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Market Inefficiency, Insurance Mandate and Welfare: U.S. Health Care Reform 2010*

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Abstract

In this paper we develop a stochastic dynamic general equilibrium overlapping generations (OLG) model with endogenous health capital to study the macroeconomic effects of the *Affordable Care Act* of March 2010 also known as the Obama health care reform. We find that the insurance mandate enforced with fines and premium subsidies successfully reduces adverse selection in private health insurance markets and subsequently leads to almost universal coverage of the working age population. On other hand, spending on health care services increases by almost 6 percent due to moral hazard of the newly insured. Notably, this increase in health spending is partly financed by the larger pool of insured individuals and by government spending. In order to finance the subsidies the government needs to either introduce a 2.7 percent payroll tax on individuals with incomes over $200,000, increase the consumption tax rate by about 1.1 percent, or cut government spending about 1 percent of GDP. A stable outcome across all simulated policies is that the reform triggers increases in health capital, decreases in labor supply, and decreases in the capital stock due to crowding out effects and tax distortions. As a consequence steady state output decreases by up to 2 percent. Overall, we find that the reform is socially beneficial as welfare gains are observed for most generations along the transition path to the new long run equilibrium.

JEL: H51, I18, I38, E21, E62

Keywords: Affordable Care Act 2010, endogenous health capital, life-cycle health spending and financing, dynamic stochastic general equilibrium

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1 Introduction

Most industrialized countries have a health care system that is dominated by the public sector. In the U.S. health care system, on the other hand, a large part of the working age population obtains health insurance from their employers who can benefit from a tax deduction when purchasing private health insurance for their employees. In the U.S. government run health insurance programs are limited to cover the retired population (Medicare) and the poor (Medicaid). This fragmented health insurance system exposes households to considerable financial risk and leaves over 45 million people uninsured. In addition the U.S. health care system is the most expensive in the world with health care spending reaching 17 percent of GDP in 2010. The increase in health care costs threatens the solvency of public health insurance programs like Medicare and Medicaid and in extension the harms the overall government budget deficit. The situation is made worse by demographic shifts that increase the fraction of the older population which tends to spend more on health care.

In reaction to these challenges, a number of comprehensive health care reforms have been implemented in recent years with the goal to control the rise of health care spending while also increasing the number of individuals with health insurance. Of particular importance is the recently passed *Affordable Care Act* (March 2010) or the "Obama health care reform," as it is often called.[1] This reform represents a serious effort towards universal coverage. However, many of the financing issues and therefore the long term financial viability of the program have been questioned. Also, little is known about the reform's wider implications on the economy, especially with respect to the additional taxes that will be required to pay for this reform. Critics maintain that the reform is underfunded and will worsen the U.S. budget deficit over the next decade.

In this paper we conduct a general equilibrium analysis of the Obama health care reform i.e. the *Affordable Care Act* that was passed in the Spring of 2010. We propose an augmented stochastic dynamic general equilibrium framework that combines a stochastic dynamic general equilibrium overlapping generations models with heterogenous agents (e.g. see Imrohoroglu, Imrohoroglu and Joines (1995) and Huggett (1996)) with the Grossman health capital model (Grossman (1972a)) developed in health economics. We also add idiosyncratic health risk and public and private health insurance options to model. In addition we account for important institutional details of the U.S. health insurance system and distinguish between employer provided group insurance and insurance bought in the individual markets. The main difference between these two types of insurances is that group insurance premiums are tax deductible and community rated. Retired individuals are insured under Medicare. As a consequence, the demand for medical services and the demand for health insurance are endogenously derived from the household optimization problem together with consumption, labor supply and savings

[1] The bill was passed in two steps. The Patient Protection and Affordable Care Act was signed into law on March 23, 2010 and was amended by the Health Care and Education Reconciliation Act on March 30, 2010. The name "Affordable Care Act" is used to refer to the final, amended version of the bill (see also http://www.healthcare.gov).

decision. The discipline of our approach requires the model to be consistent with an individual's behavior over the life-cycle. The model matches insurance take-up rates, health expenditures, the labor supply, and the aggregate asset accumulation profile over the life-cycle. Important adverse selection and moral hazard effects are captured due to the endogeneity of insurance take-up rates and health capital accumulation. Since the model is a general equilibrium model it also accounts for important price feedback effects that naturally arise as a consequence of this sizeable health insurance reform.

To conduct quantitative analysis we first calibrate the model to data from the U.S. economy before the reform. We find that our model is able to produce life-cycle profiles of health expenditures and health insurance take up ratios that are consistent with data from the Medical Expenditure Panel Survey (MEPS) as well as important macro economic aggregates. We next apply the model to study the macroeconomic effects of the Obama health care reform. Our key results can be summarized as follows.

First, the fraction of workers insured increases from 61.8 percent in the benchmark economy to 97.8 percent after the reform. Indeed, mandatory health insurance, enforced by fines and premium subsidies, alter the trade-off between efficiency losses and welfare benefits of buying health insurance. The reform subsequently induces low risk workers who now face higher cost of not having health insurance to participate in the health insurance market. Having more healthy workers participating in the health insurance markets improves risk-sharing and drives premiums down. This in return attracts more low risk agents to participate in the health insurance market and demonstrates how the reform successfully eliminates the adverse selection problem that plagues private health insurance markets. Most of the increase in insurance coverage comes from individual markets as the coverage ratios in group markets where already very high in the pre-reform equilibrium.

Second, health spending increases by about 6 percent due to a moral hazard effect triggered by the newly insured agents. This increase in health spending is partly financed by the larger pool of insured individuals as well as government subsidies. However, in order to finance the reform the government needs to either introduce a 2.7 percent payroll tax on individuals with incomes over $200,000, cut government spending by about 1 percent of GDP, or increase consumption taxes by about 1 percent.

Third, in all these experiments the reform triggers increases in health capital and decreases in labor supply and capital stock due to crowding out effects and tax distortions. What follows is an efficiency loss that results in decreases of steady state output (GDP) of up to 1.7 percent in some experiments.

Finally, the reform is socially beneficial as welfare gains are observed for generations born up to five periods (25 years) before the implementation of the reform. Generations born after the reform experience welfare gains between 1 or 2 percent of their average per period consumption. This result implies that the current health insurance system (i.e. the benchmark economy) does not efficiently trade off the insurance (i.e. gains from risk sharing, reduction of adverse selection etc.) and incentive effects (i.e. efficiency loss due to tax distortions, moral hazard, etc.). The additional welfare gain from strengthening the insurance effect outweighs the possible welfare reduction due to the efficiency loss caused by tax distortions and other adverse effects triggered by almost universal health insurance coverage. The current old generation experiences welfare losses as they do not live long enough to experience the gains from increases in health capital due to better access to health care as the reform primarily benefits working age individuals. Under some scenarios the old generation helps finance the reform (e.g. when the reform is financed by consumption or lump-sum taxes) without receiving a direct benefit. The welfare effects are amplified for the sick and poor as they react more strongly to changes in government policies.

Related literature. Our paper is related to a growing macro-health literature. Jeske and Kitao (2009) is one of the first efforts to conduct health policy reform using a large scale life-cycle model with a rich set of institutional details (e.g. distinction between employer provided group insurance and individually purchased health insurance, realistic taxes, etc.). Kashiwase (2009) examines a number of fiscal policies for universal insurance as well as for financing the growing health care costs. However, these models ignore the micro-foundations of endogenous health accumulation, utilization of health care and health spending as they model health expenditures as purely exogenous expenditure shocks. These models can therefore not account for moral hazard effects triggered by changes in insurance coverage ratios. We therefore extend the analysis and include the process of life-cycle health accumulation, health spending and financing into a unified modeling framework in order to capture the most important interactions between health spending and financing over the life-cycle. Our model therefore incorporates the moral hazard and adverse selection effects that will influence the market equilibrium adjustments on insurance coverage and aggregate health spending. The model also captures possible productivity effects of changes in health capital directly. Since these effects can be large, there is a newly evolving macro-health literature that starts integrating health accumulation processes into more realistic (general equilibrium) life-cycle models for the U.S. economy (e.g. Suen (2006), Jung and Tran (2008), Jung and Tran (2009), Forseca, Michaud, Galama and Kapteyn (2009), Feng (2009), Halliday, He and Zhang (2010) and Mariacristina, French and Jones (2010)).

This paper introduces a rich institutional setup to specifically model the *Affordable Care Act* from a macro dynamic perspective. Other recent papers that have looked at this reform are Brugenmann and Manovskii (2010) who investigate the implications on firms decisions to offer health insurance. They use an infinite horizon model with exogenous health expenditure shocks and with institutional details of employer-provided health insurance markets. Closely related to our study is Pashchenko and Porapakkarm (2010) who also study the welfare effects of the health insurance reform bill 2010. However, their model abstracts from labor-leisure choice, endogenous health accumulation, and endogenous health expenditures. In addition, they focus on steady state welfare effects and neglect welfare implications over the transition to the new steady state equilibrium. We believe that these omitted features are important to fully understand the macroeconomic effects of the reform in both short-run and long-run horizons. Our analysis therefore includes all these missing features.

The paper is structured as follows. Section 2 provides a brief overview of the *Affordable Care Act* 2010. Section 3 presents the model. In section 4 we present the calibration of the model. Section 5 contains the results of simulating the reform bill. Section 6 contains results from alternative policy experiments and section 7 concludes. The appendix contains the definition of equilibrium as well as all tables and figures. A technical appendix with additional details about the solution algorithm and the data calibration is available on the authors' website.[2]

2 The *Affordable Care Act*

The *Affordable Care Act (ACA)* introduces a variety of measures to decrease the number of uninsured individuals and to protect individuals who already have insurance. Some of the immediate changes include a $250 Medicare drug cost rebate to alleviate the problems caused by the donut hole in Medicare Part D[3] as well as a provision that allows young adults to stay on their parents' health insurance up to age 26. Among the most controversial policies is the insurance mandate that introduces a penalty on individuals without health insurance starting in 2014. Low income groups and some high risk groups are exempt from the penalty which can be as high as 2 percent of an individual's income. In addition, employers with more than 50 workers will be required to offer group based health insurance or pay a contribution of $2,000 per worker. In order to assist low income families to buy health insurance the bill expands the Medicaid eligibility threshold to 133 percent of the federal poverty level (FPL) uniformly across all states. In addition, starting in 2014 individuals with income between 133 and 400 percent of the FPL who do not currently have health insurance via their employers will have access to insurance exchanges where they can buy subsidized health insurance from participating private insurance companies. The subsidies are income dependent as summarized in table 1. Insurance companies will not be able to put spending caps into the contracts nor will they be allowed to discriminate by health status or deny coverage to children with pre-existing conditions. Limitations on price setting policies of insurance contracts also apply and a 40 percent excise tax on high-end insurance policies ("Gold Plated Insurance Contracts") will be introduced in 2018. The reform bill is financed by increases in payroll taxes (and expansions of the payroll tax base) for individuals with incomes higher than $200,000 per year (or $250,000 for families). Various other sources are used to generate additional revenue in order to pay for the reform (e.g. funds from social security, Medicare, student loans, and others).

[2] http://pages.towson.edu/jjung/research.htm

[3] The Donut hole refers to a coverage gap for prescription drugs in Medicare Part D. Individuals spending between $2,700 – $6,154 on prescription drugs pay fully out of pocket.

3 The model

3.1 Demographics

We use an overlapping generations framework. Agents 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. Agents die for sure after J periods. Deceased agents leave an accidental bequest that is taxed and redistributed equally to all 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

$$\mu_j = \frac{\pi_j}{(1+n)^{years}} \mu_{j-1} \text{ and } \tilde{\mu}_j = \frac{1-\pi_j}{(1+n)^{years}} \mu_{j-1},$$

where $years$ denotes the number of years per model period.

3.2 Technology and firms

In this economy, there is a continuum of identical firms that use physical capital K and human capital L to produce one type of final good. The final good can be used as either a consumption good c or as medical services m. We do not model the production of medical services m separately. The price of consumption goods is normalized to one and the price of medical services is denoted p_m. Each unit of consumption good can be traded for $\frac{1}{p_m}$ units of medical services. Firms choose physical capital K and human capital L to solve the following profit maximization problem

$$\max_{\{K,\ L\}} \left\{ F(K, L) - qK - wL \right\}, \tag{1}$$

taking the rental rate of capital q and the wage rate w as given. Capital depreciates at rate δ in each period.

3.3 Preferences

Households value consumption c, leisure l, and services s that are derived from health h. Household preferences are described by a utility function $u(c, l, s)$ where $u : R^3_{++} \to R$ is C^2 and satisfies the standard Inada conditions. The technology for the production of health services that transfers health capital from the current period into health services in the current period is

$$s = f(h), \tag{2}$$

where $f' \geq 0$ and $f'' \leq 0$.

3.4 Health and human capital accumulation

Health and human capital evolve over the lifetime of an agent and depend on the agent's investment into health as in Grossman (1972a).

Health capital accumulation. Agents produce health capital via investments into health in the form of medical expenditures m. The health accumulation process is determined by

$$h_j = i\left(m_j, h_{j-1}, \varepsilon_j^h\right), \tag{3}$$

where h_j denotes the current health capital (or health status), h_{j-1} denotes last period's health capital, m_j is the amount of medical services bought in the current period, and ε_j^h is an exogenous health shock. Health capital depreciates at rate $\delta_h(j)$ which is a function of age. The older the agent becomes the faster her health depreciates. Finally, the exogenous health shock ε_j^h follows a Markov process with age dependent transition probability matrix P_j. Transition probabilities to next period's health shock ε_{j+1} depend on the current health shock ε_j^h so that an element of transition matrix P_j is defined as the conditional probability

$$p_{\varepsilon_{j+1}^h, \varepsilon_j^h} = \Pr\left(\varepsilon_{j+1}^h | \varepsilon_j^h, j\right).$$

Effective human capital. The human capital profile $e\left(h_{j-1}, \varepsilon_j^l\right)$ depends on the health status at the beginning of the current period h_{j-1} and on the age dependent idiosyncratic labor productivity ε_j^l. The transition probabilities for the idiosyncratic labor productivity follow an age dependent Markov process with transition probability matrix Π_j. Let an element of this transition matrix be defined as the conditional probability

$$\pi_{\varepsilon_{j+1}^l, \varepsilon_j^l} = \Pr\left(\varepsilon_{j+1}^l | \varepsilon_j^l, j\right),$$

where the probability of next period's labor productivity ε_{j+1}^l depends on today's productivity ε_j^l.[4]

3.5 Health insurance arrangements

In our benchmark model, agents can buy medical services to improve their health capital. An agent's total health expenditure in any given period is $p_m m_j$ where p_m is the price of medical services and m_j is the quantity of medical services purchased to replenish the health stock. Since health shocks are age-dependent and stochastic, total health expenditures are stochastic.[5] To

[4] We abstract from the link between health and life time i.e. health capital has no effect on survival probabilities in the current model. We are aware that this presents a limitation and that certain mortality effects cannot be captures (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.

[5] Note that we only model discretionary health expenditures $p_m m_j$ in this paper so that income will have a strong effect on endogenous total medical expenses. Our setup assumes that given the same magnitude of health shocks ε_j, a richer individual will outspend a poor individual. This may be realistic in some circumstances,

cover their health care cost, agents can buy an insurance contract. We assume that there are two separate insurance arrangements: private health insurance markets for workers and Medicare for retirees.

Private health insurance for workers. Working agents have two types of health insurance policies available: individual insurance and group insurance. In order to be covered by insurance, agents have to buy insurance one period prior to the realization of their health shock. The insurance policy will become active in the following period (one period contract).[6] We distinguish between three possible insurance states and use insurance state variable in_j to indicate what type of health insurance an agent has bought in the previous period, where $in_j = 0$ indicates no insurance, $in_j = 1$ indicates individual insurance, and $in_j = 2$ stands for group insurance.

Each period an agent has a certain probability to be matched with an employer that provides group insurance which is indicated with indicator variable $i_{GI} = 1$. If an employer provides group insurance, the insurance premium p 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, $i_{GI} = 0$, then the worker has the option to buy health insurance in the individual market at premium $p(j,h)$. In this case the insurance premium is not tax deductible and the insurance company screens the worker by age and health status. The probability of being offered group insurance is highly correlated with income, so that the Markov process that governs the group insurance offer probability will be a function of the income class that an agent belongs to. Let

$$\omega_{j+1,j} = \Pr\left(i_{GI,j+1} | i_{GI,j}, income\right)$$

be the conditional probability that an agent has group insurance status $i_{GI,j+1}$ in period $j+1$ given she had group insurance status $i_{GI,j}$ in period j. We collect all conditional probabilities for group insurance status in the transition probability matrix Ω_{income} which has dimension 2×2 for each income quantile.

The working household's out of pocket health expenditure can now be summarized as

$$o(m_j) = \begin{cases} p_{m,noIns} \times m & \text{if } in_j = 0 \text{ (no insurance)}, \\ \min\left[p_{m,Ins} \times m_j, \gamma + \rho\left(p_{m,Ins} \times m_j - \gamma\right)\right] & \text{if } in_j = 1,2 \text{ (individual/group)}, \end{cases} \tag{4}$$

where γ is the deductible, ρ is the coinsurance rate, $p_{m,Ins}$ is the relative price of health care paid by insured workers, and $p_{m,noIns}$ is the price of health care paid by uninsured workers. An uninsured worker pays a higher price $p_{m,noIns} > p_{m,Ins}$ for a unit of medical care everything else equal. The coinsurance rate ρ is the fraction that the household pays after the insurance company pays $(1-\rho)$ of the post deductible amount $p_{m,Ins} \times m_j - \gamma$. Since households have

however, a large fraction of health expenditures in the U.S. is non-discretionary (e.g. health expenditures caused by catastrophic health events that require surgery etc.). In such cases a poor individual could still incur large health care costs. However, it is not unreasonable to assume that a rich person will outspend a poor person even under these circumstances.

[6] Agents in their first period are thus not covered by any insurance by construction.

to buy insurance before health shocks are revealed we assume that working households in their last period $j = J_1$ do not pay any insurance premium.

Medicare for retirees. After retirement all agents are covered by Medicare. The medicare deductible is denoted γ^{Med}. Medicare pays a fixed proportion $\left(1-\rho^{Med}\right)$ of the post deductible amount of health expenditures. The total out of pocket health expenditures of a retiree are

$$o^{R}\left(m_j\right) = \min\left[p_{m,Med}m_j, \gamma^{Med} + \rho^{Med}\left(p_{m,Med}m_j - \gamma^{Med}\right)\right], \text{ if } j > J_1, \quad (5)$$

where $p_{m,Med}$ is the price of health services that retirees with Medicare have to pay. Retired individuals pay a Medicare Plan B premium p^{Med}. We assume that old agents $j > J_1$ do not purchase private health insurance.[7]

Private health insurance contracts. Health insurance contracts are offered by private health insurance companies. We impose the following profit conditions on insurance contracts in each period where we allow for cross subsidizing across generations.[8] The profit condition for insurance contracts in the individual market is

$$(1+\omega) \times \sum_{j=2}^{J_1} \mu_j \int \left[1_{\{in_j(x_j)=1\}}\left(1-\rho\right)\max\left(0, p_{m,Ins} \times m_j\left(x_j\right) - \gamma\right)\right] d\Lambda\left(x_j\right) \quad (6)$$

$$= \quad R\sum_{j=1}^{J_1} \mu_j \int \left(1_{\{in_j(x_j)=1\}} p\left(j,h\right)\right) d\Lambda\left(x_j\right), \text{ and}$$

and the profit condition for insurance contracts in the group market is

$$(1+\omega) \times \sum_{j=2}^{J_1} \mu_j \int \left[1_{\{in_j(x_j)=2\}}\left(1-\rho\right)\max\left(0, p_{m,Ins} \times m_j\left(x_j\right) - \gamma\right)\right] d\Lambda\left(x_j\right) \quad (7)$$

$$= \quad R\sum_{j=1}^{J_1} \mu_j \int \left(1_{\{in_j(x_j)=2\}} p\right) d\Lambda\left(x_j\right),$$

where ω is a markup factor that determines the loading costs (fixed costs or profits) of the insurance companies, $1_{\{in_j(x_j)=1\}}$ is an indicator function equal to unity whenever agents bought the individual health insurance policy, $1_{\{in_j(x_j)=2\}}$ is an indicator function equal to unity whenever agents bought the group insurance policy, R is the after tax market interest rate, and x_j is a summary vector of states for every agent that will be described later. Profits are redistributed in equal amounts to all surviving agents. Alternatively, we could discard the profits ("thrown in the ocean") in which case we could think of them as loading costs (fixed costs) associated with running private insurance companies.

Moral hazard and adverse selection issues arise naturally in the model due to information asymmetry. Insurance companies cannot directly observe the idiosyncratic health shocks and

[7] According to the Medical Expendiure Panel Survey (MEPS) 2001, only 15% of total health expenditures of individuals older than 65 are covered by supplementary insurances. Cutler and Wise (2003) report that 97% of people above age 65 are enrolled in Medicare which covers 56% of their total health expenditures. Medicare Plan B requires the payment of a monthly premium and a yearly deductible. See *Medicare and You* (2007) for a brief summary of Medicare.

[8] For tractability reasons we abstain from modeling insurance companies as profit maximizing firms.

have to reimburse agents based on the actual observed levels of health care spending. Adverse selection arises because insurance companies cannot observe the risk type therefore cannot price insurance premiums accordingly. They instead have to charge an average premium that clears the insurance companies profit condition.[9]

3.6 Government

The government taxes current workers via a payroll tax and charges Medicare plan B premiums to cover the cost of the Medicare program for retirees. The program is self-financing so that

$$\begin{aligned} & \sum_{j=J_1+1}^{J} \mu_j \int \left(1-\rho^{Med}\right) \max\left(0, p_{m,Med} \times m_j\left(x_j\right) - \gamma^{Med}\right) d\Lambda\left(x_j\right) \\ = & \sum_{j=1}^{J_1} \mu_j \int \tau^{Med} \left(\left(1-l_j\left(x_j\right)\right) we \left(h_{j-1}\left(x_j\right), \varepsilon_j^l\right) - 1_{\{in_{j+1}(x_j)=2\}} p\right) d\Lambda\left(x_j\right) \\ & + \sum_{j=J_1+1}^{J} \mu_j \int p^{Med} d\Lambda\left(x_j\right). \end{aligned} \tag{8}$$

In addition, the government runs a PAYG Social Security program which is self-financed via a payroll tax so that

$$\begin{aligned} & \sum_{j=J_1+1}^{J} \mu_j \int T_j^{Soc}\left(x_j\right) d\Lambda\left(x_j\right) \\ = & \sum_{j=1}^{J_1} \mu_j \int \tau^{Soc} \left(\left(1-l_j\left(x_j\right)\right) we \left(h_{j-1}\left(x_j\right), \varepsilon_j^l\right) - 1_{\{in_{j+1}(x_j)=2\}} p\right) d\Lambda\left(x_j\right). \end{aligned} \tag{9}$$

Indicator function $1_{\{in_{j+1}(x_j)=2\}}$ equals unity whenever the agent type x_j purchases group insurance via their employer. In this case the insurance premium is tax deductible.

Finally, the government taxes consumption at rate τ^C and income (i.e. wages, interest income, interest on bequests) at a progressive tax rate $\tilde{\tau}\left(\tilde{y}_j\right)$ which is a function of taxable income $\tilde{y}$ and finances a social insurance program T^{SI} (e.g. foodstamps, Medicaid) as well as exogenous government consumption G. The government budget is balanced in each period so that

$$G + \sum_{j=1}^{J} \mu_j \int T_j^{SI}\left(x_j\right) d\Lambda\left(x_j\right) = \sum_{j=1}^{J} \mu_j \int Tax_j\left(x_j\right) d\Lambda\left(x_j\right) + \sum_{j=1}^{J} \mu_j \int \tau^C c\left(x_j\right) d\Lambda\left(x_j\right). \tag{10}$$

Government spending G plays no further role. Accidental bequests are redistributed in a lump-sum fashion to all households

$$\sum_{j=1}^{J} \mu_j \int T_j^{Beq}\left(x_j\right) d\Lambda\left(x_j\right) = \sum_{j=1}^{J} \int \tilde{\mu}_j a_j\left(x_j\right) d\Lambda\left(x_j\right), \tag{11}$$

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

[9] Individual insurance contracts do distinguish agents by age and health status but not by their health shock.

3.7 Household problem

Age j year old agents enter the period with state vector $x_j = \left(a_j, h_{j-1}, in_j, \varepsilon_j^h, \varepsilon_j^l, i_{GI,j}\right)$, where a_j is the capital stock at the beginning of the period, h_{j-1} is the health state at beginning of the period, in_j is the insurance state at the beginning of the period, ε_j^h is a negative health shock, ε_j^l is positive income shock, and i_{GI} indicates whether group insurance from the employer is available for purchase in this period. Old agents, $j > J_1$ are retired and receive pension payments. They do not experience income shocks anymore. In addition, they are assumed to be covered by Medicare. The state vector of a household of age j can be summarized as

$$x_j = \begin{cases} \left(a_j, h_{j-1}, in_j, \varepsilon_j^h, \varepsilon_j^l, i_{GI,j}\right) \in R_+ \times R_+ \times \{0,1,2\} \times R_- \times R_+ \times \{0,1\} = D_W \text{ for } j \leq J_1, \\ \left(a_j, h_{j-1}, \varepsilon_j^h\right) \in R_+ \times R_+ \times R_- = D_R \text{ for } j > J_1, \end{cases}$$

and

$$D_j = \begin{cases} D_W \text{ for } j \leq J_1, \\ D_R \text{ for } j > J_1. \end{cases}$$

For each $x_j \in D_j$ let $\Lambda(x_j)$ denote the measure of age j agents with $x_j \in D_j$. The fraction $\mu_j \Lambda(x_j)$ then denotes the measure of age-j agents with $x_j \in D_j$ with respect to the entire population of agents in the economy.

3.7.1 Workers

Agents are endowed with one unit of time. Agents can work or enjoy their time as leisure. Agents receive income in the form of wages, interest income, accidental bequests, and social insurance. The latter guarantees a minimum consumption level of $\underline{c}$. After all shocks are realized, agents simultaneously decide their consumption c_j, leisure l_j, stocks of capital for the next period a_{j+1}, and health service expenditures m_j.

Depending on the realization of the group insurance offer state $i_{GI,j}$, an agent also chooses the insurance state for the next period in_{j+1}. If the agent is offered group insurance then the agent can choose between $in_{j+1} = \{0,1,2\}$, paying premiums of zero, $p(j,h)$ for individual insurance and premium p for group insurance, respectively. If the agent is not offered group insurance, that is $i_{GI,j} = 0$, then her choice for next period's health insurance is reduced to $in_{j+1} = \{0,1\}$. The household optimization problem for workers $j = \{1, ..., J_1 - 1\}$ can be formulated recursively as

$$V(x_j) = \max_{\{c_j, l_j, m_j, a_{j+1}, in_{j+1}\}} \left\{ u(c_j, s_j, l_j) + \beta \pi_j E_{\varepsilon_{j+1}^h, \varepsilon_{j+1}^l, i_{GI} | \varepsilon_j^h, \varepsilon_j^l, i_{GI}} \left[V(x_{j+1}) \right] \right\} \quad s.t. \tag{12}$$

$$\begin{aligned} & \left(1+\tau^C\right) c_j + (1+g) a_{j+1} + o^W(m_j) + 1_{\{in_{j+1}=1\}} p(j,h) + 1_{\{in_{j+1}=2\}} p \\ = & \ (1-l_j) we\left(h_{j-1}, \varepsilon_j^l\right) + R\left(a_j + T^{Beq}\right) + Insprofit_1 + Insprofit_2 - Tax_j + T_j^{SI}, \end{aligned}$$

$0 \leq a_{j+1}$, (2) and (3) where

$$
\begin{aligned}
Tax_j &= \tilde{\tau}\left(\tilde{y}_j^W\right) + \left(\tau^{Soc} + \tau^{Med}\right)\left(\left(1 - l_j\right) we\left(j, h_{j-1}, \varepsilon_j^l\right) - 1_{\{in_{j+1}=2\}} p\right), \\
\tilde{y}_j^W &= \begin{cases} \left(1 - l_j\right) we\left(h_{j-1}, \varepsilon_j^l\right) + ra_j + rT^{Beq} + Insprofit_1 + Insprofit_2 \\ -0.5\left(\tau^{Soc} + \tau^{Med}\right)\left(w\left(1 - l_j\right) e\left(h_{j-1}, \varepsilon_j^l\right) - 1_{\{in_{j+1}=2\}} p\right) - 1_{\{in_{j+1}=2\}} p, \end{cases} \\
T_j^{SI} &= \max\left[0, \underline{c} + o^W\left(m_j\right) + Tax_j - \left(1 - l_j\right) we\left(h_{j-1}, \varepsilon_j^l\right) - R\left(a_j + T^{Beq}\right) - InsP_1 - InsP_2\right].
\end{aligned}
$$

Variable c_j is consumption, l_j is leisure, a_{j+1} is next period's capital stock[10], g is the exogenous growth rate, $o^W\left(m_j\right)$ is out-of-pocket health expenditure, m_j is total health expenditure, R is the gross interest rate paid on assets a_j from the previous period and accidental bequests T_j^{Beq}, Tax_j is total taxes paid[11], and T_j^{SI} is Social Insurance (e.g. food stamp programs, Medicaid).

The effective wage income is $w\left(1 - l_j\right) e\left(j, h_{j-1}, \varepsilon_j^l\right)$, $\tilde{\tau}\left(\tilde{y}_j^W\right)$ is the income tax, and $\tilde{y}_j^W$ is the tax base for the income tax composed of wage income and interest income on assets, interest earned on accidental bequests, and profits from insurance companies minus the employee share of payroll taxes and the premium for health insurance.[12]

The Social Insurance program T_j^{SI} guarantees a minimum consumption level $\underline{c}$. If Social Insurance is paid out then automatically $a_{j+1} = 0$ and $in_j = 0$ (the no insurance state) so that Social Insurance cannot be used to finance savings and private health insurance.[13] Agents can

[10] Agents are borrowing constrained, in the sense that that $a_{j+1} \geq 0$. Borrowing constraints can either be modeled as a wedge between the interest rates on borrowing and lending, or a threshold on the minimum asset position. See also Imrohoroglu, Imrohoroglu and Joines (1998) for a further discussion.

[11] 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

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

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 allow for income tax deductibility of insurance premiums due to IRC provision 125 (Cafeteria Plans) that allow employers to set up tax free accounts for their employees in order to pay qualified health expenses but also the employee share of health insurance premiums.

[12] We assume that only interest earned on bequests are taxed. The U.S. income tax code contains many provisions that allow for the exclusion of bequests from income taxes.

[13] The stipulations for Medicaid eligibility encompass maximum income levels but also maximum wealth levels. Some individuals who fail to be classified as 'categorically needy' because their savingsa are too high could still be eligibile as 'medically needy' (e.g. caretaker relatives, aged persons older than 65, blind individuals, etc.)

We will therefore make the simplifying assumption that before the Social Insurance program kicks in the individual has to use up all her wealth. Jeske and Kitao (2009) follows a similar approach. See also: http://www.cms.hhs.gov/MedicaidEligibility

for details on Medicaid eligibility.

only buy individual or group insurance if they have sufficient funds to do so, that is whenever

$$\begin{aligned} 1_{\{in_{j+1}=1\}} p(j,h) &< w(1-l_j)\, e\left(h_{j-1}, \varepsilon_j^l\right) + R\left(a_j + T_j^{Beq}\right) - o^W(m_j) - Tax_j, \\ 1_{\{in_{j+1}=2\}} p_j &< w(1-l_j)\, e\left(h_{j-1}, \varepsilon_j^l\right) + R\left(a_j + T_j^{Beq}\right) - o^W(m_j) - Tax_j. \end{aligned}$$

The social insurance program will not pay for their health insurance. In their last working period, workers will not buy private insurance anymore because they become eligible for Medicare when retired.

3.7.2 Retirees

Retired agents are insured under Medicare and by definition do not buy any more private health insurance. The household problem for a retired agent $j \geq J_1 + 1$ can be formulated recursively as

$$\begin{aligned} V(x_j) &= \max_{\{c_j, m_j, a_{j+1}\}} \left\{ u(c_j, s_j) + \beta \pi_j E_{\varepsilon_{j+1}^h | \varepsilon_j^h} \left[V(x_{j+1}) \right] \right\} \\ & s.t. \end{aligned} \tag{13}$$

$$\begin{aligned} \left(1+\tau^C\right) c_j + (1+g)\, a_{j+1} + o^R(m_j) + p^{Med} &= R\left(a_j + T_j^{Beq}\right) - Tax_j + T_j^{Soc} + T_j^{SI}, \\ 0 &\leq a_{j+1}, \text{ where} \end{aligned}$$

$$\begin{aligned} Tax_j &= \tilde{\tau}\left(\tilde{y}_j^R\right), \\ \tilde{y}_j^R &= r a_j + r T_j^{Beq}, \\ T_j^{SI} &= \max\left[0, \underline{c} + o^R(m_j) + Tax_j - R\left(a_j + T_j^{Beq}\right) - T_j^{Soc}\right]. \end{aligned}$$

Note that retired agents cannot buy private health insurance anymore so that $in_{j+1} = 0$ by definition. The only remaining idiosyncratic shock for retirees is the health shock ε_j^h.

4 Parameterization and estimation

We provide a definition of the competitive equilibrium of the benchmark economy in the appendix. We use a standard numeric algorithm to solve the model.[14] For the calibration we distinguish between two sets of parameters. The first set is estimated independently from our model and based on either our own estimates using data from the Medical Expenditure Panel Survey (MEPS) or estimates provided by other studies. We summarize these predetermined parameters in table 2. The second set of parameters is chosen so that model-generated data match a given set of targets from U.S. data. These free parameters are presented in table 3.

[14] We discuss the algorithm in the technical appendix, which is available on the authors' website at: http://pages.towson.edu/jjung/research.htm

Model generated data moments and target moments from U.S. data are juxtaposed in table 4.

4.1 Demographics

One period is defined as 5 years. We model households from age 20 to age 90 which results in $J = 14$ periods. The annual conditional survival probabilities are taken from U.S. life-tables in 2003 and adjusted for period length.[15] The population growth rate for the U.S. was 1.2 percent on average from 1950 to 1997 according to the *Council of Economic Advisors* (1998). In the model the total population over the age of 65 is 17.35 percent which is very close to the 17.4 percent in the census.

4.2 Technology and firms

We impose a standard Cobb-Douglas production technology,

$$F(K, L) = AK^{\alpha}L^{1-\alpha},$$

and choose a capital share of $\alpha = 0.33$ and an annual capital depreciation rate δ of 10 percent, which are both similar to standard values in the calibration literature (e.g. Kydland and Prescott (1982)).

4.3 Preferences

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

$$u(c, l, s) = \frac{\left(\left(c^{\eta}l^{1-\eta}\right)^{\kappa} s^{1-\kappa}\right)^{1-\sigma}}{1-\sigma},$$

where 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). 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 (2008). In addition, this particular functional form will facilitate the welfare analysis over the transitions as described later.

We set $\sigma = 2.5$ and the time preference parameter $\beta = 1.0$ to match the capital output ratio and the interest rate. It is understood that in a general equilibrium model every parameter affects all equilibrium variables. Here we associate parameters with those equilibrium variables that are the most directly (quantitatively) affected. The intensity parameter η is 0.25 to match the average labor supply and the shape of the life-cycle labor supply curve, and κ is 0.79 to match the ratio between final goods consumption and medical consumption. In conjunction with the health productivity parameters (ϕ_j and ξ) these preference weights also ensure that

[15] ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Publications/NVSR/54_14/Table01.xls

the model matches total health spending and the fraction of agents with health insurance per age group.

We assume that health services are produced according to

$$s = f(h) = Bh^{\varrho},$$

where B and ϱ are parameters governing the process of transforming health capital into flows of health services. In order to limit the number of parameters in the preferences we follow Grossman (1972a) and assume a linear technology i.e. $\varrho = 1$. Since we assume that the preferences have a Cobb-Douglas form, parameter B is simply a scaling factor and has no effect on the relative allocation of resources. We normalize $B = 1$.

4.4 Health capital accumulation

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

$$h_j = i\left(m_j, h_{j-1}, \varepsilon_j^h\right) = \overbrace{\phi_j m_j^{\xi}}^{\text{Smooth}} + \overbrace{(1-\delta_{h,j})\, h_{j-1}}^{\text{Trend}} + \overbrace{\varepsilon_j^h}^{\text{Disturbance}} . \tag{14}$$

The first component is a health production function that uses health services m as inputs to produce new quantities of health capital. Agents can use health services to smooth their holdings of health capital. The second component presents the trend of natural health deterioration over time. Depreciation rate $\delta_{h,j}$ is the per period health depreciation of an individual of age j. Finally, the third component represents a stochastic disturbance to health which is assumed to be age dependent. This law of motion for health is widely used in the Grossman literature. Indeed, the first two components are employed in the original deterministic analysis of Grossman (1972a). The third component can be thought of as a random depreciation rate as discussed in Grossman (2000). Calibrating the law of motion for health is non-trivial for two reasons. First, there is no consensus on how to measure health capital. Second, to the best of our knowledge suitable estimates for health production processes within macro modeling frameworks do not exist.

A proxy for health capital. The Medical Expenditure Panel Survey (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 ($SF-12v2$).[16] Many previous studies use the former as a proxy for health capital and health shocks (e.g. Mariacristina, French and Jones (2010)). However this measure is very subjective and not really comparable over age (i.e. the definition of "excellent" health may mean something entirely different for a 20 or 60 year old individual). The $SF-12v2$ is a more objective

[16] The $SF-12v2$ includes twelve health measures about physical and mental health. There are two versions of this index available, one for physical health and one for mental health. Both measures use the same variables 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 will concentrate on the physical health component of the measure.

measure of health. This index is widely used in the health economics literature to assess health improvements after medical treatments in hospitals. For this reason, we use the $SF-12v2$ as measure for health capital in our model.

A metric space for health capital. In order to construct a health capital grid in the model based on data, we use a linear transformation function. We first find the distance between actual thresholds for minimum and maximum holdings of health capital in the data and then transform these thresholds into suitable model values. We do so by normalizing the distance between the observed minimum value $h_d^{\min}$ and the observed maximum value $h_d^{\max}$ (subscript d indicates that this variable originates from the data) of the $SF-12v2$. This normalized range of the health capital measure can be written as $r_d = \left(\frac{h_d^{max}-h_d^{\min}}{h_d^{\min}}\right)$. In the second step, we define the lower bound of the health grid in the model $h_m^{\min}$ (subscript m indicates that this variable originates from the model) and calculate the corresponding upper bound of health capital in the model as $h_m^{\max} = r_d \times h_m^{\min} + h_m^{\min}$. The lower bound $h_m^{\min}$ is treated as a free 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.

Health depreciation rates. We next approximate the natural rate of health depreciation $\delta_{h,j}$ per age group. We again use MEPS data to calculate the average health capital $\bar{h}_j$ (as measured by the $SF-12v2$ index) per age group of individuals with group insurance and zero health spending in any given year. We then postulate that such individuals did not incur a negative health shock in this period as they could easily afford to buy medical services m to replenish their health due to their insurance status. This means that for those individuals $\varepsilon_j^h = 0$ and $m_j = 0$. By setting m_j and ε_j^h in expression (14) equal to zero, we can approximate the average law of motion to

$$\bar{h}_j = \overbrace{(1-\delta_{h,j})\,\bar{h}_{j-1}}^{\text{Trend}},$$

from which we can recover the age dependent natural rate of health depreciation $\delta_{h,j}$. The depreciation rates 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.

Health shocks. We separate individuals into three groups: group 1, whose health capital levels fall into the 33rd percentile of age j individuals, group 2 whose health capital levels fall between the 33rd and the 66th percentile, and group 3 whose health capital is above the 66 health capital percentile. We then assume that group 1 experienced a "good" health shock, group two experienced a "moderate" health shock, and group three suffered from a "bad" health shock. We then construct the transition probability matrix of health shocks by counting how many individuals move across groups between two consecutive years in MEPS data. The health transition matrices range from

$$P(j=1) = \begin{pmatrix} 0.81 & 0.19 & 0.01 \\ 0.81 & 0.19 & 0.01 \\ 0.79 & 0.19 & 0.01 \end{pmatrix} \text{ to } P(j=13) = \begin{pmatrix} 0.15 & 0.58 & 0.28 \\ 0.11 & 0.57 & 0.33 \\ 0.09 & 0.56 & 0.35 \end{pmatrix}. \quad (15)$$

[17]

To construct the magnitude of health shocks, we normalize the size of the "good" health shock to zero. The magnitude of the "moderate" and the "bad" health shocks, experienced by group two and three, is the distance between the health capital averages of the three groups in the data, scaled according to our health grid size $\left(\overline{h}_j^1 - \overline{h}_j^2\right) \frac{h_m^{max} - h_m^{\min}}{h_d^{max} - h_d^{\min}}$, $\left(\overline{h}_j^1 - \overline{h}_j^3\right) \frac{h_m^{max} - h_m^{\min}}{h_d^{max} - h_d^{\min}}$ which results in age dependent health shocks ranging from

$$\varepsilon_1^h = \{0.0,\ -0.60,\ -1.53\} \text{ to } \varepsilon_{14}^h = \{0.0,\ -0.82,\ -1.60\}. \tag{16}$$

The health production technology. Grossman (1972) 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 (3). Previous studies using similar health production technology normalize the productivity parameter ϕ_j to unity and set ξ to match medical expenditures as a share of GDP (e.g. see Suen (2006)). We follow a similar approach to pin down the range for these parameter values. However, we allow ϕ_j to be age-dependent and calibrate ξ and ϕ_j together to match aggregate health expenditures and the medical expenditure profile over age (see figure 2).

4.5 Human capital accumulation

Effective human capital evolves according to

$$e_j = e\left(h_{j-1}, \varepsilon_j^l\right) = \left(\varepsilon_j^l\right)^{\chi} \left(h_{j-1}^{\theta}\right)^{1-\chi} \text{ for } j = \{1, ..., J_1\}, \tag{17}$$

where ε_j^l is working productivity, h_{j-1} is the agent's health capital in the previous period, $\theta \geq 0$ is a parameter governing how health capital contributes to effective labor (or human capital) and $\chi \in [0, 1]$ is an aggregation parameter.

Labor productivity profiles. Profile ε_j^l is exogenously estimated from MEPS data and mimics the hump-shaped income process over the life-cycle for three separate income groups: *low*, *middle*, and *high* and is based on hours worked. We estimate efficiency profiles for three separate income quantiles and then calculate the transition probabilities of going from one quantile to another, conditioning on the age of the worker. The resulting estimates for the age dependent income transition probability matrices Π_j used in the model range from

$$\Pi_1 = \begin{pmatrix} 0.43 & 0.38 & 0.19 \\ 0.34 & 0.42 & 0.24 \\ 0.25 & 0.42 & 0.33 \end{pmatrix} \text{ to } \Pi_8 = \begin{pmatrix} 0.78 & 0.16 & 0.53 \\ 0.35 & 0.48 & 0.16 \\ 0.06 & 0.24 & 0.70 \end{pmatrix}, \tag{18}$$

where $j = \{1, ..., J_1 - 1\}$.

Health as an investment good. Effective human capital e_j is dependent on the agent's productivity endowment ε_j^l and health state h_{j-1} guided by parameters on θ and χ. We use parameter θ to determine the degree of the investment function of health. In other words, an otherwise identical individual will be more productive and have higher income if she has relatively better health (e.g. fewer sick days, better career advancement of healthy individuals, etc.). Tuning parameter θ allows us to gradually diminish the influence of health on the production process while holding the exogenous age dependent component fixed. This parameter determines to what degree health is an investment good. If $\theta = 0$ then health is a consumption good only and does not influence wage income anymore. If $\theta > 0$, wage income becomes health dependent and therefore health has investment good characteristics as well. In our benchmark model we pick $\theta = 0$ so that health is a pure consumption good. We then consider a case with $\theta > 0$ in a section on sensitivity analysis. We are not aware of any estimates for parameter χ and set it equal to 0.9 to match labor supply over the life-cycle.

Taking the endogenous health capital accumulation into account, the model reproduces the hump shaped average efficiency units that can be observed in the data (e.g. Fernandez-Villaverde and Krueger (2004) show similar income patterns using data from the Consumer Expenditures Survey).

4.6 Health insurance markets

Group insurance offer. MEPS data contains information about whether agents have received a group health insurance offer from their employer. Since we need to track two possible insurance offer states $no-offer$ and $offer$, we need to construct a 2×2 transition matrix. We use variables from MEPS, OFFER31X, OFFER42X, and OFFER53X. These are dummy variables that indicate whether an individual was offered health insurance by her employer in the specific year. The numbers 31, 42, and 53 refer to the interview round within the year (individuals are interviewed 5 times in two years). We assume that an individual was offered group health insurance when either one of the three variables indicates so. Since the probability of a group insurance offer will be highly correlated with income, we condition on the income class of an individual when constructing the transition matrices. That is, for each income class we count what fraction of individuals with a group offer in year 2004 was still offered group insurance in 2005. This results in probability $\pi_i^{s',s}$, where $s = \{no-offer, offer\}$ in year j, $s' = \{no-offer, offer\}$ in year $j+1$ and i denotes the income class. The following income dependent group insurance offer transition probability matrices are used in the model:

$$\Omega_{low} = \begin{pmatrix} 0.61 & 0.39 \\ 0.55 & 0.45 \end{pmatrix}, \Omega_{middle} = \begin{pmatrix} 0.47 & 0.53 \\ 0.33 & 0.67 \end{pmatrix}, \text{ and } \Omega_{high} = \begin{pmatrix} 0.40 & 0.60 \\ 0.21 & 0.79 \end{pmatrix}. \qquad (19)$$

Insurance premiums, deductibles and coinsurance rates. Insurance premiums in the individual markets are dependent on a person's age and health status. Since age and health status are highly correlated, we simplify the analysis and assume that insurance companies in the individual market will price discriminate according to age only. We then use a base premium and a vector of exogenous age dependent markup rates. Base premiums for group and individual insurances p_0^G and p_0^I will adjust to clear the insurance companies profit conditions

(6) and (7). We use data on average premiums provided in *The Cost and Benefit of Individual Health Insurance Plans* (2005) to estimate the exogenous age dependent premium markup rate g_j according to

$$g_j = \beta_0 + \beta_1 \times j + \beta_2 \times j^2 + u_j, \tag{20}$$

where u_j is an iid random variable with $E[u_j|j] = 0$. The age dependent insurance premium in the individual market is then the base premium times the markup rate

$$p_j = p_0^I \times g_j, \text{for all } j \in \{1, ..., J_1\}. \tag{21}$$

We use MEPS data from 1996−2007 and estimate a median coinsurance rate ρ of 29 percent for private insurance contracts (Suen (2006) uses a coinsurance rate of 25 percent). We assume that individual and group insurance contracts have identical coinsurance rates. Deductibles are endogenous in the model and are expressed as fractions of median income. We impose that the deductible for private health insurance is $\gamma = 6.4$ percent of median income (vs. 1.7 percent based on our own calculations with information from Fronstin and Collins (2006), Claxton, Gabel, Gil, Pickreign, HeidiWhitmore, Finder, DiJulio and Hawkins (2006), and U.S. Department of Health 2006). We chose a slightly higher deductible in order to keep premiums low enough to match the insurance take-up ratios from MEPS.

Price of medical services. In order to pin down the relative price of consumption goods vs. medical services, we use the average ratio of the consumer price index (CPI) and the Medical CPI between 1992 and 2006. We calculate the relative price to be $p_m = 1.15$.[18] The price of medical services for uninsured agents is higher than for insured agents. Various studies have pointed to the fact that uninsured individuals pay up to 50 percent (and more) higher prices for prescription drugs as well as hospital services (see *Playing Fair, State Action to Lower Prescription Drug Prices* (2000)). The national average is a markup of around 60 percent for the uninsured population (Brown (2006)). We therefore pick $p_{m,nIns} = 1.55$.

4.7 Government

Social security taxes are $\tau^{Soc} = 12.4$ percent on earnings up to \$97,500. This contribution is made by both, employees and employers. The Old-Age and Survivors Insurance Security tax rate is a little lower at 10.6 percent and has been used by Jeske and Kitao (2009) in a similar calibration. We therefore match τ^{Soc} at 9 percent by picking the appropriate pension replacement ratio Ψ to be 43 percent.[19] The resulting size of the social security program amounts to 6 percent of GDP. This is close to the number reported in the budget tables of the Office of

[18] Compare: http://data.bls.gov/cgi-bin/surveymost?cu

[19] In the model social security transfers are defined as $T_j^{Soc}(x) = \Psi w e_j(h_{j-1})$ and they are the same for all agents. Transfers are a function of the active wage of a worker in her last period of work, so that $j = J_1$. In addition we assume that h_{j-1} is a constant and the same for all agents. We pick it to be equal $\frac{h_{0,J_1} + h_{ggridh,J_1}}{2}$, which is the "middle" health state of the health grid vector. Biggs, Brown and Springstead (2005) report a 45% replacement rate for the average worker in the U.S. and Whitehouse (2003) finds similar rates for OECD countries.

Management and Budget (OMB) for 2008 which is close to 5 percent.

The Medicare tax τ^{Med} adjusts to clear expression (8). We fix the premium for Medicare p^{Med} so that Medicare premium payments are 2.11 percent of GDP as in Jeske and Kitao (2009). The model then results in a Medicare size of 3.2 percent of GDP which is close to estimates ranging between 2.5 to 3 percent of GDP reported in *Medicare and You* (2007) with a Medicare payroll tax of 2.53 percent in the model.[20]

Using the current U.S. income tax rates by income group we follow Guner, Kaygusuz and Ventura (2007) and estimate the following polynomial

$$margTaxRate\left(income\right) = \beta_0 + \beta_1 \log\left(income\right) + u_{income}, \tag{22}$$

where $margTaxRate(income)$ is the marginal tax rate that applies when taxable income equals $income$ and u_{income} is an iid random variable with $E\left[u_{income}|income\right] = 0$. Variable $income$ is household income normalized with an assumed maximum income level of \$400,000. We then fit equation (22) to the normalized income data. The estimated coefficients for the tax function are then $\hat{\beta}_0 = 0.3411$ and $\hat{\beta}_1 = 0.0659$ so that the approximate income tax per household becomes

$$T\left(taxable\ income\right) = \left(0.3411 + 0.0659 \log\left(income\right)\right) \times taxable\ income.^{21} \tag{23}$$

In our model, we similarly normalize taxable income of every agent with the maximum income of the richest agent in the economy to get the normalized variable $income$. We use this normalized income directly in expression (23) to calculate income taxes for each individual.[22]

We finally choose residual government consumption G as a fraction of output Y to be 16.5 percent so that the consumption tax rate is 5.7 percent (Mendoza, Razin and Tesar (1994) report 5.67 percent).

We use data from MEPS 2000-2007 and estimate the median Medicare coinsurance rate to be 34 percent which includes copayments and expenditures on prescription drugs.[23] Deductibles are endogenous in the model and are expressed as fractions of median income. We impose that the Medicare deductible is $\gamma^{Med} = 9.9$ percent of median income (6 percent based on our calculations using data form the U.S. Department of Health 2006).

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

[22] Another method is to use the tax function estimated in Miguel and Strauss (1994).

[23] According to Medicare News from November 2005 the coinsurance rates for hospital services under the Outpatient Prospective Payment System (OPPS) will be reduced to 20% of the hospital's total payment. Overall, average beneficiary copayments for all outpatient services are expected to fall from 33% of total payments in 2005 to 29% in 2006.

Visit: http://www.cms.hhs.gov/apps/media/press/release.asp?Counter=1506

5 Results

In this section we present the results of the calibrated economy and report on the model fit. We then simulate the main features of the *Affordable Care Act* and assess the effects of the reform on output and welfare.

5.1 Benchmark model

The main goal in the calibration section was to match the model to the life-cycle profiles of health expenditures, insurance take-up rates, labor supply, and assets holdings from MEPS and other sources.

Life-Cycle Medical Expenditures. Medical consumption accounts for a substantial part of consumption. The reported fraction of aggregate medical expenditure as share of GDP is around 16 percent in 2007 according to OECD Health Data 2009. Our model generates total medical expenditures of 16 percent in terms of GDP. More importantly, our model also matches the life-cycle pattern of medical expenditures as a fraction of income. The standard models of consumption and savings in the macroeconomic literature focus on explaining the hump-shape of non-medical consumption over the life-cycle (e.g. see Fernandez-Villaverde and Krueger (2007)) while neglecting medical consumption. It is documented that health expenditure is an increasing function in age (e.g. see Jung and Tran (2010)), which indicates that agents are not able to smooth their medical consumption over age. While the health economics literature has discussed the effects of age as well as the effects of uncertainty and insurance on the demand for health capital and the demand for health care over the life-cycle (e.g. Grossman (2000)), the effects that the deterioration of health has on the consumption and savings portfolio has been largely neglected. Only recently have there been studies investigating this connection. Mariacristina, French and Jones (2010) uses exogenous health expenditure shocks to replicate the upward trend in health expenditures over ages. Very few studies model an endogenous health capital process that can react to policy changes in the insurance structure. Our macro-health life-cycle model with endogenous health expenditures is one of these (see panel two in figure 2). The distribution of medical expenditures is rather extreme. A very small percentage of the population spends a large share of total health expenditures. A current limitation of the model is that we cannot match this distribution. We therefore concentrate our life-cycle analysis of health spending on group averages (i.e. poor vs. rich, sick vs. healthy).

Number of Insured Workers and Life-Cycle Take-up Ratio. Panel one in figure 2 presents the hump-shape profile of the fraction of insured agents over the life-cycle from MEPS. Young agents with low income are less likely on average to buy private health insurance compared to middle aged agents at the peak of their life-cycle income. Young individuals facing low health risk 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 generates take-up rates over the life-cycle that are very close to the data.

Life-Cycle Wealth and Income Distribution. Panel three in figure 2 displays average normalized asset holdings over the life-cycle. The model reproduces the hump shaped pattern in the data. The data is from Fernandez-Villaverde and Krueger (2009) who use data from the Survey of Consumer Finances (SCF) to construct asset profiles. The model does not match the U.S. wealth and income distribution. This is not a surprise since previous studies (e.g. see De Nardi (2004)) have shown that life-cycle models fail to match the wealth distribution in the U.S., especially the top end of the distribution unless additional savings motives like bequests and intergenerational links are introduced. Panel four shows the labor supply profile over the life-cycle using data from MEPS 2000-2007.

Life-Cycle Health Capital Accumulation. As discussed in the calibration section we use the health index Short-Form 12 Version 2 to characterize the dynamics of health over the life-cycle. Note that initial health endowments, depreciation rates and health shocks are exogenous inputs to the model. We let individuals optimally decide on health capital accumulation over their life time. The life-cycle pattern of health capital accumulation is completely determined by equilibrium conditions within the model. To check whether health capital accumulation is consistent with the data we plot average health capital levels per age group in panel five of figure 2. The model is able to generate a life-cycle pattern of health capital close to the data. We also compare the distribution of health capital to the data and find that the model tracks the distribution well except that it overpredicts the very high health capital levels.

Table 4 summarizes the remaining model output and compares it to the data.

5.2 Benchmark experiment

In this section we study the effects of the ACA 2010. We concentrate on modeling the following key elements of the reform bill.

- **Mandate**: Private health insurance is compulsory for all workers. Workers who do not have health insurance face a tax penalty of 2 percent of their income.

- **Insurance Exchange**: Workers who are not offered insurance from their employers and whose income is between 133 and 400 percent of the FPL are eligible to buy health insurance at insurance exchanges at subsidized rates according to table 1. In the model we divide agents with incomes between 133 and 400 percent of the FPL into three income groups and assign subsidy rates of either 19, 52, or 86 percent to them. We choose the thresholds for the FPL in the model to match the population proportions of agent groups below the FPL and between the new eligibility thresholds of 133 to 400 percent of the FPL. Table 5 summarizes the share of the newly subsidized individuals together with the applied subsidy rates.

- **Expansion of Medicaid**: The reform bill expands the Medicaid eligibility threshold uniformly to individuals whose income is below 133 percent of the FPL. In the model, agents with incomes lower than 133 percent of the federal poverty level (FPL) are therefore supported with a subsidy rate of 94 percent which according to table 1 is the highest possible subsidy rate that the bill allows. Individuals who still cannot afford insurance or whose income is so low that it does not support their minimum level of consumption will by covered by the social insurance program (i.e. foodstamps) that will pay for consumption and medical care and maintain a minimum level of consumption and health.

- **Financing**: The reform bill is financed by increases in payroll taxes (and expansions of the payroll tax base) for individuals with incomes higher than $200,000 per year (or $250,000 for families). Various other sources are used to generate additional revenue in order to pay for the reform (e.g. funds from social security, Medicare, student loans, and others). In our benchmark experiment, we implement a payroll tax on individuals with incomes higher than $200k$ to cover the cost of the reform. We will also study alternative financing instruments in the next section.

- **Screening:** The reform puts new restrictions on the price setting and screening procedures of insurance companies. Some of them do not allow screening for pre-existing conditions etc. We therefore, in the model, do not allow for screening in the individual market anymore, so that the price setting in group and individual markets is now identical except for the fact that group insurance premiums are still tax deductible.

We report steady state results of the benchmark experiment in column 1 and 2 of table 6. We also solve for the transition paths between the two steady state equilibria. Our results are summarized next.

Health insurance coverage. The reform increases the fraction of insured workers from 61.8 percent in the benchmark economy to 97.8 percent in the new regime. This indicates that the reform greatly reduces the adverse selection problem that plagues private health insurance markets in general. The key mechanism behind this result is mandatory health insurance, enforced by a fine and premium subsidies. The reform imposes a higher cost of staying uninsured to low risk individuals. Especially healthy and young workers, who tend to be very sensitive to changes in the insurance premium, start buying health insurance due to the reform. Once some of these low risk types start buying insurance, premiums decrease significantly i.e. premiums for individual-based insurance and for group-based insurance drop by 20 and 2 percent, respectively. This in return attracts additional low risk agents to participate in the health insurance market. The almost universal insurance pool in the new equilibrium improves risk-sharing across agents of all types and mitigates the negative effects of adverse selection that is prevalent in the current health insurance system.

The expansion of the Medicaid program, another important element of the reform, could potentially harm some segments of the private health insurance market as it “crowds out” low income individuals from the private health insurance markets. If, on the other hand, it turns out that most of these individuals are high costs agents with low health status levels, then the expansion of the Medicare program can potentially have a positive effect on the private health insurance markets (i.e. lower the premiums) despite the crowding out. This is similar to automatic "cream skimming" where the private health insurance markets retain the low risk types as Medicaid pools the costly high risk types. This can lower the premiums in the private markets which in turn attracts additional low risk types. Since in our model most of the Medicaid eligible population buys private health insurance with the help of the newly established government subsidies, the size of the social insurance program (that pays for a minimum level of consumption and health for the lowest income groups) will shrink from 0.6 percent of output to 0.48 percent.[24]

Health spending. Our results indicate that this particular health care reform increases total health expenditures by almost 7 percent and the share of GDP spent on health care increases from 16 to 17.25 percent. As individuals are insured they face a lower effective price of medical services and they end up buying more of it (moral hazard). Under the reform a large fraction of the population becomes newly insured and increases its health expenditures. Note that this increase in health spending is financed partly via cost sharing within the larger insurance pool of individual workers (i.e. healthier individuals cross finance sicker ones) and partly by taxes on the rich.

The model captures the dynamics of the health insurance market adjustments to changes in individuals' choices of health, health insurance and health expenditures simultaneously. So the interaction of moral hazard effects with adverse selection effects fully play out in the model. Moral hazard is made worse as more people having health insurance tend to spend more which increases insurance premiums and counteracts the reductions in adverse selection effects described earlier. The previous studies with exogenous health expenditures fail to reflect these important dynamics.

Fiscal cost. We find that a tax penalty of 2 percent of income of the uninsured together with a new payroll tax of 2.7 percent on individuals with incomes higher than $\$200,000$ is sufficient to pay for the subsidies. The new taxes, however, will have distortionary effects as discussed next.

Aggregate variables. The introduction of a new public health insurance system results in adverse effects on capital accumulation and labor supply. However, these effects tend to be relatively small. Aggregate capital is reduced by 1.4 percent due to disincentives for precautionary savings. Since individuals in the model face health and income risk they have two primary options to insure against such adverse scenarios: (*i*) self-insurance, i.e. private income from precautionary savings and extra labor and (*ii*) private or public health insurance contracts. These two options are substitutable. Almost 35 percent of workers who were uninsured before the reform and therefore relied on self-insurance in the benchmark economy now buy health

[24] In the model the effects of crowding out of private insurance markets by Medicaid are likely to be underestimated as parts of the Medicaid program in the model is run via private insurances.

insurance under the new insurance system. Under the subsidized system previously uninsured agents substitute self-insurance for a market contract. Subsequently, aggregate capital stock and labor supply decline, the latter is directly triggered by the payroll tax for higher income individuals and by a general income effect on the newly insured (i.e. health care as part of their consumption basket has just become cheaper which triggers income and substitution effects).

Increases in health care spending lead to higher health capital holdings. Since health capital does not enter the formation of human capital in the benchmark economy (i.e. tuning parameter $\theta = 0$ in expression (17)), effective human capital decreases with the decrease in labor supply. Lower human capital together with lower levels of physical capital result in a drop in output of about 0.5 percent. Notably, the crowding out effect is small because the reform does not lead to a great expansion of the public health insurance program. Only a small faction of the population (roughly 10 percent) who are poor enough is eligible for the new subsidies. Indeed, the reform "boosts" private health insurance markets as it induces "good" agents to switch from precautionary savings to participate in the insurance market. On the other hand, capital accumulated through insurance markets is not wasteful as insurance companies invest their collected premiums in capital markets, which eventually augment the productive capacity of the entire economy. In summary, the crowding out of capital accumulation is small since the expansion of the public program is relatively modest.[25]

As the economy shrinks, so does household income (compare the drop in wage rates). Since the government still has to pay for the social insurance program and the exogenously fixed government consumption and we impose a balanced budget condition, we observe a slight rise in the consumption tax rate from 5.7 to 6.5 percent. This increase in the sales tax together with the decrease in the effective price of medical services of the newly insured leads to lower aggregate consumption levels (2 percent drop).

Welfare. We next examine the welfare effects of the new health insurance system. The main mechanism explaining the welfare outcomes in our benchmark experiment is the trade off between (positive) insurance and (negative) incentive effects. As established in the social insurance literature, when insurance markets are incomplete, the introduction of a social insurance program can potentially improve welfare. However, the success of these programs depends on how the welfare gains from the *insurance effect* compare to the efficiency losses created by distortions of the *incentive effect*. The ACA, like any other publicly run program, should also be evaluated in the context of this trade-off.

The new health insurance system leads more agents to buy into insurance which results in higher levels of health capital and reduced exposure to risk, both of which are welfare improving (positive insurance effects). On the other hand, the new policy discourages individuals to save for self-insurance, increases tax rates, and encourages higher spending on health (moral hazard) which leads to efficiency losses (negative incentive effects). The direct result is a drop in output

[25] In previous work (Jung and Tran (2009)) we model a situation where the government directly provides universal health insurance via a medical voucher program so that the capital accumulation process is affected more drastically and declines of steady state capital of about 10 percent were realized under some specific financing policies.

which lowers household income.

To explore how these two effects interact in terms of consumer welfare after the reform we use expected utility of new born generations. Our steady state results in column two of table 8 reveal that the new health insurance system results in an overall welfare gain. This result implies that the health insurance system in the benchmark economy does not efficiently trade off between the insurance and incentive effects. The reform indeed improves that trade off so that the additional welfare gain from strengthening the insurance effect outweighs the welfare losses triggered by the drop in output. We conclude that new born generations prefer the new system.

To get a clearer picture of the welfare effects we solve for transitions and use compensating consumption as a more intuitive measure of welfare. Transition dynamics are reported in figure 3 for the main macro aggregates. We then calculate (for every agent over transition time t) the fixed percentage of consumption that has to be added/subtracted in each period to make the agent indifferent between the steady state of the original health insurance system and the new situation under the Obama reform 2010. If an agent's compensation turns out to be positive, then the agent loses from the reform as she has to be compensated in order to make her as well off as she was before the reform was introduced. If the agent's compensation is negative, then the agent benefits from the reform. We report two measures of compensating consumption. The first is the aggregate compensating consumption over all agents in each time period after the reform expressed as fraction of GDP (first panel in figure 4). This measure puts a clear price tag on the reform as it is measures lost (or gained) aggregate consumption in terms of GDP for each period after the reform. The second measure concentrates on evaluating the reform from the point of view of a particular generation. It expresses the average compensating consumption of a generation as percentage of the average lifetime consumption of that generation (second panel in figure 4). The second measure identifies the winner or loser generations from the reform.[26] We find that current retirees lose because of the reform (see panel [2]) while the current working generation and generations born after the reform is implemented gain up to about 1 percent of their average life-time consumption.

This is an interesting result, since the transition graph in figure 3 reveals that aggregate consumption rates drop slightly. However, aggregate health capital levels increase and so does the rate of leisure. Both these increases outweigh the drop in consumption rates. That is, the value of health as a consumption good, outweighs the moderate loss of final consumption goods so that in terms of welfare, agents are better off. Older agents do not benefit from this trade-off since they only get to experience a higher consumption tax and the efficiency loss without the benefit of increased health. Their health is primarily determined by Medicare which is not affected in a major way by the reform.

Welfare effects by agent type. Finally, we evaluate the welfare effects by health status and income group. We present compensating consumption levels for sick and healthy agents as

[26] We present details of the welfare measures in a technical appendix that is available on our website under: http://pages.towson.edu/jjung/research.htm

well as for rich and poor agents (see panels 3 and 4 of figure 4). We find that current retirees lose while current workers gain, regardless of health status and income levels. However, the magnitudes of the welfare effects differ substantially across intra cohort agent types. Current retirees with poor health and low income suffer more from the reform compared to the healthy and rich retirees. Since the poor and unhealthy retirees are already participants of public health insurance programs before the reform, they do not benefit from the new health insurance arrangement and therefore suffer from tax distortions and the decline in income. Meanwhile, current workers with poor health gain significantly more from the reform, compared to healthy workers. The intuition is straightforward. The reform makes the health insurance market more accessible for the low income working population. Those agents, who are poor and sick and were left out of the health insurance market before the reform now have better access to a more efficient health insurance market.

These welfare results carry important political economy implications. Since the health insurance reform results in uneven re-distributional effects, the current retiring population should optimally oppose such a reform while the current working population should support it. Note that the support from the rich workers is relatively weak, while the support from poor or sick workers is strong as they benefit the most from the reform.

6 Alternative policies and sensitivity analysis

6.1 Alternative financing instruments

In this section we conduct a number of alternative policy experiments to examine how financing the reform can affect the outcome. We consider two alternative financing instruments: a tax neutral reduction of exogenous government consumption (Experiment 2) and a consumption tax (Experiment 3). We summarize the steady state results in column 3 and 4 in table 6.

Adjusting government consumption. In our first alternative policy experiment we assume the government adjusts its own consumption to finance the reform. We denote this as a tax neutral reform since all tax rates remain unchanged. Note that government consumption is not productive in our model. When we let government consumption adjust we can eliminate any distortionary effects caused by new or higher taxes. This experiment allows for a rough estimate of the pure fiscal cost of the reform absent any of the tax distortions. Second, this experiment reveals how an insurance mandate with fines and premium subsidies affects the individuals' optimal portfolio choice independent of distortionary effects triggered by changes in the tax system.

Our simulation results indicate that the cost of the reform is less than 1 percent of GDP. Note that we assume that the government keeps tax rates unchanged and adjusts the level of government consumption, which is wasteful in our model, to finance the extra spending. Increases in government spending for the insurance premium subsidy program and the expansion of Medicaid is relatively small and very close to the results of the earlier reform. Similarly, this reform results in efficiency losses while positive welfare effects are maintained.

Adjusting consumption taxes. In experiment number 3 we assume that the government increases the consumption tax rate to finance the premium subsidies and the expansion of the Medicaid program. We report the main results of this experiment in column 4 of table 6. The reform leads to very similar outcomes, compared to Regime 1 where a payroll tax on the rich financed the reform. As before, the reform triggers an increase in the number of individuals buying health insurance contracts. The number of insured workers increases from 62 percent to 97.85 percent. The intuition is similar. That is, the reform mitigates the adverse selection issue in the private health insurance market. In addition, we also find that aggregate health expenditures increase. Aggregate spending on health care as a fraction of GDP increases from 16 to 17.2 percent. The logic behind this is that first, the increase in health spending by previously uninsured young agents increases due to moral hazard. Second, since the relative price of the final consumption good increases significantly, agents who were previously insured will also increase their health spending. In addition, the slight drop in output also increases this ratio.

We find a small decrease in capital accumulation, which leads to a small decrease of steady state output of 0.14 percent. The decline in the capital stock is much smaller than under regime 1 as the tax distortion triggered by the consumption tax is more moderate than the tax distortion triggered by the payroll tax in regime 1. Consumption taxes only increase moderately from 5.7 percent to 6.8 percent in the new steady state. This relatively small increase in the consumption tax rate compared to the 3 percent payroll tax in regime 1 is explained by the fact that the entire population pays the consumption tax whereas the payroll tax under regime 1 was only levied on the relatively small fraction of individuals with incomes over $\$200,000$ (roughly 4 percent of the population). In response to the increase in the consumption tax rate agents consume less of the final consumption good and direct their spending towards the consumption of medical services and savings. However, since the negative income effects are much smaller under the consumption tax regime, aggregate consumption drops by less than in the benchmark experiment. Overall, we find that this reform results in an mild efficiency loss while maintaining a positive welfare outcome.

6.2 Alternative subsidy and penalty rates

In this section we study the role of the penalties for not having insurance and the subsidies as enforcement mechanisms of the insurance mandate. We first consider a situation without any penalties for uninsured individuals and second, we analyze the effects of the policy without subsidies to low income individuals.

Absence of tax penalty for individuals without health insurances. We set the penalty rate for uninsured individuals to zero and re-run the experiment under the three financing regimes: (*i*) payroll tax, (*ii*) government consumption, and (*iii*) consumption tax. We report the results in table 7. We find that in the absence of a significant penalty for not buying private health insurance, the private insurance coverage rates only increase to 72 percent leaving a large portion of the population uninsured. This indicates that the subsidies alone have a small effect on insurance coverage and if health insurance is not enforced by a tax penalty on people without health insurance, the low risk type agents will opt out of insurance. From column 2 in table 7 we also see that in the absence of the penalty, the payroll tax to finance the reform is actually slightly higher than in the benchmark regime and the negative efficiency effects (measured as drop in output) are slightly larger. This result carries an important policy implication. If the reform is enacted using a flawed process (i.e. absence of real enforcement of the mandate) the outcomes of the reform do not meet the target to significantly increase the population with health insurance, while also worsening the growth prospects of the economy.

Zero subsidy rates. We next investigate the effects of a zero subsidy rate i.e. the government enforces the health insurance mandate with a penalty on individuals without health insurance but does not financially support low income families to buy health insurance.[27] We report the results of this experiment in table 8. This confirms that the subsidies have little effect on the insurance take up ratio. This process is really driven more by the tax penalties which implies that some of the uninsured do either not benefit at all or too little from the subsidies. In addition, the subsidies to low income families have the most distortive effect on the economy. So while a significant portion of the highly productive population is taxed, the welfare gains triggered are modest.

6.3 Health as investment good

In the previous experiments we did abstract from any human capital effects triggered by changes in health status. That is, a sick individual with a low health state had the same effective human capital (and by extension labor income) as a healthy individual, everything else equal. Differences in income between sick and healthy were only indirectly triggered by the persistence of negative health shocks and the funding requirements that these health shocks impose on households. In the following experiment we model a more direct channel by letting health capital become a direct contributing factor to the production of effective human capital, so that health affects an individual's wage income directly. In order to do this we set the scaling parameter θ in expression (17) equal to 0.5. We report steady state results in table 9.

The difference in the effects on output and the fraction of the newly insured population is small compared to the experiment without this direct health effect on the formation of human capital. However, we point to the fact that once health status has a direct effect on an individual's income, the respective tax financing instrument that will be used plays a more important role than before. The difference in the output effect between regime 1 (payroll tax on the rich) and regime 3 (consumption tax on everybody) are now significantly larger than before as the tax distortion from the newly established payroll tax becomes amplified. Since

[27] In the model, individuals with income lower than 133 percent of the FPL are still eligible for Medicaid and receive a subsidy of 94 percent. Only individuals with income between 133 and 400 percent of the FPL do not receive any more subsidies in this particular experiment. We can therefore observe a large drop in the subsidies compared to the earlier experiments.

the health status contributes to worker productivity, the labor supply of richer workers becomes more sensitive to increases in the payroll tax as this negative income effect can potentially hurt their health which then feeds back into lower income etc. Under this scenario, we can observe a clear preference for using a consumption tax, instead of a payroll tax, to finance the reform as negative output effects can be alleviated by almost 1 percent of GDP while still insuring the same number of additional people. Before, the differences between the financing regimes were not as stark and in certain scenarios even reversed (compare table 6).

7 Conclusion

Confronted with an ever increasing number of uninsured Americans and health expenditures exceeding 16 percent of GDP, President Obama signed the *Affordable Care Act* in early 2010. This reform is believed to have unknown effects on the U.S. economy and on the welfare of current and future generations. Many macroeconomic aspects of the reform are largely unexplored and controversial and public opinion on the benefits of the reform has been divided. In this paper we develop a realistic OLG general-equilibrium model with endogenous health capital and evaluate the short and long run macroeconomic effects of the Obama health-care reform 2010. The general equilibrium approach that we propose is novel and necessary to capture the dynamics between health accumulation, health spending, health insurance, and the remaining optimal portfolio decisions of U.S. households.

Our results indicate that the reform almost completely eliminates the adverse selection issue that is prevalent in today's private health insurance markets and partly responsible for the high insurance premiums and the large number of uninsured individuals. The reform increases the fraction of insured workers to over 98 percent in almost all scenarios. However, the large number of newly insured workers is also responsible for a 7 percent increase in the aggregate spending on health care. This is a typical moral hazard effect that often arises in conjunction with the introduction of any type of insurance. In order to finance the reform the government has to either introduce a 2.7 percent payroll tax on the rich, cut government spending by about 1 percent of GDP, or increase consumption taxes by about 1 percent. In most scenarios the reform triggers an increase in the aggregate health stock, a decrease in labor supply and capital stock due to tax distortions, and decreases in steady state output of up to 2 percent.

Our quantitative analysis is informative for academics and also useful for policymakers it merges aspects of health economics, macro economics, and public finance to shed light on the likely effects of an important comprehensive health care reform bill. Our paper contributes to a rapidly growing literature that uses standard macroeconomic models to examine issues pertaining to health care spending. This paper is another effort to bridge the gap between macroeconomics and health economics.

Our model can be extended to address a wide range of other health related issues. For example, the model can be easily modified to include long-term care, health-related behavior (such as smoking or exercising), and dietary choice. The extended model can then be used to examine issues such as long-term care insurance and obesity etc. Our model can also be extended to include different education levels within each age group. The model can then be used to examine the relationship between income inequality and inequality in health outcomes. We leave these potential extensions for future work.

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8 Appendix

8.1 Equilibrium status quo

Definition 1 *Given the transition probability matrices* $\{P_j, \Pi_j\}_{j=1}^{J}$, *and* Ω_{income}, *the survival probabilities* $\{\pi_j\}_{j=1}^{J}$ *and the exogenous government policies* $\left\{\tilde{\tau}\left(\tilde{y}\left(x_j\right)\right), \tau^C\right\}_{j=1}^{J}$, *a competitive equilibrium is a collection of sequences of distributions* $\left\{\mu_j, \Lambda_j\left(x_j\right)\right\}_{j=1}^{J}$ *of individual household decisions*
$\{c_j(x_j), l_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^{J}$, *aggregate stocks of physical capital and human capital* $\{K, L\}$, *factor prices* $\{w, q, R\}$, *and insurance premiums* $\{p, p(j,h)\}_{j=1}^{J}$ *such that*

(*a*) $\{c_j(x_j), l_l(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^{J}$ *solves the consumer problem* (12) *and* (13),

(*b*) *the firm first order conditions hold*

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

(*c*) *markets clear*

$$\begin{aligned} K &= \sum\nolimits_{j=1}^{J} \mu_j \int \left(a\left(x_j\right)\right) d\Lambda\left(x_j\right) + \sum\nolimits_{j=1j}^{J} \int \tilde{\mu}_j a_j\left(x_j\right) d\Lambda\left(x_j\right) \\ &\quad + \sum\nolimits_{j=1}^{J_1} \mu_j \int 1_{\{in_{j+1}=3\}}\left(x_j\right)\left[i_{GI}\left(x_j\right) p + \left(1 - i_{GI}\left(x_j\right) p\left(j,h\right)\right)\right] d\Lambda\left(x_j\right), \\ T^{Beq} &= \sum\nolimits_{j=1j}^{J} \int \tilde{\mu}_j a_j\left(x_j\right) d\Lambda\left(x_j\right), \\ L &= \sum\nolimits_{j=1}^{J_1} \mu_j \int \left(1 - l_j\left(x_j\right)\right) e_j(x_j) d\Lambda\left(x_j\right), \end{aligned}$$

(*d*) *the aggregate resource constraint holds*

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

(*e*) *the government programs clear so that* (8), (9), (10), *and* (11) *hold,*

(*f*) *the zero profit conditions of the insurance companies* (6) *and* (7) *hold, and*

(*g*) *the distribution is stationary*

$$\left(\mu_{j+1}, \Lambda\left(x_{j+1}\right)\right) = T_{\mu,\Lambda}\left(\mu_j, \Lambda\left(x_j\right)\right),$$

where $T_{\mu,\Lambda}$ *is a one period transition operator on the distribution.*

Income in percent of FPL	Premium subsidy rate
$100 - 150\%$	94%
$150 - 200\%$	77%
$200 - 250\%$	62%
$250 - 300\%$	42%
$300 - 350\%$	25%
$350 - 400\%$	13%

Table 1: Income Levels and Insurance Premium Subsidies for an individual according to An Analysis of Health Insurance Premiums Under the Patient Protection and Affordable Care Act by the Congressional Budget Offic, 2009.

8.2 Tables and figures

Parameters	Model	Data	Source	
- Medical expenses per GDP: $\frac{p_m \times M}{Y}$	16.05%	16%	MEPS (population 20-85)	1
- Fraction of insured workers: (private insurance, not counting uninsured in first generation)	62%	60%	MEPS 2004/2005	1
- Capital output ratio: K/Y	2.96	3	NIPA	1
- Interest rate: R	4.07%	4%	NIPA	1
- Private plan: $\gamma/Median\ Income$	6.5%	1.7%	own calculations	1
- Medicare: $\gamma^{Med}/Median\ Income$	9.9%	6%	own calculations	1
- Size of Social Security: $SocSec/Y$	6%	5%	OMB 2008	1
- Size of Medicare: $Medicare/Y$	3.2%	$2.5 - 3.1\%$	U.S. Department of Health 2007	1
- Payroll tax Social Security: τ^{Soc}	9%	$6\% - 10\%$	IRS	1
- Consumption tax: τ^{C}	5.7%	5.67%		1
- Payroll tax Medicare: τ^{Med}	2.53%	$1.5 - 2.9\%$	Social Security Update 2007	1
-Total tax revenue/Y	24.5%	28.3%	Stephenson (1998) and Barro and Sahasakul (1986)	1
- Savings profile		see figure 2		6
- Insurance take-up ratios		see figure 2		6
Total number of Moments				24

Table 4: Data vs. Model

Parameters:		Explanation/Source:
- Periods working	$J_1 = 9$	
- Periods retired	$J_2 = 5$	
- Population growth rate	$n = 1.2\%$	CEA (1998)
- Years modeled	$years = 70$	from age 20 to 90
- Total factor productivity	$A = 1$	normalization
- Capital share in production	$\alpha = 0.33$	standard value
- Capital depreciation	$\delta = 10\%$	Kydland and Prescott (1982)
- Health depreciation	$\delta_{h,j}= [0.6\% - 2.13\%]$	MEPS 2004/2005
- Survival probabilities	π_j	U.S. Life tables 2003
- Health Shocks	see (16)	MEPS 2004/2005
- Health transition prob.	see (15)	MEPS 2004/2005
- Productivity shocks	see text section 4	MEPS 2004/2005
- Productivity transition prob.	see (18)	MEPS 2004/2005
- Group insurance transition prob.	see (19)	MEPS 2004/2005
- Price for medical care for insured	$p_{m,Ins} = 1.15$	
- Price for medical care for uninsured	$p_{m,nIns} = 1.55$	U.S. Census 2004
- Deductible (in % of median income)	$\gamma = 6.4\%$	own calculations based on data from the U.S. Department of Health
- Coinsurance rate	$\rho = 0.29$	0.25 in Suen (2006)
- Medicare premiums/GDP:	2.11%	Jeske and Kitao (2010)
Medicare deductible (in % of median income)	$\gamma^{Med} = 9.9\%$	own calculations based on data from the U.S. Department of Health
- Coinsurance rate, Medicare	$\rho^{Med} = 0.34$	Center for Medicare and Medicaid Services (2005)

Table 2: External Parameters

Parameters:		Explanation/Source:	
- Relative risk aversion	$\sigma = 2.5$	to match $\frac{K}{Y}$ and R	1
- Preference on consumption vs. leisure:	$\eta = 0.25$	to match labor supply and $\frac{p \times M}{Y}$	1
- Preference on consumption and leisure vs. health	$\kappa = 0.79$	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 $\frac{p \times M}{Y}$	14
- Production parameter of health	$\xi = 0.175$	to match $\frac{p \times M}{Y}$	1
- Human capital production	$\chi = 0.9$	to match labor supply	1
- Health productivity	$\theta = 0$	used for sensitivity analysis	1
- Pension replacement rate	$\Psi = 43\%$	to match $\tau^{soc} = 10\%$	1
- Residual Government spending	$\Delta_C = 16.5\%$	to match size of tax revenue	1
- Minimum health state	$h_{\min} = 0.01$	to match health spending	1
-Total number of free parameters:			24

Table 3: Free parameters used to match a set of target moments in the data.

Income	**Population share Data**	**Population share Model**	**Premium subsidy rates (Model)**
$< 100\%$ of FPL	$9.6 - 12\%$	10.2%	94%
$100 - 133\%$ of FPL	$14.5 - 16.9\%$	15%	94%
$133 - 400\%$ of FPL	38.7%	37%	staggered from [19− 86%]
$> 200k$	3.96%	4.01%	0% and they pay a payroll tax to finance the reform

Table 5: Income levels and insurance premium subsidies for an individual according to An Analysis of Health Insurance Premiums Under the Patient Protection and Affordable Care Act by the Congressional Budget Office, 2009.

	Benchmark	[1] τ_V	[2] Δ_{Cg}	[3] τ_C
Output: Y	100.000	99.547	99.408	99.862
Capital: K	100.000	98.589	98.107	99.113
Medical spending: $p_m * M$	100.000	106.973	107.247	106.955
Medical spending: $p_m * M/Y$ in %	16.055	17.253	17.321	17.195
Consumption: C	100.000	98.061	99.317	98.409
C/Y	0.399	0.393	0.399	0.394
Weekly hours worked:	39.673	39.741	39.700	39.797
Health capital: H	100.000	101.265	101.300	101.262
Human capital: Hk	100.000	100.022	100.056	100.234
HH gross income	2.108	2.076	2.076	2.078
Workers insured in %	61.777	97.805	98.919	97.847
K/Y	2.961	2.933	2.923	2.939
Interest rate: R in %	4.077	4.122	4.176	4.105
Wages: w	100.000	99.525	99.353	99.629
Welfare	-100.000	-99.564	-99.160	-99.555
Consumption tax: τ^C	5.724	6.505	5.724	6.813
Payroll tax: τ^V	0.000	2.733	0.000	0.000
Social security tax: τ_{SS} in %	9.018	9.182	9.014	9.181
Medicare Tax: τ_{Med} in %	2.527	1.794	2.077	1.803
Income tax rev. in % of GDP:	14.594	14.272	14.372	14.314
Total tax rev. in % of GDP:	24.450	24.172	23.895	24.145
Social insurance in % of GDP	0.610	0.483	0.477	0.482
Subsidy in % of GDP:	0.000	0.211	0.192	0.203
Penalty in % of GDP:	0.000	0.019	0.009	0.018
Govt consumption in % of GDP:	16.500	16.500	15.868	16.500
Base premium ind.:	100.000	80.075	72.989	80.109
Premium group:	100.000	98.743	86.582	98.603
Premium Medicare:	100.000	105.176	99.050	105.383

Table 6: Reform - Obama: Steady state results for the benchmark economy and three policy experiments with health productivity $\theta = 0$. Column one is the benchmark regime before the reform. The subsidy rates for health insurance premiums for income groups: $100\% - 200\%$ of FPL, $200\% - 300\%$ of FPL, and $300\% - 400\%$ of FPL are 86%, 52%, and 19% respectively. The subsidy rate for individuals with income below 100% of the FPL is 94%. The penalty for not buying insurance is 2% of gross income. Regime 1: payroll tax on individuals with income $>$ 200k, Regime 2: tax neutral reform where government consumption adjusts, and Regime 3: consumption tax is used to finance the reform.

	Benchmark	[1] τ_V	[2] Δ_{Cg}	[3] τ_C
Output: Y	100.000	99.379	99.746	99.708
Capital: K	100.000	99.033	99.231	99.642
Medical spending: $p_m * M$	100.000	106.250	106.983	106.389
Medical spending: $p_m * M/Y$ in %	16.055	17.165	17.220	17.131
Consumption: C	100.000	99.430	99.740	99.718
C/Y	0.399	0.400	0.399	0.399
Weekly hours worked:	39.673	39.482	39.669	39.510
Health capital: H	100.000	100.648	100.920	100.655
Human capital: Hk	100.000	99.550	100.001	99.741
HH gross income	2.108	2.086	2.080	2.089
Workers insured in %	61.777	72.096	84.080	72.148
K/Y	2.961	2.951	2.946	2.960
Interest rate: R in %	4.077	4.101	4.107	4.082
Wages: w	100.000	99.829	99.745	99.967
Welfare	-100.000	-99.341	-99.227	-99.339
Consumption tax: τ^C	5.724	5.894	5.724	6.255
Payroll tax: τ^V	0.000	2.992	0.000	0.000
Social security tax: τ_{SS} in %	9.018	9.015	8.968	9.013
Medicare Tax: τ_{Med} in %	2.527	2.104	2.136	2.112
Income tax rev. in % of GDP:	14.594	14.466	14.435	14.512
Total tax rev. in % of GDP:	24.450	24.350	24.011	24.327
Social insurance in % of GDP	0.610	0.527	0.500	0.524
Subsidy in % of GDP:	0.000	0.216	0.196	0.214
Penalty in % of GDP:	0.000	0.000	0.000	0.000
Govt consumption in % of GDP:	16.500	16.500	15.900	16.500
Base premium ind.:	100.000	79.873	72.744	79.842
Premium group:	100.000	124.916	94.408	124.976
Premium Medicare:	100.000	100.166	99.189	100.386

Table 7: Sensitivity analysis - **no penalty** enforcment: Steady state results for the benchmark economy and three policy experiments with health productivity $\theta = 0$. Column one is the benchmark regime before the reform. The subsidy rates for health insurance premiums for income groups: $100\% - 200\%$ of FPL, $200\% - 300\%$ of FPL, and $300\% - 400\%$ of FPL are 86%, 52%, and 19% respectively. The subsidy rate for individuals with income below 100% of the FPL is 94%. **The penalty for not buying insurance is** 0% **of gross income.** Regime 1: payroll tax on individuals with income > 200k, Regime 2: tax neutral reform where government consumption adjusts, and Regime 3: consumption tax is used to finance the reform.

	Benchmark	[1] τ_V	[2] Δ_{Cg}	[3] τ_C
Output: Y	100.000	99.204	99.151	99.363
Capital: K	100.000	98.189	97.783	98.487
Medical spending: $p_m * M$	100.000	106.754	107.185	106.719
Medical spending: $p_m * M/Y$ in %	16.055	17.277	17.356	17.244
Consumption: C	100.000	97.748	98.964	97.892
C/Y	0.399	0.394	0.399	0.394
Weekly hours worked:	39.673	39.545	39.570	39.538
Health capital: H	100.000	101.235	101.293	101.230
Human capital: Hk	100.000	99.708	99.831	99.797
HH gross income	2.108	2.074	2.075	2.075
Workers insured in %	61.777	97.246	98.912	97.254
K/Y	2.961	2.931	2.921	2.935
Interest rate: R in %	4.077	4.128	4.188	4.112
Wages: w	100.000	99.495	99.318	99.565
Welfare	-100.000	-99.638	-99.233	-99.654
Consumption tax: τ^C	5.724	6.499	5.724	6.755
Payroll tax: τ^V	0.000	1.955	0.000	0.000
Social security tax: τ_{SS} in %	9.018	9.182	9.015	9.181
Medicare Tax: τ_{Med} in %	2.527	1.815	2.088	1.819
Income tax rev. in % of GDP:	14.594	14.280	14.381	14.306
Total tax rev. in % of GDP:	24.450	24.140	23.910	24.126
Social insurance in % of GDP	0.610	0.491	0.480	0.491
Subsidy in % of GDP:	0.000	0.157	0.137	0.163
Penalty in % of GDP:	0.000	0.024	0.009	0.024
Govt consumption in % of GDP:	16.500	16.500	15.894	16.500
Base premium ind.:	100.000	79.948	72.919	79.940
Premium group:	100.000	98.776	86.494	98.776
Premium Medicare:	100.000	104.827	98.746	105.007

Table 8: Sensitivity analysis - **no subsidies**: Steady state results for the benchmark economy and three policy experiments with health productivity $\theta = 0$. Column one is the benchmark regime before the reform. The subsidy rate for individuals with income below 100% of the FPL is 94%. **No subsidies are pay for any other income groups.** The penalty for not buying insurance is 2% of gross income. Regime 1: payroll tax on individuals with income > 200k, Regime 2: tax neutral reform where government consumption adjusts, and Regime 3: consumption tax is used to finance the reform.

	Benchmark	[1] τ_V	[2] Δ_{Cg}	[3] τ_C
Output: Y	100.000	98.302	99.155	99.560
Capital: K	100.000	97.727	97.577	98.636
Medical spending: $p_m * M$	100.000	105.815	106.417	106.290
Medical spending: $p_m * M/Y$ in %	15.858	17.070	17.020	16.930
Consumption: C	100.000	96.949	99.424	98.366
C/Y	0.402	0.396	0.403	0.397
Weekly hours worked:	39.668	39.530	39.601	39.638
Health capital: H	100.000	101.138	101.177	101.153
Human capital: Hk	100.000	98.587	99.942	100.018
HH gross income	2.238	2.199	2.200	2.206
Workers insured in %	63.237	98.582	99.091	98.498
K/Y	2.957	2.940	2.910	2.929
Interest rate: R in %	4.108	4.119	4.202	4.142
Wages: w	100.000	99.711	99.213	99.542
Welfare	-100.000	-99.811	-99.198	-99.594
Consumption tax: τ^C	5.414	6.458	5.414	6.571
Payroll tax: τ^V	0.000	6.576	0.000	0.000
Social security tax: τ_{SS} in %	8.979	9.183	8.914	9.135
Medicare Tax: τ_{Med} in %	2.555	1.847	2.281	1.969
Income tax rev. in % of GDP:	14.677	14.227	14.451	14.412
Total tax rev. in % of GDP:	24.416	24.060	23.941	24.251
Social insurance in % of GDP	0.586	0.485	0.473	0.476
Subsidy in % of GDP:	0.000	0.243	0.224	0.240
Penalty in % of GDP:	0.000	0.011	0.007	0.012
Govt consumption in % of GDP:	16.500	16.500	15.803	16.500
Base premium ind.:	100.000	83.679	75.529	83.379
Premium group:	100.000	97.076	85.025	96.588
Premium Medicare:	100.000	106.329	97.094	104.582

Table 9: Reform - Obama: Steady state results for the benchmark economy and three policy experiments with **health productivity** $\theta = 0.5$. Column one is the benchmark regime before the reform. The subsidy rates for health insurance premiums for income groups: $100\% - 200\%$ of FPL, $200\% - 300\%$ of FPL, and $300\% - 400\%$ of FPL are 86%, 52%, and 19% respectively. The subsidy rate for individuals with income below 100% of the FPL is 94%. The penalty for not buying insurance is 2% of gross income. Regime 1: payroll tax on individuals with income $>$ 200k, Regime 2: tax neutral reform where government consumption adjusts, and Regime 3: consumption tax is used to finance the reform.

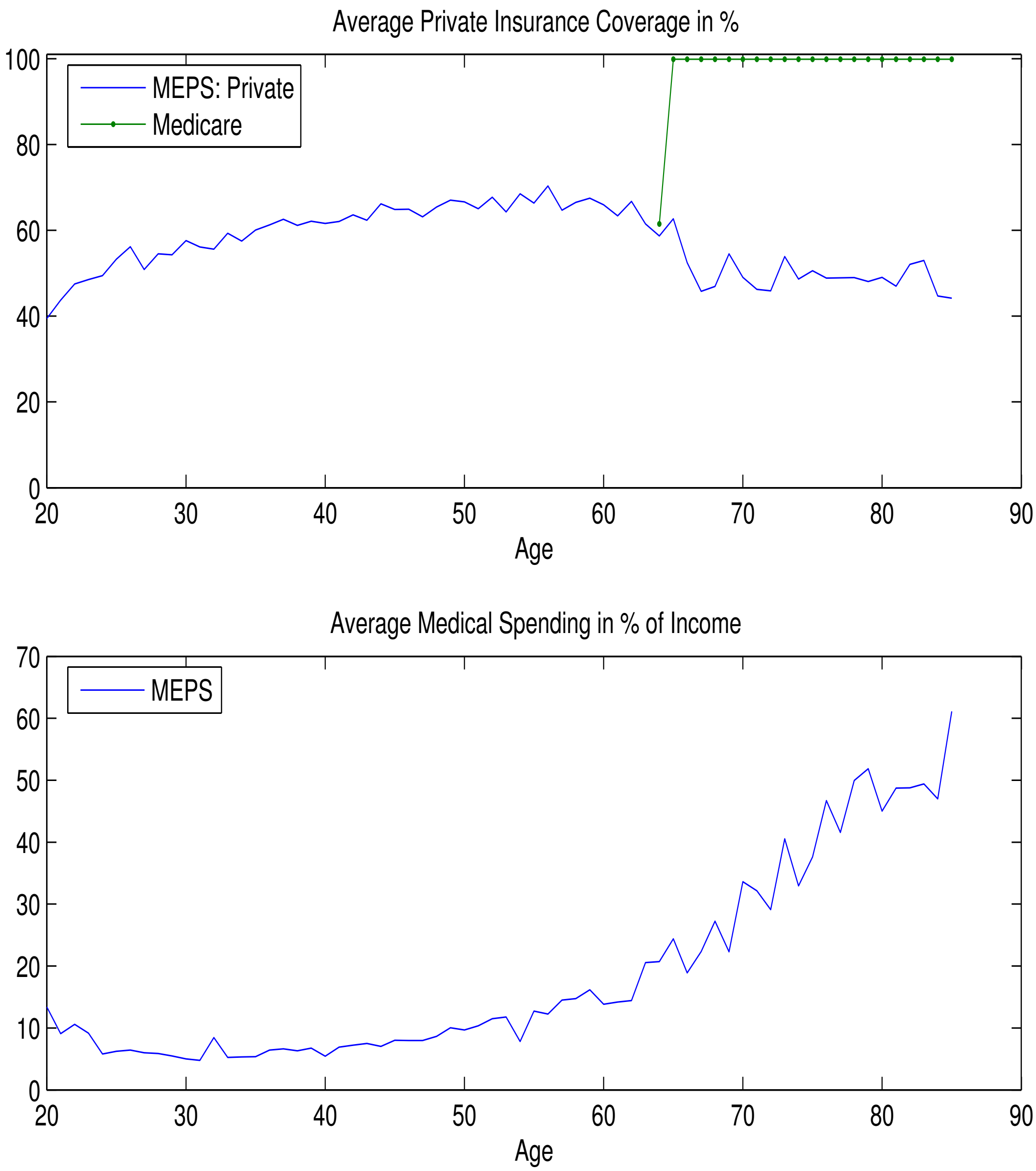

Figure 1: MEPS 2004/2005 take up rates of private health insurance and health spending as percent of household income over the life-cycle.

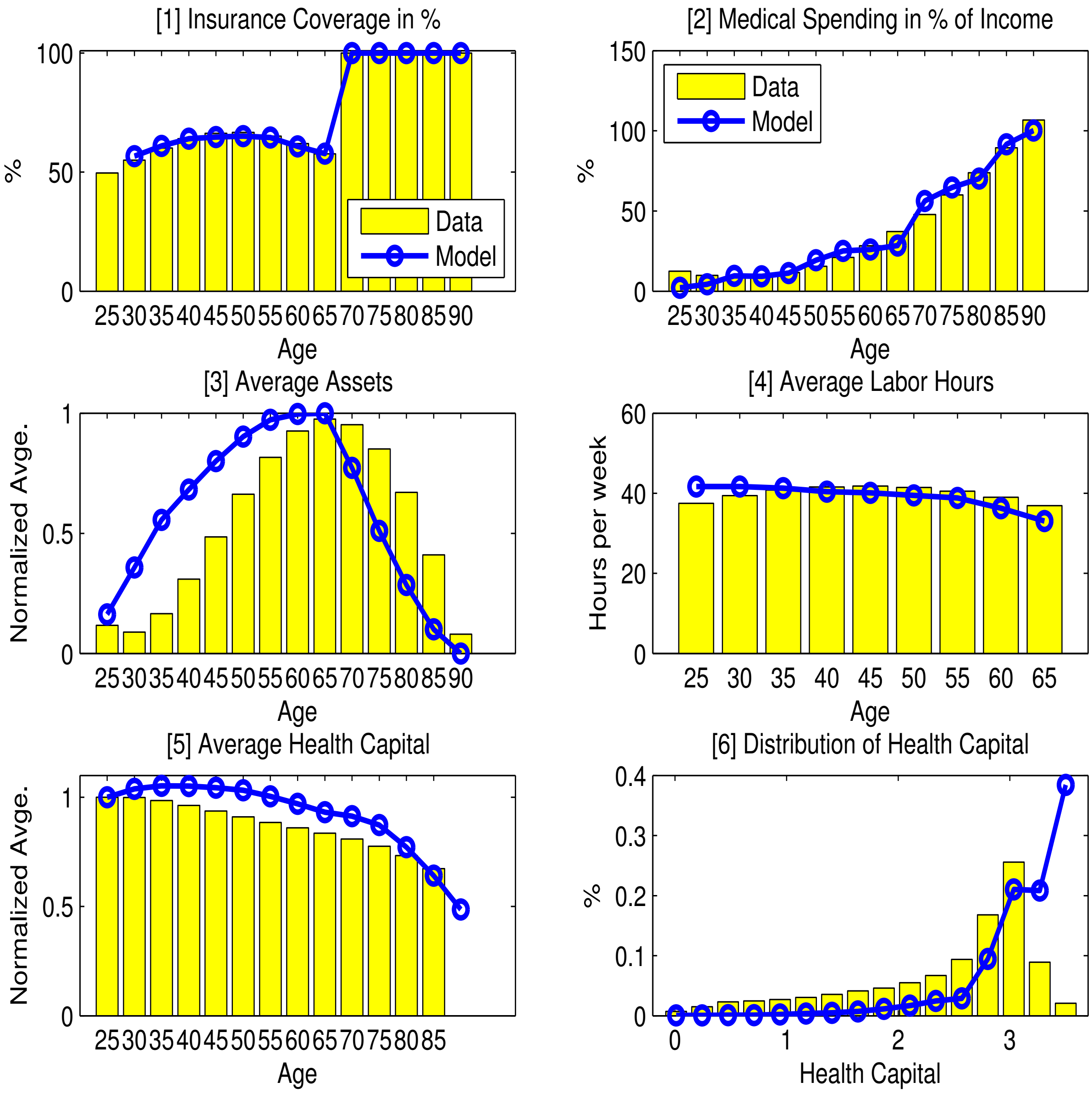

Figure 2: MEPS 2000 – 2007 and the model.

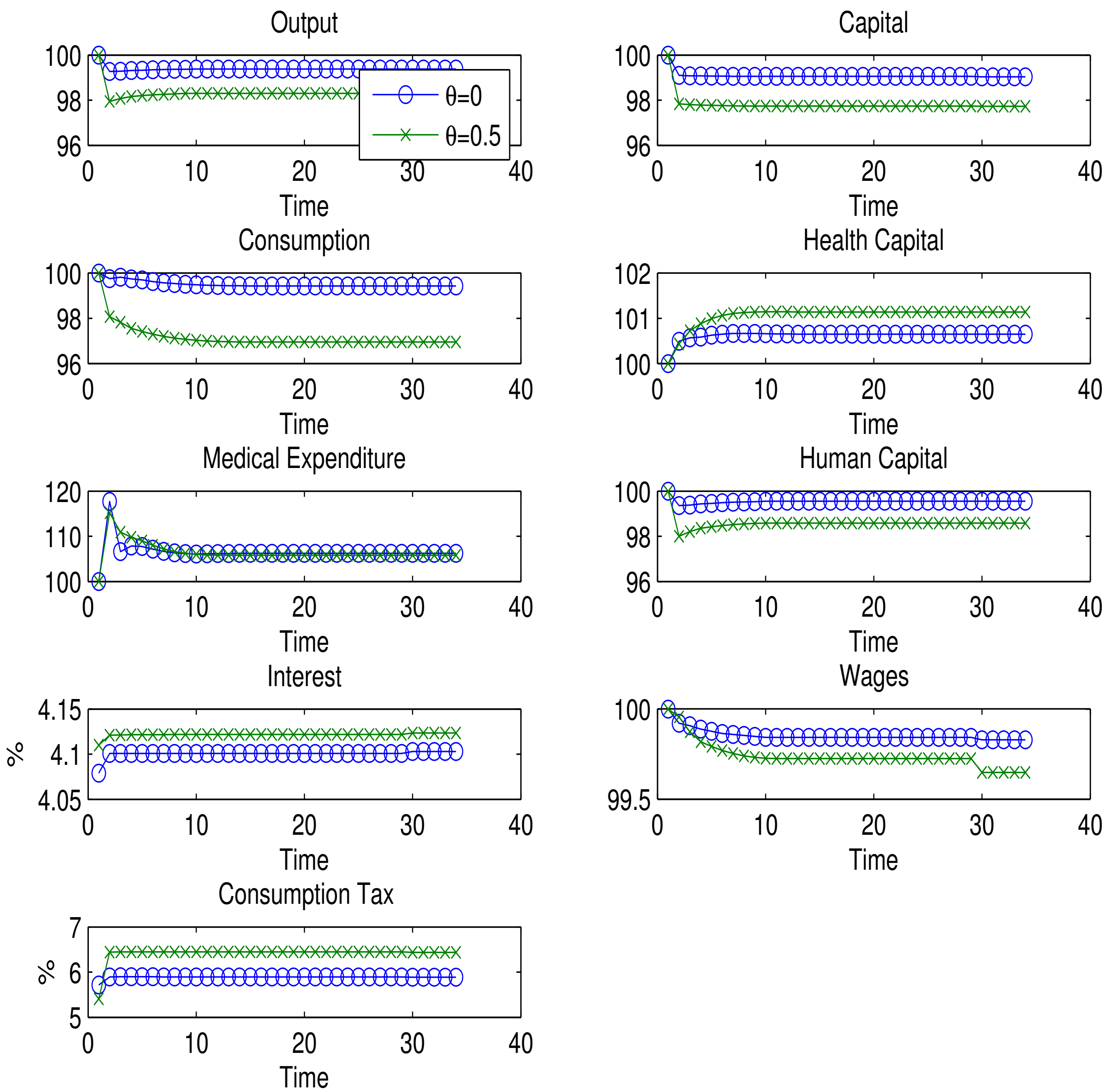

Figure 3: Transitions with a payroll tax on the rich financing the reform.

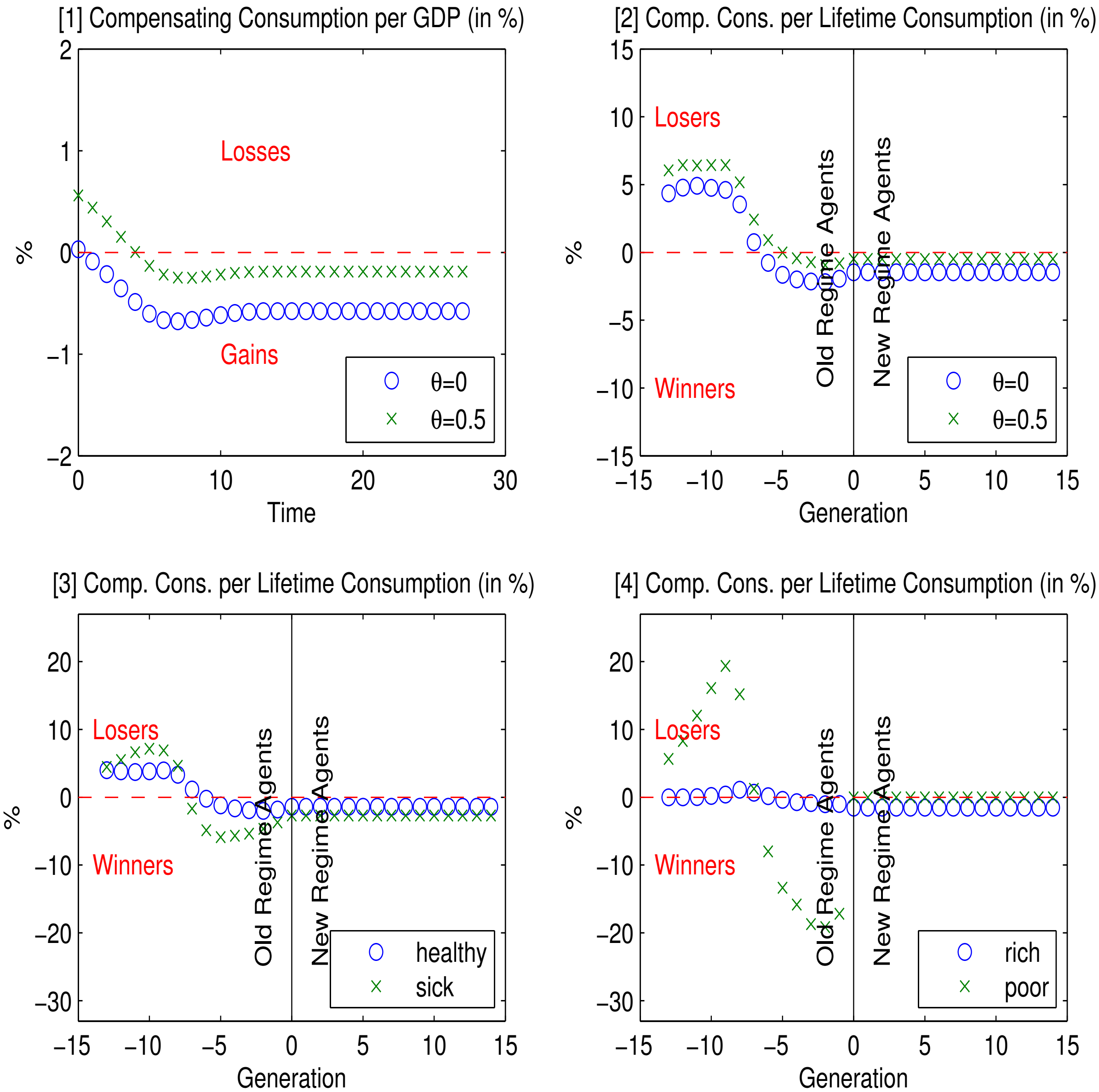

Figure 4: Welfare over transitions with a payroll tax on the rich financing the reform. The measure in panel [1] puts a price tag on the reform and measures aggregate compensating consumption in terms of GDP. Panels [2] , [3] , and [4] measure average compensating consumption per generation in terms of that generations average life-time consumption. The latter identifies which generations gain or lose form the reform.

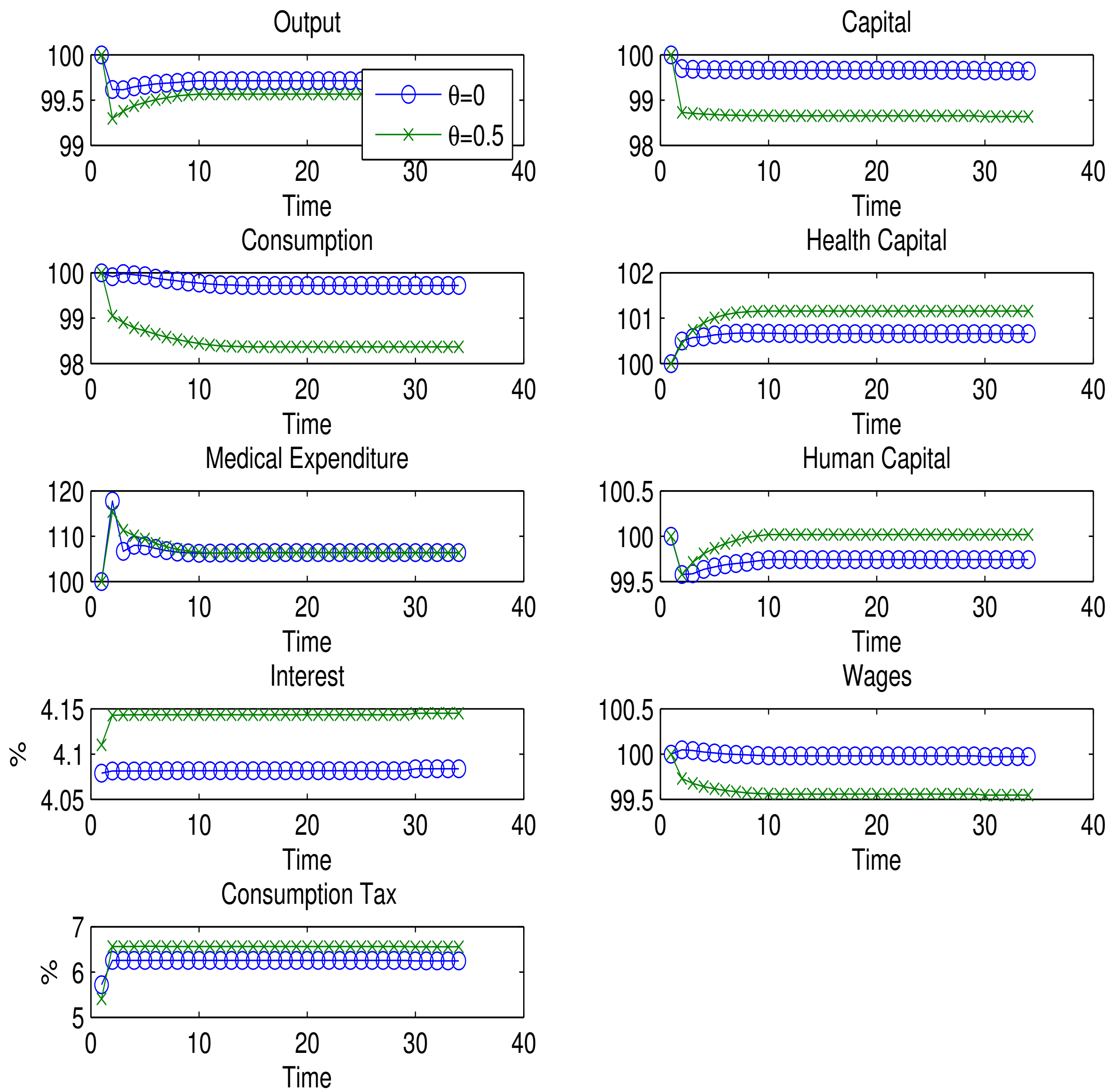

Figure 5: Transitions with a consumption tax financing the reform.

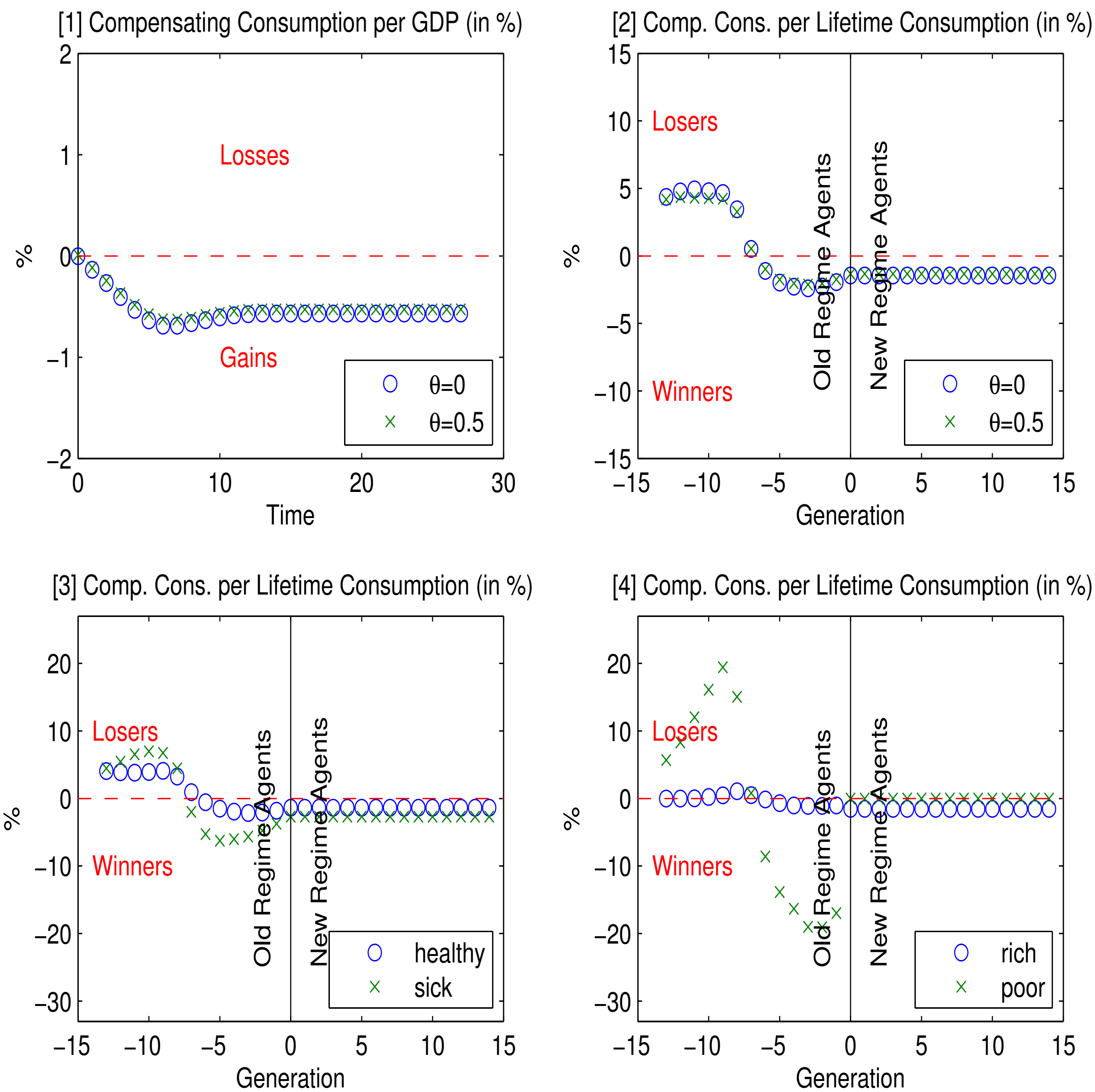

Figure 6: Welfare over transitions with a consumption tax financing the reform. The measure in panel [1] puts a price tag on the reform and measures aggregate compensating consumption in terms of GDP. Panels [2], [3], and [4] measure average compensating consumption per generation in terms of that generations average life-time consumption. The latter identifies which generations gain or lose form the reform.