Social Health Insurance: A Quantitative Exploration*

(Preliminary and Incomplete)

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Abstract

We quantitatively explore the effect of health insurance provided by different health insurance systems in a dynamic general equilibrium, incomplete markets model with endogenous health capital accumulation that reproduces the lifecycle structure of US income and health risk. We compare the following insurance regimes: (*i*) a US-style mixed system that provides partial health insurance coverage, (*ii*) a universal public health insurance (UPHI) system that is financed by taxes, and (*iii*) a private health insurance system with government subsidies and price regulation. Our results indicate that welfare gains triggered by a combination of improved risk sharing and wealth redistribution dominate welfare losses caused by tax distortions and ex-post moral hazard in all three health insurance systems. Furthermore, the UPHI system outperforms the other systems, which only lead to partial insurance take-up, in terms of welfare gains, even though it causes more aggregate efficiency losses due to larger distortionary effects. We solve for optimal coinsurance rates that balance the trade-off between the positive insurance effects and the negative incentive effects and find that low income households benefit more from a public system whereas high income households benefit more from a private system.

JEL: I13, D52, E62, H31

Keywords: Lifecycle health risk, incomplete markets, social health insurance, public health insurance, endogenous health accumulation, dynamic stochastic general equilibrium, health capital.

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1 Introduction

Health risk is highly correlated with age due to the biological aging process. Health expenditures therefore follow a distinct upward trend over the lifecycle with exponential increases at very high ages (see Figure 1). Individuals at the end of their lifecycle spend at least five times as much on healthcare as individuals in their twenties. There is an ongoing debate among academics and policymakers about which policies are best suited to reduce this type of risk.

A common view in the health insurance literature is that health risk is not easily insurable via private health insurance markets because of information asymmetries. The presence of such market frictions often serves as justification for government intervention.[1] Pauly (1974*a*) and Rothschild and Stiglitz (1976) are seminal contributions that demonstrate how insurance markets can fail to provide sufficient insurance. They also argue that the introduction of public health insurance can improve the pooling of health risk and thereby lead to welfare improvements. In practice, almost all countries have some kind of collective financing for health care services via taxes or direct contributions to public insurance systems. These systems are often characterized by mandatory membership, open enrollment and community rating (see Carrin and James (2005)). However, the designs of social health insurance systems vary greatly across OECD countries. While the majority of European countries favor public over private insurance and often reach almost universal coverage (compare Figure 2), the US uses a mixed system in which the government insures low income and retired individuals and private health insurances cover the working population (see Figure 3). In the US the fraction of private contributions to total health expenditures far exceeds the share of private contributions in other OECD countries (compare Figure 2).

It is well documented in the health insurance literature that public health insurance creates a mechanism for more equitable risk sharing. We will refer to this as the *insurance effect* of public health insurance. However, public health insurance does distort household incentives to save, work and consume medical services which triggers a moral hazard problem. We refer to this as the *incentive effect* of public health insurance.[2] Finally, public health insurance needs to be financed. Taxes or mandatory contributions to public health insurance cause additional distortions which we will refer to as the *financing effect* of public health insurance.

The universal provision of public health insurance in European style designs emphasizes the insurance effect and completely removes adverse selection issues that tend to be a problem for private insurance markets. However, it also amplifies the adverse incentive effects. Conversely, the mixed system approach in the US that leads to only partial coverage fails to eliminate the adverse selection issue which can lead to premium increases and subsequent collapses of insurance markets but triggers smaller tax distortions due to the smaller size of the public

[1] Social or public health insurance is also often justified based on efficiency and equity arguments. See Spence and Zeckhauser (1971), Pauly (1974*a*), Rothschild and Stiglitz (1976), Blomqvist and Horn (1984), Besley (1988), Rochet (1991), Culyer and Wagstaff (1993), Cremer and Pestieau (1996), and Nyman (2003).

[2] See Spence and Zeckhauser (1971), Pauly (1974*a*), Blomqvist and Horn (1984), Besley (1988), Besley (1989), and Petretto (1999)

insurance component. The "best" design of a social health insurance system will depend on a society's preferences for risk exposure, efficiency and equity as the different designs present certain trade-offs between those. The purpose of this paper is to conduct a quantitative assessment of different designs of social health insurance for the US economy. We analyze and compare lifecycle patterns of aggregate household measures as well as welfare comparisons.

To do this, we formulate a Bewley model with individual income risk and incomplete markets (Bewley (1986)) and incorporate key features from the Grossman model of health capital accumulation (Grossman (1972a)) under uncertainty. In a conventional Bewley model individuals are exposed to income risk and have an exogenously limited set of instruments that allows them to smooth their consumption in the presence of idiosyncratic income shocks. Additional to consumption goods, individuals value their health. Health also affects the labor market productivity of workers so that health serves as a consumption as well as an investment good. Individuals are exposed to idiosyncratic health shocks and choose their investment into health capital via purchases of medical services. The inclusion of health capital into the model endogenizes health care and health insurance decisions so that they are jointly determined with consumption, savings and the labor supply over the lifecycle. Elements of adverse selection in private insurance markets and ex-post moral hazard in health expenditures are present in our framework.

To discipline our quantitative analysis we require our benchmark model to match macroeconomic aggregates of the US as well as average lifecycle behavior of health spending and financing. The model reproduces the lifecycle trends of average medical expenditures as presented in MEPS data. 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 rise exponentially later in life because individuals are exposed to more health shocks. Our model also produces a hump-shaped lifecycle profile of insurance take-up rates in the US. We then use the calibrated version of the model to quantify welfare implications of public health insurance.

We next construct a baseline case for comparison and we remove all private and public health insurance arrangements from the calibrated version of the model. Individuals are forced to self finance all health expenditures in this environment. As in a conventional Bewley model, a welfare cost appears because of the of missing consumption insurance and the residual uncertainty of individual consumption over the lifecycle. 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 of an individual's budget constraint: income risk and (health) expenditure risk. The lack of market instruments to insure against health risk interacts with a limited set of market instruments against income risk and amplifies the welfare cost of consumption variance. 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 use an economy without any insurance as the baseline using the parameters from the calibrated US model and then introduce different insurance structures into the baseline model. Adding these insurance instruments decreases the risk exposure of the population which is welfare increasing but also imposes costs.

We start the analysis an assessment of how well the US health insurance system (pre - Affordable Care Act in 2010) compares to the benchmark without any insurance. The US health insurance system is a mix of public and private health insurance options. The retirees and the poor workers have access to Medicare and Medicaid, while working individuals have options to participate in private health insurance markets. This mixed system fails to eliminate adverse section. Even though it can not provide universal coverage, it results in significant welfare gains across all income groups, compared to the no insurance benchmark.

Next, we consider a universal public health insurance (UPHI) system. 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. We summarize these effects under the umbrella of negative efficiency effects due to the publicly financed health insurance system. However, 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. Moreover, in our model since there is 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. We call these outcomes positive insurance/redistributive effects. The dominating effect will determine whether or not public health insurance is socially desirable for the economy as a whole. Our result implies that the positive insurance effect is dominant so that overall welfare gains are achieved. We identify an optimal UPHI coinsurance rate that balances out these two opposing effects and maximizes the social welfare defined by expected utility of newborns. Interestingly, we find that the UPHI system outperforms the US health insurance system in terms of welfare gains, even though it causes larger aggregate efficiency losses.

Finally, we explore the extent to which private insurance markets reduce health risk exposure. We consider a setting in which only private health insurance is available and analyze a market structure with no government 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 and up to 83 percent of the active working population chooses to buy insurance. Welfare gains can be realized but they are relatively small compared to the welfare gains generated by the universal public health insurance system. The main reason is that redistributive effects are limited.

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 macro-models with heterogenous agents started 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 against income and longevity risks (e.g., Hubbard and Judd (1987), Hansen and Imrohoroglu (1992), Imrohoroglu, Imrohoroglu and Jones (1995), Golosov and Tsyvinski (2006), Conesa, Kitao and Krueger (2009), Krueger and Perri (2011) and Huggett and Parra (2010)). An important risk that is often considered in this model is labor income risk. Individual workers experience substantial idiosyncratic wage shocks that are not related to systematic lifecycle effects or to aggregate fluctuations (e.g., see Heathcote, Storesletten and Violante (2008)). A common view is that labor income cannot be easily insured because it is also determined by an individual's unobserved work effort. This literature concludes that if risk sharing is limited publicly provided risk sharing mechanisms potentially improve the allocation of risk and increase welfare. Notice that, this literature focuses on the welfare cost of missing (non-medical) consumption insurance against labor income risk. In this paper, we extend the previous literature to incorporate health risk and medical consumption into the Bewley framework. This extension allows us to analyze the welfare cost of missing insurance against both income and health risks.

There are a number of studies on 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 extended the exogenous health expenditure shocks into large-scale dynamic general equilibrium models and evaluate the macroeconomic effects of health insurance reforms (Jeske and Kitao (2009) and Pashchenko and Porapakkarm (2013)). Unlike these studies we consider the micro-foundations of health accumulation and fully endogenize health expenditures. We are therefore able to account for the two-way interaction between insurance status and health expenditure. Our approach captures the behavioral response to health insurance and the effects of 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 is 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 microfoundations of medical spending (see Grossman (2000) for a review). However, the Grossman literature abstracts from matching the models to the stylized facts of health related lifecycle behaviors. As an extension, our Grossman model incorporates 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 private health insurance in the US data. Similar papers that have used the Grossman framework in quantitative models of health accumulation are Suen (2006), Hall and Jones (2007) Hugonnier, Pelgrin and St-Amour (2012), Yogo (2009), Fonseca, Michaud, Galama and Kapteyn (2013) and Jung and Tran (2008, 2014). We differ from these papers in that we study incentive effects of various types of health insurance systems within a calibrated framework that matches US data.

Our paper is closely related to the literature on mixed public-private health insurance systems (e.g., Besley (1989), Selden (1997), Blomqvist and Johansson (1997) and Petretto (1999)). These studies aim to investigate analytically the optimal structure of mixed insurance in terms of efficiency and equity in 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, interest rates and wage rates is simultaneously determined in insurance, capital and labor markets respectively. Third, we account for interactions between distortionary taxes and individuals' economic behavior.

Finally, our paper is related directly to an emerging macro-health economics literature that connects the literature analyzing health as an investment or consumption good with the literature on stochastic dynamic general equilibrium modeling. This approach completely endogenizes the households' decisions on health expenditures and health insurance together with consumption/saving decisions in an unified optimization problem. Similarly, in our previous work (Jung and Tran (2008) and Jung and Tran (2010)) we integrate health capital into a quantitative lifecycle model for the US and study the macroeconomic and welfare effects of the healthcare reforms in the US In this paper, we analyze the welfare value of various designs of social health insurance.

The paper is structured as follows. Section 2 presents the fully dynamic model without health insurance. Section 3 describes our calibration strategy. Section 4 introduces health insurance and describes quantitative results. Section 5 concludes. The Appendix A contains more details about the calibration data and strategy. Appendix B presents all calibration tables. Appendix C includes all figures.

2 Model

2.1 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.

2.2 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 $u : R^3_{++} \rightarrow R$ is C^2, increases in consumption c and health h, and decreases in labor l.[3] 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 unit $e\left(\vartheta, h_j, \epsilon^l_j\right)$. The transition probabilities for the idiosyncratic productivity shock ϵ^l_j follow an age-dependent Markov process with transition probability matrix Π^l. Let an element of this transition matrix be 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 $\epsilon^l_{i,j}$.[4]

2.3 Health capital, insurance and spending

Health capital. Health capital depreciates due to aging at rate δ^h_j and idiosyncratic health shocks ϵ^h_j. Agents can buy medical services to improve their health capital as in Grossman (1972a). Health evolves endogenously over the lifetime of an agent according to

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

where h_j denotes the current health capital, h_{j-1} denotes last period's health capital, and m_j is the amount of medical services bought in period j. 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 $\Pr\left(\epsilon^h_{j+1}|\epsilon^h_j\right)$.

Health insurance. The health insurance systems consists of private health insurance companies and public health insurance programs. Insurance companies offer health insurance policies and agents are required to buy insurance one period prior to the realization of their health shock. The insurance policy will become active in the following period. The insurance policy needs to be renewed each period. The public health insurance program available to

[3]Our specification implicitly assumes a linear relationship between health capital and service flows derived from health capital which is similar to the assumption in the original Grossman model, see Grossman (1972a).

[4]We abstract from the link between health and survival probabilities. We are aware that this presents a limitation and that certain mortality effects cannot be captured (see Ehrlich and Chuma (1990) and Hall and Jones (2007)). However, given the complexity of the current model we opted to simplify this dimension to keep the computational structure more tractable.

some or all agents, depending on which design of social health insurance system which will be specified later. The health insurance state in_j can therefore take on the following values

$$in_j = \begin{cases} 0 & \text{if not insured,} \\ 1 & \text{if private health insurance,} \\ 2 & \text{if public health insurance.} \end{cases}$$

Health spending. If an individual have health insurance, her health insurance state variable $in_j \geq 1$ and 0 otherwise. The individual's out-of-pocket expenditure is given by:

$$o\left(m_j\right) = \begin{cases} p_m^{in_j} \times m_j, & \text{if } in_j = 0 \\ \gamma^{in_j} \times \left(p_m^{in_j} \times m_j\right), & \text{if } in_j \geq 1, \end{cases}$$

where p^{in_j} is the price of health care services, $p^{in_j} \times m_j$ is the total health care spending, and γ^{in_j} is the insurance state specific coinsurance rates, $0 \leq \gamma^{in_j} \leq 1$, that determines the level of health spending that remains after the insurance pays its share to the provider.

2.4 Technology and firms

The economy consists of two separate production sectors that produce two types of final consumption goods. 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

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

The price p_m is a base price for medical services. The price paid by consumers is insurance state dependent so that $p_j^{noIns} = \left(1 + \nu^{noIns}\right) p_m$ where ν^{noIns} is a markup factor that will generate a profit for medical care providers, denoted Profit^M. Profits are redistributed in equal amounts to all surviving agents.

2.5 Government

Pensions. The government runs a PAYG Social Security program which is self-financed via a payroll tax so that

$$\sum_{j=J_1+1}^{J} \mu_j \int t_j^{\mathrm{SS}}(x_j)\, d\Lambda(x_j) = \sum_{j=1}^{J_1} \mu_j \int \left(\tau^{\mathrm{SS}} \times e_j(x_j) \times l_j(x_j) \times w\right) d\Lambda(x_j)\,. \tag{4}$$

Expenditures and taxes. The government runs social health insurance programs, a social transfer program T^{SI}, as well as consume exogenous government consumption G. Government spending G is unproductive. The government taxes consumption at rate τ^C and income at a progressive tax rate $\tilde{\tau}(\tilde{y}_j)$ which is a function of taxable income $\tilde{y}$. The government budget is balanced in each period so that

$$G + M^G + T^{\mathrm{SI}} = \sum_{j=1}^{J} \mu_j \int \left[\tau^C c(x_j) + tax_j(x_j)\right] d\Lambda(x_j)\,, \tag{5}$$

where M^G is the total government health expenditure and $T^{\mathrm{SI}} = \sum_{j=1}^{J} \mu_j \int t_j^{\mathrm{SI}}(x_j)\, d\Lambda(x_j)$ is the government social transfer. Finally, the government collects and redistributes accidental bequests in a lump-sum fashion to working-age households

$$\sum_{j=1}^{J_1} \mu_j \int t_j^{\mathrm{Beq}}(x_j)\, d\Lambda(x_j) = \sum_{j=1}^{J} \int \tilde{\mu}_j a_j(x_j)\, d\Lambda(x_j)\,, \tag{6}$$

where μ_j and $\tilde{\mu}_j$ denote the surviving and deceased number of agents at age j in time t, respectively.

2.6 Household problem

Workers. Agents with age $j \leq J_1$ are workers and thus exposed to labor shocks. The agent's state vector at age j is given by $x_j = \left(a_j, h_{j-1}, \vartheta, \epsilon_j^l, \epsilon_j^h, in_j\right)$, 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, and in_j is the insurance state. Note that, $x_j \in D_W \equiv R_+ \times R_+ \times \{1,4\} \times R_+ \times R_- \times \{0,1\}\,.$

After realization of the state variables, agents simultaneously decide their consumption c_j, labor supply l_j, health service expenditures m_j, asset holdings for the next period a_{j+1}, and insurance state for the next period in_{j+1} to maximize their lifetime utility. The household optimization problem for workers $j = \{1, ..., J_1\}$ can be formulated recursively as

$$V(x_j) = \max_{\{c_j, l_j, m_j, a_{j+1}, in_{j+1}\}} \left\{ u(c_j, h_j, l_j) + \beta \pi_j E\left[V(x_{j+1}) \mid \epsilon_j^l, \epsilon_j^h\right] \right\} s.t. \tag{7}$$

$$\left(1+\tau^{C}\right)c_j+(1+g)\,a_{j+1}+o\left(m_j\right)+1_{\{in_{j+1}>0\}}\text{prem} = y_j+t_j^{\text{SI}}-tax_j,$$
$$0 \leq a_{j+1},\ 0\leq l_j\leq 1,\ \text{and}\ (1),$$

where

$$\begin{aligned}
y_j &= e\left(\vartheta,h_j,\epsilon_j^l\right)\times l_j\times w+R\left(a_j+t^{\text{Beq}}\right)+\text{profits}^M, \qquad (8)\\
tax_j &= \tilde{\tau}\left(\tilde{y}_j\right)+tax_j^{SS},\\
\tilde{y}_j &= y_j-a_j-t^{\text{Beq}}-tax_j^{SS},\\
tax_j^{SS} &= \tau^{\text{SS}}\times\min\left(\bar{y}_{ss},\ e\left(\vartheta,h_j,\epsilon_j^l\right)\times l_j\times w\right),\\
t_j^{\text{SI}} &= \max\left[0,\ \underline{c}+o\left(m_j\right)+tax_j-y_j\right].
\end{aligned}$$

Variable τ^C is the consumption tax rate, g is the exogenous growth rate of the economy, $o(m_j)$ is out-of-pocket medical spending, y_j is the sum of all income including labor, assets, bequests, and profits from medical providers (profits^M) and insurance companies ($\text{profits}^{\text{Ins}}$). Variable w is the market wage rate, R is the gross interest rate, t_j^{Beq} denotes accidental bequests, tax_j is total taxes paid[5], and t_j^{SI} is social insurance (e.g. food stamp programs). Taxable income is denoted $\tilde{y}_j$ which is composed of wage income and interest income on assets, interest earned on accidental bequests, and profits from medical services providers minus the employee share of payroll taxes. The payroll tax for social security is tax_j^{SS} and it is paid on wage income below $\bar{y}_{ss}$ (i.e. $106,800 in 2010).

The social insurance program 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.

Retirees. Old agents, $j>J_1$ are retired and receive pension payments. They do not face labor market shocks anymore. The only remaining idiosyncratic shock for retirees is the health shock ϵ_j^h. The state vector of a retired agent therefore reduces to $x_j=\left(a_j,h_{j-1},\epsilon_j^h,in_j\right)\in D_R\equiv R_+\times R_+\times R_-\times\{0,1\}$ and the household problem can be formulated recursively as

$$V\left(x_j\right)=\max_{\{c_j,m_j,a_{j+1}\}}\left\{u\left(c_j,h_j\right)+\beta\pi_j E\left[V\left(x_{j+1}\right)\ \mid\ \epsilon_j^h\right]\right\}\ s.t. \qquad (9)$$

[5]If health insurance was provided by the employer, so that premiums would be partly paid for by the employer, then the tax function would change to

$$tax_j=\tilde{\tau}\left(\tilde{y}_j\right)+0.5\left(\tau^{\text{Soc}}+\tau^{\text{Med}}\right)\left(\tilde{w}_j-1_{\{in_j=2\}}\left(1-\psi\right)p\right),$$

where ψ is the fraction of the premium paid for by the employer. Jeske and Kitao (2009) use a similar formulation to model private vs. employer provided health insurance. We simplify this aspect of the model and assume that all group health insurance policies are offered via the employer but that the employee pays the entire premium, so that $\psi=0$. The premium is therefore tax deductible in the employee (or household) budget constraint. We also allow for income tax deductibility of insurance premiums due to IRC provision 125 (Cafeteria Plans) that allows employers to set up tax free accounts for their employees in order to pay for qualified health expenses but also the employee share of health insurance premiums.

$$\left(1+\tau^{C}\right) c_j + (1+g)\, a_{j+1} + o\left(m_j\right) + 1_{\{in_{j+1}>0\}}\text{prem} = y_j + t_j^{\text{SI}} - tax_j,$$
$$a_{j+1} \geq 0,$$

where

$$\begin{aligned} y_j &= t_j^{\text{SS}} + R\left(a_j + t^{\text{Beq}}\right) + \text{profits}^{M}, \\ tax_j &= \tilde{\tau}\left(\tilde{y}_j^{R}\right), \\ \tilde{y}_j^{R} &= y_j - a_j - t_j^{\text{Beq}}, \\ t_j^{\text{SI}} &= \max\left[0, \underline{c} + o\left(m_j\right) + tax_j - y_j\right]. \end{aligned}$$

Variable t_j^{SS} denotes pension payments. For each $x_j \in D_j$ let $\Lambda\left(x_j\right)$ denote the measure of age j agents with $x_j \in D_j$. Then expression $\mu_j \Lambda\left(x_j\right)$ becomes the population measure of age-j agents with state vector $x_j \in D_j$ that is used for aggregation.

2.7 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 $\left\{tax\left(x_j\right), \tau^{C}, \tau^{SS}, \tau^{\text{Med}}\right\}_{j=1}^{J}$, a competitive equilibrium is a collection of sequences of distributions $\{\mu_j, \Lambda_j\left(x_j\right)\}_{j=1}^{J}$ of individual household decisions $\{c_j\left(x_j\right), l_j\left(x_j\right), a_{j+1}\left(x_j\right), m_j\left(x_j\right), in_{j+1}\left(x_j\right)\}_{j=1}^{J}$, aggregate stocks of physical capital and effective labor services $\{K, L, K_m, L_m\}$, factor prices $\{w, q, R, p_m\}$, markups $\left\{\nu^{in}\right\}$ such that

(a) $\{c_j\left(x_j\right), l_l\left(x_j\right), a_{j+1}\left(x_j\right), m_j\left(x_j\right)\}_{j=1}^{J}$ solves the consumer problems (7) and (9),

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

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

(c) markets clear

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

(d) the aggregate resource constraint holds[6]

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

(e) the government programs clear so that (4), (5), and (6) hold, and

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

3 Benchmark calibration

We choose an economy without any health insurance as a benchmark economy for comparison. To construct such benchmark economy, we follow a two steps procedure. First, we solve the model presented above which includes the main components of the pre-2010 US insurance structure – i.e., employer provided group health insurance as well as individually bought insurance for working age individuals, Medicaid for poor individuals as well as Medicare for retirees. We calibrate this model so that model output can replicate macroeconomic variables from US data. We then eliminate all private and public health insurance programs from the model but keep all the model parameters determining preferences, technologies, labor productivity and health shocks unchanged. In addition all fiscal policies, except for public health insurance programs, are maintained as well. The stripped down version of the model, called the **No Insurance** version, functions as competitive equilibrium benchmark against which we compare alternative equilibrium solutions with various insurance policies enabled.

The next section contain the details of the US model calibration and the data sources. 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 Appendix C, Table 8. *Internal* parameters are calibrated so that model-generated data match a given set of targets from US data. These parameters are presented in Appendix C, Table 9.

3.1 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.[7] The population growth rate for the US was 1.2 percent

[6] Profits from medical providers, Profit^M, are already included in the marked up prices $p_m^{ins_j(x_j)}$ for medical services on the left hand side.

[7] CMS projections.

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.

3.2 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. In addition, this functional form ensures that marginal utility of consumption declines as health deteriorates which has been pointed out in empirical work by Finkelstein, Luttmer and Notowidigdo (2013).

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. It is understood that in a general equilibrium model every parameter affects the equilibrium value of all endogenous variables to some extent. Here we associate parameters with those equilibrium variables that are the most directly affected (quantitatively). The intensity parameter η is 0.43 to match the aggregate labor supply and κ is 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 (11) 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

$$e = e_j\left(\vartheta, h_j, \epsilon^l\right) = \left(\overline{wage}_{j,\vartheta}\right)^{\chi} \times \left(\exp\left(\frac{h_j - \overline{h}_{j,\vartheta}}{\overline{h}_{j,\vartheta}}\right)\right)^{1-\chi} \times \epsilon^l \text{ for } j = \{1, ..., J_1\}, \qquad (10)$$

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 $\epsilon^l \in \{4.41;\ 3.51;\ 2.88;\ 2.37;\ 1.89\}$.

3.3 Health capital

The law of motion of health capital consists of three components:

$$h_j = i\left(m_j, h_{j-1}, \delta^h_j, \epsilon^h_j\right) = \overbrace{\phi_j m_j^{\xi}}^{\text{Investment}} + \overbrace{\left(1 - \delta^h_j\right) h_{j-1}}^{\text{Trend}} + \overbrace{\epsilon^h_j}^{\text{Disturbance}}. \tag{11}$$

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.

We use the US medical expenditure surveys data (MEPS) to calibrate health capital accumulation. 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 ($SF - 12v2$).[8] 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.

Health capital space. In order to construct a health capital grid in the model we assume a maximum health capital level $h^{max}_m = 3.5$. All other health shock and health production parameters are then re-scaled using this value. The lower bound of the health grid $h^{\min}_m$ is treated as an internal parameter whose magnitude will influence the model outcome. It therefore has to be calibrated and is chosen in conjunction with the health production parameters ϕ_j and ξ. We allow for 15 health states on this grid.

Health depreciation rate. We next approximate the natural rate of health depreciation δ^h_j per age group. We calculate the average health capital $\bar{h}_j$ per age group of individuals

[8] 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.

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 (11) disappears as $\epsilon_j^h = 0$ and $m_j = 0$. The average law of motion of health capital then reduces to $\bar{h}_j = \overbrace{\left(1 - \delta_j^H\right) \bar{h}_{j-1}}^{\text{Trend}}$, from which we can recover the age dependent natural rate of health depreciation δ_j^h. The depreciation rates are increasing in age and fall between 0.6 and 2.13 percent per period. Note that these values are rather small because they do not contain the negative health shocks that are modeled separately.

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

The health production technology. 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 (1). A recent empirical contribution by Galama, Hullegie, Meijer and Outcault (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.

3.4 Health insurance

The US has a mixed health insurance system. Public health insurance programs are limited to the retired population (Medicare) and the poor (Medicaid), while the majority of working individuals obtain private health insurance via their employers.

Medicare. We use data from CMS (Keehan, Sisko, Truffer, Poisal, Cuckler, Madison, Lizonitz and Smith (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, Banthing, Selden, Cowan and Keehan (2006) and Bernard, Cowan, Selden, Cai, Catling and Heffler (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 as 2.11 percent of per-capita GDP as in Jeske and Kitao (2009).

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 are on some form of public health insurance. In the model we therefore calibrate the Medicaid eligibility level to 70 percent of the FPL ($FPL_{\mathrm{Maid}} = 0.7 \times \mathrm{FPL}$) 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). We base on MEPS data to set the age dependent coinsurance rate for Medicaid to ρ_j^{Maid} which results in a Medicaid size for workers of 0.5 percent of GDP in the model.

Private insurance. Private 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 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.

Group insurance offer. We estimate a Markov process that governs the group insurance offer probability from MEPS. MEPS data contain information about whether agents have received a group health insurance offer from their employer i.e. offer shock $\epsilon^{\mathrm{GHI}} = \{0,1\}$ where 0 indicates no offer and 1 indicates a group insurance offer. Since the probability of a GHI offer will be highly correlated with income, we also condition on the skill type ϑ of an individual when constructing the transition matrix $\Pi_{j,\vartheta}^{\mathrm{GHI}}$ with elements $\Pr\left(\epsilon_{j+1}^{\mathrm{GHI}} | \epsilon_j^{\mathrm{GHI}}, \vartheta\right)$. 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. Insurance companies in the individual markets screen their customers and price discriminate according to age and health status. The insurance premium, $\text{prem}^{\text{IHI}}(j,h)$, adjusts to balance expression (12). Age and health dependent markup profits $\omega_{j,h}^{\text{IHI}}$ are calibrated to match the take-up rate over age of IHI. Similarly, prem^{GHI} adjusts to balance expression (12) and the markup profit ω^{GHI} is calibrated to match the insurance take-up rate of GHI.[9] 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 use MEPS data to estimate coinsurance rates ρ^{IHI} and ρ^{GHI} for individual and group insurance 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 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 :

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

3.5 Technology 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).

[9] 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 into it to match the take-up rate in the data.

3.6 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 $t^{\text{Soc}}(\vartheta) = \Psi(\vartheta) \times w \times \bar{L}(\vartheta)$ be pension payments, where $\Psi(\vartheta)$ is a scaling vector 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 in the model.

Taxes. We use the formula from Gouveia and Strauss (1994) to calculate the progressive federal 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 Medicare tax τ^{Mcare} is set to 2.9 percent. Medicare payroll taxes are 2×1.45 percent on all earnings split in employer and employee contributions (see *Social Security Update 2007* (2007)). 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 that has been used by Jeske and Kitao (2009) in a similar calibration. Both payroll taxes are collected on labor income up to a maximum of $97.500.

Finally, 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.

3.7 Model fit

Model generated data moments and target moments from US data are juxtaposed in Table 10. We use a standard numeric algorithm to solve the model.[10] Figures 4 and 5 and Tables 1 and 10 summarize the model output.

Our calibrated model is capable of producing the lifecycle trends of average medical expenditures that matches the US data. 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 expose more to 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

[10] 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 solve for a new price vector using firm first order conditions. We then update the price vector and repeat all the steps until the price vector converges. The algorithm is implemented on a multi-core server in parallel Fortran.

expenditures of 17.7 percent of gross household income which matches data provided by CMS.[11] 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 1 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.

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 1: Select quantiles of the income distribution

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 10 compares model moments with first moments from MEPS, CMS, and National Income data.

4 A quantitative analysis of alternative insurance schemes

In our environment the lack of options to insure against health risk interacts with a limited set of market instruments against income risk (i.e., borrowing constraints) and amplifies consumption variance and the welfare cost. The overall welfare cost is the sum of the cost of missing insurance

[11] Personal communication with OACT/CMS.

against income risk, the cost of incomplete health insurance against health risk and dynamic interaction between the two. Our goal is to quantify the trade off between welfare gains from health risk sharing and the welfare losses due to incentive distortions when instituting different health insurance schemes.

In order to construct a baseline case for comparison, we formulate an incomplete markets economy in which individuals face health risks over the lifecycle without any health insurance scheme available. We call the model with no health insurance Model [1], or **No Insurance** version. Next, we examine a wide range of health insurance arrangements including (*i*) the US health insurance system, Model [2], (*ii*) universal health insurance with Medicare or Medicaid for all individuals, Model [3], and (*iii*) private insurance markets with IHI or GHI plan for all individuals, Model [4].

4.1 The US health insurance system

The US version of the model inherits all features of the no Insurance version and adds GHI and IHI schemes for the working population, Medicaid for the poor and Medicare for the retired population. Premiums for GHI are tax free and group rated. Premiums for IHI depend on age and risk group and are not tax deductible. Medicare is financed by a payroll tax and Medicaid is financed by general tax revenue.

We summarize main results in Table 2. Column 2 presents Model [1] with no health insurance, while column 3 presents Model [2] with the pre-2010 US health insurance system. We normalize the values of Model [1] to 0 or 100 to facilitate model comparison. The value differences between Model [1] and Model [2] are interpreted as the impact of introducing the insurance components of the US health insurance system into a perfectly competitive economy with health risk and borrowing constraints.

	[1] No Insurance	**[2] The US Insurance System**
Insured (%):	0.00	77.46
+ IHI (%)	0.00	6.37
+ GHI (%)	0.00	61.43
+ Medicaid (%)	0.00	9.65
+ Medicare (%)	0.00	17.68
Med. consumption (M)	100.00	107.71
Med. spending ($p_m M$)	100.00	88.35
Capital (K_c)	100.00	87.47
Output (Y_c)	100.00	92.69
Welfare (CEV):	0.00	+3.79
+ Income Group 1 (low)	0.00	+4.45
+ Income Group 2	0.00	+5.29
+ Income Group 3	0.00	+1.73
+ Income Group 4	0.00	+0.80

Table 2: The effects of mixed public and private health insurance systems. Note that Mix I: The US pre-2010 system; Mix II: The US after-2010 system; Mix III:

Aggregates. As seen column [1], there is no health insurance as all forms of public and private health insurance are completely removed. In this setting, individuals rely on their own investments to self-insure against health risk by either accumulating risk-free assets or health capital or deciding to work longer hours. Conversely, in the US pre-2010 model, individuals have access to a mixed public and private insurance system to insure against health risk. The introduction of the health insurance system introduces significant distortion to individuals' incentives to save and consume. Capital accumulation decreases by about 12 percent. 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 as a results of demand side changes triggered by the wide availability of insurance. This is a typical ex-post moral hazard effect. The introduction of insurance decreases the effective price for the consumer via two channels: (i) health insurance picks up a share of the medical bill so that households only pay a fraction of the price and (ii) 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.

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 simply the uniform percentage decrease in consumption required to make an agent indifferent between being born under the scenario of no health insurance (benchmark case) relative to being born under the US system. A negative (positive) CEV reflects a welfare decrease (increase) due to the introduction of insurance instruments.

In a conventional Bewley model, idiosyncratic income shocks and missing consumption insurance impose welfare costs due to consumption uncertainty. Our model is an extended Bewley model with health shocks that provide an additional source of idiosyncratic risk. The health shock introduces a new source of disturbance to individual consumption and health capital holdings. Risk-averse individuals benefit, at least on expectation, from health insurance contracts against health risk as they facilitate consumption smoothing. In model [1], there is no market or government insurance scheme to help individuals insure their health risk over the lifecycle. In such a setting, individuals will be better off if they have access to a larger set of insurance options which helps them to smooth consumption, leisure and health capital over the lifecycle.

In model [2] with the US health insurance system in place, 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 seen in column [2] of Table 2, we observe welfare gains across all four income groups. The low income groups benefits more from the pre-2010 health insurance arrangement in the US. Specifically, the lowest income group experiences the largest welfare gains of about 4.45 percent in terms of CEV. This outcome is mainly due to the redistribution effect of Medicare and Medicaid programs that target low income groups.

Overall, allowing individuals to access to the US health insurance system results in a significant welfare gain of about 3.8 percent. Arguably, the significant decreases in aggregate income due to introducing insurance also triggers negative welfare effects in our model. However, the positive welfare effects from reducing exposure to health risk and from income redistribution outweigh the negative welfare effect triggered by incentive distortions and moral hazard. Other things equal, all income groups prefer to live in an economy with the US health insurance system, compared to no health insurance at all.

4.2 Universal public health insurance system

We next consider a universal public health insurance system (UPHI system) with mandatory membership (i.e., universal coverage via a Medicare for all system) financed by taxes similar to single payer systems in many OECD countries. In this setting, the out-of-pocket health expenditures of the household are given by

$$o(m_j) = \rho^{Med}(p_m \times m_j),$$

where ρ^{Med} is the coinsurance rate of public health insurance with $\rho^{Med} \in [0,1]$. The government uses the coinsurance rate to control share healthcare expenditure between the government and household sectors. When $\rho^{Med} = 0$, all health expenditure is covered by government and the out-of-pocket health expenditure is zero. In this section, we set $\rho^{Med} = 0.2$, which is the level in the benchmark model calibrated to the US economy.

We report the results in Table 3. Model [1] no health insurance as a baseline comparison is reported in column 2. Model [3] presents a universal public health insurance (UPHI) with $\rho^{Med} = 0.2$. We consider two alternative tax financing instruments: (a) consumption tax τ_C and (b) payroll tax τ_V.

	[1] No Ins.	**[3] UPHI ($\rho^{Med} = 0.2$)**	
		(a) UPHI via τ_C	(b) UPHI via τ_V
Insured (%):	0.00	100.00	100.00
+ Public health insurance (%)	0.00	100.00	100.00
Cons. tax - τ_C (%)	4.31	19.59	3.60
Payroll tax - τ_V(%)	0.00	0.00	13.49
Med. consumption (M)	100.00	117.09	111.57
Med. spending ($p_m M$)	13.39	87.04	82.5
Capital (K_c)	100.00	87.96	80.25
Output (Y_c)	100.00	91.78	86.90
Welfare (CEV):	0.00	+4.06	+4.06
+ Income Group 1 (low)	0.00	+18.69	+25.52
+ Income Group 2	0.00	+6.19	+5.22
+ Income Group 3	0.00	−8.1	−11.96
+ Income Group 4	0.00	−13.13	−16.50

Table 3: The effects of the social health insurance

Aggregates. Individuals who live under the UPHI system rely less on self-insurance 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 public insurance. Notice that the introduction of the UPHI system completely eliminates the adverse selection problem as participation in the UPHI is automatic through the tax system. 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.

Welfare. As is well documented in the literature, all social insurance programs that are financed by tax revenues face a trade-off between the gains from insurance and the losses created by distortions of incentives. The UPHI system is no exception. On one hand, the UPHI system pools all individuals together to share health risk 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-ante moral hazard) which potentially leads to efficiency and welfare losses (incentive effect).

We analyze that classic insurance-incentive trade off in model [3-a]. We find that the welfare effects vary significantly across agent types. First low skill types experience welfare gains while the high skill group experience welfare losses, compared to the no health insurance benchmark 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 distributional effect and welfare gains might depend on which tax policy the government uses to finance the public health insurance system. To examine this point we consider a payroll tax (see column 4 of Model [3-b]). This payroll tax is more progressive as it redistributes incomes from high skill individuals to low skill and/or less healthy individuals. We find that the positive welfare effects on low income groups are now much larger while the negative welfare effects on high income groups become more pronounced as well. However, the aggregate welfare effect is surprisingly similar across the two financing regimes.

Overall we find that the UPHI system results in larger aggregate efficiency losses in terms of decreases in capital accumulation and output than the US system. On the other hand, the UPHI system results in much larger overall welfare gains as the UPHI is pooling risk more efficiently across the different population 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).[12]

Optimal coinsurance rate. In our model, the coinsurance rate is a policy tool to control health cost sharing between households and government sector. Smaller coinsurance rate means that households pay less, while the government pay more for every dollar spent on medical services. We quantify the trade off between insurance and incentive effects under different coinsurance rates and characterize an optimal coinsurance policy. We first consider a range of coinsurance rates between 0.1 and 0.5, $\rho^{Med} = [0.1., 0.2, 0.3, 0.4, 0.5]$. We report the results in Table 4.

	[3c] UPHI with τ_C				
$\rho^{Med} =$	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 4: The effects of the social health insurance

The improved risk sharing and redistributional measures embedded in the UPHI system result in welfare gains of low income individuals in poor health, and conversely, in welfare losses of high income individuals in good health. The overall welfare effect depends on the strength of the negative effects triggered by the ex-post moral hazard and fiscal distortions. In our framework, the size of these negative forces depends on how small or big the coinsurance rate is. When the coinsurance rate is relatively small, individuals share a relative smaller share of total health expenditure. This implies a bigger ex-post moral hazard effect due to relatively lower medical price and bigger tax distortion due to the fact that the government has to impose higher taxes to cover a bigger share of total health expenditure. Notice that, the former only exists in our model with endogenous health capital accumulation. We find welfare loss with a coinsurance rate as $\rho^{Med} = 0.1$. That is, the welfare losses due to the ex-post moral hazard effect, i.e. increased medical consumption by 49%, and fiscal distortion, i.e. $\tau_C = 31\%$, are relatively strong, which subsequently dominate the welfare gains associated with improved risk sharing and income distribution. However, the positive welfare effects are realized when the government increases the coinsurance rate. Interestingly, when the coinsurance rate becomes very large the positive welfare gains decreases. These hump share pattern of the welfare outcomes highlights how the health insurance system trades off between the insurance and incentive effects. We find a similar pattern when we let the government adjust payroll tax; however, the overall welfare

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

gain is relatively smaller.

In order to find out which level of the coinsurance rate that optimally balances out between two forces, we consider an optimal policy problem. We follow the approach in Conesa, Kitao and Krueger (2009) to characterize the optimal insurance rate. We assume that the government wants to maximize the ex-ante lifetime utility of an agent born into the stationary equilibrium implied by the chosen coinsurance rate. The government's objective is defined as

$$SWF\left(\rho^{Med}\right) = \max_{\rho^{Med}} \int V\left(x_{j=1}\right) d\Lambda\left(x_{j=1}\right).$$

Notice that, the government maximizes the social welfare function over the coinsurance rate only, i.e., one policy dimension, while keeping all other policy variables unchanged. We assume that the government either consumption tax or payroll tax adjust to finance public share of total health expenditure. We find that there is an optimal coinsurance rate of 0.285 that efficiently trades off the positive insurance/redistribution effects with the negative incentive effects. When we let the government adjust payroll tax, we also find an optimal coinsurance rate of 0.293.

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.

4.3 Private health insurance markets

Common wisdom in 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 welfare gains of purely private health insurance systems that result in partial health insurance coverage. We then contrast these results to the previous results on UPHI systems and demonstrate that government insurance is potentially very valuable to consumers - especially to the sicker types with low income.

Private health insurance contracts for workers. In the model we impose that individuals can decide whether to buy private health insurance which becomes active in the following period. The contract needs to be renewed each period if the individuals desires to stay insured. This timing setup guarantees that insurance is bought before health shocks are realized. We consider two market arrangements: (a) an unregulated insurance market without any government imposed regulation and (b) a regulated insurance market where the government regulates how insurance premiums can be set.

In the unregulated insurance market, insurance companies are free to screen and discriminate their clients and charge differential premiums according to individual-specific risk. Agents therefore end up paying an individual specific premium, $\text{prem}^{\text{IHI}}(j,h)$, that does depend on how old and how healthy a person is. This market structure is similar to individual health insurance (IHI) in the pre-2010 US market.

In the regulated insurance market the government intervenes in two ways: (i) the government does not allow insurance companies to price discriminate based on health status and age; and (ii) the government gives tax credit to individuals who buy private insurance. This market is similar to group health insurance plans (GHI) in the pre-2010 US market. In the GHI market premiums are group rated and sold at the average premium prem^{GHI}.

For simplicity we abstain from modeling insurance companies as profit maximizing firms and simply allow for a premium markup ω. Let $ins = \{\text{IHI and GHI}\}$ stand for insurance scheme type. The clearing condition for the health insurance companies of the two respective market is then

$$\begin{aligned} & \left(1+\omega^{ins}\right)\sum_{j=2}^{J_1}\mu_j\int\left[1_{[in_j(x_j)=ins]}\left(1-\rho^{ins}\right)p_m^{ins}m_j\left(x_j\right)\right]d\Lambda\left(x_j\right) \qquad (12)\\ = \quad & R\sum_{j=1}^{J_1-1}\mu_j\int\left(1_{[in_j(x_j)=ins]}\text{prem}^{ins}\right)d\Lambda\left(x_j\right), \end{aligned}$$

where ω^{ins} are markup factors that determine loading costs (fixed costs or profits), $1_{[in_j(x_j)=ins]}$ is an indicator function equal to unity whenever agents buy the health insurance policy, ρ^{ins} is the coinsurance rate and p_m^{ins} is the price for health care services for the two insurance types. The respective first line in the above expression summarizes aggregate payments made by insurance companies, whereas the second corresponds to the aggregate premium collection 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 $\mathit{Profit}^{\text{Ins}}$, that are redistributed in equal amounts to all surviving individuals.

We run the experiments of two market arrangements and report results in Table 5.

Adverse selection. We start from Model [1] with no health insurance and introduce IHI health insurance for all workers and retirees, i.e. Model [4-a]. We find that in this setup - with the given risk structure - an unregulated private health insurance market breaks down and cannot exist. The underlying reason is due to the nature of health capital evolution over the lifecycle. Individuals are exposed to more health risk as they age. Price discrimination according to health status and age eliminates risk sharing between healthy and unhealthy individuals. 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. This result indicates that the adverse selection problems are highly prevalent

	[1] No Ins.	[4] Private Health Insurance	
		(*a*) Unregulated - IHI	(*b*) Regulated - GHI
Insured (%)	0.00	0.00	82.90
+ IHI (%)	0.00	0.00	0.00
+ GHI (%)	0.00	0.00	82.90
Med. consumption	100.00	100.00	104.60
Med. spending	100.00	100.00	83.12
Capital (K_c)	100.00	100.00	98.57
Output (Y_c)	100.00	100.00	100.45
Welfare (CEV)	0.00	0.00	+0.97
+ Income Group 1 (low)	0.00	0.00	+1.11
+ Income Group 2	0.00	0.00	+0.93
+ Income Group 3	0.00	0.00	+0.60
+ Income Group 4	0.00	0.00	+2.84

Table 5: The effects of private health insurance.

in private health insurance markets. In equilibrium, no individual can afford private health insurance. This situation of market failures in our framework is consistent with the classic result documented in the insurance literature (e.g., Pauly (1974*b*) and Rothschild and Stiglitz (1976)).

Regulation and insurance coverage. We next consider an economy in which the government regulates private insurance companies. Market regulations induce more individual 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 column [4-b], the coverage of private health insurance markets expands substantially. In this setting, up to 82.9 percent of the population is insured. However, even with such market regulations the insurance system fails to provide full coverage. This is mainly due to young and healthy individuals who face very small health risk and thus opt out of private health insurance markets and low income types who cannot afford the premiums.

Aggregates. In a model with no health insurance individuals can either use precautionary savings or investments into health capital (i.e., precautionary health investments) to insure against health risk. The latter channel is relatively new as it only appears in models with endogenous health capital accumulation. When individuals have market options to insure against health risk they tend to reduce their reliance on self-insurance. In models [4-b] where more individuals are in the private health insurance markets, medical consumption increases by 4.6 percent while medical spending drops significantly by 17 percent. The decrease in medical spending is mainly driven by the decrease in medical price due to the lower prices that insurance companies are able to negotiate.[13]

We find that there are positive aggregate efficiency gains when introducing private insurance.

[13]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 invididual matches price differences observed in the data.

Stock of aggregate capital reduces 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 0.5 percent and a large increase in production of medical services by 4.4 percent.

Welfare. The existence of private health insurance markets in model [4-b] 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. This market-based approach can only provide partial insurance coverage with the an insurance take-up rate around 83 percent. Even though this risk sharing mechanism is incomplete we still find welfare gains for all income groups as reported in the lower part of Table 5.

In short, 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 in the previous section, this leads to a lower degree of risk pooling as well as to a lower degree of redistribution of wealth and therefore lower welfare gains overall but especially for low income groups and individuals with low health states. 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 contracts for workers and retirees. In the next experiment we allow retirees to have access to a self clearing GHI-market. The GHI-market for workers is maintained with identical parameters as in the US benchmark. We then vary the coinsurance rate for the GHI-contracts for retirees according to Table 6. 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.

We find that coinsurance rates that are not generous enough (i.e., $\rho^{\mathrm{GHI}} > 40\%$) lead to the erosion of the GHI for the old. Similarly, GHI contracts that are too generous (i.e., $\rho^{\mathrm{GHI}} < 10\%$) also loose market share as they are too expensive. Is is interesting to point out that the welfare effects are such that the richer cohorts benefit the most from very generous GHI contracts whereas low income cohorts benefit less. This is in contrast to the results in Table 4 for public health insurance, where welfare effects were more favorable for the low income types. Private health insurance lacks the redistribution element of the UPHI system and is therefore less desirable for low income households.

	[4c] 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
+ Income Group 1 (low)	+1.26	+1.38	+1.35	+1.27	+1.13
+ Income Group 2	+3.36	+3.78	+3.65	+3.49	+0.95
+ Income Group 3	+6.37	+6.55	+6.19	+5.38	+0.62
+ Income Group 4	+10.30	+10.13	+9.62	+9.12	+2.89

Table 6: The effects of GHI for retirees with various coinsurance rates.

5 Conclusion

In this paper we investigate the welfare and efficiency implications of public and private health insurance systems in a model with incomplete insurance markets. We formulate a generalized Bewley-Grossman model that includes lifecycle health risk. We calibrate the model to match 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 compare four different settings: (*i*) without any insurance, (*ii*) with a mixed public/private insurance system similar to pre-2010 US, (*iii*) a universal public health insurance system (UPHI) and (*iv*) a private health insurance system with and without government intervention.

We find that the availability of public health insurance leads to aggregate welfare gains. The mixed system and the private system with government intervention can only provide a partial health insurance coverage. Moreover, we demonstrate that in a UPHI system the positive insurance/redistribution effects strongly dominate the negative incentive effects caused by tax distortions and ex-post moral hazard. Despite the fact that the UPHI system generates the largest efficiency losses in terms of output of final consumption goods, the UPHI system improves risk sharing across households and redistribution of wealth so that it results in the largest welfare gains of all the systems we analyzed. We characterize quantitatively how the UPHI system trades off the insurance effect with the incentive effect by varying the coinsurance rate. Finally, we solve for optimal coinsurance rates that balance the trade-off between the positive insurance effects and the negative incentive effects and find that low income households benefit more from a public system whereas high income households benefit more from a private system.

Several possible extensions are left for future work. The lack of a bequest motive and the imposed independence of survival from health states leads to lower than observed assets holdings of the retired cohorts and affects households' self insurance motive via savings. Optimality of insurance contracts is currently restricted to optimize over 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.

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6 Appendix A: MEPS and PSID data

MEPS. We primarily use data from the Medical Expenditure Panel Survey (MEPS) from the years 1999 to 2009 for our estimation. MEPS provides a nationally representative survey about health care use, health expenditures, health insurance coverage as well as demographic data on income, health status, and other socioeconomic characteristics. The original household component of MEPS was initiated in 1996. Each year about $15,000$ households are selected and interviewed five times over two full calendar years. MEPS groups individuals into Health Insurance Eligibility Units (HIEU). We do abstract from family size effects and concentrate on adults aged 20 to 91 who are the head of the household. We remove individuals with income smaller than \$500. If we only keep individuals with observations in two consecutive years, we are left with $131,121$ head-of-household/year observations. We calculate population weighted health expenditure profiles, as well as Markov transition probability matrices for income shocks, health shocks, and employer matching shocks. Summary statistics are presented in Table 7. All dollar values are denominated in 2009 dollars using the Personal Consumption Expenditures (PCE - chain price) index for monetary measures. All distributional statistics for income are calculated for working age individuals between age $20-65$ as the eligibility thresholds for Medicaid and subsidies in the ACA reform are most relevant to these cohorts. The details of our calibration results are presented in Appendix B.

Variable	**Mean**	**St.Err.**	**Obs.**
Age	47.53	0.14	$131,121$
Female	44.6%	0.002	$131,121$
Person total income	\$39,976	\$271	$131,121$
Hourly wage	\$20.0	\$0.12	$85,149$
Health expenditure	\$4,203	\$54.85	$131,121$
Health capital $(4.56-74.38)$	49.48	0.07	$112,672^{(*)}$
No insurance	21.1%	0.003	$91,538^{(**)}$
Workers on individual health insurance(IHI)	7.2%	0.001	$91,538$
Workers on group health insurance (GHI)	62.17%	0.004	$91,538$
Workers with GHI offer	63.07%	0.003	$91,538$
Workers on Medicaid/Public	9.60%	0.002	$91,538$
Coinsurance IHI	0.50	N/A	$4,646^{(***)}$
Coinsurance GHI	0.32	0.002	$42,186$
Coinsurance Medicaid	0.17	N/A	$10,855$
Coinsurance Medicare	0.31	N/A	$28,381$

Table 7: Summary statistics MEPS 1999-2009. (*) Individuals in the first wave 1999 do not report health capital states. (**) The insurance take-up statistics are calculated from the subgroup of 25-65 year old individuals. (***) Coinsurance rates are only calculated for individuals with positive health expenditures and some form of health insurance.

PSID. We use eight waves of the Panel Study of Income Dynamics (PSID) in combination with the wealth surveys of 1984, 1989, 1994, 1999, 2001, 2003 and 2005 to calculate the initial asset distribution of agents in period one. We use variable Sx16, which is the sum of all asset value types net of debt value and home equity (x refers to wave) and drop values above $800,000. All values are converted to 2009 dollars using the Personal Consumption Expenditures index.

7 Appendix B: 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	$\delta_{h,j}= [0.6\% - 2.13\%]$	MEPS 1999/2009
- Survival probabilities	π_j	CMS 2010
- Health Shocks	see technical appendix	MEPS 1999/2009
- Health transition prob.	see technical appendix	MEPS 1999/2009
- Productivity shocks	see text section 3	MEPS 1999/2009
- Productivity transition prob.	see technical appendix	MEPS 1999/2009
- Group insurance transition prob.	see 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	$\rho = 0.20$	MEPS 1999/2009
- Medicare premiums/GDP	2.11%	Jeske and Kitao (2010)
- Public coinsurance rate	$\rho^{Mcare} = \rho^{Maid} = 0.20$	Center for Medicare and Medicaid Services (2005)

Table 8: 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 9: 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
- 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
- Medical spend. profile		see figure 4		15
Total number of moments				26

Table 10: Model vs. data

8 Appendix C: Figures

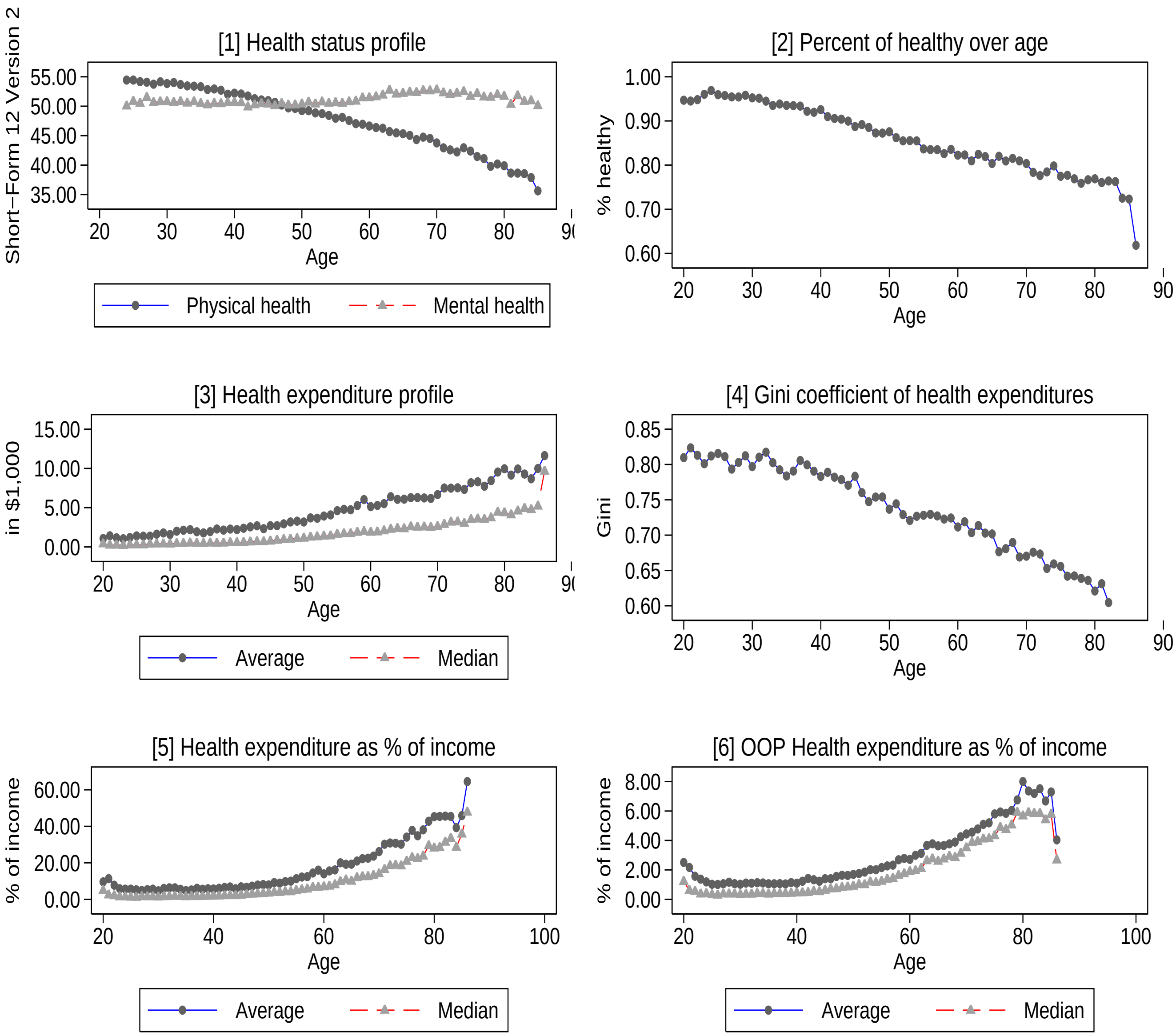

Figure 1: Health status and spending over the lifecycle: MEPS 1996-2007

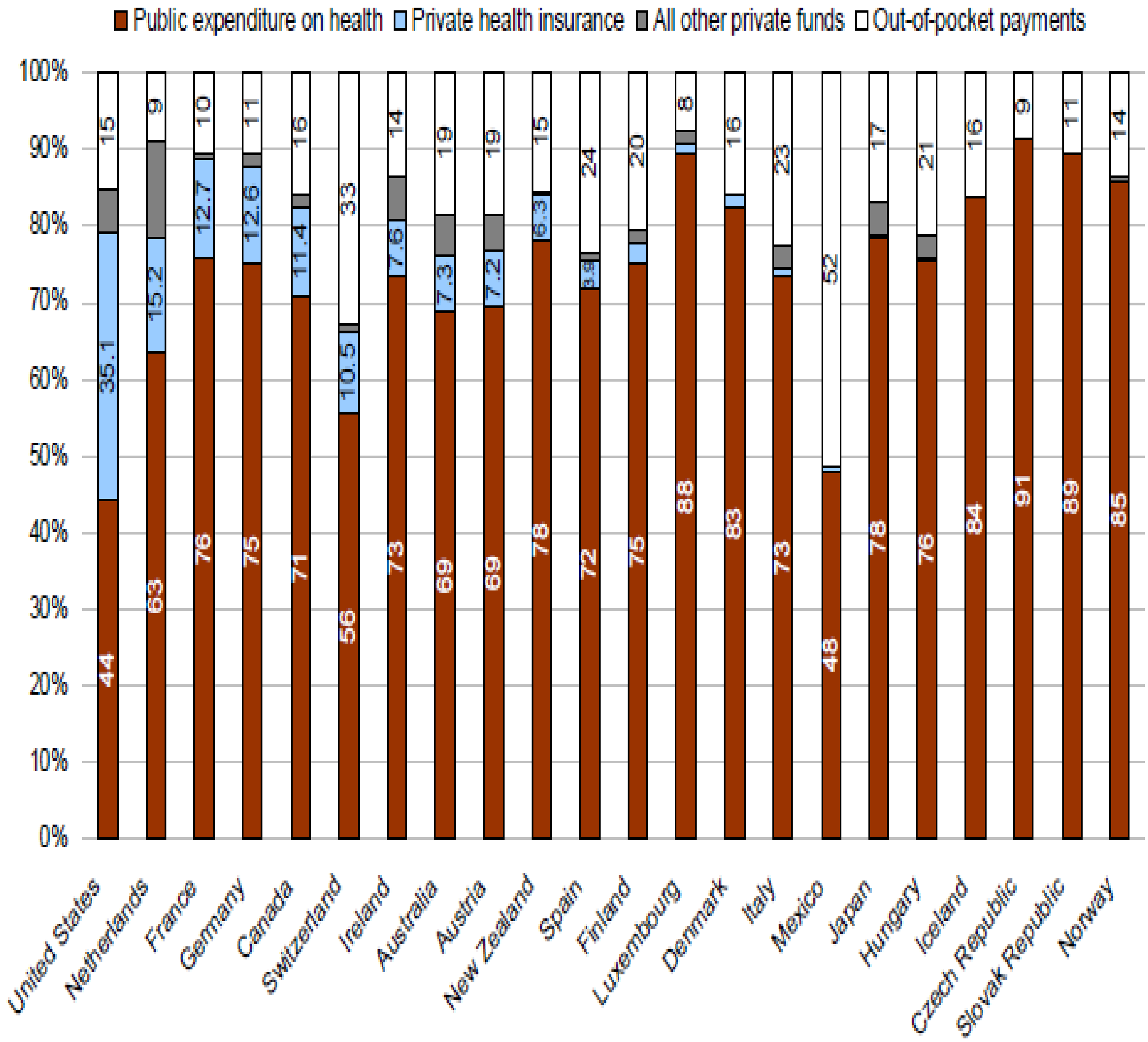

Figure 2: Health expenditures by sources in advanced economies (OECD, 2004)

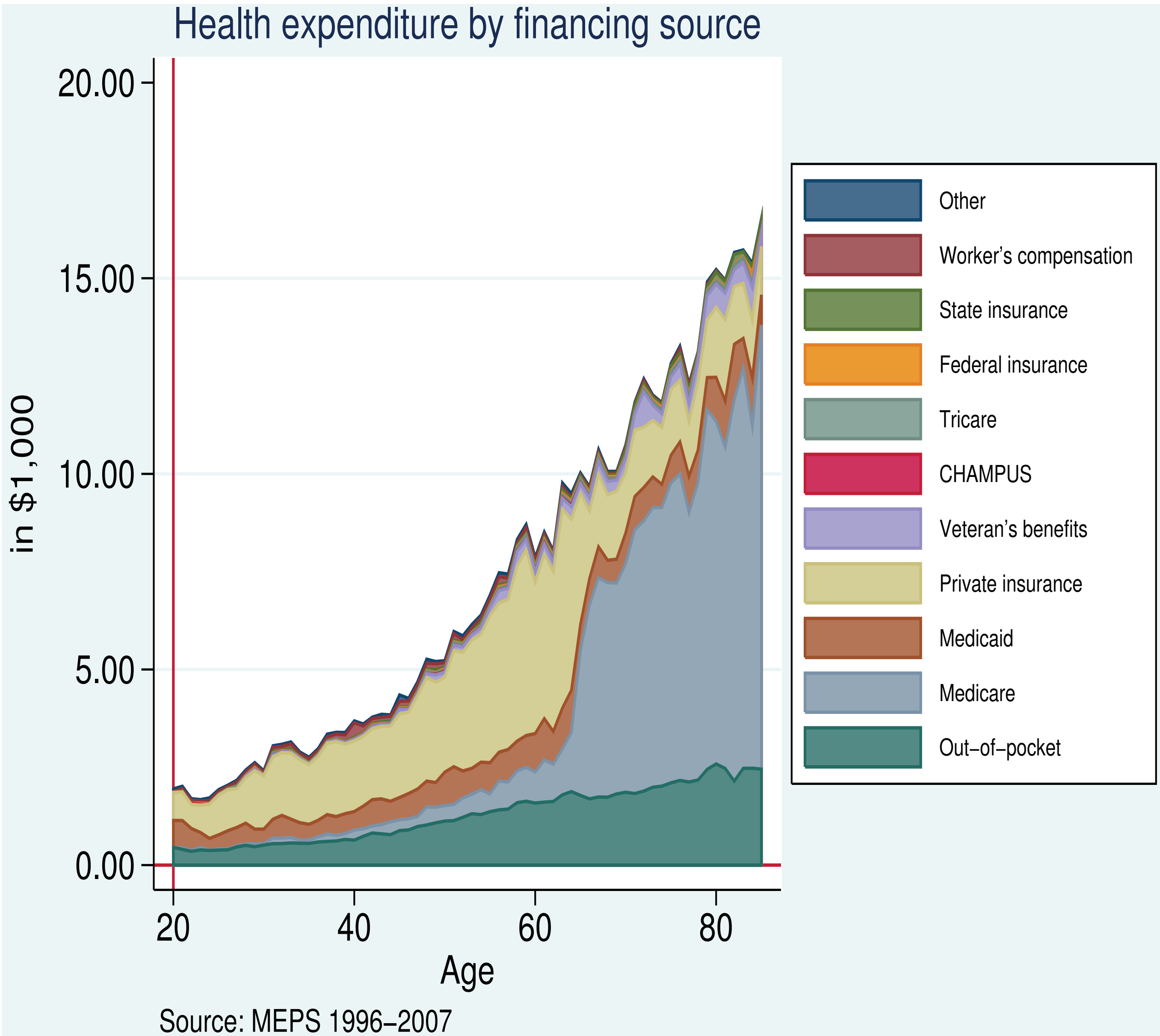

Figure 3: Health spending over the lifecycle: MEPS 1996-2007

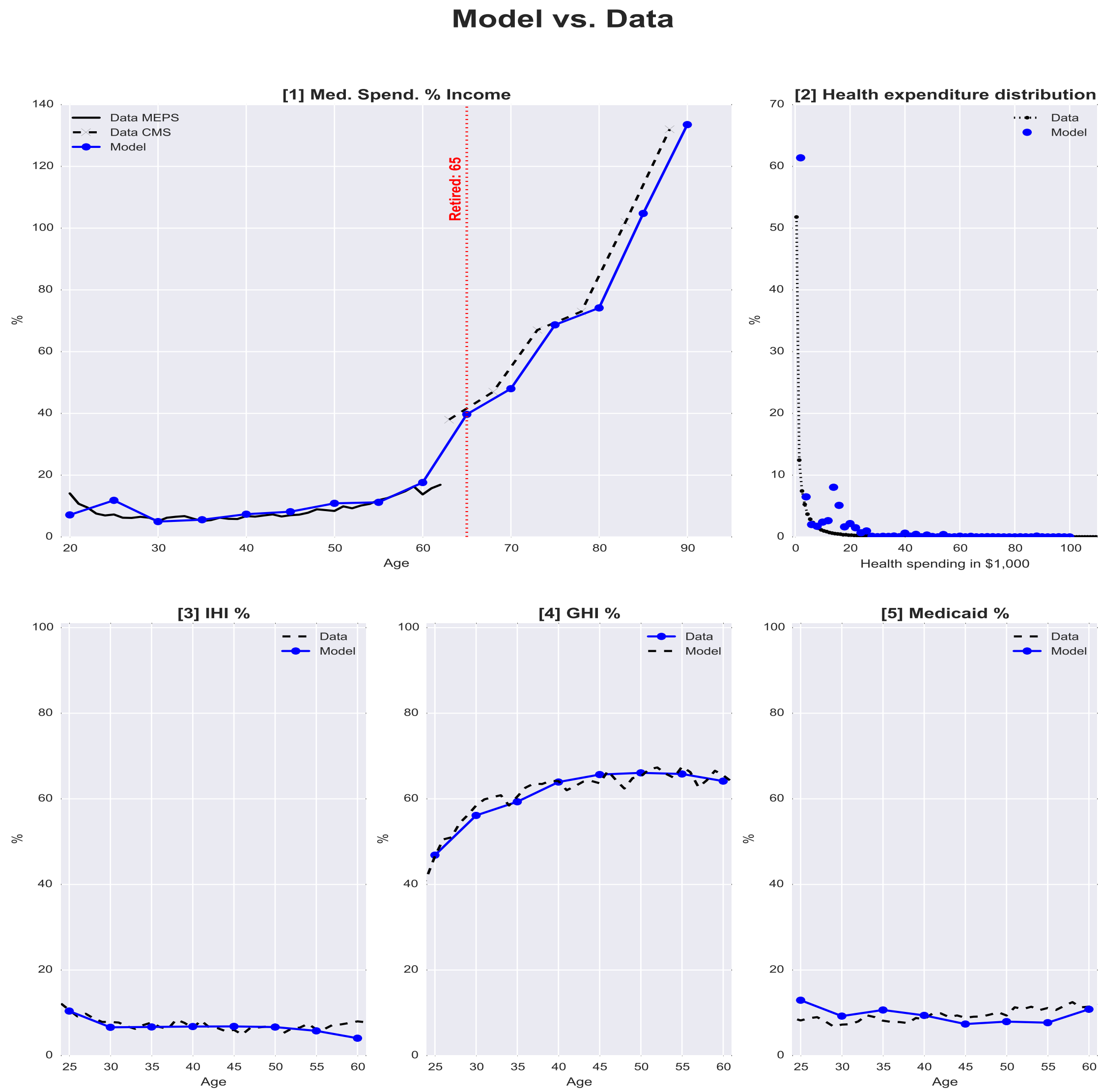

Figure 4: Health expenditure and insurance take-up rate: Model vs. data

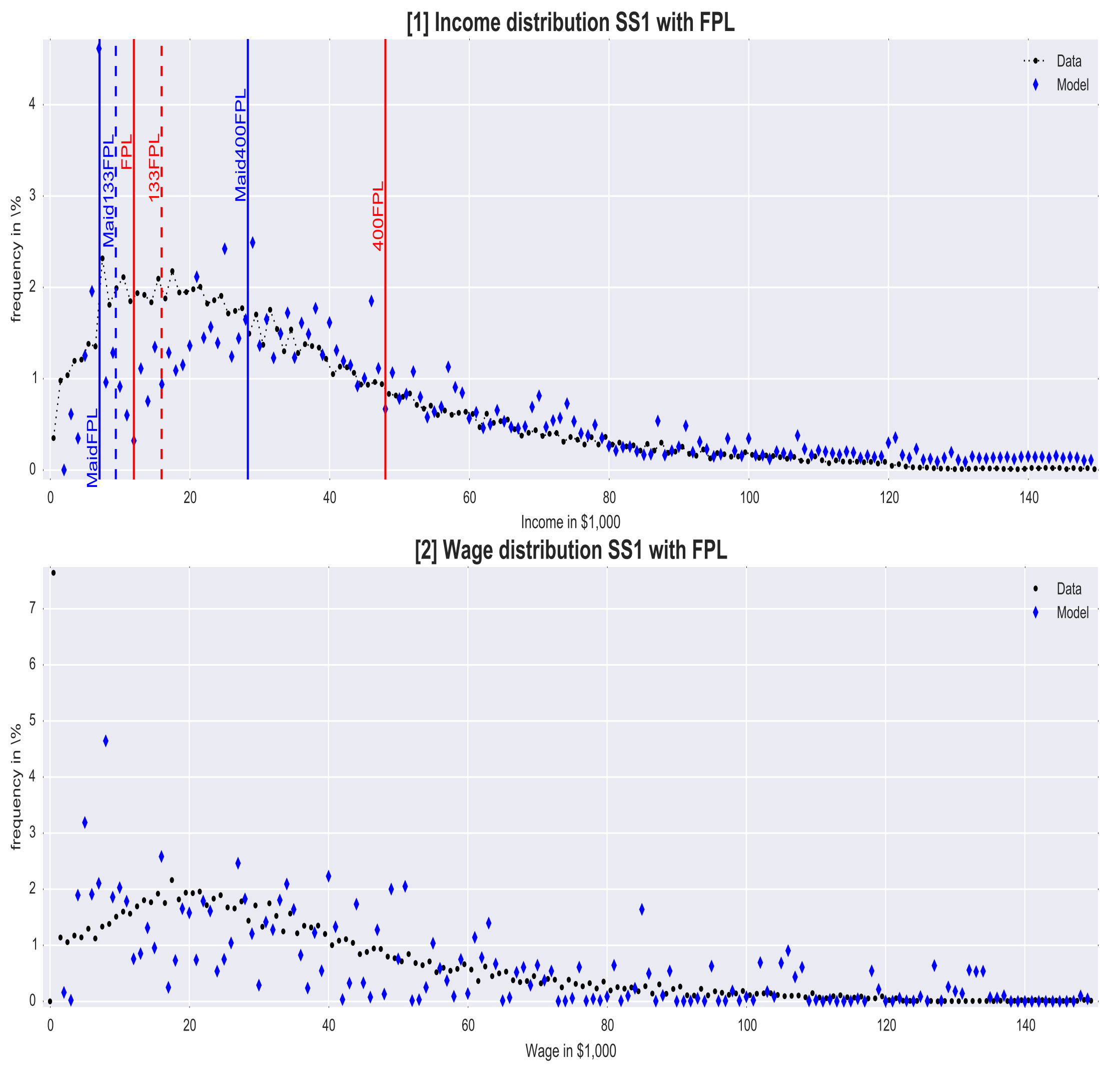

Figure 5: Income and wage distribution: Model vs. MEPS data 1999-2009

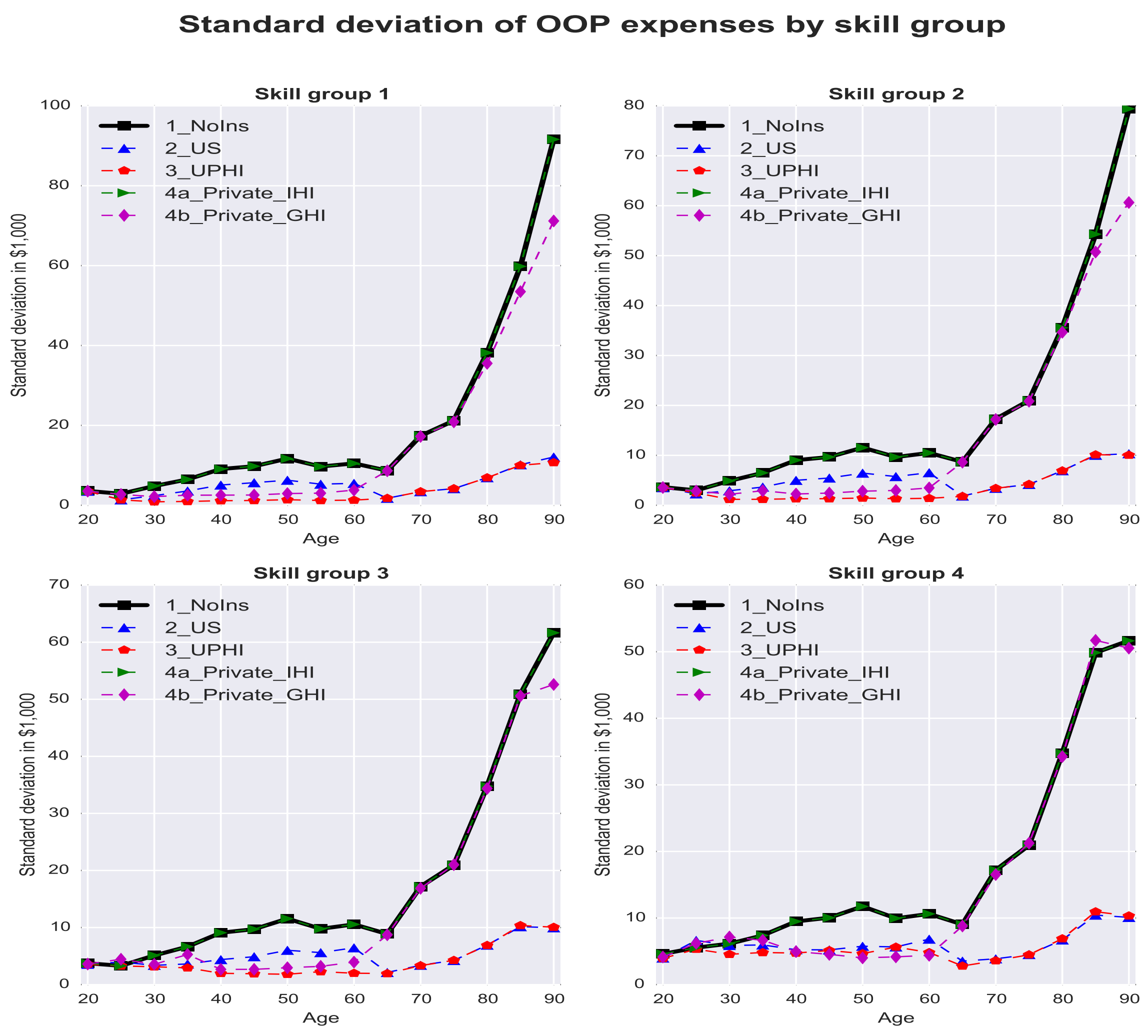

Figure 6: Standard deviation of out-of-pocket health expenditure over the lifecycle for various insurance regimes.

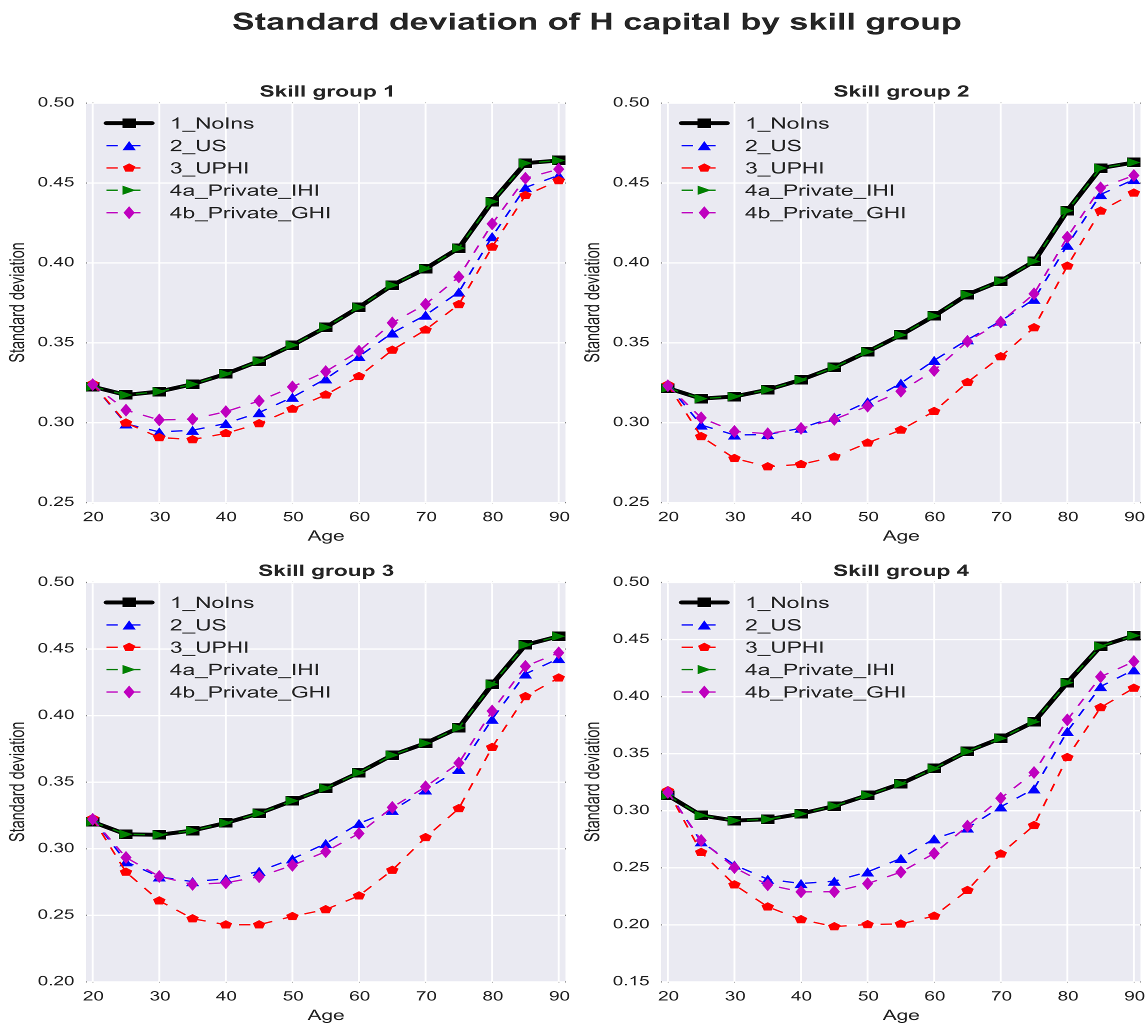

Figure 7: Standard deviation of health capital over the lifecycle for various insurance regimes.

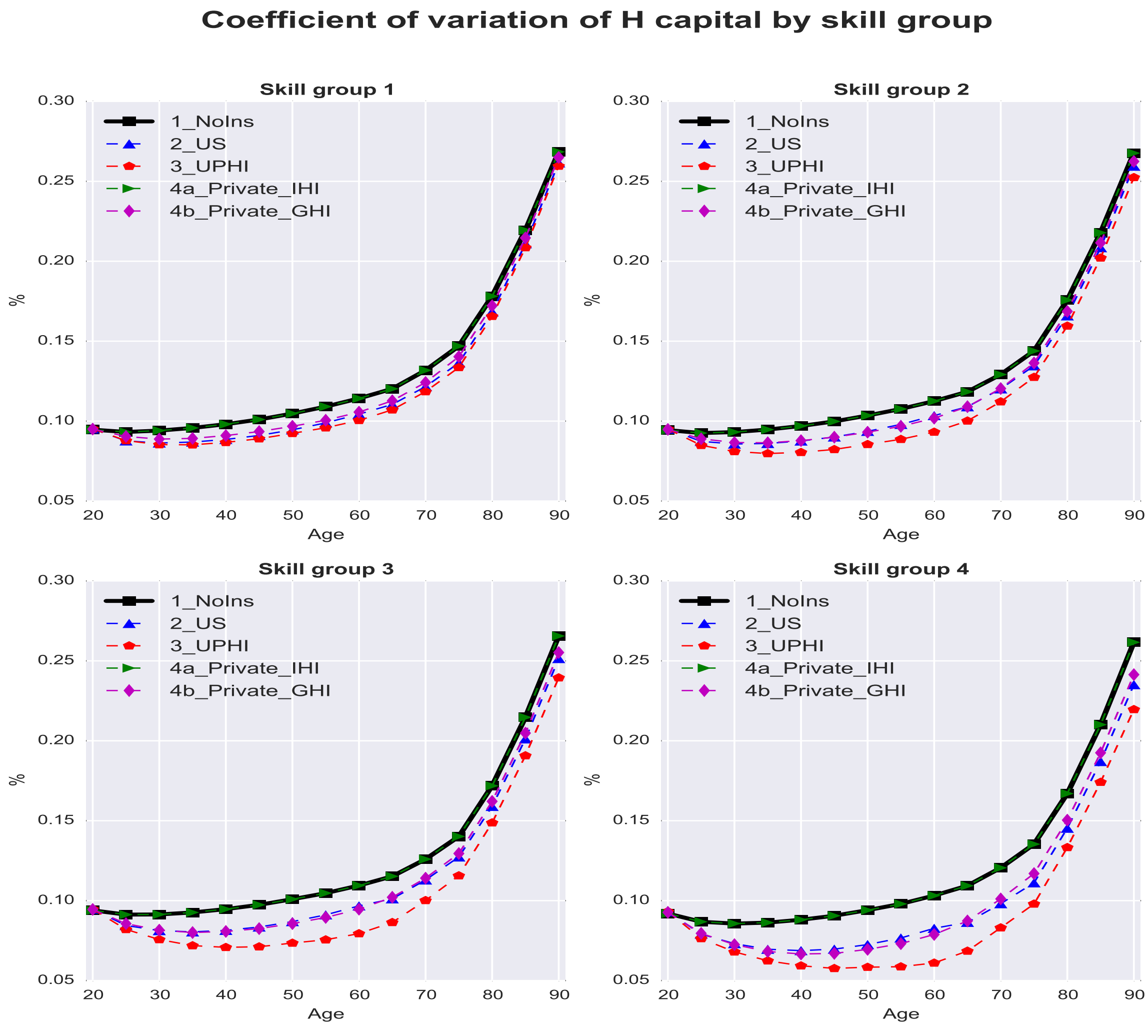

Figure 8: Coefficient of variation of health capital over the lifecycle for various insurance regimes.