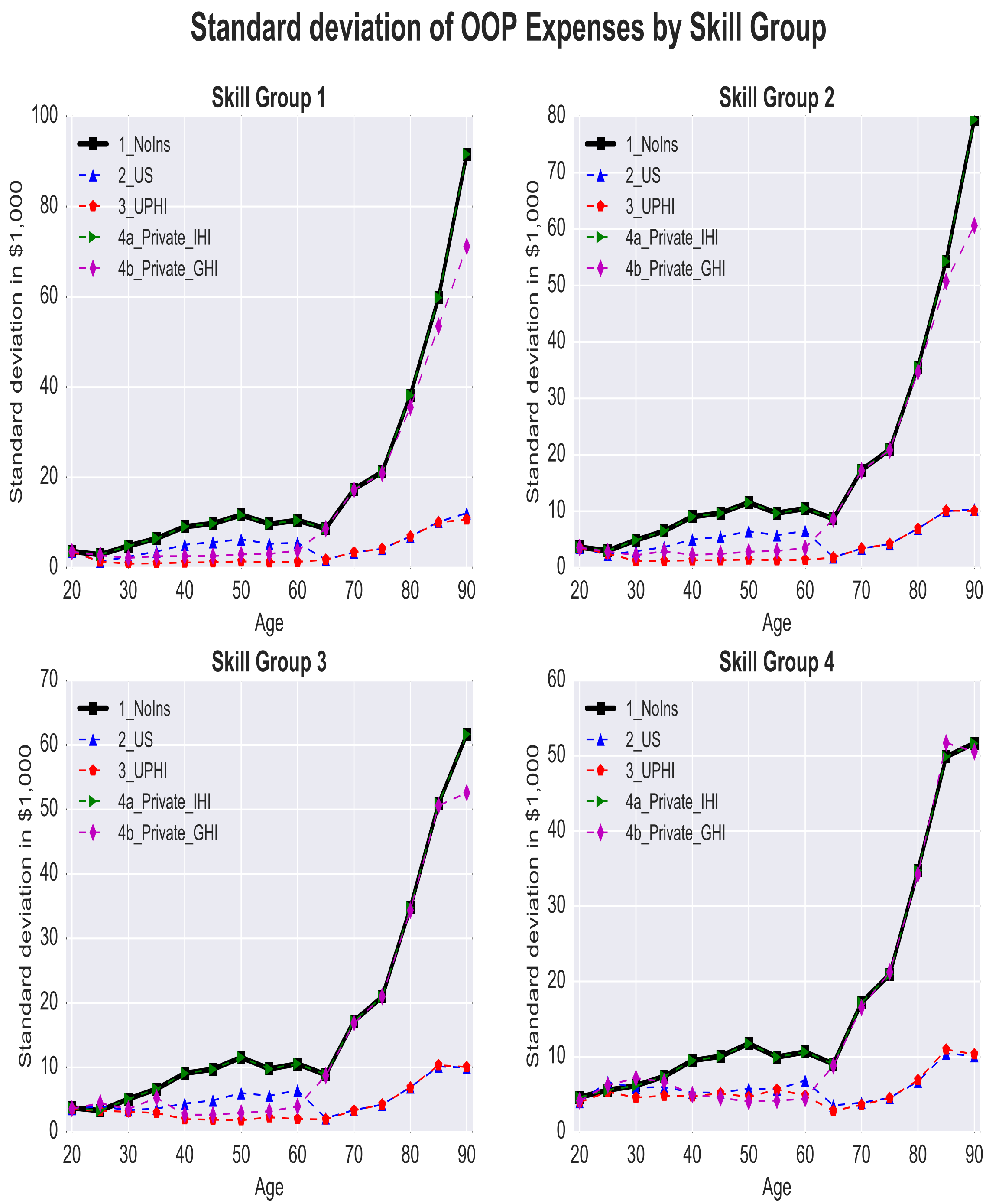

Figure 5: **Standard Deviation of OOP Health Expenditure over the Lifecycle.**
Panel [1] shows the standard deviations of out-of-pocket health expenditures of 5-year age-cohorts over the lifecycle for different policy regimes for skill group 1 (lowest wage quartile). The regime without any insurance (denoted: 1_NoIns) exhibits the largest standard deviations throughout the lifecycle. The regime with universal public health insurance (denoted: 3_UPHI) exhibits the least amount of variation over the lifecycle. The remaining panels show the standard deviations over the lifecycle for the second, third and fourth wage quartile.

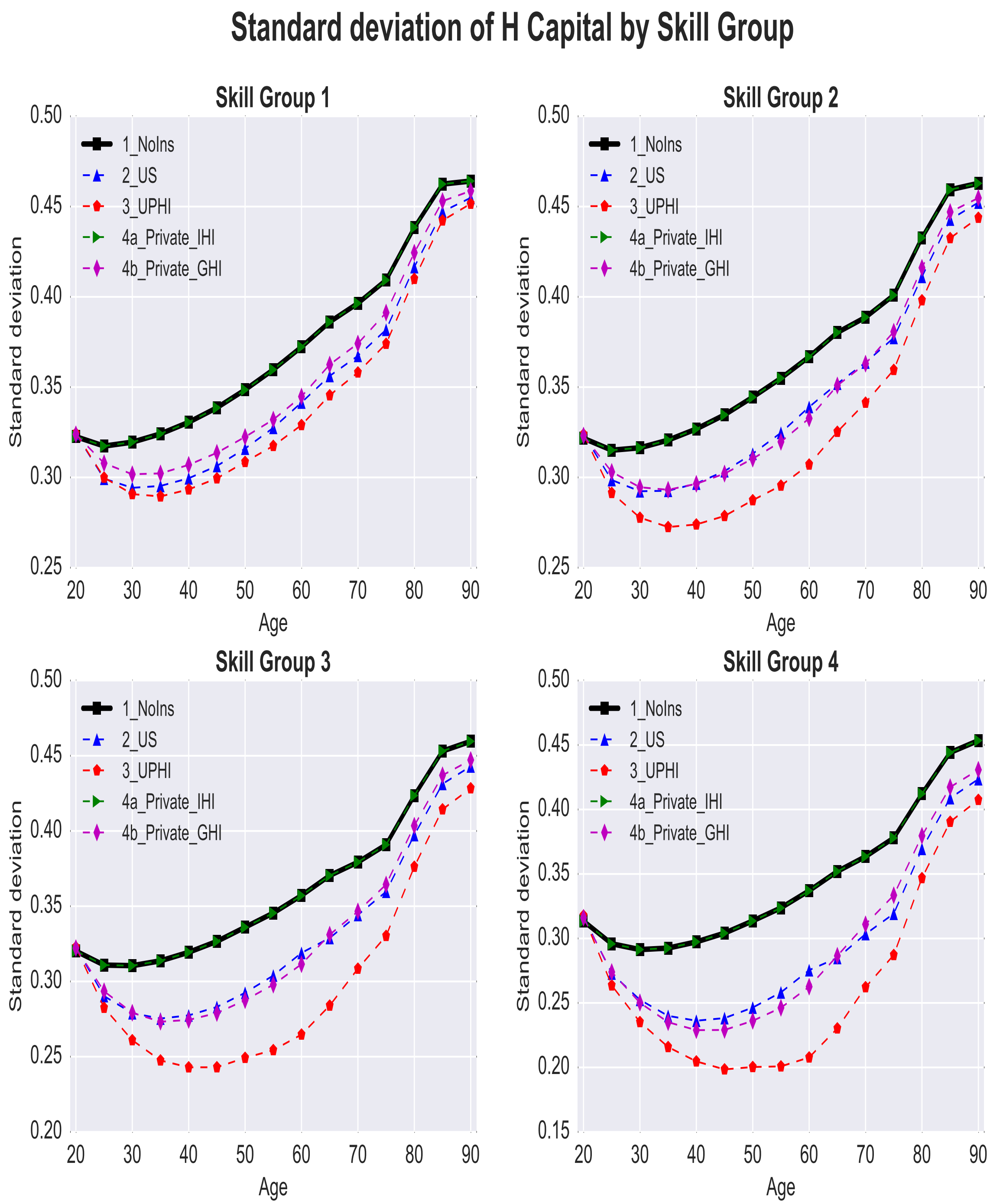

Figure 6: **Standard Deviation of Health Capital over the Lifecycle.**

Panel [1] shows the standard deviations of health capital of 5-year age-cohorts over the lifecycle for different policy regimes for skill group 1 (lowest wage quartile). The regime without any insurance (denoted: 1_NoIns) exhibits the largest standard deviations throughout the lifecycle. The regime with universal public health insurance (denoted: 3_UPHI) exhibits the least amount of variation over the lifecycle. The remaining panels show the standard deviations over the lifecycle for the second, third and fourth wage quartile.

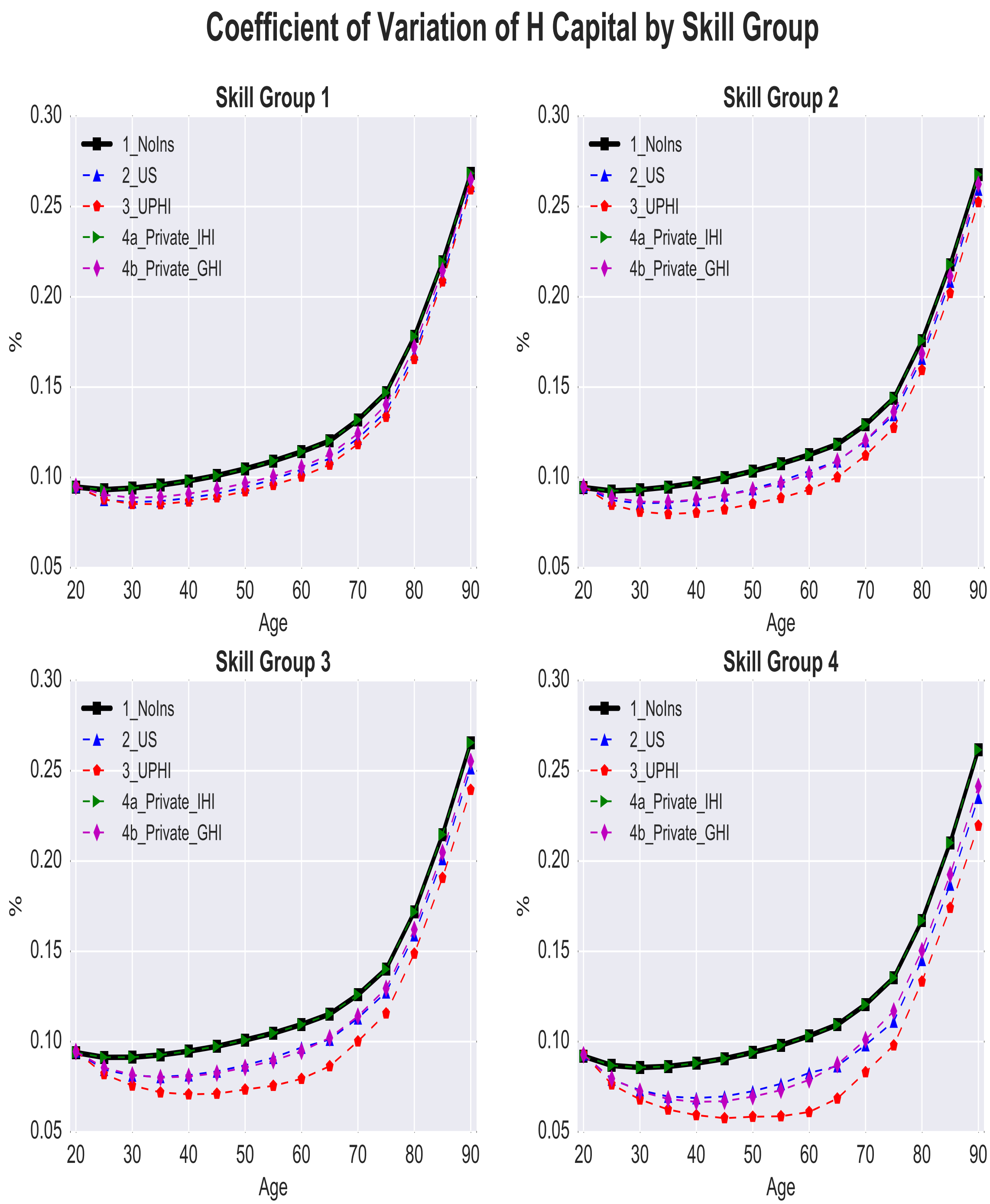

Figure 7: **Coefficient of Variation of Health Capital over the Lifecycle.**
Panel [1] shows the coefficients of variation of health capital of 5-year age-cohorts over the lifecycle for different policy regimes for skill group 1 (lowest wage quartile). The regime without any insurance (denoted: 1_NoIns) exhibits the largest variations throughout the lifecycle. The regime with universal public health insurance (denoted: 3_UPHI) exhibits the least amount of variation over the lifecycle. The remaining panels show the coefficients of variation over the lifecycle for the second, third and fourth wage quartile.