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Health Care Financing over the Life Cycle, Universal Medical Vouchers and Welfare

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Abstract

In this paper we develop a general equilibrium overlapping generations (OLG) model with health shocks to analyze the life-cycle pattern of insurance choice and health care spending. We use data from the Medical Expenditure Panel Survey (MEPS) and show that our model is able to match the life-cycle trends of insurance take up ratios and average medical expenditures in the U.S. We then demonstrate how this model can be used to conduct health care policy analysis by evaluating the macroeconomic effects of a counter factual health care reform using a system of universal health insurance vouchers. Our results suggest that health insurance vouchers are able to extend insurance coverage to the entire population but they also increase aggregate spending on health. More importantly, we find that the positive *insurance effect* (efficient risk pooling) dominates the negative *incentive effect* (tax distortions and moral hazard) which results in significant welfare gains for all generations when a payroll tax is used to finance the voucher program. In addition, our results suggest that the choice of tax financing instrument and accounting for general equilibrium price adjustments are critical in determining the performance of the voucher program.

JEL: H51, I18, I38

Keywords: Public health insurance, private health insurance, vouchers, dynamic stochastic general equilibrium model, endogenous health production

1 Introduction

The U.S. health care system has come under great pressure in recent years. Close to 50 million people do not have health insurance while the U.S. spends already more than 16 percent of GDP on health care, more than any other OECD country. In addition, medical expenditures keep increasing as Americans age. Increases in medical spending and low take-up ratios of private health insurance do burden employers and households and jeopardize the solvency of public health insurance programs like Medicare and Medicaid. Many economists and policy makers have therefore called for a comprehensive reform of the U.S. health care system.

Data from the Medical Expenditure Panel Survey (MEPS) 2004/2005 reveal an increasing trend of health care spending over the life-cycle. The young spend a very small fraction of their income on medical services whereas the old spend more than half of their income on medical services (see figure 1). In addition, MEPS data also reveal a life-cycle pattern of private health insurance take up rates that peak around age 55. Understanding the life-cycle behavior of health care financing and spending and how changes in public health policy affect an economy's resource allocation, welfare and government budget is central to assessing the effects of health care policy reforms. The overall goals of this paper are to, first, explore whether a model with an endogenous health production process can reproduce the life-cycle patterns of insurance take-up rates and health spending? Second, are these life-cycle patterns indicative of health insurance market failure or of bad government policies? Third, what are the effects of a comprehensive public health policy program using health insurance vouchers on aggregates (i.e. optimal allocations and prices) and welfare?

In this paper we therefore make two key contributions. First, we develop a stochastic overlapping generations (OLG) model with an explicit role for health accumulation and insurance to explore individual decision making on health insurance and medical spending over the life-cycle. We first develop a simple two-period model to explore analytically how insurance and health spending decisions interact with consumption and savings decisions in a dynamic setting. Our simple dynamic two-period model with endogenous health indicates that the health insurance and spending decisions are confounded with savings- and human capital effects that make the multi-period setting more intricate than the simple one period settings of classical insurance papers like Pauly (1968). In addition, our simple model suggests that low income agents are less likely to buy health insurance and so are low risk agents. This implies that the demand for health and health insurance changes over the life-cycle. Individuals spend less and are less willing to buy health insurance at ages when incomes and health risk are low.

In an extension, we explore the life-cycle behavior of health insurance choice and health spending in a more realistic multi-period overlapping generations model. Our full dynamic model also accounts for general equilibrium channels such as equilibrium prices, interactions between health insurance markets and other financial markets, and tax financing instruments. We calibrate our full dynamic model to the U.S. economy. Our calibrated model with endogenous health accumulation is capable to match the life-cycle trends of average medical expenditures and insurance take-up

ratios from the MEPS data.

Next, we demonstrate how the model can be used to conduct health care policy analysis. Specifically, we apply our model to analyze the macroeconomic effects of a universal health insurance voucher program that allows individuals to purchase health insurance from private insurance companies with funds provided by the government. This voucher program would completely replace Medicare and employer provided (tax free) health insurance. The voucher reform we have in mind is motivated by the discussion in Kotlikoff (2007) and Emanuel and Fuchs (2007) and is purely counter factual. The plan works as follows. Each year an individual receives a voucher to purchase insurance coverage from private insurance companies for the next year. The size of the voucher is based on the individual's current medical condition. The government runs an experience rating system that estimates the expected health expenditure of an individual for the next period. The government issues a voucher of that exact size to the individual. A sick person will therefore receive a larger voucher than a healthy person. Insurance companies compete for the vouchers of patients. Participants can switch plans every year. The annual budget for health vouchers is fixed by the government as a share of GDP. Medicare, Medicaid, and employer-based health insurance tax breaks are eliminated.[1]

We are interested in the policy question whether a universal public health insurance program is able to increase the number of people with health insurance while simultaneously decreasing aggregate health care spending. Our results from our first experiment where we use a payroll tax to finance the vouchers suggest that a voucher system would result in full coverage of the U.S. population but also increases the share of GDP spent on health care by 0.6 percent. The main driver behind the increase in health spending is a moral hazard effect. Simultaneously, we observe a certain amount of crowding out of savings that leads to lower long-run capital stocks. As GDP falls the health expenditure to GDP ratio increases even further. We summarize these effects under the umbrella of *negative efficiency effects* due to the publicly financed voucher system. On the other hand we also observe a complete disappearance of adverse selection effects as insurance is automatically available to the entire population. This leads to improvements in risk pooling and higher levels of health. Since health is a consumption good, these effects increase welfare. We call these outcomes *positive insurance effects*. Whichever of these two groups of effects dominates, will determine the welfare outcome for the entire economy. We find that choosing the right tax instruments to finance the vouchers will be critical in achieving positive welfare effects for large shares of the population. We find that a payroll tax dominates a consumption and lump-sum tax

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[1]Kotlikoff (2007) attributes the idea to Economists Peter Ferrara at the Institute for Policy Innovation and John Goodman, president of the National Center for Policy Analysis. An earlier contribution suggesting the use of vouchers to reform Medicare is Butler, Moffit and Liu (1995). A World Bank publication, WorldBank (2005), provides a summary of the mechanics of health care vouchers. The system proposed by Kotlikoff (2007) is termed the Medical Security System (MSS) and the system proposed by Emanuel and Fuchs (2007) is referred to as Universal Healthcare Vouchers (UHV). The main differences between the MMS and the UHV are that

1. UHV do the experience rating at the level of the insurer or HMO, which still leaves some of the adverse selection problems in the system.

2. UHV would maintain Medicare, which according to Kotlikoff (2007) is not a viable option, since Medicare will bankrupt the system eventually.

in terms of welfare, but not in terms of efficiency.

We find that voucher systems financed by either a consumption or lump-sum tax lead to significant smaller decreases in aggregate capital stock that in the earlier experiment that used a payroll tax to finance the vouchers. Meanwhile, aggregate consumption decreases by a full percentage point more than under the payroll tax regime due to price substitution effects. A higher consumption tax increases the price of consumption and moves funds towards savings and medical expenditures. Consequently, we find that all generations born before and after the reform experience welfare losses. These opposing results highlight the importance of modelling health insurance, medical spending, and general equilibrium effects together in order to comprehensively analyze health care reform proposals. It also points to the fact that it will be crucial to find the correct financing instrument for any such health care reform as different taxes result in vastly different outcomes.

Our work contributes directly to an emerging macro-health economics literature that connects the literature analyzing health as an investment or consumption good as pioneered by Grossman (1972b) with the literature on stochastic dynamic general equilibrium modelling (e.g. Imrohoroglu, Imrohoroglu and Jones (1995), Imrohoroglu (1998), and Conesa, Kitao and Krueger (2009)). Recent work by Suen (2006), Jung and Tran (2008), Halliday, He and Zhang (2009), and Feng (2009) starts integrating health processes into more realistic life-cycle models for the U.S. These models are primarily used to study policy reforms in realistic settings. However, these models often fall short in: (i) integrating the demand for health care and health insurance with other aspects of the household decision making process; (ii) taking into account life-cycle behavior of health spending and health insurance; (iii) capturing interactions between public and private health insurance, and interactions between insurance markets and other markets in the economy; and (iv) accounting for important institutional details (e.g. tax sheltered employer provided health insurance) in the U.S. health care and insurance sector. We advance this literature by addressing all these points in one unified framework, where we account for an endogenous health accumulation process with health risk, uncertainty about the availability of different types of private insurance contracts, wage income uncertainty, and public insurance programs like social security and Medicare. More importantly, since we explicitly model the role of health we completely endogenize the households' decision on health expenditures and health insurance. Our model also captures the general equilibrium effects of public health insurance on the demand for private health insurance, precautionary savings and health capital accumulation. Our paper is also connected to the literature on health insurance and savings with exogenous health expenditure shocks (e.g. see Kotlikoff (1988), Levin (1995), Hubbard, Skinner and Zeldes (1995), Palumbo (1999), De Nardi, French and Jones (2009) and Jeske and Kitao (2009)). Different from these studies in our model health expenditures are endogenous and determined together with health insurance and savings based on a utility maximization problem. We also expand our own study on health savings accounts (Jung and Tran (2008)) by introducing a more realistic insurance setting (group and individual insurance), income shocks, and transitions. The latter enables us to perform a complete welfare analysis of the policy reforms.

The paper is structured as follows. The next section introduces a simple two period version of the model. Section 3 presents the fully dynamic model. In section 4 we present the calibration

of the model. Section 5 contains the results of our policy experiments and section 6 concludes. The appendix contains all tables and figures and equilibrium definitions. There is also a technical appendix available on our website that contains the derivations of the welfare measures, solutions to the simple model, and additional details about the model estimation parts using data from MEPS.[2]

2   A simple model

We start with a simple two period model with health risk and health insurance markets and investigate how individuals deal with this type of risk and how government interventions affect the risk-sharing mechanism. As in any insurance market adverse selection and moral hazard will play a role. However, in a multi-period setting with endogenous health this role is confounded with savings effects and human capital effects that make the multi-period setting more intricate than the simple one period settings of classical insurance papers like Pauly (1968).

We consider an overlapping generations economy where individuals live for two periods: young and old. Every agent is born with income w_i, which is drawn from a known distribution $f(w_i)$. Agents will receive this income in period one and in period two. Young agents value utility from consumption whereas old agents value utility from consumption and health status.[3] In the second period agents experience a health shock and health expenditures. A private health insurance market is available to insure against such health shocks.

In the first period, agents decide on how much to consume and save and on whether to purchase health insurance to insure against the health shock in the second period. Agent i solves the following maximization problem

$$\max_{\left\{c_i^y, s_i, in_i\right\}} \left\{u\left(c_i^y\right) + \beta EV\left(s_i, z_i\right) : s.t. \ c_i^y + s_i + 1_{\{in_i=0\}} p_i = w_i\right\},$$

where c_i^y is consumption when young; s_i is savings; $in_i \in \{0, 1\}$ is the insurance state where $in_i = 0$ indicates that no insurance is bought and $in_i = 1$ indicates that the agent decided to buy insurance; p_i is the health insurance premium; w_i is the individual income, and z_i is the health shock when old.

In the second period the agent derives utility from consumption c_i^o and health h_i. The health capital stock is determined by $h_i = g(z_i, m_i)$, where z_i is an individual specific health shock when old and m_i is the amount of medical services consumed. We assume there are two possible health shocks: bad and good, $z_i = \left\{z_i^B, z_i^G\right\}$, with $z_i^B < z_i^G$. With probability π the agent suffers a bad health shock z^B and with probability $(1 - \pi)$ her health remains good z^G. Let p_m denote the price of medical services. Total medical expenditure is $p_m m_i$. Total out-of-pocket spending on medical treatments is denoted $o(m_i)$ which is a function of whether the agent bought insurance in the first

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[2] The technical appendix can be downloaded from: http://pages.towson.edu/jjung/papers/healthvoucher111009supplement.pdf

[3] For simplicity, we assume that agents do not have any health problems when they are young, so that their utility is simply a function of consumption and their income is a function of wages and some basic health status that we normalize to one.

period

$$o\left(m_{i}\right) = \begin{cases} p_{m} m_{i} & \text{if uninsured, } in_{i} = 0, \\ \rho \times p_{m} m_{i} & \text{if insured, } in_{i} = 1, \end{cases}$$

where the coinsurance rate ρ is the fraction that the household pays after the insurance pays $(1 - \rho)$ of total health expenditures. The agent then decides how much to spend on consumption and medical treatments in the second period of her life as follows

$$V\left(s_{i}, z_{i}\right) = \max_{c_{i}^{o}, m_{i}} \left\{ u\left(c_{i}^{o}, h_{i}\right) : \text{ s.t. } c_{i}^{o} + o\left(m_{i}\right) = R s_{i} + w_{i} e_{i}, \ h_{i} = g(z_{i}, m_{i}) \text{ and } e_{i} = f\left(h_{i}\right). \right\}$$

We assume a perfectly competitive insurance market, where insurance companies collect actuarially fair premiums to cover their cost so that

$$p = (1 - \rho) p_{m} \int \left[\pi \times 1_{\{in_{i}=1\}} m_{i}\left(z^{B}\right) + (1 - \pi) \times 1_{\{in_{i}=1\}} m_{i}\left(z^{G}\right) \right] f\left(w_{i}\right) dw_{i}.$$

We refer to this base model as our benchmark model.

In order to solve the model we assume that preferences follow $u\left(c^{y}\right) = \frac{(c^{y})^{1-\sigma}}{1-\sigma}$ and $u\left(c^{o}, h\right) = \frac{(c^{o})^{1-\sigma}}{1-\sigma} + \chi \frac{h^{1-\sigma}}{1-\sigma}$ when agents are young and old, respectively. The health production function is linear $g(z_{i}, m_{i}) = z \times m$ and human capital is produced by $f\left(h_{i}\right) = h^{\theta}$, where θ can either be 0 or 1. In the first case health is not productive and therefore only a consumption good and in the second case health is productive and therefore also an investment good. Solving the household problem we obtain the following solutions for agents buying insurance and agents not buying insurance. We distinguish these agents according to superscript $ins_{i} = \{I \text{ or } NI\}$, where I stands for agents buying insurance and NI indicates agents that do not buy insurance. We assume that $\theta = 0$ and solve the household problem to obtain the following optimal allocation.[4]

$$s_{i}^{ins} = \frac{\left[\beta R\left(\pi \Omega^{ins,B} + (1-\pi)\Omega^{ins,G}\right)\right]^{\frac{1}{\sigma}}}{R + \left[\beta R\left(\pi \Omega^{ins,B} + (1-\pi)\Omega^{ins,G}\right)\right]^{\frac{1}{\sigma}}} \left(w_{i} - p^{ins}\right), \tag{1}$$

$$m_{i}^{ins} = \frac{1}{z_{i}} \frac{\left(\chi \frac{1}{p_{h}^{ins}}\right)^{\frac{1}{\sigma}}}{1 + p_{h}^{ins}\left(\chi \frac{1}{p_{h}^{ins}}\right)^{\frac{1}{\sigma}}} R s_{i}, \tag{2}$$

with $ins_{i} = \{I \text{ or } NI\}$,

$$p^{ins} = \begin{cases} p & \text{if buying insurance,} \\ 0 & \text{if not buying insurance,} \end{cases} \quad \text{and} \quad p_{h}^{ins} = \begin{cases} \frac{\rho \times p_{m} m}{z} & \text{if insured,} \\ \frac{p_{m} m}{z} & \text{if not insured.} \end{cases}$$

Our simple model indicates that there are interactions between the decisions on consumption, savings, insurance, and medical spending. We will discuss these interactions briefly.

Health insurance vs. precautionary savings. Individuals face health risk and have two options to insure themselves: private savings (or self-insurance) and private health insurance. The

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[4] We provide details to the solution in a technical appendix on our website.

existence of private health insurance has two opposing effects on individuals' welfare. Insurance provides a risk sharing mechanism, which is welfare improving. On other hand, insurance contracts are costly to obtain and may therefore lower welfare due to a negative income effect that lowers consumption and savings when young. Let V^I and V^{NI} be the value functions of an agent buying insurance and of an agent not buying insurance, respectively. An agent will demand health insurance as long as $V^I \geq V^{NI}$. More specifically, for each individual i there exists a maximum willingness to pay for insurance p_i^*. If the market premium for insurance $p \leq p_i^*$ then individual i will buy the insurance.

The maximum willingness to pay p_i^* depends on the curvature of the value function (i.e. the individual's risk aversion) and the individual's income endowment w_i. We find that the willingness to pay for insurance is an increasing function in income due to the dynamic structure of the model.[5] The intuition is as follows. Since the marginal utility of consumption when young is higher for the poor agents than it is for rich, the utility cost of buying health insurance in terms of forgone consumption is much higher. For a given distribution of income, there is a distribution of willingness to buy health insurance. Given a positive insurance premium there will be some agents who optimally choose not to buy insurance and rely on precautionary savings only as their maximum willingness is lower than the premium. Low income agents are less likely to buy health insurance. This implies that over the life-cycle, individuals are less willing to buy health insurance at ages when incomes are low.

As established in previous studies, the presence of health risk and health expenditure uncertainty increases precautionary savings and the demand for health insurance (e.g. see Kotlikoff (1988), Levin (1995), Hubbard, Skinner and Zeldes (1995), Palumbo (1999)). In our model, the demand for health insurance crowds out savings as demonstrated in equation (1). That is, if individuals buy insurance contracts in the private market, they have to give up part of their income when young to pay the market insurance premium p, which directly lowers income and therefore savings. This result is consistent with empirical evidence provided by Gruber and Yelowitz (1999).

When assuming that individuals face idiosyncratic (bad) health shocks with probability π, the classic issue of adverse selection in insurance markets appears (e.g. Rothschild and Stiglitz (1976)). High risk agents benefit more from buying health insurance and therefore are more willing to buy health insurance while the low risk agents opt out. When insurance companies are not allowed to charge individual specific premiums they have to charge an average premium to everybody and will end up attracting a pool of high risk agents. Consequently, low risk agents self insure via private savings. Therefore young individuals with low health risk are less likely to buy health insurance.

Insurance contract and health expenditure. The existence of a health insurance market affects an individuals' health expenditure. Insured agents tend to spend more on medical services due to a price substitution effect (moral hazard). Our model captures this channel in equation (2). Individuals consume more medical services $\frac{\partial m_i^{ins}}{\partial p_h} < 0$ as they face a lower effective price of medical service p_h. In addition, our model links the choice on health spending with the dynamic

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[5] A formal proof is available upon request from the authors. In one shot games larger wealth levels decrease the risk premium, so that the willingness to pay for insurance is actually decreasing in income in such environments.

consumption/savings problem. When an agent decides to buy health insurance, the agent saves less when young $s^I < s^{NI}$, which leads to lower savings/interest income when old. Subsequently, due to this income effect or "savings effect", insured agents have less money available to buy health services. However, they are eligible to pay the cheaper price for health services in their second period when the insurance becomes effective. The net effect determines whether medical expenditures will increase or decrease. If the substitution effect is dominant, agents will spend more on medical services in this multi-period setting.

Trade-offs in public health insurance. When private insurance markets fail to provide insurance to all individuals due to adverse selection, the introduction of a universal health insurance voucher program could be welfare improving as it alleviates a market failure. Like any other publicly run program, health insurance vouchers should be evaluated in the context of the trade-off between insurance (equity) and incentives (efficiency). Equity implies a more equal income distribution while efficiency implies minimization of distortionary effects of public health insurance on private insurance choice, health spending, and savings behavior. The existence of this new risk sharing arrangement fundamentally affects individuals' savings, insurance decisions and health spending and also has impacts on the market equilibrium. On one hand, a universal health insurance voucher system creates incentives for all individuals to buy health insurance and therefore offers a possible solution for the coverage problem (insurance). On the other hand, the voucher system carries an inherent incentive problem as it discourages individuals from saving while it also encourages increased spending on health care. The later increases the adverse effects of moral hazard in private health insurance markets and leads to additional efficiency loss (incentives). A good public health insurance program should efficiently trade off insurance and incentives.

Health and labor productivity. That new risk-sharing arrangement affects the market equilibrium and prices, which in turn affects the demand for health care and health capital accumulation. If health is associated with labor productivity then spending on health is an investment good as argued in Grossman (1972b). The voucher program would therefore directly affect the formation of human capital and influence the overall efficiency of the economy. In our model we can "turn on" the human capital channel by setting parameter $\theta = 1$. The demand for health and the demand for medical services are then given by

$$m_i^{ins} = \frac{1}{z_i} \frac{\left(\chi \frac{1}{p_h^{ins} - w_i}\right)^{\frac{1}{\sigma}}}{1 + \left(p_h^{ins} - w_i\right)\left(\chi \frac{1}{p_h^{ins} - w_i}\right)^{\frac{1}{\sigma}}} R s_i, \tag{3}$$

$$h_i^{ins} = \frac{\left(\chi \frac{1}{p_h^{ins} - w_i}\right)^{\frac{1}{\sigma}}}{1 + \left(p_h^{ins} - w_i\right)\left(\chi \frac{1}{p_h^{ins} - w_i}\right)^{\frac{1}{\sigma}}} R s_i. \tag{4}$$

Comparing medical spending (3) to medical spending without the human capital effect of health (2) we see that $m_i^{ins}(\theta = 1) > m_i^{ins}(\theta = 0)$. In other words, when health is an investment good (in addition to also being a consumption good), then agents have more incentive to spend higher

amounts of medical services and to accumulate more health capital. The new term $[-w_i]$ in the demand equations above captures the additional margin.

Equation (4) indicates how health insurance influences health capital accumulation. Uninsured agents accumulate less health capital $h_i^{ins} > h_i^{noins}$ as they have to pay higher prices for medical services $p_h^{ins} < p_h^{noins}$. In an economy where insurance markets are incomplete, under-investment in health capital could exist for uninsured agents. In such an economy, public intervention to expand health insurance coverage could result in efficiency gains. This channel also influences the trade-off between equity and efficiency and has implications for welfare. Accounting for this channel is important to judge whether the health insurance voucher program could be a good replacement for the current system.

General equilibrium effects. In a general equilibrium framework, the new risk-sharing arrangement affects the intertemporal allocation of funds, which in turn determines equilibrium market prices such as the wage rate w, interest rates r, and insurance premiums p. Prices feed back on the individual's insurance choice and health spending. The tax financing instruments that are used to finance the voucher program also affect general equilibrium outcomes. The final effects on coverage, medical expenditure, and welfare depend on how these general equilibrium mechanisms play out. In the next section, we therefore develop a full general equilibrium model to explore the full effects of the introduction of health insurance vouchers into the current U.S. health insurance system.

3 Fully dynamic model[6]

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 there is an exogenous survival probability of cohort j which we denote 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

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

where *years* denotes the number of years modelled for each agent.

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[6]In the current version of the model we abstract from modelling competition in health insurance markets. Our model is therefore not able to capture potential efficiency gains of the voucher system due to increased competition in private health insurance markets. Second, we also do not model the effects of private insurance companies monitoring health care providers and potential gains from increased monitoring due to vouchers. However, there is some evidence pointing to only very small cost savings effects due to increased competition (e.g. Medicare advantage plans were introduced with a similar goal in mind. Cost containments were however not realized.).

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

$$\max_{\{K,\ L\}} \{F(K,L) - qK - wL\}, \tag{5}$$

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 and services s that are derived from health h. Household preferences are described by a utility function $u(c,s)$ where $u : R^2 \to R$ is C^2 and satisfies the standard Inada conditions. We assume the following technology for the production of health services that transfers health capital from the current period into health services in the current period,

$$s = f(h),$$

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 agents investment into health.

Health capital accumulation. Agents produce health capital via investments into health denoted as medical expenditure m. We follow Grossman (1972b) and use the following accumulation process for health capital

$$h_j = i(m_j, h_{j-1}, \varepsilon_j), \tag{6}$$

where h_j denotes the current health capital (or health status), h_{j-1} denotes last period's health capital, m_j is amount of medical services bought in the current period, and ε_j 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 follows a Markov process with transition matrix P. Transition probabilities to the next health state depend on the current health shock ε_j so that an element of transition matrix P_j is defined as

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

Human capital accumulation. The endowment process is defined by human capital profile $e(j, h_{j-1}, \epsilon_j)$ which depends on age j, health status at the beginning of the current period h_{j-1}, and working ability ϵ_j. Let

$$\pi_{\epsilon_{j+1}, \epsilon_j} = \Pr(\epsilon_{j+1}|\epsilon_j, j)$$

be the conditional probability for age $j+1$ working ability being ϵ_{j+1} when age j working ability is ϵ_j. We summarize all such probabilities in Markov matrix Π_j.

3.5 Health expenditures and insurance arrangements

In our benchmark model, agents can buy medical services to improve their health capital. The total health expenditure that agents have to pay to improve their health capital is $p_m m_j$ where p_m is the price of medical services. Since health shocks are age-dependent and stochastic, total health expenditures are stochastic.[7] To 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). Agents in their first period of life are thus not covered by any insurance by construction. 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.

We also assume that 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. 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. Let

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

be the conditional probability that an agent has group insurance status $i_{GI,j+1}$ in period $j+1$ given

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[7]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 shock ε_j, a richer individual will outspend a poor individual. This may be realistic in some circumstances, however, a large fraction of health expenditures in the U.S. are probably 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. We do not cover this case in the current model.

she had group insurance status $i_{GI,j}$ in period j. We collect all conditional probabilities for group insurance status in transition 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

$$o(m_j) = \begin{cases} p_{m,noIns}m & \text{if } in_j = 0, \text{ (no insurance)} \\ \min\left[p_{m,Ins}m_j, \gamma + \rho\left(p_{m,Ins}m_j - \gamma\right)\right] & \text{if } in_j = 1,2 \text{ (individual/group insurance)} \end{cases} \tag{7}$$

where γ is the deductible, ρ is the coinsurance rate, $p_{m,Ins}$ is the relative price of health expenditures paid by insured workers, and $p_{m,noIns}$ is the price of health expenditures paid by uninsured workers. An uninsured worker pays a higher price $p_{m,noIns} > p_{m,Ins}$. The coinsurance rate ρ is the fraction that the household pays after the insurance company pays $(1 - \rho)$ of the post deductible amount $p_{m,Ins}m_j - \gamma$. Since households have to buy insurance before health shocks are revealed we assume that working households in their last period $j = J_1$ already decide to buy into Medicare (e.g. Medicare Plan B premiums).

Medicare. 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

$$o^R(m_j) = \min\left[p_{m,Med}m_j, \gamma^{Med} + \rho^{Med}\left(p_{m,Med}m_j - \gamma^{Med}\right)\right], \text{ if } j > J_1 + 1, \tag{8}$$

where $p_{m,Med}$ is the price of health services that retirees with Medicare have to pay. Agents have to pay a Medicare Plan B premium p^{Med}. We assume that old agents $j > J_1 + 1$ do not purchase private health insurance.[8]

Private health insurance companies. Insurance companies satisfy their budget constraint within each period and we allow for cross subsidizing across generations. The constraints are

$$(1 + \omega) \times \sum_{j=2}^{J_1+1} \mu_j \int \left[1_{\{in_j(x_j)=1\}}(1 - \rho)\max\left(0, p_{m,Ins}m_j(x_j) - \gamma\right)\right] d\Lambda(x_j) \tag{9}$$

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

$$(1 + \omega) \times \sum_{j=2}^{J_1+1} \mu_j \int \left[1_{\{in_j(x_j)=2\}}(1 - \rho)\max\left(0, p_{m,Ins}m_j(x_j) - \gamma\right)\right] d\Lambda(x_j) \tag{10}$$

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

---

[8] 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.

where ω is a markup factor that determines the profit of the insurance company, $1_{\{in_j(x_j)=1\}}$ 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 market after tax 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.

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

$$\sum_{j=J_1+1}^{J} \mu_j \int \left(1 - \rho^{Med}\right) \max\left(0, p_{m,Med} m_j(x_j) - \gamma^{Med}\right) d\Lambda(x_j) \tag{11}$$
$$= \sum_{j=1}^{J_1} \mu_j \int \tau^{Med}\left(we(j, h_j, \epsilon) - 1_{\{in_{j+1}=2\}} p\right) d\Lambda(x_j) + \sum_{j=J_1+1}^{J} \mu_j \int p^{Med} d\Lambda_j(x).$$

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

$$\sum_{j=J_1+1}^{J} \mu_j \int T_j^{Soc}(x_j) d\Lambda(x_j) = \sum_{j=1}^{J_1} \mu_j \int \tau^{Soc}\left(we(j, h_j, \epsilon) - 1_{\{in_{j+1}=2\}} p\right) d\Lambda(x_j). \tag{12}$$

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

$$G + \sum_{j=1}^{J} \mu_j \int T_j^{SI}(x_j) d\Lambda(x_j) = \sum_{j=1}^{J} \mu_j \int Tax_j(x_j) d\Lambda(x_j) + \sum_{j=1}^{J} \mu_j \int \tau^C c(x_j) d\Lambda(x_j). \tag{13}$$

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

$$\sum_{j=1}^{J} \mu_j \int T_j^{Beq}(x_j) d\Lambda(x_j) = \sum_{j=1}^{J} \int \tilde{\mu}_j a_j(x_j) d\Lambda(x_j), \tag{14}$$

where $\tilde{\mu}_j$ denotes the deceased mass of agents aged j in time t. An equivalent notation applies for the surviving population of workers and retirees denoted μ_j.

3.7 Household problem

Age j year old agents enter the period with state vector $x_j = (a_j, h_j, in_j, \varepsilon_j, \epsilon_j, i_{GI})$, 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 is a negative health shock, ϵ_j

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. They do not experience an income shock anymore and they are assumed to be covered by Medicare. The state vector of a household of age j can be summarized as

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

and

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

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

3.7.1   Workers

Agents are endowed with one unit of time that they supply inelastically to the labor market. Agents therefore 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 health shocks are realized, agents simultaneously decide their consumption c_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}, an agent chooses the insurance state for the next period.

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 problem for workers $j = \{1, ..., J_1 - 1\}$ can be formulated recursively as

$$
\begin{aligned}
V(x_j) &= \max_{\{c_j, m_j, a_{j+1}, in_{j+1}\}} \left\{ u(c_j, s_j) + \beta \pi_j E_{\varepsilon_{j+1}, \epsilon_{j+1}, i_{GI}|\varepsilon_j, \epsilon_j, i_{GI}} [V(x_{j+1})] \right\} \\
&\quad s.t.
\end{aligned} \tag{15}
$$

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

where

$$Tax_j = \tilde{\tau}\left(\tilde{y}_j^W\right) + \left(\tau^{Soc} + \tau^{Med}\right)\left(we\left(j, h_j, \epsilon\right) - 1_{\{in_{j+1}=2\}}p\right),$$

$$\tilde{y}_j^W = \begin{cases} we\left(j, h_j, \epsilon\right) + ra_j + rT^{Beq} + Insprofit_1 + Insprofit_2 \\ \\ -0.5\left(\tau^{Soc} + \tau^{Med}\right)\left(we\left(j, h_j, \epsilon\right) - 1_{\{in_{j+1}=2\}}p\right) - 1_{\{in_{j+1}=2\}}p, \end{cases}$$

$$T_j^{SI} = \max\left[0, \underline{c} + Tax_j - we\left(j, h_j, \epsilon\right) - R\left(a_j + T^{Beq}\right) - InsP_1 - InsP_2\right].$$

Variable c_j is consumption, a_{j+1} is next period's capital stock[9], 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[10] and T_j^{SI} is Social Insurance (e.g. food stamp programs).

The effective wage income is $we\left(j, h, \epsilon\right)$, $\tilde{\tau}\left(\tilde{y}_j^W\right)$ 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.[11]

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.[12] Agents can only buy

---

[9]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.

[10]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.

[11]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.

[12]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 they have to much savings 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 (2005) follows a similar approach. See also: http://www.cms.hhs.gov/MedicaidEligibility

for details on Medicaid eligibility.

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

$$1_{\{in_{j+1}=1\}} p(j, h) \quad < \quad we(j, h_j, \epsilon) + R\left(a_j + T_j^{Beq}\right) - o^W(m_j) - Tax_j,$$

$$1_{\{in_{j+1}=2\}} p_j \quad < \quad we(j, h_j, \epsilon) + R\left(a_j + T_j^{Beq}\right) - o^W(m_j) - Tax_j.$$

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

$$V(x_j) = \max_{\{c_j, m_j, a_{j+1}\}} \left\{ u(c_j, s_j) + \beta \pi_j E_{\varepsilon_{j+1}, \epsilon_{j+1}|\varepsilon_j, \epsilon_j} \left[V(x_{j+1})\right] \right\} \tag{16}$$

$$s.t.$$

$$\left(1 + \tau^C\right) c_j + (1 + g) a_{j+1} + o^R(m_j) + p^{Med} = R\left(a_j + T_j^{Beq}\right) - Tax_j + T_j^{Soc} + T_j^{SI},$$

$$0 \leq a_{j+1},$$

where

$$Tax_j = \tilde{\tau}\left(\tilde{y}_j^R\right),$$

$$\tilde{y}_j^R = ra_j + rT_j^{Beq},$$

$$T_j^{SI} = \max\left[0, \underline{c} + o^R(m_j) + Tax_j - R\left(a_j + T_j^{Beq}\right) - T_j^{Soc}\right].$$

Note that retired agents cannot buy private health insurance anymore so that $in_{j+1} = 0$ by definition.

3.8 Health insurance vouchers

In our alternative regime, Medicare is eliminated and the government runs a health insurance voucher program, instead. Households receive a health voucher each period that they can use to buy their basic health insurance coverage. The amount of the voucher depends on the discounted (and mortality adjusted) expected health expenditure of the agent in the next period. We can therefore write the size of the voucher for each agent as a function of the agent state vector x_j

$$v(x_j) = p(x_j) = \pi_j E_{\varepsilon_{j+1}, \epsilon_{j+1}|\varepsilon_j, \epsilon_j} \left[(1 - \rho) \max\left(0, \ p_{m,Ins} m_{j+1}(x_{j+1}) - \gamma\right)\right].$$

3.8.1 Insurance company

In the model with health vouchers, insurance companies are allowed to charge idiosyncratic premiums that are equal to the expected health spending of the agent in the next period. This premium can be written as

$$p_j\left(x_j\right) = \pi_j \times E\left[\left(1 - \rho\right)\max\left(0, p_{m,Ins}m_{j+1}\left(x_{j+1}\right) - \gamma\right)\right].$$

Since premiums p_j are paid for by vouchers from the government and the size of the vouchers is equal to the expected future health expenditure of the agent, it has to hold that

$$p_j\left(x_j\right) = v\left(x_j\right).$$

Again, insurance companies satisfy their budget constraint within each period. We allow for cross subsidizing across generations.

$$\left(1 + \omega\right) \times \sum\nolimits_{j=1}^{J} \mu_j \int \left[\left(1 - \rho\right)\max\left(0, p_{m,Ins}m_j\left(x_j\right) - \gamma\right)\right] d\Lambda\left(x_j\right) \qquad (17)$$
$$= R\sum\nolimits_{j=1}^{J} \mu_j \int v_j\left(x_j\right) d\Lambda\left(x_j\right), \text{ and}$$

where ω is a markup factor that determines the profit (or loading costs) of the insurance company.

We do not model the possible premium reductions from increased competition due to vouchers but instead assume a perfectly competitive insurance market where insurance companies make zero profit. This will underestimate the effects of vouchers on the reduction of insurance premiums and the reduction of health expenditures in general. However, some literature on competition in health insurance and health care markets questions the beneficial effects of increased competition on welfare and health care quality (e.g. Frank and Lamiroud (2008), Gaynor (2006), DeFeo and Hindriks (2005), Bundorf (2003), Cutler and Reber (1998)). We therefore assume that the additional cost savings or price reduction effects from vouchers due to increased competition in health insurance markets are small and hence not crucial for our analysis.

3.8.2 Government

The aggregate cost of vouchers is

$$\sum\nolimits_{j=1}^{J-1} \mu_j \int v\left(x_j\right) d\Lambda\left(x_j\right) = \sum\nolimits_{j=2}^{J} \mu_j \int \left[\left(1 - \rho\right)\max\left(0, \ p_{m,Ins}m_{j+1}\left(x_{j+1}\right) - \gamma\right)\right] d\Lambda\left(x_j\right). \quad (18)$$

We assume that vouchers are financed either by a payroll tax τ^V, a sales tax on final goods consumption τ^C, or a lump-sum tax τ^{LS}. The government budget constraint for the voucher regimes

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can therefore be expressed as either

$$G + \sum_{j=1}^{J} \mu_j \int \left(T_j^{SI}(x_j) + v(x_j) \right) d\Lambda(x_j) = \sum_{j=1}^{J} \mu_j \int Tax_j(x_j) + \sum_{j=1}^{J_1} \mu_j \int \tau^V we(x_j) d\Lambda(x_j) \tag{19}$$

$$G + \sum_{j=1}^{J} \mu_j \int \left(T_j^{SI}(x_j) + v(x_j) \right) d\Lambda(x_j) = \sum_{j=1}^{J} \mu_j \int \left(Tax_j(x_j) + \tau^C c(x_j) \right) d\Lambda(x_j), \tag{20}$$

$$G + \sum_{j=1}^{J} \mu_j \int \left(T_j^{SI}(x_j) + v(x_j) \right) d\Lambda(x_j) = \sum_{j=1}^{J} \mu_j \int \left(Tax_j(x_j) + \tau^{LS} \right) d\Lambda(x_j). \tag{21}$$

3.8.3 Household

Age j year old agents enter the period with state vector $x_j = (a_j, h_j, \varepsilon_j, \epsilon_j)$, 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, ε_j is a negative health shock, and ϵ_j is positive income shock. The state vector of a household of age j can be summarized as

$$x_j = \left\{ \ (a_j, h_{j-1}, \varepsilon_j, \epsilon_j) \in R_+ \times R_+ \times R_- \times R_+ = D. \right.$$

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

Workers. The worker's dynamic programming problem is given by

$$V(x_j) = \max_{\{c_j, m_j, a_{j+1}\}} \left\{ u(c_j, s_j) + \beta \pi_j E_{\varepsilon_{j+1}, \epsilon_{j+1} | \varepsilon_j, \epsilon_j} \left[V(x_{j+1}) \right] \right\}$$

$$\text{s.t.} \tag{22}$$

$$\left(1 + \tau^C \right) c_j + (1 + g) a_{j+1} + o^W(m_j) + p(x_j)$$
$$= \left(1 - \tau^V \right) we(j, h_j, \epsilon) + R \left(a_j + T^{Beq} \right) - Tax_j + T_j^{SI} + v_j - \tau^{LS},$$
$$0 \leq a_{j+1},$$

where

$$v_j = p(x_j),$$
$$Tax_j = \tilde{\tau}(\tilde{y}_j^W) + \tau^{Soc} we(j, h_j, \epsilon),$$
$$\tilde{y}_j^W = we(j, h_j, \epsilon) + ra_j + rT^{Beq},$$
$$T_j^{SI} = \max \left[0, \underline{c} + Tax_j - we(j, h_j, \epsilon) - R \left(a_j + T_j^{Beq} \right) \right].$$

Variable c_j is consumption, a_{j+1} is next period's capital stock, g is the exogenous growth rate, $o^W(m_j)$ is out-of-pocket health expenditure, m_j is total health expenditure, $p(x_j)$ is the insurance premium, 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, T_j^{SI} is Social Insurance (e.g. food stamp programs), τ^C is a consumption tax, τ^V is special payroll tax, and τ^{LS} is a special lump sum tax. Either τ^C, τ^V, or τ^{LS} will be active to finance the voucher program.

The effective wage income is $we\left(j, h, \epsilon\right)$, $\tilde{\tau}\left(\tilde{y}_j^W\right)$ captures progressive income tax, $\tau^{Soc}we\left(j, h_j, \epsilon\right)$ is the payroll tax that the household pays for Social Security, and $\tilde{y}_j^W$ is the tax base for the income tax composed of wage income and interest income on assets and accidental bequests. The Social Insurance program T_j^{SI} guarantees a minimum consumption level $\underline{c}$. If Social Insurance is paid out then automatically $a_{j+1} = 0$.

Retirees. Retired agents are similar to working agents except they lack the working income and are thus not exposed to the income shock. In addition they receive pension payments. They are not enrolled in Medicare anymore.

4 Parameterization and estimation

We provide definitions of a competitive equilibrium of the benchmark model and the model with vouchers in the appendix. We use a standard numeric algorithm to solve the model.[13]

We distinguish two sets of parameters. The first set is estimated independently from our model and based on either our own estimates using data from MEPS or estimates provided by other studies (Table 1). The second set of free parameters is chosen so that model-generated data match a given set of targets (Table 2). We present the target moments that we match with our model in table 3.

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.[14] The population growth rate for the U.S. was 1.2 percent on average from 1950 to 1997 according to the 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 fraction of 17.4 percent in the Census.

4.2 Technology and firms

We impose a standard Cobb-Douglas production technology,

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

and choose a capital share of $\alpha = 0.36$ which is a standard value. In our model we pick a capital depreciation rate of $\delta = 15$ percent which is close to standard values in the calibration literature

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[13]We discuss the algorithm in the technical appendix, which is available on the authors' website at
http://pages.towson.edu/jjung/papers/healthvoucher111009supplement.pdf

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

(e.g. Kydland and Prescott (1982)). The depreciation per period is then $1 - (1 - \delta)^{(years/J)}$.

4.3 Preferences

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

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

where η is the intensity parameter of consumption, and σ is the inverse of the intertemporal rate of substitution (or relative risk aversion parameter). We set $\sigma = 2.5$ and $\eta = 0.9$. In conjunction with the magnitudes of the health shocks this weight ensures that the model matches total health spending and the take-up ratio of health insurance of the different age groups. In addition we assume that health services are produced according to

$$s = f(h) = h.$$

The annual discount factor β is picked 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.

4.4 Health and the human capital accumulation

The period's health state is produced according to

$$h_j = i(m_j, h_{j-1}, \varepsilon_j) = \phi m_j^{\xi} + (1 - \delta_j) h_{j-1} + \varepsilon_j.$$

The productivity parameter ϕ of the health production function is normalized to unity. This is similar to the production parameter in Suen (2006) for a very similar production function of health. In addition, Grossman (1972a) and Stratmann (1999) estimate positive effects of medical services on measures of health outcomes. We set $\xi = 0.32$. We do not have data on these parameters, however these parameters are important in targeting total aggregate health expenditure and the expenditure profile over age, so that we get a good idea about their magnitude by matching the model generated moments to aggregate data.

The relative price of health and consumption can be expressed as $p_m \left(\frac{1}{\phi \xi} m^{1-\xi}\right)$, where the term in brackets is the marginal contribution to health of an additional unit of health care.[15] We assume that health depreciates depending on age so that the depreciation rates vary between $\delta_{j=1} = 0.06$ and $\delta_{j=J} = 0.52$. These are health depreciation rates over 5 year periods. This choice ensures that health depreciates faster as the agent ages. Hugonnier, Pelgrin and St-Amour (2009) estimate depreciation rates of 0.176 per year, which translates into a five year depreciation rate of $1 - (1 - 0.176)^5 = 0.6211$. Their estimate is based on individuals older than 65.

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[15]Compare Suen (2006) for a similar formulation.

4.4.1 Transition probabilities

The Markov transition probabilities for income shocks and group health insurance offers are estimated with data from MEPS 2004 and 2005. We estimate efficiency profiles for separate income quantiles and then calculate the transition probabilities of going from one quantile to another conditioning on the age of the worker. We then get estimates for age dependent Markov matrices Π_j where $j = \{1, ..., J_1\}$. Jung and Tran (2009) contains the details of the estimation procedure as well as the tables with the estimates.

MEPS data also contains information about whether agents have received a group health insurance offer from their employer. We found that these offers are highly correlated with income so that we estimate the transition probability matrices conditional on the respective income quantile of the agents, which results in matrices Ω_{income}. Again, Jung and Tran (2009) contains the details.

Finally, we chose the Markov transition matrix for health shocks $P(\varepsilon_j, \varepsilon_{j-1})$ to match aggregate health service expenditure as well as average insurance pickup rates over the agents' life cycle. The transition probabilities range from

$$P(j = 1) = \begin{pmatrix} 0.85 & 0.15 \\ 0.60 & 0.40 \end{pmatrix} \text{ to } P(j \geq 10) = \begin{pmatrix} 0.4 & 0.6 \\ 0.4 & 0.6 \end{pmatrix}.$$

4.4.2 Magnitude of health shocks

We chose the magnitude of the health shocks $\varepsilon = \{0.01,\ 0.91\}$ to match the insurance coverage take-up rate (percentage of workers buying health insurance per age group) and the share of medical spending in GDP.

4.4.3 Human capital profile

Effective human capital $e(j, h_{j-1}, \epsilon_j)$ evolves according to

$$e_j = \epsilon_j^{\chi} \left(h_{j-1}^{\theta} \right)^{1-\chi} \quad \text{for} \quad j = \{1, ..., J_1\}, \tag{23}$$

where ϵ_j is working productivity estimated from MEPS 2004-2005 data for separate income quantiles, $\chi \in [0, 1]$, and $\theta \geq 0$. This formulation mimics the hump-shaped income process over the life-cycle and makes the wage income of agents dependent on their health state. 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.

After taking the endogenous health capital into account, the model reproduces the hump shaped average efficiency units of the human capital profile. We normalized the profile and compare it to the normalized income profile from the data. Fernandez-Villaverde and Krueger (2004) show similar income patterns using data from the Consumer Expenditures Survey over the period 1980-1998.

For parameter χ we pick 0.9. We are not aware of any estimates for parameter χ and will therefore conduct sensitivity analysis. We then use parameter θ to determine the degree of the investment good function of health. A parameter $\theta = 0$ indicates that health is a pure consumption good and as such unproductive and $\theta = 1$ indicates that health is also an investment good with strong effects on the formation of human capital.

4.5   Health insurance markets

4.5.1   Insurance premiums, deductibles and coinsurance rates

Insurance premiums in the individual markets are dependent on age and the health status. Age is highly correlated with health. We therefore 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 p_0 and exogenous markups for age. Base premiums p_0 will adjust to clear the insurance companies budget constraint (9). We use data on average premiums provided in *The Cost and Benefit of Individual Health Insurance Plans* (2005) and estimate the exogenous age dependent premium growth rate g_j according to

$$g_{age} = x_0 + x_1 \times age + x_2 \times age^2 + u_{age}, \tag{24}$$

where u_{age} is an iid random variable with $E\left[u_{age}|age\right] = 0$. The insurance premium is then the base premium times the growth rate, or

$$p\left(j\right) = p_0 \times g_j, \text{for all } j \in \{1, ..., J_1\}. \tag{25}$$

We pick coinsurance rate $\rho = 34$ percent (Suen (2006) uses a coinsurance rate of 25 percent). Deductibles are endogenous in the model and are expressed as fractions of median income. We impose that the deductible for private health insurance is 1.7 percent of median income. We also relate the private insurance premiums to premiums from Medicare Plan B according to Claxton, Gabel, Gil, Pickreign, Whitmore, Finder, DiJulio and Hawkins (2006). These parameters result in insurance premiums that are close to the average insurance premium as a fraction of income in the data. All ratios, data and model generated, are reported in table 3.

4.5.2   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 $p_m = 1.15$.[16]

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*

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

Prescription Drug Prices (2000)). The national average is a markup of around 60 percent for the uninsured population (Brown (2006)). We therefore pick $p_{m,nIns} = 1.55$.

4.6 Government

Social security taxes are $\tau^{Soc} = 12.4$ percent on earnings up to $\$97,500$. This contribution is made by both employee and employer. 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 10.6 percent picking the appropriate pension replacement ratio Ψ to be 45 percent.[17] The size of the social security program is then 6 percent of GDP. This is close to the number reported in *The 2002 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Disability Insurance Trust Funds* (2002) which is 5 percent for 2002.

The Medicare tax τ^{Med} adjusts to clear expression (11). We fix the premium for Medicare p^{Med} so that premium payments are 1 percent of GDP. The model then results in a Medicare size of 2.08 percent of GDP which is close to the 2.5 percent reported in *2002 Annual Report of the Board of Trustees of the Federal Hospital Insurance and Federal Supplementary Medical Insurance Trust Funds* (2002) with a Medicare payroll tax of 2.1 percent. Medicare payroll taxes are 2×1.45 percent on all earnings split in employer and employee contributions(see *Social Security Update 2007* (2007)).

Using the income tax rates of the U.S. income tax of 2005 we follow Guner, Kaygusuz and Ventura (2007) and estimate the following equation describing marginal income tax rates

$$margTax\,(income) = \beta_0 + \beta_1 \log\,(income) + u_{income}, \tag{26}$$

where $margTax\,(income)$ is the marginal tax rate that applies when taxable income equals $income$, and ε is an iid random variable where u_{income} is an iid random variable with $E\,[u_{income}|income] = 0$. Variable $income$ is household income normalized with an assumed maximum income level of $\$400,000$. We then fit equation (26) 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 income tax function becomes

$$T\,(\text{taxable income}) = margTax\,(income) \times \text{taxable income}, \tag{27}$$

where $T\,(\text{taxable income})$ is total income tax paid. In addition, we impose a lower bound of 0 percent and an upper bound of 35 percent on the marginal income tax rate. 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 (27) to get the marginal tax rate and the sum total of payable income tax for each

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[17]Social security transfers are defined as $T_j^{Soc}\,(x) = \Psi we_j\,(h_{j-1})$ 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.

individual.[18]

Since income tax revenue and consumption tax revenue is collected to pay for the social insurance program T^{SI} (e.g. foodstamps, etc.) and the residual becomes government consumption G, we want to make sure that the size of government consumption also conforms to the data ($G/Y = 18$ percent as reported in Jeske and Kitao (2009), or 20 percent reported in Castaneda, Diaz-Gimenez and Rios-Rull (2003)) which results in a consumption tax $\tau_c = 7$ percent (Mendoza, Razin and Tesar (1994) reports 5.67 percent). The social insurance program finances minimum consumption $\underline{c}$ at 9.8 percent of median income (Jeske and Kitao (2009) use 23.9 percent of average earnings).

We fix the Medicare coinsurance rate at 30 percent. 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.[19]

Deductibles are endogenous in the model and are expressed as fractions of average health expenditure. We impose that the Medicare deductible is $\gamma^{Med} = 6$ percent of median income.

4.7 Key calibration results

In general we calibrate our model to match U.S. data from MEPS in 2004/2005 unless we indicate another data source. We match several important features of the data including insurance coverage, medical expenditures, and wealth accumulation over the life-cycle.

Number of Insured Workers and Life-Cycle Take-up Ratio. Panel one in figure 2 shows the fraction of insured agents over the life-cycle. We present both insurance take up ratios from the data and from the model. We see that the model slightly overestimates the take up rate of insurance for young workers and underestimates the take-up rate for older workers. Overall, the model generates take up rates over the life-cycle that are very close to the data.

Life-Cycle Medical Expenditures. We match two important measures of medical expenditures; the share of medical spending as a fraction of GDP and life-cycle medical expenditures as fraction of income. First, our model generates total medical expenditures of 10 percent in terms of GDP, which is lower than the reported range of 15 to 17 percent of GDP for the US in 2005 according to Baicker (2006) and Fang and Gavazza (2007). We think this lower number is justified as we concentrate our analysis on the 20 to 85 year old population which leaves out health care spending for children and teenagers. In addition, we do not model Medicaid. Second, our model also matches the life-cycle pattern of medical expenditure as a fraction of income, which is an increasing function in age (panel two in figure 2).

Life-Cycle Wealth. Panel two in figure 2 shows the asset distribution over various age groups.

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

[19]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

We see that the model reproduces the hump shaped pattern in the data. The data is from the U.S. Census in 2000.

5   Policy experiments and results

After calibrating the model to its initial steady state (see first column in table 4) we introduce a universal health insurance voucher program that insures all workers and also replaces Medicare. In our first experiment we use a payroll tax to finance the voucher program, the program is denoted Regime 1 in table 4. We find that the introduction of health insurance vouchers together with the elimination of Medicare results in a number of important general equilibrium effects.

Efficiency loss. This universal public health insurance program results in efficiency loss. That is, aggregate capital is reduced by 11 percent and subsequently output is lowered by 3.8 percent. The decline in capital accumulation is mainly due to disincentives on savings. The agents who are uninsured and had to rely on their own income and savings to cover medical costs have now less incentive to save under the health insurance voucher program. Also, agents are forced to pay higher taxes which reduces their income and therefore lowers savings.

Universal coverage and cost. The introduction of a universal health insurance voucher program completely eliminates the adverse selection problem that plagues private health insurance markets as it is now optimal for every agent to buy health insurance since the voucher covers 100 percent of the premium. In order to finance this program the government has to introduce a new payroll tax τ_v in the amount of 8.2 percent. On the other hand, Medicare is abolished so that the Medicare payroll tax drops to zero. The difference between the new payroll tax for vouchers and the old payroll tax for Medicare is about 6 percent and represents a direct measure of the cost of full insurance coverage in the U.S.

Health spending. The microeconomic-based insurance literature predicts that medical spending increases with the introduction of insurance programs due to moral hazard. In contrast, our macroeconomic-based model results are more complex. The effect on medical spending is not driven only by individuals' optimal reaction to relatively "cheaper" medical services but also by general equilibrium effects on savings and consumption. The latter effects are caused by increased payroll taxes and by general equilibrium price and income adjustments. Specifically, a new risk sharing mechanism with health insurance vouchers severely affects individuals' choice of consumption, savings, insurance, and medical services, which in turn affect equilibrium prices such as the wage rate, the rental rate of capital and the insurance premium. These changes in prices feed back into determining household income and the relative resource allocations between consumption and savings. These general equilibrium price substitution and income effects are important determinants of whether individuals end up spending more or less on their health. The final or overall effect of vouchers on medical expenditure therefore depends on how all these effects play out.

Our results indicate that this particular health care reform increases the share of GDP spent on health care by 0.6 percent. Multiple effects are at work. The higher payroll tax creates a very large negative income effect that will decrease spending on health services. However, a large fraction

of the population is now newly insured and will increase their health expenditure (moral hazard). Total health expenditures increase by 1.5 percent. Or in other words, poorer agents end up buying more of the cheaper good.

Welfare. All social insurance programs that are financed by tax revenues face a trade-off between the gains from *insurance* and the losses created by distortions of *incentives*. The universal health insurance voucher program is no exception. On one hand, the system creates incentives for all individuals to buy health insurance (insurance effect). On the other hand, the voucher system creates incentive problems as it increases tax rates, discourages individuals to save for self-insurance, and encourages increased health spending (moral hazard) which leads to efficiency loss (incentive effect).

We next explore how these two effects interact in terms of consumer welfare. We calculate transition dynamics of welfare from the status quo equilibrium without vouchers to an equilibrium with universal health insurance vouchers. We then use two welfare measures, the first is compensating consumption as fraction of GDP in each time period and the second is compensating consumption as percentage of lifetime income for each generation. The first measure puts a price tag on the reform as it expresses lost (or gained) consumption in terms of GDP. The second measure identifies the winner or loser generation from the reform. We present details of the welfare measures in a technical appendix that is available from our website. The welfare effects are shown in figure 4.

The introduction of a universal public health insurance program has two opposing effects on individual welfare. On one hand, public health insurance lowers welfare because of higher tax rates that are required to finance the public program. Higher taxes crowd out savings and therefore lower aggregate capital. On the other hand, the public insurance program provides a mechanism to share health risk across families and age groups, which is welfare improving. In addition, some previously uninsured individuals have now access to cheap health care and are able to increase their health levels.

We find that the voucher program results in an overall welfare gain. This result indicates that the welfare gain resulting from the insurance function of the public voucher program outweighs the welfare loss due to the efficiency loss caused by higher tax rates. 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 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. It also implies that the current health insurance system does not efficiently trade off *insurance* and *efficiency*.

The first panel indicates how much it would cost in terms of GDP to make all agents indifferent between the reform and the status quo. The graph indicates that welfare gains are between 3 and 6 percent of GDP.

The second panel in figure 4 indicates that all the generations born before and after the health care voucher reform would benefit from it. It also shows a non-monotonicity in welfare gains. The generations born before the reform gain between 20 to 30 percent of their lifetime consumption (hence the negative! compensating consumption measures). The generations born after the reform

gain roughly 5 percent of their lifetime consumption. These retired agents have higher welfare gain because of two reasons. First, the new public health insurance program crowds out private savings, which results in less capital accumulation and higher interest rates. The retired agents who had made their savings decision based on lower interest rates before become richer due to capital gain. Hence, the unanticipated voucher reform results in increasing interest rates and the general equilibrium wealth effect. The retired agents' savings income go up due to this general equilibrium effect. Second, the retired agents do not work so they have no labor income. Higher payroll tax and negative general equilibrium wage adjustment result no wealth effect. Throughout the analysis we therefore see retired households benefiting more from the reform in welfare terms than ones who are born after the reform.

Somewhat different from studies about privatizing social security using stochastic dynamic general equilibrium models (e.g. see Auerbach and Kotlikoff (1987) and Imrohoroglu, Imrohoroglu and Joines (1995)), our welfare results imply that publicly financed health insurance vouchers lead to welfare gains over a system where workers are either insured by private insurance companies or where workers decide to self insure by increasing their savings rate.

Alternative financing instruments. We next explore the effects of alternative tax financing instruments like a consumption tax (Regime 2) and a lump-sum tax (Regime 3).

Consumption tax: In contrast to the previous experiment (Regime 1: payroll tax), we find a higher rate of capital accumulation when consumption tax is used as a financing instrument (Regime 2) so that steady state capital stock only decreases by 1.7 percent. There are at least two reasons for this. When the government decides to abolish Medicare which is financed by a payroll tax in order to replace it with vouchers that are financed by a consumption tax, the effective price of final consumption goods increases as the consumption tax increases from 5.1 percent in the initial steady state to 18 percent in the new steady state. Agents will start consuming less of the final consumption good and start directing their spending towards medical services. Second, the abolishment of Medicare presents a savings motive as older agents cannot expect to receive cheap healthcare when old. Savings can happen in two forms, either additional investments into health capital or as investments into physical capital. The availability of health insurance, makes the first more attractive, so that the physical savings rate drops slightly below benchmark.

In addition, we find that aggregate health expenditures as a fraction of GDP increase. The logic behind this is that first, the increase in health spending by previously uninsured young agents increases due to moral hazard. Also, 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.

Transitions are presented in figure 5 and welfare results are presented in figure 6. The graph indicates welfare losses of 2 to 3 percent of compensating consumption as a fraction of GDP for the periods after the reform. This welfare loss is due to the severe drop in final goods consumption rates and a direct consequence of the high sales taxes. When investigating welfare for each generation we do find welfare gains for some generations born and retired before the reform. We already pointed out before that retired generations can partly benefit from sightly higher interest rates

which increases their income from savings.

Lump-sum tax: Finally we investigate how a voucher program financed by a lump-sum tax (Regime 3) on all households would affect the insurance vs. efficiency trade-off. Lump-sum taxation is considered less distortive than payroll taxes so that this experiment is almost output neutral. The capital stock only drops by 2.5 percent and output drops by 0.8 percent. However, the redistributive or "insurance" effects are smaller since there is no progressivity built into this type of tax system. In addition, the negative income effect lowers the consumption possibilities of the agents. Overall we find that the negative effects outweigh the positive effects in terms of welfare (see figure 8).

Health Productivity and Human Capital Effect. The new risk-sharing arrangement will also affect capital accumulation and equilibrium prices, which in turn influence the demand for health care and health capital accumulation. If health is associated with labor productivity and spending on health is an investment as argued in Grossman (1972b), then the formation of human capital will be affected by the voucher program. That is, the voucher system induces individuals to accumulate more health capital as it eliminates the adverse selection problem.

In all our previous experiments we chose health productivity parameter $\theta = 0$ so that we effectively turned off the influence of health on the formation of human capital. Health is therefore only held for its consumption value. Health therefore did not affect income or output via the production process. If, on the other hand, one believes that health can also be an investment good, as it produces more healthy work time, then $\theta > 0$ and health will affect the formation of human capital. This has important consequences for individual household income but also for aggregate output, which in turn has implications on welfare.

We therefore set $\theta = 1$ and recalibrate the model as our new benchmark. We then conduct the same policy experiments that we already described above when $\theta = 0$ and the human capital effect was turned off. We first introduce the universal voucher system financed by a payroll tax (Regime 1), then a consumption tax (Regime 2), and finally a lump-sum tax (Regime 3). We report the results of these experiments in table 5.

In general we find that our results are still valid when the human capital effect is turned on. For Regime 1 where a new payroll tax finances the vouchers, we again find that the negative income effects due to the higher payroll tax stifles savings, which in turn lowers the new steady state capital stock. However, the human capital effect mitigates the drop in savings somewhat compared to our earlier experiment so that aggregate output drops by less. At the same time the growth in health capital is lower with the human capital effect turned on. The reason is again a general equilibrium effect via wages. As we can see from the transition graph in figure

The differences in the effects between regime 1 with $\theta = 0$ and regime 1 with $\theta = 1$ are small though and the differences in terms of welfare are negligible, compared the two curves in figure 4.

When consumption taxes finance the vouchers, we see that the efficiency results are strengthened. The savings rate increases marginally by 0.08 percent. This has to do with higher prices for final consumption goods, but also with higher health capital levels. Since higher health capital levels now increase human capital levels, firms will demand more physical capital as it is complementary to human capital in the final goods production process. This channel was absent in our earlier

analysis with $\theta = 0$ (no human capital effect of health). We find small efficiency gains as overall output increases by 0.3 percent (when $\theta = 0$, output decrease by 0.7 percent). As every agent holds insurance, health spending increases (moral hazard) which increases the health capital stock. Since health capital is productive, more physical will be accumulated as well due to complementarities in the final goods production process. Overall, the output effect will be magnified. This in turn creates larger income effects. As consumption taxes again rise from 4.6 percent in the benchmark economy to more than 17 percent, agents experience welfare losses despite their better health states.

Regime 3 results change the most when the human capital effect is active. Now the policy reform increase output (efficiency gain). However, the lump-sum tax creates a large enough negative income effect, to decrease welfare for most generations.

6 Conclusion

In this paper we make two key contributions to the literature. First, we integrate the health accumulation and health insurance decisions into a dynamic general equilibrium consumption/savings model where households are exposed to health shocks over the life-cycle. In our model households choose consumption, savings, health insurance, and medical expenditures to maximize expected lifetime utility. That is, demand for health insurance and demand for medical services/expenditures are explicitly derived from a household utility maximization problem. Our calibrated model is capable to match life-cycle trends of average medical expenditures and insurance take-up ratios from MEPS. Second, this comprehensive modelling tool allows us to analyze the macroeconomic effects of reforming public and private health insurance markets. More specifically, we apply our model to study the implications of a universal health insurance voucher system.

Health insurance voucher programs seem to be a promising solution to insure 100 percent of the U.S. population but cannot control the steady increase in health care expenditures. Proponents of vouchers have argued that the government is better able to control the rise in health care spending using a voucher system as vouchers will replace government run Medicare (which will be insolvent soon) with private health insurance contracts. Private insurers are supposedly better able to monitor health care providers and to control costs. Our analysis however suggests, that aggregate spending on health would increase and possible growth effects due to better health do not compensate for the additional spending. Growth effects only materialize when the right financing instrument is in place. It is therefore crucial to use either a consumption or lump-sum tax in order to trigger growth effects.

We think our approach presents a conservative evaluation of a voucher system as we completely abstract from any efficiency gains due to increased competition and monitoring. However, there is some empirical evidence suggesting that these efficiency gains could be small. Future work needs to carefully model the competitive environment that the insurance companies work in. Our analysis also raises the important question about how to best finance the health care reform. Or in other words, what is the best mix of taxes to achieve maximum insurance effects and gain maximum efficiency? In addition, as the labor-leisure choice is exogenous in our model, the tax-financing

effects on labor supply via increasing payroll tax is under-estimated. As pointed out in Fuster, Imrohoroglu and Imrohoroglu (2007) this channel has important implications for welfare analysis. Finally, it will be important to analyze whether vouchers could create a possible insurance gap if the voucher system is under funded. If voucher payments turn out to be insufficient, then insurance companies would have to operate at a loss when covering certain underfunded risk types. In the extreme this could lead to a complete unravelling of the private health insurance markets, where insurance companies would drop out of the voucher market. In this case the government would have to provide a public insurance alternative if it wants to maintain high coverage rates. However, then the question of sustainability of such a publicly run system is reintroduced, as this system would face similar problems as Medicaid/Medicare faces today. We leave these important questions for future research.

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7 Appendix

7.1 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 $\{\tilde{\tau}(\tilde{y}(x_j)), \tau^C\}_{j=1}^J$, a competitive equilibrium is a collection of sequences of distributions $\{\mu_j, \Lambda_j(x_j)\}_{j=1}^J$ of individual household decisions $\{c_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^J$, 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) $\{c_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^J$ *solves the consumer problem* (15) *respectively* (16)

(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

$$
\begin{aligned}
K &= \sum_{j=1}^J \mu_j \int (a(x_j)) \, d\Lambda(x_j) + \sum_{j=1j}^J \int \tilde{\mu}_j a_j(x_j) \, d\Lambda(x_j) \\
&\quad + \sum_{j=1}^{J_1} \mu_j \int 1_{\{in_{j+1}=3\}}(x_j) [i_{GI}(x_j) p + (1 - i_{GI}(x_j) p(j,h))] \, d\Lambda(x_j) - B,
\end{aligned}
$$

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

$$
L = \sum_{j=1}^{J_1} \mu_j \int e_j(x_j) d\Lambda(x_j),
$$

(d) the aggregate resource constraint holds

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

(e) the government programs clear so that (11), (12), (13), *and* (14) *hold,*

(f) the budget constraints of insurance companies (9) *and* (10) *hold*

(g) the distribution is stationary

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

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

7.2 Equilibrium with health insurance vouchers

Definition 2 *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 $\{\tilde{\tau}(\tilde{y}(x_j)), \tau^C, \tau^V, \tau^{LS}, v(x_j)\}_{j=1}^{J}$, a competitive equilibrium with health insurance vouchers is a collection of sequences of distributions $\{\mu_j, \Lambda_j(x_j)\}_{j=1}^{J}$ of individual household decisions $\{c_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^{J}$, aggregate stocks of physical capital and human capital $\{K, L\}$, factor prices $\{w, q, R\}$, and insurance premiums $\{p(x_j)\}_{j=1}^{J}$ such that*

(a) $\{c_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^{J}$ solves the consumer problem (22)

(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

$$
\begin{aligned}
K &= \sum_{j=1}^{J} \mu_j \int (a(x_j)) \, d\Lambda(x_j) + \sum_{j=1j}^{J} \int \tilde{\mu}_j a_j(x_j) \, d\Lambda(x_j) \\
&\quad + \sum_{j=1}^{J_1} \mu_j \int p(x_j) \, d\Lambda(x_j) - B, \\
T^{Beq} &= \sum_{j=1j}^{J} \int \tilde{\mu}_j a_j(x_j) \, d\Lambda(x_j), \\
L &= \sum_{j=1}^{J_1} \mu_j \int e_j(x_j) d\Lambda(x_j),
\end{aligned}
$$

(d) the aggregate resource constraint holds

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

(e) the government programs clear so that $(12), (14)$, and either $(19), (20)$, or (21) hold,

(f) the health voucher payments clear (18)

(g) the distribution is stationary

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

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

7.3 Tables and figures

Parameters:		Explanation/Source:
- Periods working	$J_1 = 9$	
- Periods retired	$J_2 = 5$	
- Population growth rate	$n = 1.2\%$	CEA (1998)
- Years modeled	$years = 72$	from age 20 to 92
- Total factor productivity	$A = 1$	normalization
- Capital share in production	$\alpha = 0.36$	standard value
- Capital depreciation	$\delta = 15\%$	Kydland and Prescott (1982)
- Price for medical care for insured	$p_{m,Ins} = 1.15$	U.S. Census 2004
- Price for medical care for uninsured	$p_{m,nIns} = 1.55$	U.S. Census 2004
- Deductible (in % of median income)	$\gamma = 1.7\%$	
- Coinsurance rate	$\rho = 0.34$	0.25 in Suen (2006)
- Medicare deductible (in percent of average health spending of the old)	$\gamma^{Med} = 6\%$	to match $\gamma/\gamma^{Med} = 0.28$ according to Fronstin and Collins (2006) and the U.S. Department of Health
- Coinsurance rate, Medicare	$\rho^{Med} = 0.30$	Center for Medicare and Medicaid Services (2005)

Table 1: External Paramters

Parameters:		Explanation/Source:	
- Relative risk aversion	$\sigma = 2.5$	to match $\frac{K}{Y}$ and R	1
- Preference on consumption	$\eta = 0.9$	to match $\frac{p \times M}{Y}$	1
- Discount factor	$\beta = 1.01$	to match $\frac{K}{Y}$ and R	1
- Health production productivity	$\phi_j = 1$ for all $j = \{1, ..., J\}$	to match $\frac{p \times M}{Y}$	1
- Production parameter of health	$\xi = 0.32$	to match $\frac{p \times M}{Y}$	1
- Health depreciation	$\delta_h = [.0675 - 0.52]$	to match $\frac{p \times M}{Y}$	9
- Human capital production	$\chi = 0.9$	to match income distribution	1
- Health productivity	$\theta = 0$	used for sensitivity analysis	1
- Health Shocks	$[0.01, 0.91]$		2
- Health transition prob.	see text		2
- Pension replacement rate	$\Psi = 45\%$	to match $\tau^{soc} = 10\%$	1
- Medicare premium/GDP:	1%	to match size of Medicare of 2.5%.	1
-Total number of free parameters:			22

Table 2: Free parameters used to match some target moments in the data.

Parameters	Model	Data	Source	
- Medical expenses per GDP: $\frac{p_m \times M}{Y}$	10.01%	12%	MEPS (population 20-85)	1
- Fraction of insured workers: (private insurance, not counting uninsured in first generation)	60%	60%	MEPS 2005	1
- Fraction of insured retirees: Ratio deductible vs. average premium	100%	99.7%	MEPS 2005	
- Private plan: $\gamma / \sum_j \mu_j p_j$	0.3	0.07 to0.23	Fronstin and Collins (2006), Claxton et al. (2006), and U.S. Department of Health 2006	1
- Medicare: $\gamma^{Med} / \sum_j \mu_j p_j^{med}$	1	1	U.S. Department of Health 2006	1
- Capital output ratio: K/Y	2.6	3	NIPA	1
- Interest rate: R	4%	4%	NIPA	1
- Residual Government spending: G/Y	18%	20.2%	Castaneda et al. (2003)	1
- Size of Social Security: SocSec/Y	6%	5%	Social Security Administration 2002	1
- Size of Medicare: Medicare/Y	2.1%	2.5%	U.S. Department of Health 2002	1
- Fraction over 65	17.34%	17.4%	U.S. Census 2005	
- Payroll tax Social Security: τ^{Soc}	10.0%	6% - 10%	IRS	1
- Consumption tax: τ^C	7%			1
- Payroll tax Medicare: τ^{Med}	2.1%	2.5%	Social Security Update 2007	1
-Total tax revenue/Y	26%	28.3%	Stephenson (1998) and Barro and Sahasakul (1986)	1
- Gini Income	0.27	0.55	Budria-Rodriguez et al. (2002)	1
- Savings profile		see figure 2		3
- Insurance take-up ratios		see figure 2		3
Total number of Moments				22

Table 3: Data vs. Model

	Benchmark	Voucher: Regime 1	Regime 2	Regime 3
Output: Y	100.000	96.210	99.382	99.138
Capital: K	100.000	89.823	98.293	97.625
Medical spending: $p_m * M$	100.000	101.538	107.858	105.126
Medical spending: $p_m * M/Y$	0.100	0.106	0.109	0.106
Consumption: C	100.000	97.602	96.227	96.497
C/Y	0.403	0.409	0.390	0.392
Human capital: H	100.000	100.000	100.000	100.000
HH gross income	11.100	10.733	10.905	10.930
K/Y	2.608	2.435	2.579	2.568
Interest rate: R in %	3.981	4.704	3.958	4.076
Wages: w	100.000	96.210	99.382	99.138
Voucher Payments in % of GDP	0.000	5.208	5.583	5.373
Consumption tax: τ_C	5.155	5.676	18.049	4.406
Payroll voucher tax: τ_V	0.000	8.227	0.000	0.000
Lump sum voucher tax: τ_{Lump} in % of HH income	0.000	0.000	0.000	6.407
Social security tax: τ_{SS} in %	9.538	9.300	9.231	9.326
Medicare Tax: τ_{Med} in %	2.087	0.000	0.000	0.000
Income tax rev. in % of GDP:	15.781	15.538	16.111	16.166
Total tax rev. in % of GDP:	25.177	29.075	29.060	29.199
Social insurance: T_{Si}/Y	0.000	0.000	0.000	0.000

Table 4: Steady state results for the benchmark economy and three policy experiments with health productivity $\theta = 0$. Column one is the no voucher regime, Regime 1: payroll tax, Regime 2: consumption tax, and Regime 3: lump-sum tax.

	Benchmark	Voucher: Regime 1	Regime 2	Regime 3
Output: Y	100.000	96.747	100.273	100.249
Capital: K	100.000	90.902	100.078	100.115
Medical spending: $p_m * M$	100.000	98.577	107.454	104.084
Medical spending: $p_m * M/Y$	0.103	0.105	0.111	0.107
Consumption: C	100.000	98.346	96.548	96.893
C/Y	0.408	0.415	0.393	0.394
Human capital: H	100.000	100.199	100.382	100.324
HH gross income	11.994	11.651	11.853	11.900
K/Y	2.550	2.396	2.545	2.547
Interest rate: R in %	4.251	4.919	4.121	4.181
Wages: w	100.000	96.555	99.891	99.925
Voucher Payments in % of GDP	0.000	5.227	5.673	5.521
Consumption tax: τ_C	4.611	5.036	17.619	3.842
Payroll voucher tax: τ_V	0.000	8.244	0.000	0.000
Lump sum voucher tax: $\tau_L ump$ in % of HH income	0.000	0.000	0.000	6.551
Social security tax: τ_{SS} in %	9.583	9.302	9.224	9.344
Medicare Tax: τ_{Med} in %	1.804	0.000	0.000	0.000
Income tax rev. in % of GDP:	15.976	15.786	16.338	16.394
Total tax rev. in % of GDP:	24.995	29.102	29.158	29.352
Social insurance: T_{Si}/Y	0.000	0.000	0.000	0.000

Table 5: Steady state results for the benchmark economy and three policy experiments with health productivity $\theta = 1$. Column one is the no voucher regime, Regime 1: payroll tax, Regime 2: consumption tax, and Regime 3: lump-sum tax.
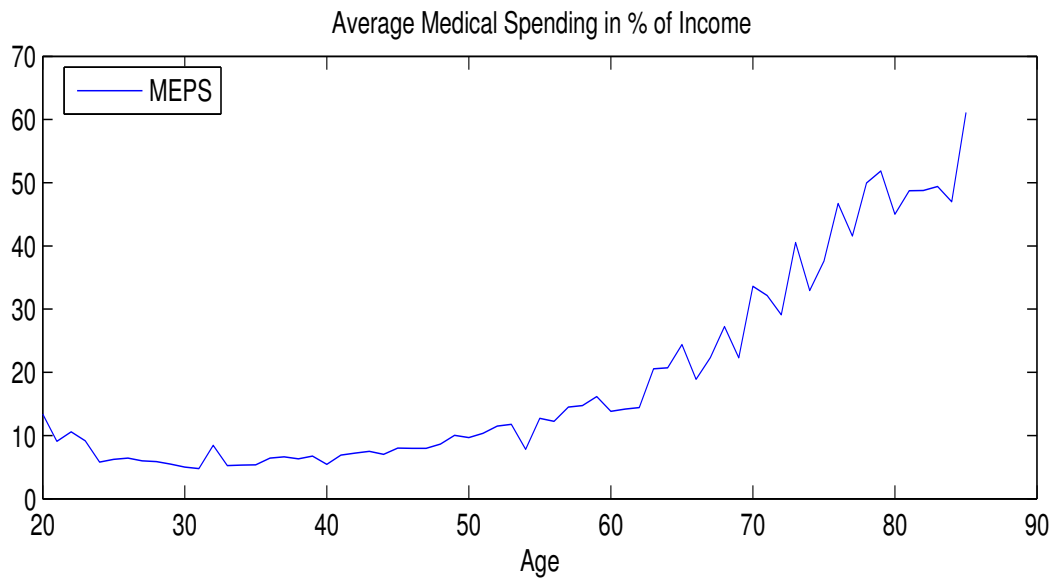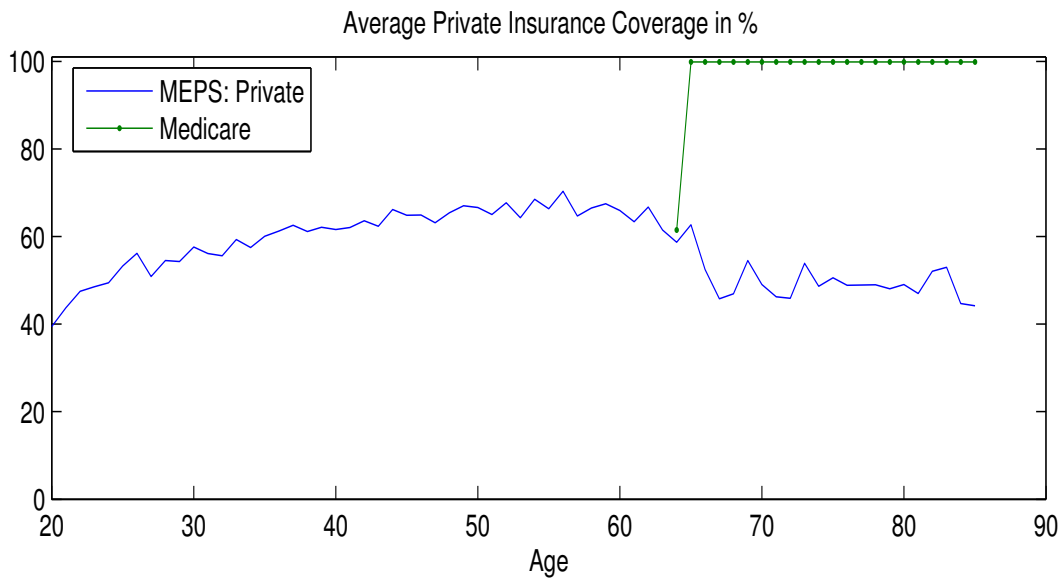
Figure 1: MEPS 2004/2005 take up rates of private health insurance and health spending as percent of household income over the life-cycle.
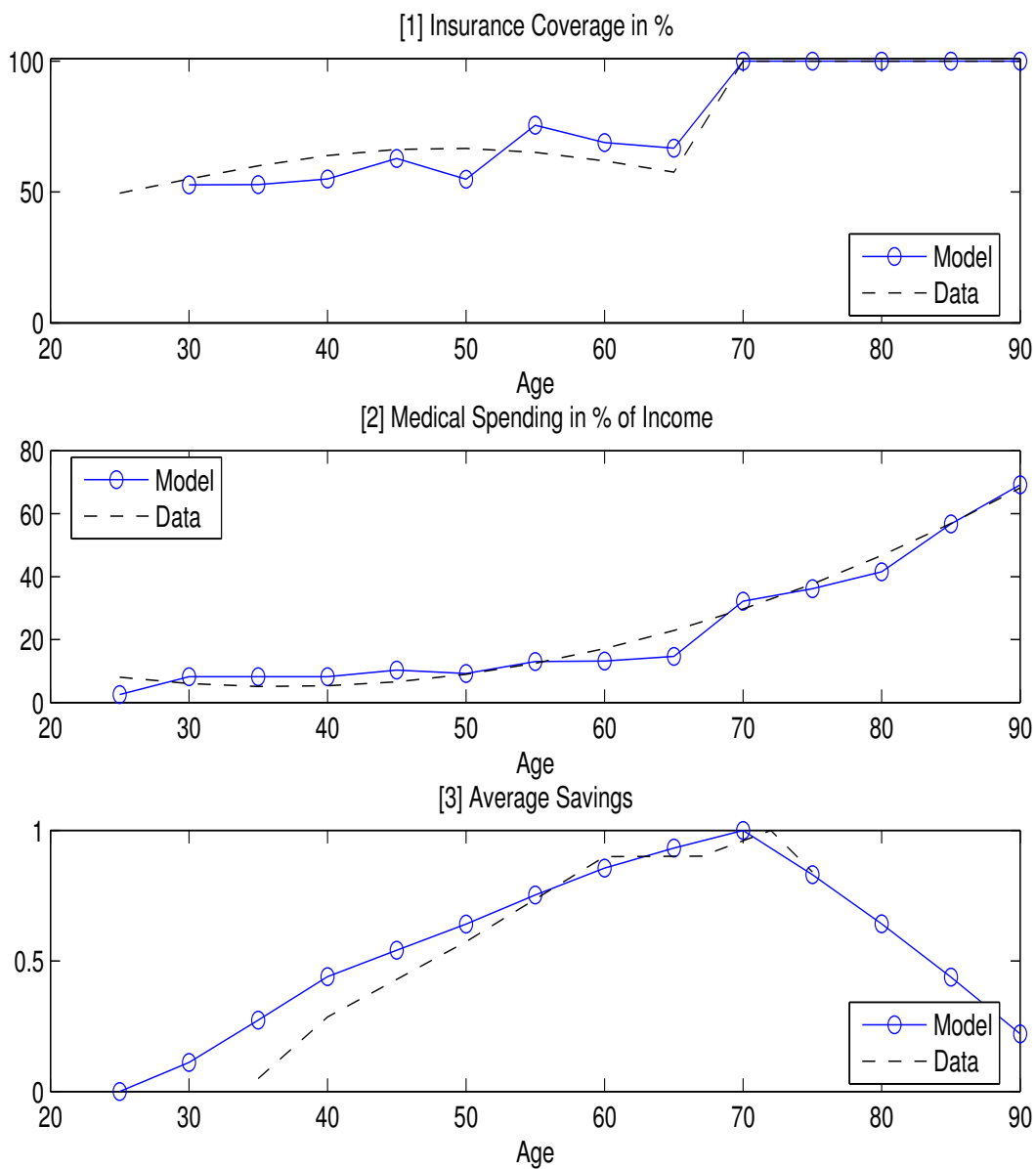
Figure 2: Steady state results for the benchmark (U.S.) economy and the economy with universal health insurance vouchers and $\theta = 0$.
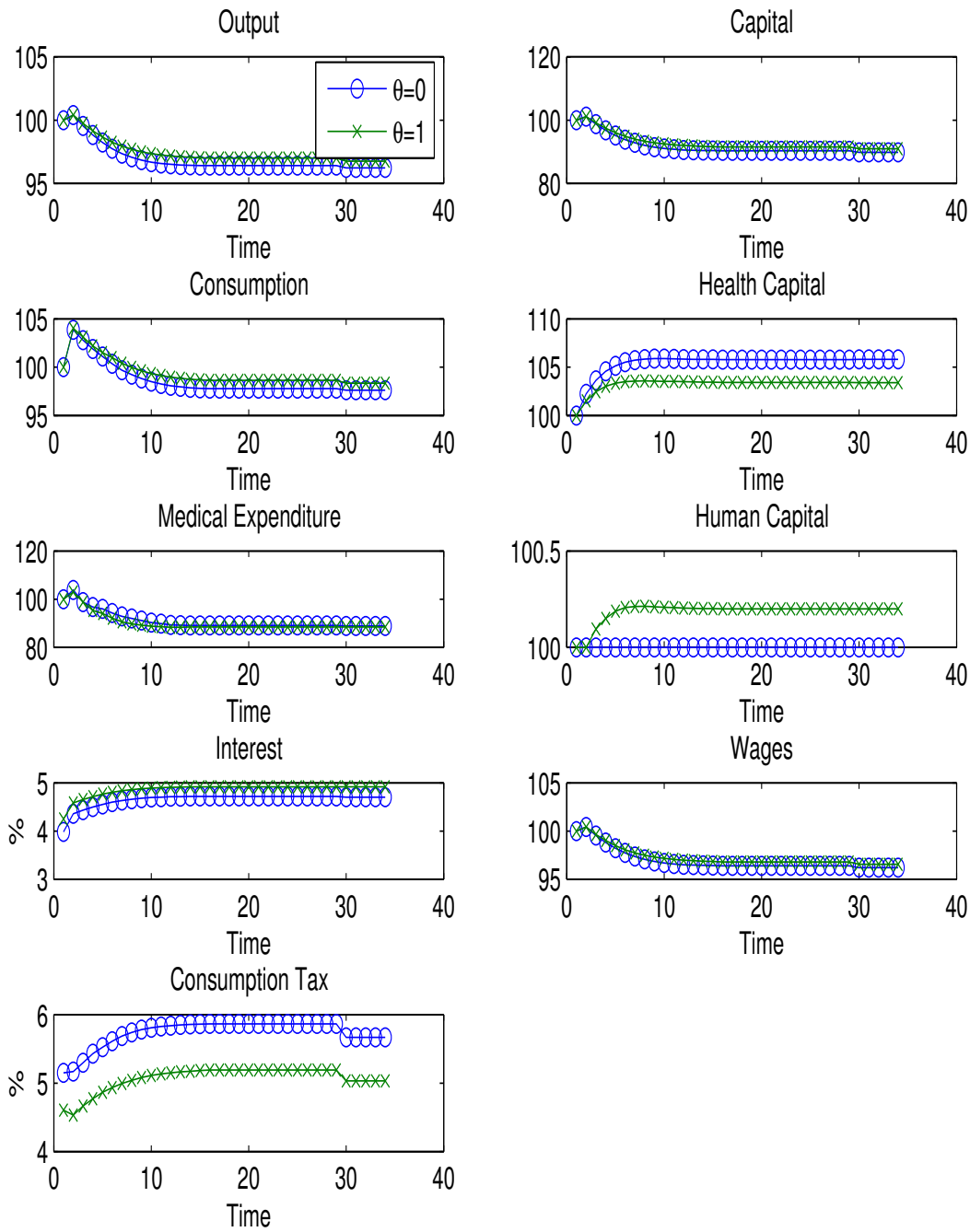
Figure 3: Regime 1 (payroll tax): Transition dynamics due to the introduction of universal health insurance vouchers into the current U.S. economy and a payroll tax finances the vouchers.
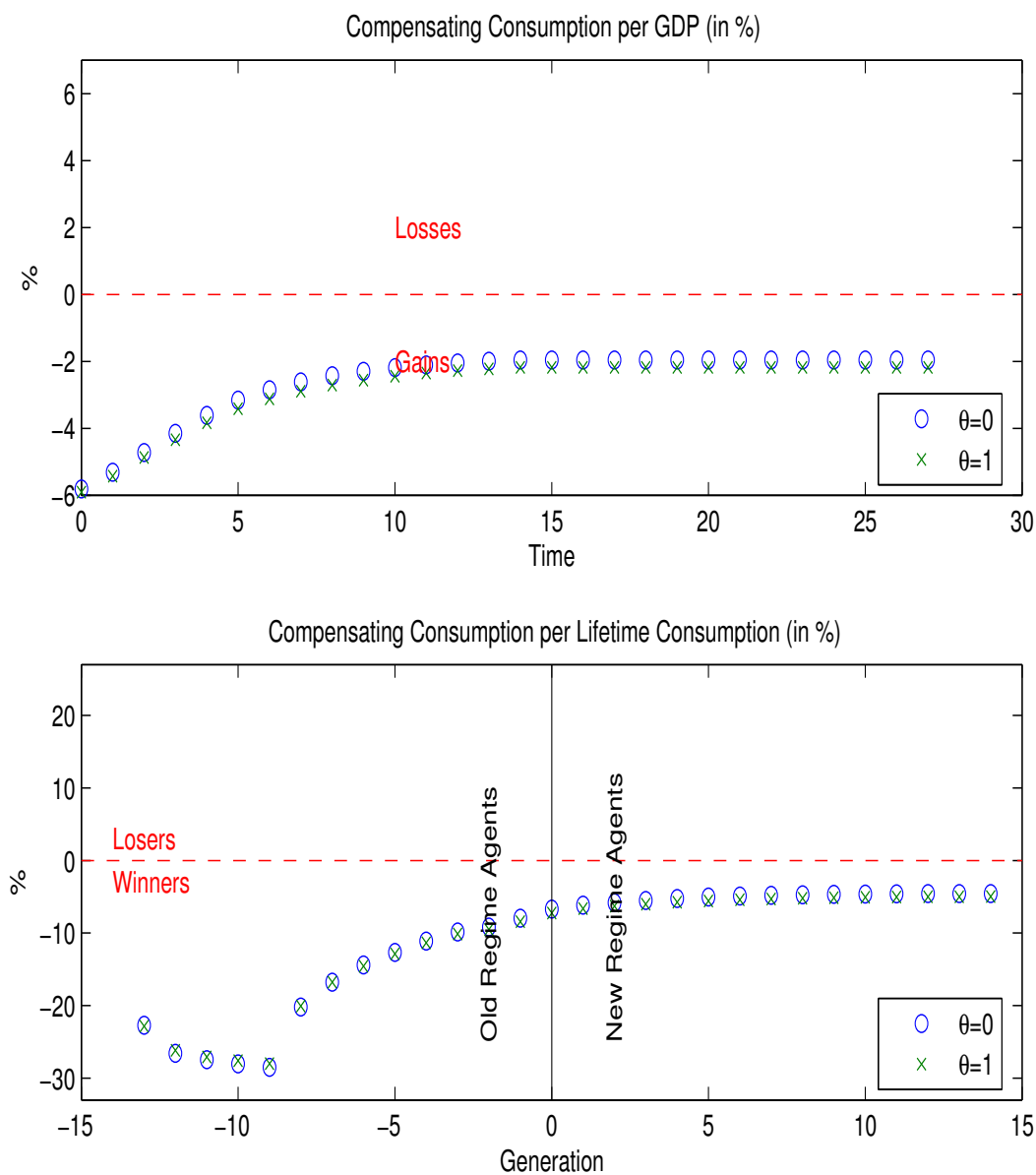
Figure 4: Regime 1 (payroll tax): Welfare dynamics resulting from the introduction of universal health care vouchers and a payroll tax finances the vouchers.
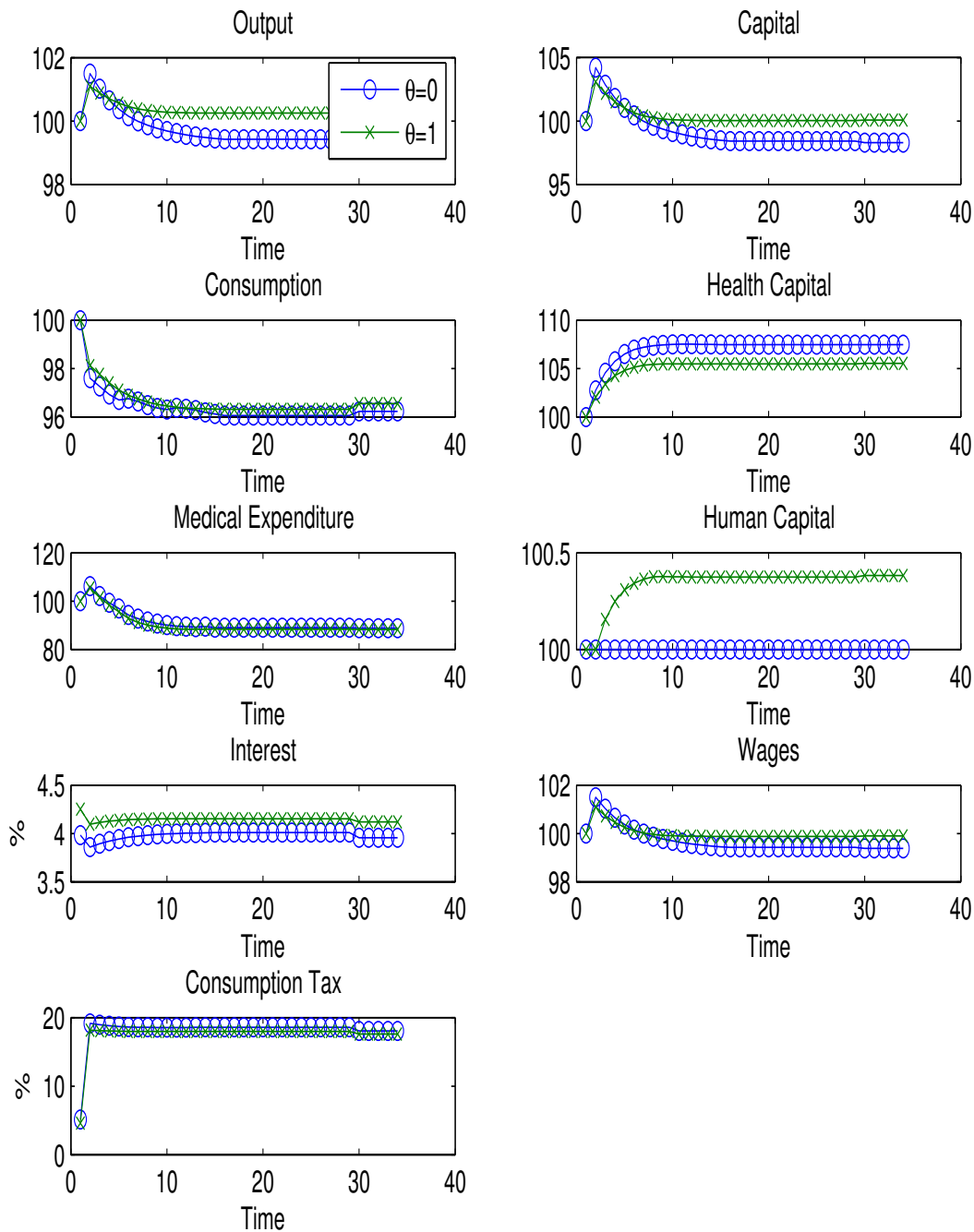
Figure 5: Regime 2 (consumption tax): Transition dynamics due to the introduction of universal health insurance vouchers into the current U.S. economy and a consumption tax finances the vouchers.
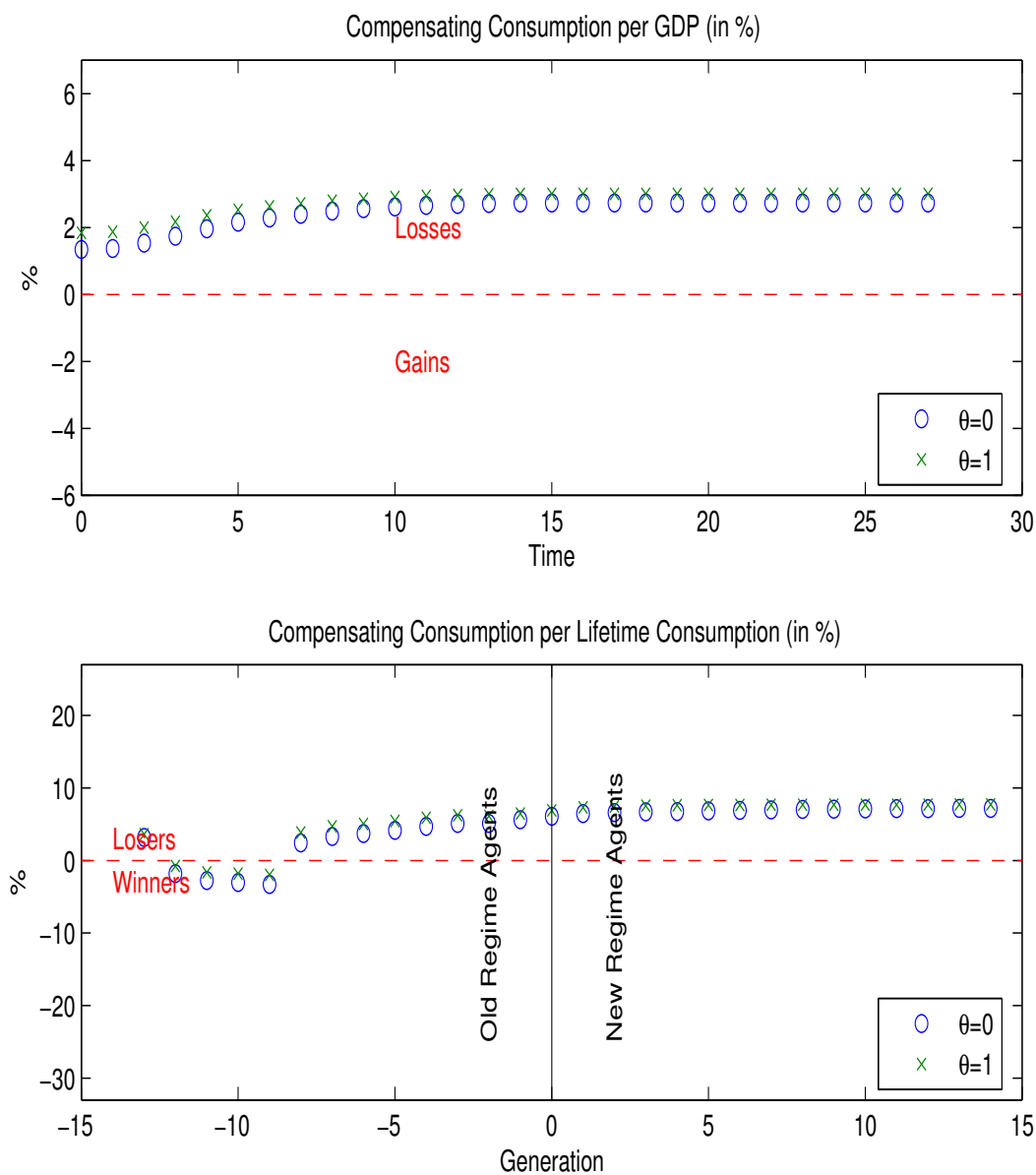
Figure 6: Regime 2 (consumption tax): Welfare dynamics resulting from the introduction of universal health care vouchers and $\theta = 0$ and a consumption tax finances the vouchers.
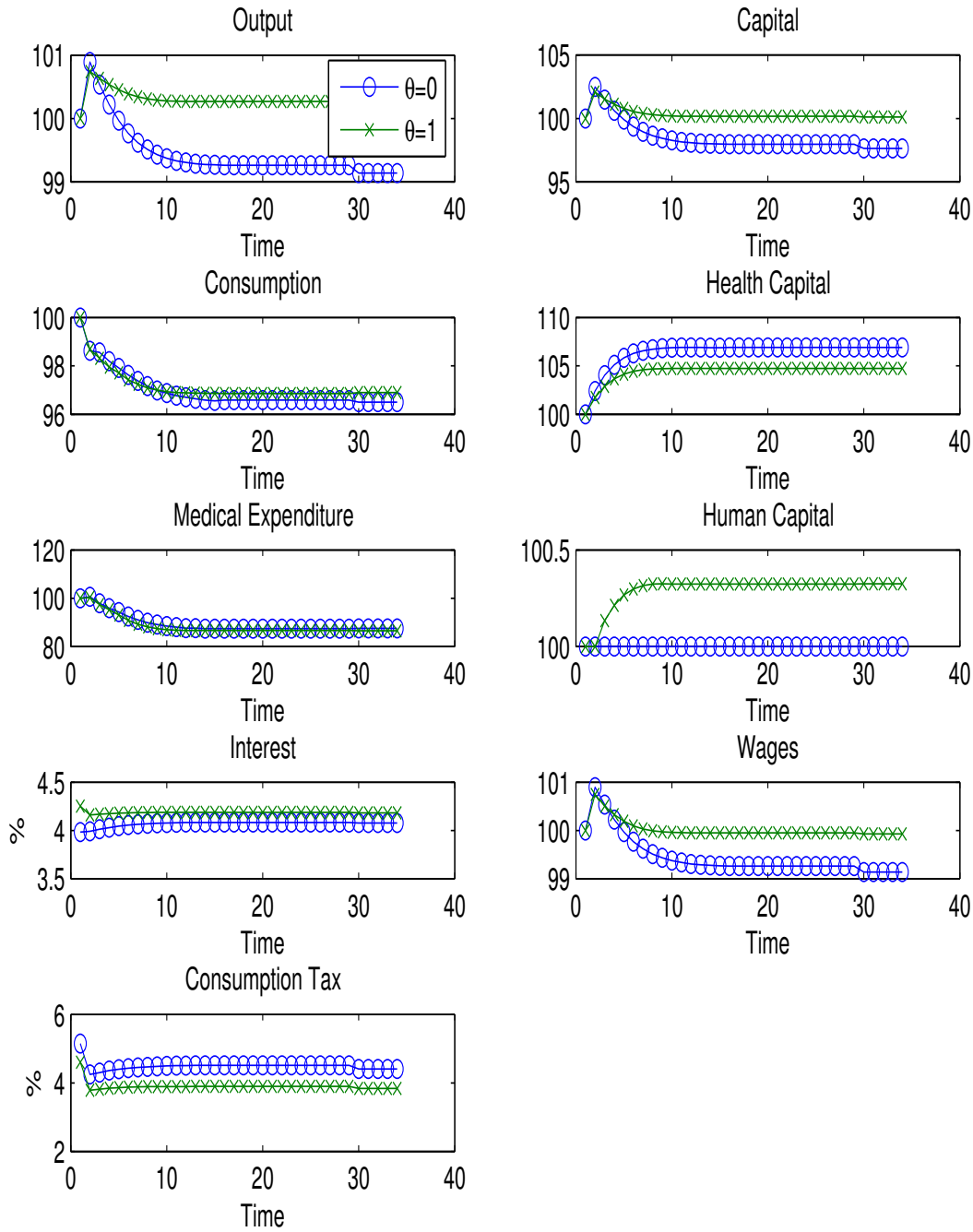
Figure 7: Regime 3 (lump-sum tax): Transition dynamics due to the introduction of universal health insurance vouchers into the current U.S. economy and a lump-sum tax finances the vouchers.

Compensating Consumption per GDP (in %)

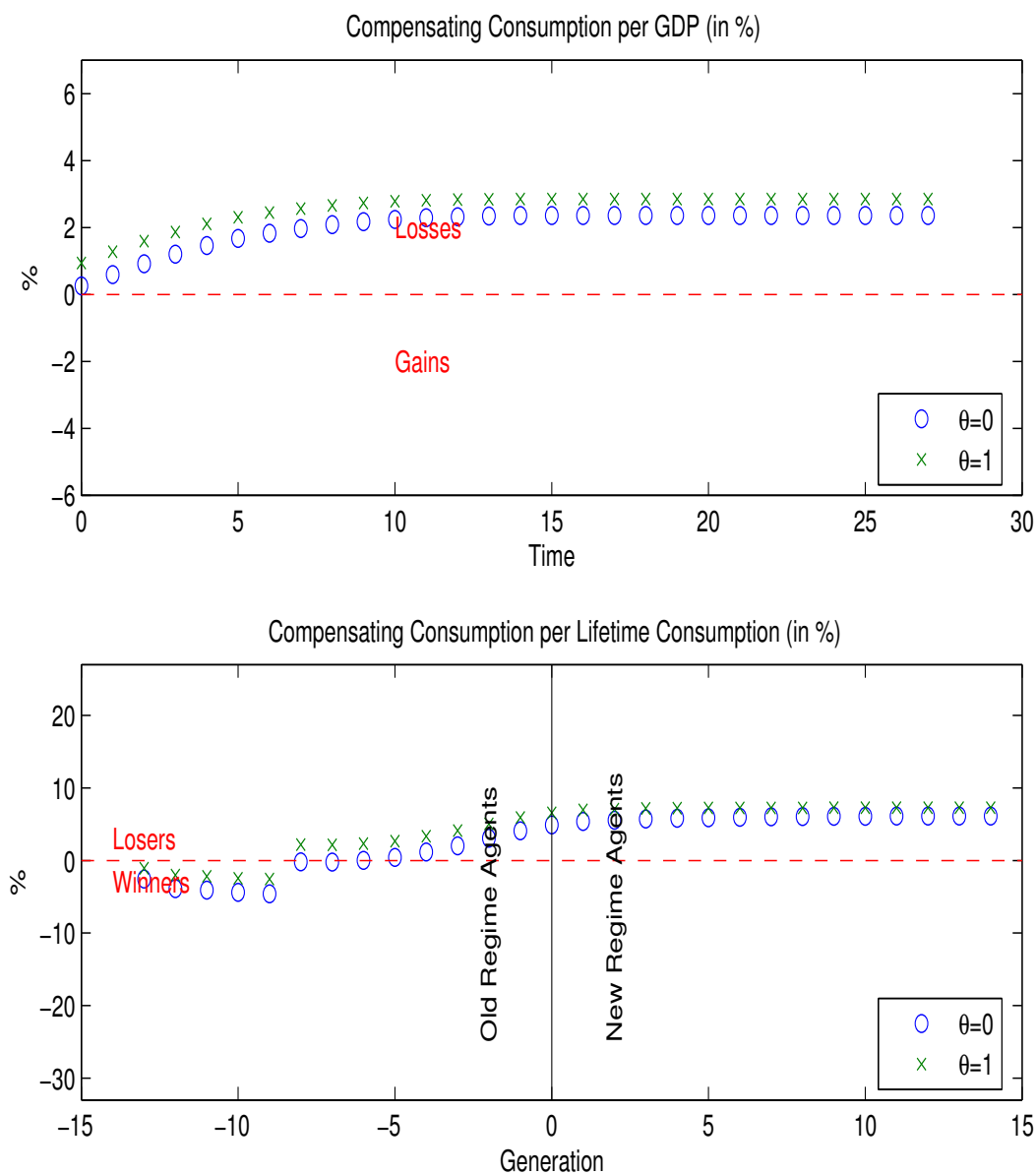## Compensating Consumption per Lifetime Consumption (in %)

Figure 8: Regime 3 (lump-sum tax): Welfare dynamics resulting from the introduction of universal health care vouchers and a lump-sum tax finances the vouchers.