Social Health Insurance: A Quantitative Exploration

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Social Health Insurance: A Quantitative Exploration*

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Abstract

We quantify the welfare implications of three alternative approaches to providing social health insurance: (*i*) a mix of private and public health insurance (US-style), (*ii*) compulsory universal public health insurance (UPHI), and (*iii*) private health insurance for workers combined with government subsidies and price regulation. We use a Bewley-Grossman lifecycle model calibrated to match the lifecycle structure of earnings and health risks in the US. For all three systems we find that welfare gains triggered by a combination of improvements in risk sharing and wealth redistribution dominate welfare losses caused by tax distortions and ex-post moral hazard effects. Overall, the UPHI system outperforms the other two systems in terms of welfare gains if the coinsurance rate is properly designed. A switch from the US system to a well-designed UPHI system results in large welfare gains. However, such a radical reform faces political impediments due to opposing welfare effects across different income groups.

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Keywords: Health capital, lifecycle health risk, incomplete insurance markets, social insurance, optimal policy, dynamic general equilibrium with idiosyncratic shocks.

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1 Introduction

Health risk is an important source of uncertainty over the lifecycle. A common view in the health insurance literature is that health risk is not easily insurable via private health insurance markets. This is mainly due to do the nature of the risk itself (e.g., autocorrelated shocks, age dependent shock magnitudes) and information asymmetries that result in moral hazard and adverse selection issues. Insurance market failures therefore often serve as justification for government intervention (Rothschild and Stiglitz (1976)). The purpose of this paper is to quantify welfare implications of different approaches to designing a social health insurance system using a stylized model calibrated to the US.

Many countries have introduced some kind of collective financing of health care services via taxes or direct contributions (Carrin and James (2005)). Public health insurance systems are often characterized by mandatory membership, open enrollment and community rating. However, there is no uniform approach to the public provision of health insurance across OECD countries. Most European countries have a compulsory public health insurance system with almost universal insurance take-up where voluntary private health insurance provides supplementary insurance. The US, on the other hand, has a mixed system with a significant market-based component. Public health insurance covers retirees and low income individuals, whereas private health insurance covers most of the working population (Figure 1). The two approaches result in significant differences in insurance take-up rates, the fraction of cost sharing, the level of health expenditures at the individual and aggregate levels and the share of private vs. public contributions to total health expenditures (Figure 2).

The introduction of a social health insurance program is often justified based on the classic trade-off between insurance vs. incentive effects. The public provision of health insurance decreases adverse selection issues and usually institutes more equitable risk sharing which is usually referred as the *insurance effect*. On the other hand, a social health insurance program needs to be financed by mandatory contributions or taxes which distort household incentives to consume, save and work. In addition, health insurance in general triggers a moral hazard problem. These distortions are summarized under the umbrella of the *incentive effect* in the literature.[1] Arguably, a government-based approach with a universal public health insurance system has the advantage of eliminating the adverse selection issue; but it also increases the adverse effects on incentives due to moral hazard and large tax distortions. Conversely, mixed systems that employ significant shares of both government- and market-based approaches cannot completely eliminate the adverse selection issue which leads to inefficient market outcomes with low insurance take-up rates. On the other hand, these US-style systems trigger smaller tax distortions due to the smaller size of the public insurance components.

The literature is inconclusive about which approach is better overall. The answer to this questions hinges on the economic fundamentals of an economy including the preferences for risk exposure, efficiency and equity. Every design of a social health insurance system presents

[1]Compare Spence and Zeckhauser (1971), Pauly (1974), Blomqvist and Horn (1984), Besley (1988), Besley (1989), and Petretto (1999).

certain trade-offs, and the final welfare outcome of implementing a specific system depends on how these trade-offs play out quantitatively.

In this paper we develop a Bewley model with individual income risk and incomplete markets (Bewley (1986)) and incorporate key features from the Grossman health capital model (Grossman (1972a)) under uncertainty. Our Bewley-Grossman lifecycle model is able to capture the lifecycle structure of health risk in conjunction with income risk as observed in the data (Figure 3). In the model individuals value their health in addition to a consumption goods basket. Health affects the labor market productivity of workers so that health serves as a consumption and as an investment good. Individuals subsequently smooth their consumption in the presence of idiosyncratic earnings shocks using a limited set of instruments. In addition to earnings shocks individuals are also exposed to idiosyncratic health shocks. Individuals choose to invest in their health via purchases of medical services. The inclusion of health capital into the model endogenizes health care spending and health insurance take-up rates so that they are jointly determined with consumption, savings and the labor supply over the lifecycle. Elements of adverse selection and ex-post moral hazard in health expenditures are thus present in our framework.[2]

To discipline our quantitative analysis we require our benchmark model to match the lifecycle patterns of shocks to income and health, labor supply, asset holdings, consumption and health expenditures in the US. Health expenditures are low early in life because of high initial health capital and low health risk and subsequently rise as health capital depreciates. Health expenditures then rise exponentially later in life because individuals are exposed to more frequent and larger health shocks. Our benchmark model also 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.

We use the calibrated model to quantitatively explore the welfare implications of different approaches to providing social health insurance. We compare three distinct health insurance systems: (*i*) a mixed private-public health insurance system (US-style), (*ii*) a government-based system with compulsory universal public health insurance (UPHI), and (*iii*) a market-based system with only private health insurance for working individuals in combination with government subsidies and price regulations.

We first construct a baseline case for comparison where we remove all private and public health insurance arrangements from the calibrated version of the model. In this laissez-faire competitive economy individuals are forced to self-finance all health expenditures. We are thus able to quantify the welfare cost that a complete lack of insurance contracts would impose on a society with economic fundamentals similar to the US economy. This is a well-known result from a large literature (e.g., Deaton (1991), Huggett (1993), Aiyagari (1994) and Levine and Zame (2002)). In our model, by construction, idiosyncratic risk takes the form of shocks to both sides

[2]Ex-ante moral hazard (i.e., increasing the probability of health shocks when insured) and self-protection (i.e., reducing the probability of health shocks by being more prudent) are not present in the model.

of an individual's budget constraint: income risk and health shocks that translate into (health) expenditure risk. The lack of market instruments to insure 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 augmented consumption variance viz-a-viz a standard Bewley model without health risk. In our model the overall welfare cost is the sum of the cost of missing insurance against income risk, the cost of incomplete health insurance against health risk and the interaction between the two.

Since individuals are risk-averse they benefit, at least in expectation, from health insurance contracts that insure partially against health risk. We start the analysis with an assessment of how well the benchmark US health insurance system (pre - Affordable Care Act in 2010) compares to a world without any insurance (laissez-faire economy).[3] Retirees and poor individuals benefit from public insurance through Medicare and Medicaid, while working individuals have the option to participate in private health insurance markets. This mixed system fails to eliminate adverse selection and therefore does not provide universal insurance take-up. Still, the US system results in significant welfare gains across all income groups when compared to an economy without any health insurance contracts. The overall welfare gain is large at about 5.2 percent of compensating equivalent consumption variation (CEV) measured as percent of lifetime consumption of a newborn individual.

In a second step we evaluate a universal public health insurance (UPHI) system against the no insurance case. Not surprisingly we observe a significant reduction of self insurance via savings that leads to a 12 percent decline in the long-run capital stock. The share of GDP spent on health care increases due to an ex-post moral hazard effect. As GDP falls the health expenditure to GDP ratio increases even further. Tax distortions add to the negative income effect. We summarize these effects under the umbrella of negative efficiency effects due to the publicly financed health insurance system. On the other hand, adverse selection effects completely disappear as the entire population enters the insurance pool which leads to improvements in the allocation of risk and subsequent welfare gains. Since the model exhibits a negative correlation between labor productivity and health risk, public health insurance financed by flat taxes implicitly redistributes wealth and subsequently improves welfare of the high-risk low-income cohorts. This outcome is triggered by positive insurance/redistributive effects. The dominating effect (incentive vs. insurance) will determine whether or not public health insurance is socially desirable – measured as welfare gains/losses over laissez-faire – for the economy as a whole. Our result implies that the positive insurance effect is dominant. In addition, we are able to identify "optimal" coinsurance rates for UPHI that result in welfare gains over US-style mixed systems as they better balance the insurance and incentive effects and are not negatively affected by adverse selection.

Next we explore the extent to which a more market-based approach can reduce the health risk exposure. We first consider a setting in which only private health insurance is available for working-age individuals (we still allow for Medicare for the old) without any further government

[3] In our related work (Jung and Tran (2014)) we analyze the long-run effects of the ACA.

regulation. This is similar to an insurance market that is only comprised of individual health insurances (IHI) where insurers are relatively free to adjust insurance premiums and are allowed to price discriminate between different risk groups. We find that IHI markets by themselves are not maintainable due to an adverse selection spiral. However, once the government introduces additional regulation on insurance premiums, medical prices and tax deductibility of insurance premiums similar to group health insurance plans (GHI) in the US system, private health insurance becomes viable with insurance take-up rates within the active working population of close to 83 percent. Welfare gains can be realized but they are relatively small compared to the welfare gains generated by the US and UPHI systems. The main reason is that income is not redistributed as forcefully as under UPHI.

In our final experiment we explore the effects of switching from the US system to a UPHI system. We find that the UPHI system with sufficiently large coinsurance rates outperforms the US health insurance system in terms of efficiency and welfare. This outcome is mainly driven by welfare gains of low income groups as middle and high income groups would actually prefer the US system over the UPHI system. The opposing welfare effects highlight the political challenge associated with radically reforming the US system into a UPHI system.

Related Literature. Our work is connected to different branches of the quantitative macroeconomics and health economics literature. First, our paper is related to the 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), Hansen and Imrohoroglu (1992), Imrohoroglu, Imrohoroglu and Joines (1995), Golosov and Tsyvinski (2006), Heathcote, Storesletten and Violante (2008), Conesa, Kitao and Krueger (2009), Krueger and Perri (2011) and Huggett and Parra (2010)). This literature shows that if the ability of risk sharing in private markets is limited, then publicly provided risk sharing mechanisms improve the allocation of risk and increase welfare. This literature focuses on the welfare cost triggered by labor income risk in combination with a lack of insurance for non-medical consumption. In this paper, we extend this literature by incorporating health risk and medical consumption into the Bewley framework. This allows us to analyze the welfare cost of shocks to both, income and health when no insurance instruments are available.

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) and Pashchenko and Porapakkarm (2013)). Unlike these studies we consider the micro-foundations of health capital accumulation and therefore endogenize decisions on health care expenditures and health insurance take-up. We are therefore able to account for the two-way interaction between insurance status and health expenditures which is an important determinant of the behavioral response (i.e., ex-post moral hazard) arising from changes in the insurance system.

Our work can be viewed as a quantitative extension of the Grossman health capital model. The roots of the health accumulation process in our model are established in the Grossman literature on health capital (Grossman (1972a) and Grossman (1972b)). Follow-up studies in health economics concentrate on examining the theoretical and empirical micro-foundations of medical spending. Grossman (2000) provides a review of this literature. 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. We extend the Grossman model and incorporate health shocks, private insurance choice, a realistic institutional setting and general equilibrium channels. We demonstrate that a calibrated version of our generalized Grossman model can generate the lifecycle patterns of health expenditures and the take-up rates of different types of private health insurance in US data. Similar papers that have used the Grossman framework in quantitative models of health accumulation are Suen (2006), Hall and Jones (2007), Jung and Tran (2008), Yogo (2009), De Nardi, French and Jones (2010), Hugonnier, Pelgrin and St-Amour (2012), Fonseca et al. (2013) and Scholz and Seshadri (2013). We differ from these papers in that we explore an optimal approach to providing social health insurance. This paper is closely related to our own work in Jung and Tran (2014) where we follow a similar modeling approach and analyze the long-run effects of the Affordable Care Act.

Our paper contributes to the literature on optimal insurance and government redistribution (e.g., Blomqvist and Horn (1984), 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 rather simplified models. We extend this literature and provide a quantitative analysis using more realistic assumptions. First, we take general equilibrium effects from price changes in factor markets and insurance markets on savings and health care expenditures into account. Second, the formation of health insurance premiums, the price of medical care, interest rates and wage rates is simultaneously determined in insurance, medical care, capital and labor markets, respectively. Third, we account for interactions between distortionary taxes and individual's economic behavior.

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

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

where $Eu(h_2, c_2) = \int u(h_2, c_2) f(h_2) dh_2$ 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 as a function of health status. Note that, it is assumed that the utility function $u(c)$ has 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 $u_{c_1}(c_1) = R\beta E u_{c_2}(h_2, c_2)$. 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 (ρ) 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 $\tau n_1 w_1 = \int (1-\rho) m(h_2) f(h_2) dh_2$. Let Γ_2 denote state variable in this setting so that the optimization problem can be written as

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

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 ρ 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 ρ and a tax rate τ so that the aggregate expected lifetime welfare is maximized. The government problem can be written as

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

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

$$\rho^* = 1 - \frac{\beta R \int [u_{c_2} m_2 f(h_2)] dh_2 - u_{c_1}\mu}{u_{c_1}\mu \frac{n_1'}{n_1}},$$

where $\mu = \int m(h_2) f(h_2) dh_2$ 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. A quantitative judgment of this trade-off is challenging. 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 of the US economy where some of these factors are taken into account. We then quantify the welfare implications of different approaches to designing a health insurance system and search for the optimal coinsurance rate.

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. 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.

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 (1972a). 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. Sector one is populated by a continuum of identical firms that use physical capital K and effective labor services L to produce non-medical consumption goods c with a normalized price of one. Firms in the non-medical sector are perfectly competitive and solve the following maximization problem

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

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. Firms in the medical sector maximize

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

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 social insurance through a public health insurance program (M^G) and 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

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

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, in_j is the insurance state and $\mathcal{I}$ denotes the dimension of the insurance state. After the realization of the state variables, agents simultaneously chose from their choice set

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

where c_j is consumption, l_j is labor supply, m_j are health care services, a_{j+1} are asset holdings for the next period and in_{j+1} is the insurance state 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

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

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

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

where $o(m_j)$ is out-of-pocket medical spending, $i(in_{j+1})$ is the net contribution of the insurance system, 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

$$y_j = \begin{cases} e\left(\vartheta, h_j, \epsilon_j^l\right) \times l_j \times w + R\left(a_j + t^{\text{Beq}}\right) + t_j^{\text{SI}} & \text{if } j \leq J_1, \\ t_j^{\text{SS}} + R\left(a_j + t^{\text{Beq}}\right) \;\; + t_j^{\text{SI}} & \text{if } j > J_1, \end{cases} \tag{6}$$

$$\begin{aligned} tax_j &= \tilde{\tau}(\tilde{y}_j), \\ \tilde{y}_j &= y_j - a_j - t^{\text{Beq}} - 0.5 \times tax_j^{SS} \\ tax_j^{SS} &= \tau^{\text{SS}} \times \min\left(\bar{y}_{ss},\; e\left(\vartheta, h_j, \epsilon_j^l\right) \times l_j \times w\right), \\ t_j^{\text{SI}} &= \max\left[0,\; \underline{c} + o(m_j) + tax_j - y_j\right]. \end{aligned} \tag{7}$$

Variable w is the market wage rate and R is the gross interest rate. Variable $\tilde{y}_j$ is taxable income, $\tilde{\tau}(\tilde{y}_j)$ 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 $\underline{c}$. If social insurance is paid out, then automatically $a_{j+1} = 0$, so that social insurance cannot be used to finance savings.

The contribution of the insurance system $i(in_{j+1})$ depends on the design of the health insurance system and may include premium payments, tax contributions to public insurance, tax refunds and shares in insurance company profits.

For each $x_j \in D_j$ let $\Lambda(x_j)$ denote the measure of age j agents with $x_j \in D_j$. Then expression $\mu_j \Lambda(x_j)$ 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 $\{\pi_j\}_{j=1}^J$ and exogenous government policies $\left\{tax(x_j), \tau^C, \tau^{SS}, \underline{c}, \bar{y}_{ss}\right\}_{j=1}^J$, a competitive equilibrium is a collection of sequences of distributions $\{\mu_j, \Lambda_j(x_j)\}_{j=1}^J$ of individual household decisions $\{c_j(x_j), l_j(x_j), a_{j+1}(x_j), m_j(x_j), \mathrm{in}_{j+1}(x_j)\}_{j=1}^J$, aggregate stocks of physical capital and effective labor services $\{K, L, K_m, L_m\}$, and factor prices $\{w, q, R, p_m\}$ such that

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

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

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

(c) markets clear

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

(d) the aggregate resource constraint holds

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

(e) the government programs clear

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

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

(f) the accidental bequest redistribution program clears

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

(g) the insurance system is self-financed so that insurance payouts over all participants equal premium contributions and/or ear marked tax collections and[4]

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

3.8 Health Insurance Systems

We now specify three approaches to providing social health insurance: System [1] is a mixed private-public health insurance system similar to the US system. System [2] is a universal public health insurance system. System [3] is a private health insurance system for workers.

3.8.1 System 1: Mixed Public/Private US-Style Health Insurance

The health insurance systems consists of private health insurance companies and public health insurance programs. Insurance companies offer two types of health insurance policies: an individual health insurance plan (IHI) and a group health insurance plan (GHI). IHI can be bought by any agent for an age and health dependent premium, $\mathrm{prem}^{\mathrm{IHI}}(j, h)$. GHI can only be bought by workers who are randomly matched with an employer that offers GHI which is indicated by random variable $\epsilon^{\mathrm{GHI}} = 1$. 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.

There is a Markov process that governs the group insurance offer probability. The Markov process is a function of the permanent skill type ϑ 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 group insurance status $\epsilon_{j+1}^{\mathrm{GHI}}$ at age $j+1$ given 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.

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

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.

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:

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

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.

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. The out-of-pocket health expenditure of a working-age agent is given by

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

where $0 \leq \rho^{in_j} \leq 1$ are the insurance state specific coinsurance rates. The coinsurance rate denotes the fraction of the medical bill that the patient has to pay out-of-pocket.[5] A retiree's out-of-pocket expenditure is $o\left(m_j\right) = \rho^R \times \left(p_m^R \times m_j\right)$, where ρ^R is the coinsurance rate of Medicare and p_m^R is the price that a retiree pays for medical services.

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

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

and the insurance system component that enters the household problem is

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

[5] For simplicity we include deductibles and co-pays into the coinsurance rate.

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:

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

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

Insurance Sector. 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, $\text{prem}^{\text{IHI}}(j,h)$, adjusts to balance

$$\begin{aligned}
&\left(1+\omega_{j,h}^{\text{IHI}}\right)\mu_j \int \left[1_{[in_j(x_j,h)=1]}\left(1-\rho^{\text{IHI}}\right)p_m^{\text{IHI}} m_{j,h}\left(x_{j,h}\right)\right] d\Lambda\left(x_{j,-h}\right) \qquad (10)\\
&= R\mu_{j-1}\int \left(1_{[in_{j-1,h}(x_{j-1,h})=1]}\text{prem}^{\text{IHI}}(j-1,h)\right) d\Lambda\left(x_{j-1,-h}\right),
\end{aligned}$$

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

$$\begin{aligned}
&\left(1+\omega^{\text{GHI}}\right)\sum_{j=2}^{J_1}\mu_j \int \left[1_{[in_j(x_j)=2]}\left(1-\rho^{\text{GHI}}\right)p_m^{\text{GHI}} m_j\left(x_j\right)\right] d\Lambda\left(x_j\right) \qquad (11)\\
&= R\sum_{j=1}^{J_1-1}\mu_j \int \left(1_{[in_j(x_j)=2]}\text{prem}^{\text{GHI}}\right) d\Lambda\left(x_j\right),
\end{aligned}$$

where $\omega_{j,h}^{\text{IHI}}$ and ω^{GHI} are markup factors that determine loading costs (fixed costs or profits), ρ^{IHI} and ρ^{GHI} are the 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, denoted $\textit{profit}^{\text{In}}$. These are redistributed in equal (per-capita) amounts, denoted $\textit{profit}^{\text{In}}$, to all surviving agents.[6]

[6] 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

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

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

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

3.8.2 System 2: Universal Public Health Insurance

The universal public health insurance system (UPHI system) is mandatory and financed by taxes. In this setting, the out-of-pocket health expenditures of the household are given by

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

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

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 problem is either

$$
i\left(in_j = \text{UPHI}\right) = \tau_C \times c_j \text{ for } \forall\ j,
$$

if a consumption τ_C is used to finance the system or

$$
i\left(in_j = \text{UPHI}\right) = \tau_V \times \left(e\left(\vartheta, h_j, \epsilon_j^l\right) \times l_j \times w\right) \text{ for } j \leq J_1,
$$

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

if a payroll tax τ_V is used.

Insurance Sector. The UPHI system results in aggregate insurance payments of

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

The system is balanced. In the case with the consumption tax financing the system the government budget constraint changes to

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

If a payroll tax finances the UPHI system then

$$\text{InsPay}^{\text{UPHI}} = \sum_{j=1}^{J_1} \mu_j \int \left[\tau^{\text{V}} \times e_j (x_j) l_j (x_j) w \right] d\Lambda (x_j) . \tag{13}$$

has to hold in addition to the government budget constraint in expression (8).

3.8.3 System 3: Private Health Insurance for Workers

We model two cases. An unregulated market where premiums are individually priced for all workers (similar to IHI in the US system) and a regulated market where (*i*) the government does not allow insurance companies to price discriminate based on health status and age; and (*ii*) the government gives tax credits to individuals who buy private insurance. This market is similar to group health insurance plans (GHI) in the US system. Medicaid for workers is not available anymore. Retired workers are still insured via a Medicare type program.

The premiums for the two cases are again denoted by $\text{prem}^{\text{IHI}} (j, h)$ or prem^{GHI}, respectively. The health insurance state in_j for workers can therefore take on the following values:

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

After retirement ($j > J_1$) all agents are covered by a public health insurance program which is a combination of Medicare and Medicaid for which they pay a premium, prem^R. The out-of-pocket health expenditures of a worker depend on the insurance state

$$o (m_j) = \begin{cases} p_m^{in_j} m_j, & \text{if } in_j = 0, \\ \rho^{in_j} \times \left(p_m^{in_j} m_j \right), & \text{if } in_j > 0 \end{cases} \tag{14}$$

where $0 \leq \rho^{in_j} \leq 1$ are the insurance type specific coinsurance rates. A retired agent's out-of-pocket expenditure is $o (m_j) = \rho^R \times \left(p_m^R \times m_j \right)$, where ρ^R is the coinsurance rate of Medicare and p_m^R is the price that a retiree pays for medical services.

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

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

the household choice set is

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

and the insurance system component that enters the household problem is

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

with

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

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 profits^M and per capita insurance company profits are denoted profits^{In}. Taxable income $\tilde{y}_j$ now includes provider profits, GHI premium deductions for the case with GHI 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 Sector. The respective IHI and GHI sectors are set up identically to the US case in expressions (10) or (11), respectively.

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 and match it to US data before the implementation of the Affordable Care Act in 2010.[7] We use a standard numeric algorithm to solve the model and determine parameter values.[8]

[7] Jung and Tran (2014) analyze the long-run effects of the ACA. Here we investigate alternative social health insurance systems.

[8] 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

For our calibration we use data from the Medical Expenditure Survey from 1999-2009, the Panel Study of Income Dynamics (PSID) from 1984-2005 as well as data from the National Income Accounts (NIPA). More details about the data is provided in an Online Appendix. In our calibration, we distinguish between two sets of parameters that we refer to as *external* and *internal* parameters. *External* parameters are estimated independently from our model and either based on our own estimates using data from MEPS and CMS, or estimates provided by other studies. We summarize these external parameters in the Appendix, Table 7. *Internal* parameters are calibrated so that model-generated data match a given set of targets from US data. These parameters are presented in the Appendix, Table 8. We next discuss how we choose the parameters, followed by a discussion of how well the US-model fits the data.

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.[9] 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 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.[10]

Fixed cost of working is set in order to match labor hours per age group. Parameter σ is set to 3.5 and the time preference parameter β is set to 1.001 to match the capital output ratio and the interest rate.[11] We set the intensity parameter $\eta = 0.43$ to match the aggregate

firm first order conditions. We then update the price vector and repeat all the steps until the price vector converges.

[9]CMS projections.

[10]Palumbo (1999), French (2005), De Nardi, French and Jones (2010) and French and Jones (2011) use similar setups where health status shifts preferences.

[11]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

labor supply and $\kappa = 0.89$ to match the ratio between final goods consumption and medical consumption. In conjunction with the health productivity parameters ϕ_j and ξ from expression (16) 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

$$e_j\left(\vartheta, h_j, \epsilon^l\right) = \left(\overline{wage}_{j,\vartheta}\right)^{\chi} \times \left(\exp\left(\frac{h_j - \overline{h}_{j,\vartheta}}{\overline{h}_{j,\vartheta}}\right)\right)^{1-\chi} \times \epsilon^l \text{ for } \; j = \{1, ..., J_1\}, \tag{15}$$

and has three components. First, we model the work efficiencies of four permanent skill types ϑ that are predetermined and evolve over age to capture the "hump" shape of lifecycle earnings. We estimate these labor efficiency profiles using average hourly wage estimates $\overline{wage}_{j,\vartheta}$ per permanent skill group ϑ and age j from MEPS data. The four permanent skill types are defined as average individual wages per wage quartile.

Second, the quality of labor can be influenced by health. Since $\overline{wage}_{j,\vartheta}$ already reflects the productivity for average health capital among the (j, ϑ) types, the idiosyncratic health effect is measured as percent deviation from the average health capital $\overline{h}_{j,\vartheta}$ per 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 specify $\log\left(\epsilon^l_{t+1}\right) = \omega_t + \epsilon_t$ and $\epsilon_t = \gamma \times \omega_t + v_t$, where $\epsilon_t \sim N\left(0, \sigma^2_\epsilon\right)$ is the transitory component and ω is the persistent component of the labor shock ϵ^l. The error term in the second equation follows a normal distribution, $v_t \sim N\left(0, \sigma^2_v\right)$. Storesletten, Telmer and Yaron (2004) estimate $\gamma = 0.935$, $\sigma^2_\epsilon = 0.01$ and $\sigma^2_v = 0.061$. We then discretize the labor shocks into a five state Markov process following Tauchen (1986) so that the magnitude of the labor shocks are $\epsilon^l \in \{4.41;\ 3.51;\ 2.88;\ 2.37;\ 1.89\}$.

4.3 Health Capital

Health Production Technology. The law of motion of health capital consists of three components:

$$h_j = h\left(m_j, h_{j-1}, \delta^h_j, \epsilon^h_j\right) = \overbrace{\phi_j m_j^{\xi}}^{\text{Investment}} + \overbrace{\left(1 - \delta^h_j\right) h_{j-1}}^{\text{Trend}} + \overbrace{\epsilon^h_j}^{\text{Disturbance}}. \tag{16}$$

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^h_j. The third component represents a random and age dependent health shock. Grossman (1972b) 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 (16). A recent empirical

the most directly affected (quantitatively).

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.

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 ($SF-12v2$).[12] 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 (16) disappears 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

[12] 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.

across risk groups between two consecutive years in MEPS data. We smooth the transition probabilities and adjust for period length.

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 skill type and average labor income. Let $\bar{L}(\vartheta)$ and $w \times \bar{L}(\vartheta)$ denote the average effective human capital and the average wage income per skill type. Let $t^{\mathrm{SS}}(\vartheta) = \Psi(\vartheta) \times w \times \bar{L}(\vartheta)$ be pension payments, where $\Psi(\vartheta)$ is a scaling factor that determines the total size of pension payments by skill type. 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. The Old-Age and Survivors Insurance Security tax rate of 10.6 percent as in Jeske and Kitao (2009). Both payroll taxes are 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% of GDP and residual (unproductive) government consumption of 12 percent.

4.6 US Health Insurance

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 $\rho^R = 0.20$, 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.[13]

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 according to Keehan et al. (2011), Sing et al. (2006) and Bernard et al. (2012). The Medicaid coinsurance rate is based on MEPS estimates and depends on age so that $\rho^{Maid} \in [0.11, 0.21]$. 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.

Insurance Premiums and Coinsurance Rates. 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.[14] 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 $\rho^{\text{IHI}} \in [0.22, 0.52]$ and $\rho^{\text{GHI}} \in [0.33, 0.5]$, respectively.

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 *Playing*

[13]Medicare payroll taxes are 2×1.45 percent on all earnings split in employer and employee contributions (see *Social Security Update 2007* (2007)).

[14]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.

Fair, State Action to Lower Prescription Drug Prices (2000), 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 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 :

$$\left[p_m^{\text{noIns}}, p_m^{\text{IHI}}, p_m^{\text{GHI}}, p_m^{\text{Maid}}, p_m^{\text{Mcare}}\right] = (1 + [0.70, 0.20, 0.10, 0.0, -0.10]) \times p_m.$$

4.7 Model Fit

Generated data moments and target moments from US data are juxtaposed in Table 9. Our calibrated model is capable of producing lifecycle trends of average medical expenditures that match US data. Figures 4 and 5 and Tables 9 and 10 summarize the model output. 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.

Medical Expenditures. Panel 1 of Figure 4 compares health expenditure profiles as fraction of income with MEPS data for heads of households. Our model generates total medical expenditures of 17.7 percent of gross household income which matches data provided by CMS. In addition, our model reproduces the distribution of health expenditures as seen in panel 2 of Figure 4.

Insurance Take-up Ratio. Panels 3, 4 and 5 of Figure 4 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.

Income Distribution. Table 10 and Figure 5 provide 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.

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 reproduces many important macroeconomic aggregates in the US data. Table 9 compares model moments with moments from MEPS, CMS, and National Income data.

5 Quantitative Analysis

In this section we examine the welfare and efficiency outcomes of three alternative health insurance systems. We use the values of the structural parameters that resulted from the calibration of the US-version of the model for three alternative health insurance settings. In order to isolate the welfare effects of the different health insurance systems we first compare each system to an economy without any health insurance. We refer to this stripped down version of the model as the **No-Insurance** version from here onward.

The No-Insurance model inherits the structural parameter values for preferences, technologies, labor productivity and health shocks from the US-calibration but eliminates all private and public health insurance programs. In addition, all fiscal policies such as social security, foodstamp programs, government consumption and taxes are maintained.

Contrary to a standard Bewley model, in the health and income risk model the lack of insurance options against health shocks interacts with the limited set of market instruments against income risk (i.e., household savings with borrowing constraints) and amplifies consumption variance. This additional variation generates a welfare cost that is the sum of welfare losses due to missing insurance options against income risk, losses due to incomplete health insurance against health risk and the dynamic interaction between the two. Our experiment quantifies the trade-off between welfare gains from sharing health risk via insurance and the welfare losses due to distorted incentives when instituting different health insurance schemes under asymmetric information. The latter triggers ex-post moral hazard and adverse selection effects.

5.1 System 1: Mixed Public/Private Insurance System

We first compare the US system introduced in Section 3.8.1 to the No-Insurance system in Table 1. We normalize the values of the No-Insurance case to 0 or 100 to facilitate model comparison. The value differences between the two columns are interpreted as the impact of introducing the insurance components of the US health insurance system into a perfectly competitive economy with health risk, income risk and borrowing constraints.

Aggregates. In the No-Insurance economy insurance take-up rates are zero and individuals rely on their own investments to self-insure against health risk by either accumulating a risk-free asset, investing in health capital or working longer hours to generate higher per period incomes. Conversely, in the US model individuals have access to a mixed public and private health insurance system. Health insurance introduces significant distortions to individuals' incentives to save and consume so that physical capital accumulation decreases by about 12 percent. 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 decreases by 7 percent.

On the other hand, the medical sector production expands by 7.7 percent 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

	No-Insurance	[1] US-System
Insured (%):	0	77.46
• IHI (%)	0	6.37
• GHI (%)	0	61.43
• Medicaid (%)	0	9.65
• Medicare (%)	0	17.68
Med. consumption (M)	100	107.71
Med. spending ($p_m M$)	100	88.35
Capital (K_c)	100	87.47
Output (Y_c)	100	92.69
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	0	+1.51

Table 1: **Mixed Public and Private Health Insurance System.** CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual.

insurance picks up a share of the medical bill so that households only pay a fraction of the price and (*ii*) the 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.[15] Overall medical spending decreases despite the increase in medical consumption. This is mainly driven by the decrease in the medical goods prices.

Welfare. 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-Insurance system and the US system. A negative CEV denotes a welfare loss and a positive CEV denotes a welfare gain of the US system over the No-Insurance case.

In a conventional Bewley model, idiosyncratic income shocks and missing consumption insurance impose a welfare cost caused by consumption uncertainty. Our model is an extended Bewley model with health shocks that introduce an additional source of disturbance to individual consumption and health capital holdings. Risk-averse individuals benefit, at least in expectation, from health insurance contracts against health risk as they facilitate consumption smoothing.

In system [1], retirees and low income workers have access to public health insurance (Medicare and Medicaid) while working individuals have the option to purchase private health insurance (IHI and GHI) as illustrated in Table 1. We therefore observe welfare gains across all four income 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. This outcome

[15]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.

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. Arguably, the significant decrease in aggregate income due to introducing insurance also triggers negative welfare effects in our model. However, the positive welfare effects from redistributing income and from reducing the exposure to health risk outweigh the negative welfare effects triggered by incentive distortions and moral hazard. Other things equal, all income groups prefer to live in an economy with a US-style health insurance system over an economy without any health insurance.

5.2 System 2: Universal Public Health Insurance (UPHI)

In this section we analyze the effects of a UPHI system as introduced in Section 3.8.2. We set the coinsurance rate $\rho^{\text{UPHI}} = 0.2$ which is identical to the calibrated value of Medicare in the US version of the model. Results for the UPHI system financed by a consumption tax are reported in Table 2, column $(2a)$ and results for UPHI financed by a payroll tax are reported in column $(2b)$.

	No Ins.	**[2] UPHI ($\rho^{Med} = 0.2$)**	
		$(2a)$ UPHI via τ_C	$(2b)$ UPHI via τ_V
Insured (%):	0	100.00	100.00
• Public health insurance (%)	0	100.00	100.00
Cons. tax - τ_C (%)	4.31	19.59	3.60
Payroll tax - τ_V(%)	0	0.00	13.49
Med. consumption (M)	100	117.09	111.57
Med. spending ($p_m M$)	100	87.04	82.5
Capital (K_c)	100	87.96	80.25
Output (Y_c)	100	91.78	86.90
Welfare (CEV):	0	+4.06	+4.06
• Income Group 1 (low)	0	+18.69	+25.52
• Income Group 2	0	+6.19	+5.22
• Income Group 3	0	−8.1	−11.96
• Income Group 4	0	−13.13	−16.50

Table 2: **UPHI:** The program is either financed by a consumption or payroll tax.

Aggregates. Individuals who live under the UPHI system rely less on self-insurance via savings to fund their health expenditures. This subsequently leads to significant decreases in capital accumulation and output. Aggregate capital stock decreases by 12 percent and subsequently output decreases by 8.2 percent compared to the No-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 UPHI. Notice that the introduction of the UPHI system completely eliminates the adverse selection problem as participation through the tax system is compulsory. In order to finance the UPHI the government has to increase the consumption tax τ^C to 19.6 percent (from a benchmark of 4.31 percent). The increase in the consumption tax rate represents a direct measure of the cost of full social health insurance coverage. If UPHI is financed by a payroll tax, then a 13.5 percent tax is needed.

Welfare. As is well documented in the literature, all social insurance programs that are financed by tax revenues trade-off gains from insurance with losses created by incentive distortions. The UPHI system is no exception. On one hand, 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 increases 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 effects vary significantly across income groups. First, low income groups experience welfare gains while higher income groups experience welfare losses, compared to the No-Insurance economy. The welfare gain is 18.7 percent for the lowest income group as opposed to a welfare loss of 13 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 4.06 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. We next consider a payroll tax in Table 2, column (2*b*). This payroll tax is more progressive as it redistributes incomes from high income individuals to low income and/or 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.

Optimal Coinsurance Rate. In our model, the coinsurance rate is a policy tool that controls the sharing of health care costs between households and the government. Smaller coinsurance rates make insurance more generous and shift the financial burden of medical care to the government. Larger coinsurance rates make insurance less generous so that households have to finance more of their health investments. In order to quantify the trade-off between insurance and incentive effects with a varying degree of generosity of the UPHI system we solve the UPHI model for a range of different coinsurance rates $\rho^{\mathrm{UPHI}} = [0.1., 0.2, 0.3, 0.4, 0.5]$ and report the results in Table 3.

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 overall welfare effect 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 forces depends on the level of the coinsurance rate. When the coinsurance rate is small, individuals share a smaller share of total health expenditure. This implies a larger ex-post moral hazard effect due to lower medical prices and larger tax distortions as the government has to impose higher taxes to finance the larger share of total health expenditure.

	[2c] UPHI with τ_C				
	$\rho^{UPHI} = 0.1$	0.2	0.3	0.4	0.5
Cons. tax - τ_C (%)	31.0	19.6	16.6	14.1	12.1
Med. consumption (M)	148.8	117.1	108.3	104.3	102.5
Med. spending ($p_m M$)	114.2	87.0	83.2	80.3	79.0
Output (Y_c)	88.3	91.8	93.7	95.2	96.4
Welfare (CEV):	-7.0	$+4.1$	$+7.3$	$+7.1$	$+6.4$
• Income Group 1 (low)	$+10.1$	$+18.7$	$+20.2$	$+18.0$	$+15.3$
• Income Group 2	-5.1	$+6.2$	$+9.4$	$+9.3$	$+8.2$
• Income Group 3	-20.6	-8.1	-4.0	-2.43	-1.63
• Income Group 4	-26.5	-13.2	-6.7	-6.71	-5.24

Table 3: **UPHI with Different Coinsurance Rates**

A coinsurance rate of $\rho^{\text{UPHI}} = 0.1$ results in welfare losses caused by a large ex-post moral hazard effect (i.e., it increases medical consumption by 49%) and fiscal distortions from a large consumption tax rate of $\tau_C = 31$ percent. Potential welfare gains from improved risk sharing and income redistribution are dominated by these losses.

However, if the coinsurance rate gets too large, then the welfare gains start to decrease. This hump-shaped pattern highlights how the health insurance system trades off the insurance and incentive effects. We find a similar pattern for the case where the government uses a payroll tax to finance the UPHI system. However, in this case the overall welfare gains are smaller.

We next follow the approach in Conesa, Kitao and Krueger (2009) and characterize an optimal coinsurance rate. We assume that the government maximizes the ex-ante lifetime utility of an individual born into the stationary equilibrium implied by the chosen coinsurance rate. The government's objective is defined as

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

Notice that the government maximizes the social welfare function over the coinsurance rate only while keeping all other policy variables unchanged. We assume that the government uses either a consumption tax or a payroll tax to finance the UPHI system. We find that a coinsurance rate of about0.32 efficiently trades off the positive insurance/redistribution effects with the negative incentive effects and results in the largest welfare of a newborn individual.

This estimate is in the range of studies by Blomqvist (1997) who find 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 is somewhat different from the classic result in the literature analyzing the welfare implications of social security in stochastic dynamic general equilibrium frameworks (e.g., Imrohoroglu, Imrohoroglu and Joines (1995)). That literature shows that the general equilibrium channels amplify the fiscal distortions caused by social security so that the introduction of a social security system generates welfare losses. Our welfare results indicate that this is not the case for social health insurance.

5.3 System 3: Private Health Insurance Markets for Workers

The health insurance literature suggests that health risk is not easily insured via private insurance markets due to information asymmetries that give rise to moral hazard and adverse selection inefficiencies. In addition, self-insurance of health shocks via savings is problematic due to the high persistence of these shocks. We next demonstrate the effects of purely private health insurance systems for the working population as introduced in Section 3.8.3 and report results in Table 4.

	No Ins.	**[3] Private Health Insurance**	
		($3a$) Unregulated - IHI	($3b$) Regulated - GHI
Insured (%)	0	0	82.90
• IHI (%)	0	0	0.00
• GHI (%)	0	0	82.90
Med. consumption	100	100	104.60
Med. spending	100	100	83.12
Capital (K_c)	100	100	98.57
Output (Y_c)	100	100	100.45
Welfare (CEV)	0	0	+0.97
• Income Group 1 (low)	0	0	+1.11
• Income Group 2	0	0	+0.93
• Income Group 3	0	0	+0.60
• Income Group 4	0	0	+2.84

Table 4: **The Effects of Private Health Insurance**

Unregulated IHI Markets. Unregulated private health insurance markets are not viable in an economy with a health risk structure similar to the US economy. Price discrimination by health status and age prevents risk sharing between healthy and unhealthy individuals as the insurance pools are kept small and separate. Young agents with low income and low health risk are less likely to buy private health insurance compared to middle aged agents at the peak of their lifecycle earnings ability. Older individuals, on the other hand, are part of high risk pools and therefore face high premiums. In equilibrium, nobody buys private health insurance. This complete market failure is consistent with classic results documented in the insurance literature (e.g., Pauly (1974) and Rothschild and Stiglitz (1976)).

Regulated GHI Markets. We next consider an economy in which the government regulates private insurance companies according to Section 3.8.3. Market regulations induce more individuals to participate in the private health insurance market as the tax deductibility of premium payments is a direct subsidy to households who choose to buy insurance. As reported in Table 4, column ($3b$), the GHI take-up is 82.9 percent of the working population. However, even with these market regulations in place the insurance system fails to provide full coverage. Young and healthy individuals who face very low health risk opt out of private health insurance markets as do low income groups who cannot afford the premiums.

Aggregates. Similar to our earlier experiments, individuals with health insurance reduce their savings. In addition, medical consumption increases by 4.6 percent while medical spending drops significantly by 17 percent. Insurance companies are again able to secure lower prices from providers than uninsured individuals who lack bargaining power.

Private insurance results in positive aggregate efficiency gains. The stock of aggregate capital decreases slightly by around 1 percent, while human capital increases due to increases in labor supply. Overall, we observe a small increase in final goods production by 0.45 percent.

Welfare. The existence of private health insurance markets in model ($3b$) provides a mechanism to pool workers so that they are able to share health risk at subsidized premium rates. This improves the allocation of health risk and redistributes income toward unhealthy individuals. Although the government does not provide health insurance directly, it implicitly provides social health insurance via subsidizing insurance premiums and regulating the insurance companies' market behavior. Even though this market-based risk sharing mechanism is incomplete (i.e., a take-up rate of 83 percent) we still find welfare gains for all income groups as reported in the lower part of Table 4.

Market-based health insurance systems, even with government subsidies and regulation, fail to eliminate the adverse selection issue and therefore cannot provide universal health insurance coverage. Compared to the UPHI system, this leads to a lower degree of risk pooling as well as to a lower degree of redistribution of wealth. Welfare gains are smaller which is especially true for low income groups and individuals in bad health. On the other hand, the efficiency losses in terms of capital accumulation and output are less pronounced with private health insurance markets as the tax burden of this system is much smaller.

Private Health Insurance for Workers and Retirees. In the next experiment we allow retirees access to a new self-clearing GHI market. The previously discussed GHI market for workers is maintained with identical parameters as in the US model. We then vary the coinsurance rate for the GHI-contract for retirees according to Table 5 and let the group premium adjust to clear the market. We do find that by appropriately choosing the coinsurance rate – which in turn determines the insurance premium and the take-up rate – about a quarter of all retirees can be insured. This falls far short of the almost universal insurance take-up rates that are achievable with public health insurance like Medicare.

	[3c] GHI for retirees				
	ρ^{GHI}=**0.1**	**0.2**	**0.25**	**0.3**	**0.4**
Insured retirees(%):					
• GHI	18.79	24.65	26.22	27.50	0.03
Med. consumption (M)	104.97	104.52	104.49	104.45	104.59
Med. spending ($p_m M$)	83.29	83.01	82.99	82.96	83.11
Capital (Y$_c$)	101.86	100.74	100.66	100.59	100.45
Output (K_c)	99.20	98.97	98.85	98.73	98.58
Welfare (CEV):	+4.08	+4.33	+4.14	+3.92	+0.99

Table 5: **The Effects of GHI for Retirees with Various Coinsurance Rates**

If coinsurance rates are not generous enough (i.e., $\rho^{\text{GHI}} > 40\%$) GHI for the old erodes. Similarly, GHI contracts that are too generous (i.e., $\rho^{\text{GHI}} < 10\%$) also loose market share as they become too expensive. Richer cohorts benefit the most from very generous GHI contracts whereas low income cohorts benefit less. This is in contrast to the UPHI results in Table 3 where welfare effects were more favorable for low income groups. Private health insurance lacks the redistribution element of the UPHI system and is therefore less desirable for low income households.

5.4 The US Insurance System vs. the UPHI System

We have demonstrated that all three social health insurance systems result in welfare gains over the No-Insurance system. In this section, we investigate a switch from the US system (pre ACA) to UPHI. We consider a range of coinsurance rates $\rho^{\text{UPHI}} = [0.2,\ 0.3,\ 0.4,\ 0.5]$ in Table 6. In these experiments the US-system serves as benchmark.

	[1] US System	**[2c] UPHI with τ_C**			
		$\rho^{\text{UPHI}} = 0.2$	0.3	0.4	0.5
Cons. tax - τ_C (%)	5.0	19.6	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: **Switching the US-System to a UPHI-System**

A switch to UPHI with a coinsurance rate of $\rho^{\text{UPHI}} = 0.2$ results in a 1 percent drop of GDP. The same experiments with a slightly less generous UPHI system, i.e. $\rho^{\text{UPHI}} \geq 0.3$ leads to GDP growth. This implies that a moderate coinsurance rate can mitigate the adverse effects from tax distortions so that risk pooling and redistribution ultimately leads to increases in capital accumulation and output.

More importantly, we observe large welfare gains from switching to a UPHI system with $\rho^{\text{UPHI}} \geq 0.3$. The UPHI system results in much larger overall welfare gains as the UPHI pools risk more efficiently across the different groups and redistributes wealth more equitable. As can be seen in Figures (6)and (7) 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).[16] The welfare gains are mainly driven by welfare gains of low income groups. High income groups fare better under the US system.

Thus, the UPHI system outperforms the US health insurance system in terms of output

[16]Figure (8) shows relative variation normalized with the mean value of health capital per age group over the lifecycle.

and welfare if the coinsurance rate is moderate. However, such radical reform faces political impediments because of opposing welfare effects across different income groups.

6 Conclusion

In this paper we investigate the welfare implications of different health insurance systems in a model with incomplete market mechanisms to insure against health risk. We develop a generalized Bewley-Grossman model and calibrate the baseline model to match the lifecycle structure of earnings and health risks in US data. We then apply the model to evaluate the benefits in terms of insurance and the cost in terms of incentive distortions across insurance systems that differ in the degree of government involvement. We consider three different systems: (*i*) a government- and market-based approach with a mixed public/private insurance system similar to the US system (pre-ACA), (*ii*) a pure government-based approach with a universal public health insurance system (UPHI) and (*iii*) a more market-based approach with a private health insurance system for workers assisted by government subsidies and market regulation.

Our results indicate that the government provision of social insurance leads to positive welfare outcomes in all three considered health insurance systems. That is, the positive insurance/redistribution effects strongly dominate the negative incentive effects caused by tax distortions and ex-post moral hazard effects. In general, the UPHI system results in the largest welfare gains if the coinsurance rate is kept at moderate levels. We solve for the optimal coinsurance rate that balances the trade-off between positive insurance and the negative incentive effects and maximizes welfare of a newborn individual. More importantly, different degrees of government involvement lead to opposing welfare effects across income groups. Low income households benefit more from the government-based approach whereas high income households benefit more from the market-based or mixed approach. This result highlights political difficulties when moving away from the US health insurance system toward a more government-based system like a UPHI system.

Several possible extensions are left for 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. The lack of a bequest motive and the imposed independence of survival from health lead to lower than observed assets holdings of the retired cohorts and affect the level of self-insurance via savings.

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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
- Capital share in production	$\alpha = 0.33$	Kydland and Prescott (1982)
- Capital in medical services production	$\alpha_m = 0.26$	Donahoe (2000)
- Capital depreciation	$\delta = 10\%$	Kydland and Prescott (1982)
- Health depreciation	$\delta_j^h \in [0.6\% - 2.13\%]$	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	Section 4	MEPS 1999/2009
- Productivity transition prob.	Technical Appendix	MEPS 1999/2009
- Group insurance 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	$\rho_j^{IHI,GHI} \in [0.22, 0.52]$	MEPS 1999/2009
- Medicare premiums/GDP	2.11%	Jeske and Kitao (2010)
- Public coinsurance rate	$\rho^{Mcare,Maid} \in [0.11, 0.22]$	Center for Medicare and Medicaid Services (2005)

Table 7: **External Parameters**

Parameters:		**Explanation/Source:**	**Nr.M.**
- Relative risk aversion	$\sigma = 3.0$	to match $\frac{K}{Y}$ and R	1
- Preference on consumption vs. leisure:	$\eta = 0.43$	to match labor supply and $\frac{p \times M}{Y}$	1
- Disutility of health spending:	$\eta_m = 1.5$	to match health capital profile	1
- Preference on c and l vs. health	$\kappa = 0.89$	to match labor supply and $\frac{p \times M}{Y}$	1
- Discount factor	$\beta = 1.0$	to match $\frac{K}{Y}$ and R	1
- Health production productivity	$\phi_j \in [0.7 - 0.99]$	to match spending profile	14
- TFP in medical production	$A_m = 0.4$	to match $\frac{p \times M}{Y}$	1
- Production parameter of health	$\xi = 0.175$	to match $\frac{p \times M}{Y}$	1
- effective labor services production	$\chi = 0.26$	to match labor supply	1
- Health productivity	$\theta = 1$	used for sensitivity analysis	1
- Pension replacement rate	$\Psi = 40\%$	to match τ^{soc}	1
- Residual Government spending	$\Delta_C = 12.0\%$	to match size of tax revenue	1
- Minimum health state	$h_{\min} = 0.01$	to match health spending	1
-Total number of internal parameters:			26

Table 8: **Internal Parameters**. Used 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
- Medical spend. profile		Panel [1], Fig. 4		15
- 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%	$2.5 - 3.1\%$	US 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
Total number of moments				26

Table 9: **Model vs. Data**

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 10: **Select Quantiles of the Income Distribution**

7.2 Appendix B: Figures

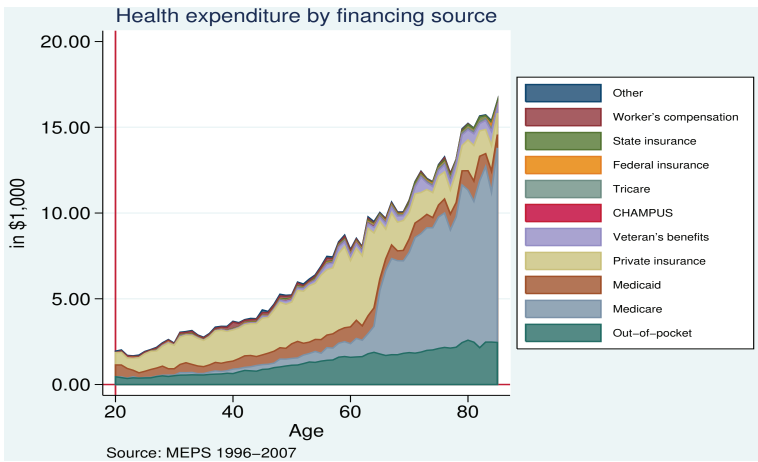

Figure 1: **Health Spending over the Lifecycle:** MEPS 1996-2007

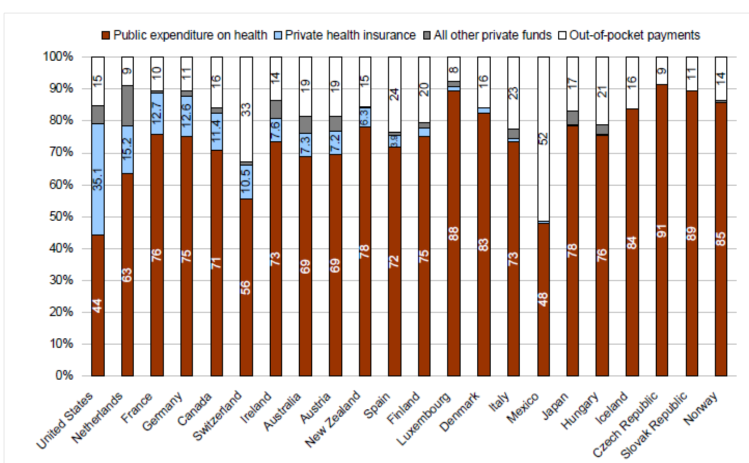

Figure 2: **Health Expenditures by Sources in OECD Economies** (OECD, 2004)

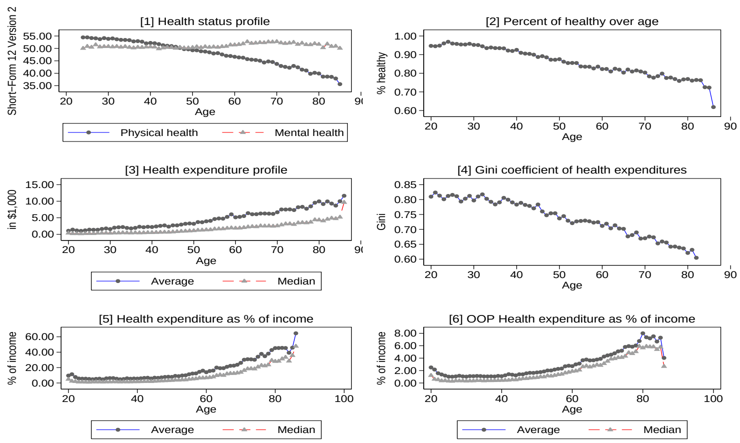

Figure 3: **Health Status and Spending over the Lifecycle:** MEPS 1996-2007

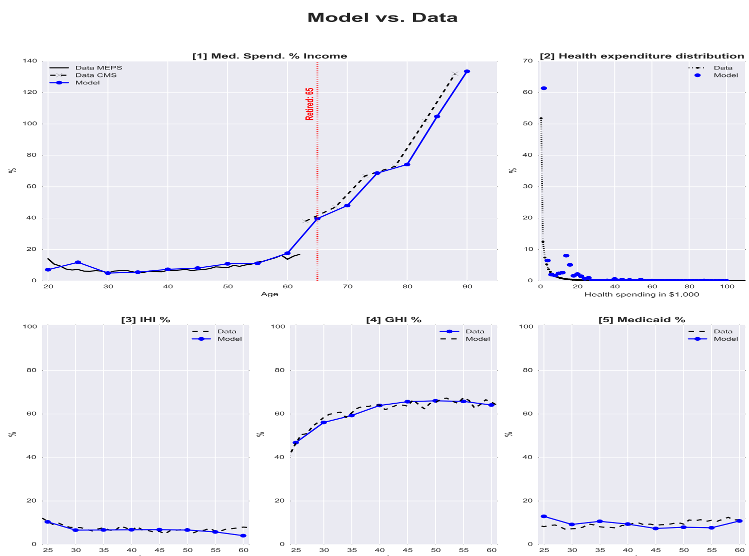

Figure 4: **Health Expenditure and Insurance Take-up:** Model vs. data

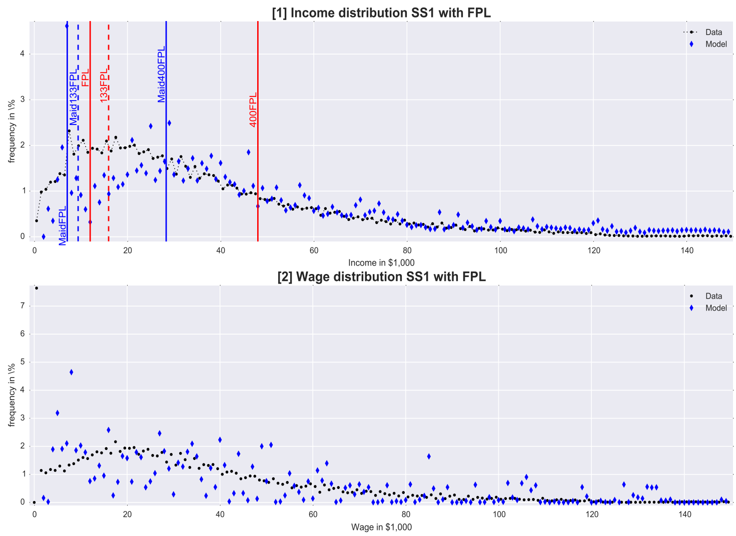

Figure 5: **Income and Wage Distribution:** Model vs. MEPS data 1999-2009

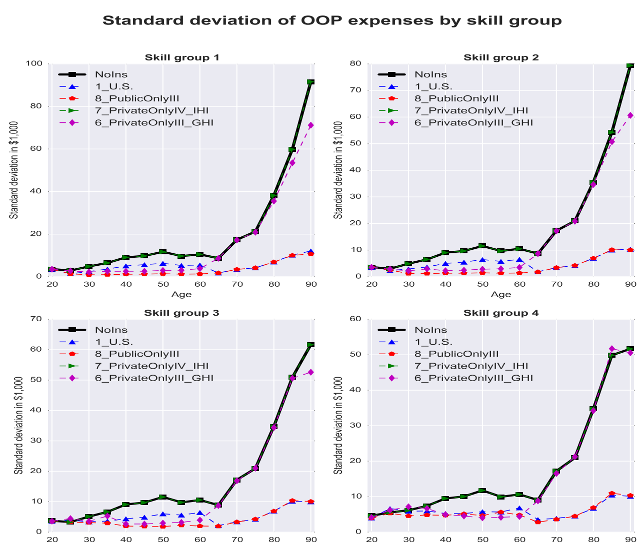

Figure 6: **Standard Deviation of Out-of-Pocket Health Expenditure over the Lifecycle**

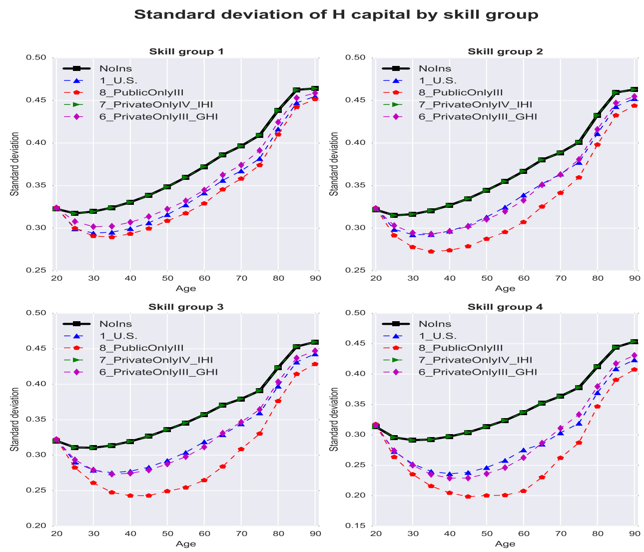

Figure 7: **Standard Deviation of Health Capital over the Lifecycle**

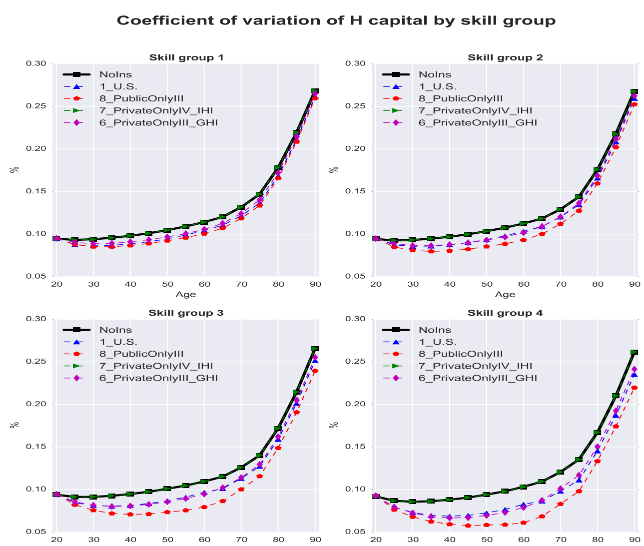

Figure 8: **Coefficient of Variation of Health Capital over the Lifecycle**