



Market inefficiency, insurance mandate and welfare: U.S. health care reform 2010[☆]



Juergen Jung^{a,*}, Chung Tran^{b,1}

^a Towson University, USA

^b Australian National University, Australia

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ABSTRACT

We quantify the effects of the Affordable Care Act (ACA) using a stochastic general equilibrium overlapping generations model with endogenous health capital accumulation calibrated to match U.S. data on health spending and insurance take-up over the lifecycle. We find that the introduction of an insurance mandate and the expansion of Medicaid which are at the core of the ACA increase the insurance take-up rate of workers to almost universal coverage but decrease capital accumulation, labor supply and aggregate output. Penalties for not having insurance as well as subsidies to assist low income individuals' purchase of insurance via health insurance market places do reduce the adverse selection problem in private health insurance markets and do counteract the crowding-out effect of the Medicaid expansion. The redistributive measures embedded in the ACA result in welfare gains for low income individuals in poor health and welfare losses for high income individuals in good health. The overall welfare effect depends on the size of the ex-post moral hazard effect, tax distortions and general equilibrium price adjustments.

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1. Introduction

Most industrialized countries have introduced large public health insurance programs in order to achieve almost universal health insurance coverage of its citizens. In the U.S., on the other hand, government run health insurance programs are limited to cover the retired population (Medicare) and the poor (Medicaid). Most working individuals receive private health insurance via their employers and only a small percentage buys private health insurance individually. This mixed health

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* Corresponding author at: Department of Economics, Towson University, USA.

E-mail addresses: jjung@towson.edu (J. Jung), chung.tran@anu.edu.au (C. Tran).

¹ Research School of Economics, The Australian National University, Canberra, ACT 2601, Australia.

insurance system leaves over 45 million Americans uninsured. In addition, the U.S. health care system is the most expensive in the world with health care spending close to 17.6 percent of GDP in 2010 (Keehan et al., 2011). The combination of low insurance coverage and high medical cost exposes many Americans to considerable financial risk. Moreover, the increase in the cost of delivering health care threatens the solvency of Medicare and Medicaid and puts pressure on the overall government budget. The fiscal situation is made worse by a demographic shift that increases the fraction of the older population.

In reaction to these challenges, a number of comprehensive health care reforms have been implemented in recent years. Of particular importance is the *Affordable Care Act* (ACA) passed in March 2010 or “Obamacare” as it is often called. The ACA has the following key features: (i) an insurance mandate that requires individuals to buy health insurance or pay a fine; (ii) the introduction of insurance exchanges where individuals who are not covered by employer-based insurance programs can buy insurance at group-based premium rates with premium subsidies for those whose income is between 133 and 400 percent of the Federal Poverty Level (FPL); and (iii) the expansion of Medicaid to a new income eligibility threshold of 133 percent of the FPL. The objective of our paper is to provide a quantitative analysis of the ACA reform with a focus on insurance take-up, medical spending, macro aggregates and welfare.

We develop a stochastic dynamic general equilibrium model with endogenous health capital accumulation and insurance choice that combines essential features of two workhorse models from macroeconomics and health economics: an incomplete markets model with heterogeneous agents (Bewley, 1986) and a lifecycle model of health capital accumulation (Grossman, 1972a). Our lifecycle modeling approach is motivated by the lifecycle patterns of health spending and financing observed in U.S. medical expenditure data (Jung and Tran, 2014). Moreover, our model incorporates two important sources of risk that individuals experience over the lifecycle: idiosyncratic labor productivity shocks and health shocks. We also incorporate a wide range of institutional details of the U.S. health insurance system including public health insurance (Medicare and Medicaid), private employer provided group health insurance (GHI) and private, individually bought, health insurance (IHI). Most importantly, adverse selection and ex-post moral hazard effects are both present in our framework.²

After we calibrate the model to U.S. data from the Medical Expenditure Panel Survey (MEPS), the Centers for Medicare and Medicaid Services (CMS) and the Panel Study of Income Dynamics (PSID), it can closely replicate the lifecycle patterns of health expenditure, the distribution of health expenditure, the lifecycle profiles of insurance take-up rates and the income distribution. In addition, the model reproduces fundamental macroeconomic aggregates of the U.S. economy. We then use this framework to study key elements of the ACA.

The main goal of the ACA is to increase the fraction of individuals with health insurance coverage, especially among low income groups. The ACA adopts a mixed approach that combines a private health insurance expansion via penalties and subsidies with the expansion of Medicaid which is a public health insurance program for low income individuals. The former is designed to induce individuals with low health risk to join the insurance pools. The expansion of Medicaid makes health insurance accessible to more low income individuals. In order to understand the mechanics behind the ACA, we first analyze each policy component separately. We start from a pre-ACA benchmark equilibrium and then introduce a single policy component at a time. We first study the insurance mandate enforced by penalties only, we then study insurance exchanges in combination with premium subsidies and we finally analyze the effects of a Medicaid expansion.

We find that the mandate and the subsidies both extend private health insurance take-up. The increase in insurance take-up rates depends on the size of imposed penalties and subsidies. Penalties are very effective in eliminating the adverse selection problem in private health insurance markets. Penalties of 5 percent of individual income or higher can achieve almost universal coverage. On the other hand, the insurance exchange with subsidies is less effective. Even very generous subsidies cannot achieve take-up rates higher than 88 percent. The reason is that the subsidies are limited to a relatively small group of low income individuals that are currently not on group health insurance and have income between 133 and 400 percent of the federal poverty level. Interestingly, we observe that the two policies result in opposing aggregate and welfare effects. Penalties result in output increases while causing welfare losses in all experiments. The increases in output are driven by higher capital accumulation as individuals reduce their consumption levels in order to maintain their health insurance status. Conversely, the insurance exchange with premium subsidies is less successful in extending insurance coverage but results in an overall positive welfare outcome. The positive welfare effects stem from income redistribution via premium subsidies financed by taxes on high income earners.

The Medicaid expansion triggers only a relatively modest expansion of insurance take-up and crowds out private health insurances, especially in the GHI market. Even if the Medicaid eligibility threshold is increased to 300 percent of the FPL, the insurance coverage can only be extended to at most 87 percent of working population. Simultaneously, the fiscal distortion created by the Medicaid expansion causes significant output losses. The larger the expansion of Medicaid, the larger these losses become. An expansion to 300 percent of the FPL causes a decrease in GDP of around 5 percent. The overall welfare outcome is non-linear, depending on the size of the Medicaid program. A small expansion of Medicaid improves welfare while relatively large expansions cause welfare losses. There are trade-offs between the positive welfare effects created by improvements in risk sharing and income distribution and the negative welfare effects associated with output losses.

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

Finally, we combine all three policies and quantify the overall effect of the ACA reform. The reform increases the fraction of insured workers to about 99.6 percent. This expansion is driven by expansions of the IHI market and Medicaid. We only detect small expansions in the GHI market. These results indicate that the reform effectively reduces the adverse selection effects that are partly responsible for the large number of uninsured individuals in the pre-ACA scenario. In order to finance the reform the government has to introduce a 1.24 percent payroll tax on high income earners above \$200,000. The ACA reform triggers a decrease in labor supply and capital accumulation due to tax distortions and subsequent decreases in steady state output of up to 1.2 percent. Moreover, we find that the welfare effects vary significantly across agent types. High income workers with good health experience welfare losses while low income workers in bad health experience welfare gains. Overall, the welfare losses caused by the fiscal distortions dominate the welfare gains resulting from improvements in risk sharing and redistribution and lead to losses of 1.7 percent of life-time consumption in the new steady state after the ACA reform.

The final welfare outcome is driven by the ex-post moral-hazard effect and subsequent tax distortions. If the ex-post moral hazard effect is large then individuals who gain access to health insurance will demand a large amount of additional medical care which will increase the financing needs of the ACA and result in large distortionary taxes. If the tax distortion is large enough, overall welfare will decrease. If, on the other hand, the ex-post moral hazard effect is small and individuals do not demand large additional amounts of medical care after the ACA is introduced, then the financing needs of the ACA remain small and tax will be low enough so that the ACA generates an overall positive welfare effect. Positive welfare outcomes are also realized when factor prices are kept fixed (i.e., a partial equilibrium outcome) or when the reform is financed by decreases in unproductive government consumption. These opposite welfare outcomes highlight the importance of accounting for the ex-post moral-hazard effects and general equilibrium price adjustments when conducting a comprehensive long-run assessment of a health care reform of such scale and complexity.

Related literature. Our paper is connected to the lifecycle consumption literature. Standard models of consumption and savings neglect medical consumption over the lifecycle (e.g., see [Carroll and Summers, 1991](#); [Deaton, 1992](#); [Hubbard et al., 1995](#); [Gourinchas and Parker, 2002](#), and [Fernandez-Villaverde and Krueger, 2007](#)). It is documented that health expenditures are an increasing function of age, and individuals are not able to smooth their medical consumption over the lifecycle easily (e.g., [Deaton and Paxson, 1998a, 1998b](#) and [Jung and Tran, 2014](#)). More recent lifecycle models include medical and non-medical consumption (e.g., [Hall and Jones, 2007](#); [Fonseca et al., 2013](#); [De Nardi et al., 2010](#); [Scholz and Seshadri, 2013](#); [Kopecky and Koreschkova, 2014](#) and [Braun et al., 2015](#)). In these studies health either directly affects utility or longevity but they abstract from the financing mechanism of health care. We advance this literature and include more realistic sources of health care financing over the lifecycle (Medicare, Medicaid, individual and group health insurance).

Our paper is also related to an emerging macro-health policy evaluation literature. [Jeske and Kitao \(2009\)](#) is one of the first efforts to conduct health policy reform using a large scale lifecycle model with a rich set of institutional details of the U.S. health care system. [Kashiwase \(2009\)](#) examines a number of fiscal policies that achieve universal insurance coverage and finance the growing cost of health care. Finally, [Brugemann and Manovskii \(2010\)](#) and [Pashchenko and Porapakkarm \(2013\)](#) evaluate the macroeconomic and welfare effects of the ACA. These models assume exogenous health expenditure shocks which do not account for health expenditure adjustments triggered by changes in the health insurance system and behavioral responses (ex-post moral hazard effects).³

Our paper contributes to bridging the gap between health economics and the macroeconomic public finance literature. First, we endogenize the demand for medical services and the demand for health insurance over the lifecycle in a macro-health model. Second, we explicitly model the production of health care services which endogenizes the supply side and thereby the determination of prices in the medical care sector. Thus, our approach incorporates ex-post moral hazard and adverse selection effects that both affect health spending and health insurance take-up rates over the lifecycle and has important implications for the welfare analysis.

The paper is structured as follows. In the next section we discuss the U.S. Health Care System and elements of the ACA. Section 3 presents the model. In section 4 we present the calibration of the model. Section 5 contains the simulation results. Section 6 concludes. The Appendix contains a detailed description of the implementation of the ACA in the model as well as all tables and figures.

2. The U.S. health care system

2.1. Some stylized facts of the U.S. health care system

The U.S. health insurance system is a mixed system where public health insurance programs are limited to the retired population (Medicare) and the poor (Medicaid) while the majority of working individuals obtain private health insurance via their employers. According to data from the Medical Expenditure Panel Survey (MEPS)⁴ individual health expenditures

³ There is a newly evolving health-macro literature that develops more realistic lifecycle (general equilibrium) models of the U.S. economy (e.g., [Suen, 2006](#); [Jung and Tran, 2009](#); [Feng, 2009](#), and [Halliday et al., 2010](#)).

⁴ The Online Appendix contains more details about MEPS data and the lifecycle profiles of health spending and financing.

increase significantly over the lifecycle. On average, individuals in their twenties spend about \$1500 per year on health care whereas older individuals in their fifties spend about \$4000 per year. Past fifty, individual health expenditures tend to rise very fast. The highest expenditures are incurred by the very old towards the end of their life and amount to approximately \$12,000 on average per year in 2009.

Private insurance reimbursements and out-of-pocket payments are the two major funding sources for medical spending. The fraction of health expenditure financed by private insurance and Medicaid decreases as an individual ages, whereas the fraction of health expenditures financed by out-of-pocket funds increases moderately. Around the retirement age of 65 there is a big shift in the magnitude of financing from private insurance toward public insurance including Medicare, Veteran's benefits, and other State run insurance plans. Despite the many different types of insurances, the U.S. health insurance system fails to provide insurance for about 50 million people. The employer-based group health insurance policies (GHI) cover only around 60 percent of the working-age population while individual-based health insurance policies (IHI) cover less than 6 percent. A large number of healthy and young individuals do not purchase health insurance, either by choice or by circumstance. The fraction of the uninsured is highest among young workers below 35. Medicaid picks up less than 10 percent of workers by covering low income individuals. Consequently, the system leaves about 25 percent of the working population without health insurance which contributes to high insurance premiums and poor risk pooling.

Over the last two decades, medical expenditures have increased substantially while the share of private insurance take-up has declined. As projected by the CBO, health care spending has become the second largest government spending program (CBO, 2012). The fiscal situation is getting worse due to population aging so that Medicare and Medicaid will soon become the largest government spending program. This threatens the solvency of public health insurance programs and puts pressure on the overall government budget.

2.2. Key features of the ACA

The Affordable Care Act (hereafter, ACA), signed by President Obama in March 2010, represents the most significant reform of the U.S. health care system since the introduction of Medicare in 1965. The many provisions of the ACA will be phased in over several years. Some of the most significant changes will take effect in 2014. The key policy instruments embedded in the ACA are: (i) the insurance mandate enforced by penalties, (ii) the introduction of insurance exchanges with premium subsidies and (iii) the Medicaid expansion.

Insurance mandate with penalties. Starting in 2014 it is compulsory for workers to have health insurance. Workers who do not have health insurance face a tax penalty of up to 2.5 percent of their income. The implementation will be phased in over several years. The penalty is 1 percent of income or \$95 in 2014 and rises to 2 percent or \$325, whichever is higher, in 2015. These penalties are scheduled to be implemented fully by 2016. Cost-of-living adjustments will be made annually after 2016. If the least expensive policy available would cost more than 8 percent of one's monthly income, no penalties apply and hardship exemptions will be permitted for those who cannot afford the cost. Moreover, employers with more than 50 full-time employees will be required to provide health insurance. Employers who do not offer health insurance face a fine of \$2000 per worker each year minus some allowances.

Insurance exchanges with premium subsidies. By 2014 state or federally run health insurance exchanges will be established in which all individuals who are either unemployed, self-employed and not currently covered by employer-sponsored health insurance can purchase insurance at subsidized premium rates. Premiums for individuals who purchase their insurance from the insurance exchanges will be based on the average health expenditure risks of those in the exchange pool. The reform also puts new restrictions on the price setting and screening procedures for health insurances traded on these markets (e.g., age discrimination is limited up to a factor of three). More importantly, workers who are not offered insurance from their employers and whose income is between 133 and 400 percent of the FPL are eligible to buy health insurance through insurance exchanges at subsidized rates.⁵

The fact that the subsidies are tied to income is important for two reasons. First, as stressed by Mulligan (2015), tying the subsidies to income generates an implicit tax on income – the standard result for needs-based transfers. Second, subsidized individuals will pay at most a fixed fraction of their income toward premiums, regardless of the premiums themselves. Premiums can double and subsidized individuals will pay no more. This limits the potential for an actuarial death spiral. Similar arguments do not apply to potential increases in copayments.⁶

Medicaid expansion. The ACA expands the Medicaid eligibility threshold uniformly to 133 percent of the FPL and removes the asset test. The asset test is an asset ceiling that an individual's asset holdings cannot exceed in order to be Medicaid eligible. However, only about half the states participate in this expansion.

Financing. The reform is financed by increases in Medicare payroll taxes from 1.45 percent to 2.35 percent for individuals with incomes higher than \$200,000 per year (or \$250,000 for families). Various other sources are used to generate additional revenue in order to pay for the reform. Among those are a 3.8 percent tax on unearned income for individuals with incomes higher than \$200,000, a 40 percent excise tax on a portion of high-end insurance policies ("Cadillac plans"), fees collected from the insurance and pharmaceutical industry, funds from social security, Medicare and student loans, in-

⁵ The detailed schedule of the subsidy rates by income level are reported in Appendix A.

⁶ We would like to thank an anonymous referee for pointing out this effect.

creased penalties on non-medical withdrawals from Health Savings Accounts, lower contribution limits to tax free Flexible Spending Accounts, a tanning tax of 10 percent, a new excise tax of 2.3 percent on medical equipment, and others.

3. The model

3.1. Demographics

The economy is populated with overlapping generations of individuals who live to a maximum of J periods. Individuals work for J_1 periods and then retire for $J - J_1$ periods. In each period individuals of age j face an exogenous survival probability π_j . Deceased agents leave an accidental bequest that is taxed and redistributed equally to all working-age agents alive. The population grows exogenously at an annual 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 $\mu_j = \frac{\pi_j}{(1+n)^{\text{years}}} \mu_{j-1}$ and $\tilde{\mu}_j = \frac{1-\pi_j}{(1+n)^{\text{years}}} \mu_{j-1}$, where *years* denotes the number of years per model period.

3.2. Endowments and preferences

In each period individuals are endowed with one unit of time that can be used for work l or leisure. Individual utility is denoted by function $u(c, l, h)$ where $u: \mathbb{R}_{++}^3 \rightarrow \mathbb{R}$ is C^2 , increases in consumption c and health h , and decreases in labor l .⁷ Individuals are born with a specific skill type ϑ that cannot be changed over their lifecycle and that together with their health state h_j and an idiosyncratic labor productivity shock ϵ_j^l determines their age-specific labor efficiency unit $e(\vartheta, h_j, \epsilon_j^l)$. The transition probabilities for the idiosyncratic productivity shock ϵ_j^l follow an age-dependent Markov process with transition probability matrix Π^l . Let an element of this transition matrix be defined as the conditional probability $\Pr(\epsilon_{j+1}^l | \epsilon_j^l)$, where the probability of next period's labor productivity ϵ_{j+1}^l depends on today's productivity shock ϵ_j^l .⁸

3.3. Health capital, insurance and medical expenditures

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

$$h_j = i(m_j, h_{j-1}, \delta_j^h, \epsilon_j^h), \quad (1)$$

where h_j denotes the current health capital, h_{j-1} denotes last period's health capital, and m_j is the amount of medical services bought in period j . The exogenous health shock ϵ_j^h follows a Markov process with age dependent transition probability matrix Π_j^h . Transition probabilities to next period's health shock ϵ_{j+1}^h depend on the current health shock ϵ_j^h so that an element of transition matrix Π_j^h is defined as the conditional probability $\Pr(\epsilon_{j+1}^h | \epsilon_j^h)$.

Health insurance. The health insurance systems consists of private health insurance companies and public health insurance programs. Insurance companies offer two types of health insurance policies: an individual health insurance plan (IHI) and a group health insurance plan (GHI). Agents are required to buy insurance one period prior to the realization of their health shock. The insurance policy will become active in the following period. The insurance policy needs to be renewed each period.⁹ IHI can be bought by any agent for an age and health dependent premium, $\text{prem}^{\text{IHI}}(j, h)$. GHI can only be bought by workers who are randomly matched with an employer that offers GHI which is indicated by random variable $\epsilon^{\text{GHI}} = 1$. The insurance premium, prem^{GHI} , is tax deductible and insurance companies are not allowed to screen workers by health or age. If a worker is not offered group insurance from the employer, i.e. $\epsilon^{\text{GHI}} = 0$, the worker can still buy IHI. In this case the insurance premium is not tax deductible and the insurance company screens the worker by age and health status. There is a Markov process that governs the group insurance offer probability. The Markov process is a function of the permanent skill type ϑ of an agent. Let $\Pr(\epsilon_{j+1}^{\text{GHI}} | \epsilon_j^{\text{GHI}}, \vartheta)$ be the conditional probability that an agent has group insurance status $\epsilon_{j+1}^{\text{GHI}}$ at age $j+1$ given she had group insurance status ϵ_j^{GHI} at age j . The 2×2 transition probability matrix $\Pi_{j,\vartheta}^{\text{GHI}}$ collects all conditional probabilities for group insurance status.

⁷ Our specification implicitly assumes a linear relationship between health capital and service flows derived from health capital which is similar to the assumption in the original Grossman model, see Grossman (1972a).

⁸ We abstract from the link between health and survival probabilities. We are aware that this presents a limitation and that certain mortality effects cannot be captured (see Ehrlich and Chuma, 1990 and Hall and Jones, 2007). However, given the complexity of the current model we opted to simplify this dimension to keep the computational structure more tractable.

⁹ By construction, agents in their first period are thus not covered by any insurance.

There are two public health insurance programs available, Medicaid for the poor and Medicare for retirees. To be eligible for Medicaid, individuals are required to pass an income and asset test. The health insurance state in_j can therefore take on the following values at age $j < J_1$:

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

After retirement ($j > J_1$) all agents are covered by a public health insurance program which is a combination of Medicare and Medicaid for which they pay a premium, $prem^R$.

Health expenditure. An agent's total health expenditure in any given period is $p_m^{in_j} \times m_j$, where the price of medical services $p_m^{in_j}$ depends on insurance state in_j .¹⁰ The out of pocket health expenditure of a working-age agent is given by

$$o(m_j) = \begin{cases} p_m^{in_j} \times m_j, & \text{if } in_j = 0, \\ \gamma^{in_j} \times (p_m^{in_j} \times m_j), & \text{if } in_j > 0 \end{cases} \quad (2)$$

where $0 \leq \gamma^{in_j} \leq 1$ are the insurance state specific coinsurance rates. The coinsurance rate denotes the fraction of the medical bill that the patient has to pay out-of-pocket.¹¹ A retired agent's out-of-pocket expenditure is $o(m_j) = \gamma^R \times (p_m^R \times m_j)$, where γ^R is the coinsurance rate of Medicare and p_m^R is the price that a retiree pays for medical services.

3.4. Technology

The economy consists of two separate production sectors and grows at the exogenous growth rate g . Sector one is populated by a continuum of identical firms that use physical capital K and effective labor services L to produce non-medical consumption goods c with a normalized price of one. Firms in the non-medical sector are perfectly competitive and solve the following maximization problem

$$\max_{\{K, L\}} \{F(K, L) - qK - wL\}, \quad (3)$$

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

Sector two, the medical sector, is also populated by a continuum of identical firms that use capital K_m and labor L_m to produce medical services m at a price of p_m . Firms in the medical sector maximize

$$\max_{\{K_m, L_m\}} \{p_m F_m(K_m, L_m) - qK_m - wL_m\}. \quad (4)$$

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

3.5. Household problem

Workers. Agents with age $j \leq J_1$ are workers and thus exposed to labor earnings and health shocks. The agent's state vector at age j is given by $x_j = (a_j, h_{j-1}, \vartheta, \epsilon_j^l, \epsilon_j^h, \epsilon_j^{GHI}, in_j)$, where a_j is the capital stock at the beginning of the period, h_{j-1} is the health state at the beginning of the period, ϑ is the skill type, ϵ_j^l is the positive labor productivity shock, ϵ_j^h is a negative health shock, ϵ_j^{GHI} indicates whether group insurance from the employer is available for purchase in this period, and in_j is the insurance state at the beginning of the period. Note that, $x_j \in D_W \equiv R_+ \times R_+ \times \{1, 2, 3, 4\} \times R_+ \times R_- \times \{0, 1\} \times \{0, 1, 2, 3\}$.

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

¹⁰ Note that we only model discretionary health expenditures so that income will have a strong effect on medical expenses. Our setup assumes that given the same magnitude of health shocks ϵ_j^h , 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. is non-discretionary (e.g., health expenditures caused by catastrophic health events that require surgery). In such cases a poor individual could still incur large health care costs. However, it is not unreasonable to assume that a rich person will outspend a poor person even under these circumstances.

¹¹ For simplicity we include deductibles and co-pays into the coinsurance rate.

$$V(x_j) = \max_{\{c_j, l_j, m_j, a_{j+1}, in_{j+1}\}} \left\{ u(c_j, h_j, l_j) + \beta \pi_j E \left[V(x_{j+1}) \mid \epsilon_j^l, \epsilon_j^h, \epsilon_j^{GHI} \right] \right\} \quad \text{s.t.} \\ (1 + \tau^C) c_j + (1 + g) a_{j+1} + o(m_j) + 1_{\{in_{j+1}=1\}} \text{prem}^{IH}(j, h) + 1_{\{in_{j+1}=2\}} \text{prem}^{GHI} = y_j + t_j^{SI} - \text{tax}_j, \quad (5)$$

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

$$y_j = e(\vartheta, h_j, \epsilon_j^l) \times l_j \times w + R \times (a_j + t_j^{\text{Beq}}) + \text{profits}^M + \text{profits}^{\text{Ins}}, \\ \text{tax}_j = \tilde{\tau}(\tilde{y}_j) + \text{tax}_j^{\text{SS}} + \text{tax}_j^{\text{Med}}, \\ \tilde{y}_j = y_j - a_j - t_j^{\text{Beq}} - 1_{\{in_{j+1}=2\}} \text{prem}^{GHI} - 0.5(\text{tax}_j^{\text{SS}} + \text{tax}_j^{\text{Med}}), \\ \text{tax}_j^{\text{SS}} = \tau^{\text{SS}} \times \min(\tilde{y}_{ss}, e(\vartheta, h_j, \epsilon_j^l) \times l_j \times w - 1_{\{in_{j+1}=2\}} \text{prem}^{GHI}), \\ \text{tax}_j^{\text{Med}} = \tau^{\text{Med}} \times (e(\vartheta, h_j, \epsilon_j^l) \times l_j \times w - 1_{\{in_{j+1}=2\}} \text{prem}^{GHI}), \\ t_j^{SI} = \max[0, \underline{c} + o(m_j) + \text{tax}_j - y_j]. \quad (6)$$

Variable τ^C is the consumption tax rate, $o(m_j)$ is out-of-pocket medical spending, y_j is the sum of all income including labor, assets, bequests, and profits from medical providers (profits^M) and insurance companies ($\text{profits}^{\text{Ins}}$). Variable w is the market wage rate, R is the gross interest rate, t_j^{Beq} denotes accidental bequests, tax_j is total taxes paid,¹² and t_j^{SI} is social insurance (e.g., food stamp programs). Taxable income is denoted \tilde{y}_j which is composed of wage income and interest income on assets, interest earned on accidental bequests, and profits from insurance companies and medical services providers minus the employee share of payroll taxes and the premium for health insurance. The payroll taxes are tax_j^{SS} for social security and $\text{tax}_j^{\text{Med}}$ for Medicare. The payroll tax for social security is raised on income below \tilde{y}_{ss} (i.e., \$106,800 in 2010). The payroll tax for Medicare is not capped.

Agents can only buy private individual or private group health insurance if they have sufficient funds. Agents become eligible for Medicaid if their income falls below the Medicaid eligibility threshold, $\tilde{y}_j \leq FPL_{\text{Maid}}$, and if their asset holdings pass the asset test, $a_j \leq a_{\text{Maid}}$. In this case the insurance choice indicator switches to $in_{j+1} = 3$ and agents do not pay any more premiums for the next period. In their last working period workers will not buy private insurance anymore because they become eligible for Medicare when retired. 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 insurance state $in_j = 3$ (Medicaid), so that social insurance cannot be used to finance savings and private health insurance.

Retirees. Old agents, $j > J_1$ are retired, receive pension payments, and therefore do not face labor earnings shocks anymore. The only remaining idiosyncratic shock for retirees is the health shock ϵ_j^h . Retirees are eligible for Medicare and do not buy any more private health insurance. The vector of choice variables is $\{c_j, m_j, a_{j+1}\}$; and the state vector of a retired agent also reduces to $x_j = (a_j, h_{j-1}, \epsilon_j^h) \in D_R \equiv R_+ \times R_+ \times R_-$. The household problem can be formulated recursively as

$$V(x_j) = \max_{\{c_j, m_j, a_{j+1}\}} \left\{ u(c_j, h_j) + \beta \pi_j E \left[V(x_{j+1}) \mid \epsilon_j^h \right] \right\} \quad \text{s.t.} \quad (7) \\ (1 + \tau^C) c_j + (1 + g) a_{j+1} + o(m_j) + \text{prem}^R = y_j + t_j^{SI} - \text{tax}_j, \\ a_{j+1} \geq 0,$$

where

$$y_j = t_j^{\text{SS}} + R \times (a_j + t_j^{\text{Beq}}) + \text{profits}^M + \text{profits}^{\text{Ins}}, \\ \text{tax}_j = \tilde{\tau}(\tilde{y}_j^R),$$

¹² 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

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

where ψ is the fraction of the premium paid for by the employer. [Jeske and Kitao \(2009\)](#) use a similar formulation to model private vs. employer provided health insurance. We simplify this aspect of the model and assume that all group health insurance policies are offered via the employer but that the employee pays the entire premium, so that $\psi = 0$. The premium is therefore tax deductible in the employee (or household) budget constraint. We also allow for income tax deductibility of insurance premiums due to IRC provision 125 (Cafeteria Plans) that allows employers to set up tax free accounts for their employees in order to pay for qualified health expenses but also the employee share of health insurance premiums. This assumption of wage pass-through has some empirical support (e.g., [Gruber, 1994](#) and [Bhattacharya and Bendorf, 2009](#)).

$$\begin{aligned}\tilde{y}_j^R &= y_j - a_j - t_j^{\text{Beq}}, \\ t_j^{\text{SI}} &= \max[0, \underline{c} + o(m_j) + \text{tax}_j - y_j].\end{aligned}$$

Variable t_j^{SS} denotes pension payments and prem^R is the insurance premium for Medicare Part B. For each $x_j \in D_j$ let $\Lambda(x_j)$ denote the distribution of age j agents with $x_j \in D_j$. Then expression $\mu_j \Lambda(x_j)$ becomes the population measure of age- j agents with state vector $x_j \in D_j$ that is used for aggregation.

3.6. Insurance sector

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

$$\begin{aligned}& (1 + \omega_{j,h}^{\text{IHI}}) \mu_j \int [1_{[in_j(x_{j,h})=1]} (1 - \gamma_j^{\text{IHI}}) p_m^{\text{IHI}} m_{j,h}(x_{j,h})] d\Lambda(x_{j,-h}) \\ &= R \mu_{j-1} \int (1_{[in_{j,h}(x_{j-1,h})=1]} \text{prem}^{\text{IHI}}(j-1, h)) d\Lambda(x_{j-1,-h}), \quad \text{for } j = \{2, \dots, J_1\}\end{aligned}\quad (8)$$

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

$$\begin{aligned}& (1 + \omega^{\text{GHI}}) \sum_{j=2}^{J_1} \mu_j \int [1_{[in_j(x_j)=2]} (1 - \gamma_j^{\text{GHI}}) p_m^{\text{GHI}} m_j(x_j)] d\Lambda(x_j) \\ &= R \sum_{j=1}^{J_1-1} \mu_j \int (1_{[in_{j+1}(x_j)=2]} \text{prem}^{\text{GHI}}) d\Lambda(x_j),\end{aligned}\quad (9)$$

where $\omega_{j,h}^{\text{IHI}}$ and ω^{GHI} are markup factors that determine loading costs (fixed costs or profits), $1_{[in_j(x_j)=1]}$ is an indicator function equal to unity whenever agents buy the individual health insurance policy, $1_{[in_j(x_j)=2]}$ is an indicator function equal to unity whenever agents buy the group insurance policy, γ^{IHI} and γ^{GHI} are the coinsurance rates, and p_m^{IHI} and p_m^{GHI} are the prices for health care services of the two insurance types. The respective left-hand-sides in the above expressions summarize aggregate payments made by insurance companies, whereas the right-hand-sides aggregate the premium collections one period prior. Since premiums are invested for one period, they enter the capital stock and we therefore multiply the term with the after tax gross interest rate R .

The premium markups generate profits, denoted $\text{Profit}^{\text{Ins}}$, that are redistributed in equal amounts to all surviving agents. The difference between the two insurance contracts is that GHI can only charge one price, prem^{GHI} , and that GHI premiums are tax deductible in the household budget constraint.

Notice that ex-post moral hazard and adverse selection issues arise naturally in the model due to information asymmetry. Insurance companies cannot directly observe the idiosyncratic health shocks and have to reimburse agents based on the actual observed levels of health care spending. Adverse selection arises because insurance companies cannot observe the risk type of agents and therefore cannot price insurance premiums accordingly. They instead have to charge an average premium that clears the insurance companies' profit condition.¹³

3.7. Government

The government taxes consumption at rate τ^C and income (i.e. wages, interest income, interest on bequests, and profits for insurance companies and medical providers) 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), Medicare and Medicaid, as well as exogenous government consumption G . Government spending G is unproductive.

Since in the model health insurance for the old is a combination of Medicare and Medicaid, we make it part of the general budget constraint. The government uses a Medicare payroll tax on workers as well as Medicare plan B premiums to cover some of the cost of Medicare and Medicaid for retirees. The government budget is balanced in each period so that

¹³ Individual insurance contracts do distinguish agents by age and health status but not by their health shock.

$$\begin{aligned}
& G + \sum_{j=1}^J \mu_j \int t_j^{\text{Sl}}(x_j) d\Lambda(x_j) + \sum_{j=2}^{J_1} \mu_j \int (1 - \gamma^{\text{MAid}}) p_m^{\text{MAid}} m_j(x_j) d\Lambda(x_j) \\
& + \sum_{j=J_1+1}^J \mu_j \int (1 - \gamma^{\text{R}}) p_m^{\text{R}} m_j(x_j) d\Lambda(x_j) \\
& = \sum_{j=1}^J \mu_j \int (\tau^{\text{C}} c(x_j) + \tilde{\tau}(\tilde{y}_j(x_j)) + \text{tax}_j^{\text{Med}}(x_j)) d\Lambda(x_j) + \sum_{j=J_1+1}^J \mu_j \int \text{prem}^{\text{R}}(x_j) d\Lambda(x_j) \\
& + \sum_{j=1}^{J_1} \mu_j \int \tau^{\text{Med}}(e_j(x_j) \times l_j(x_j) \times w - 1_{[\text{in}_{j+1}(x_j)=2]}) \text{prem}^{\text{GHI}}(x_j)) d\Lambda(x_j), \tag{10}
\end{aligned}$$

where γ^{MAid} is the coinsurance rate of Medicaid, p_m^{MAid} is the price of medical services for individuals on Medicaid, γ^{R} is the coinsurance rate for retired individuals on Medicare/Medicaid and p_m^{R} is the price for medical services for retirees. Indicator function $1_{[\text{in}_{j+1}(x_j)=2]}$ equals unity whenever the agent type x_j purchases GHI via their employer. In this case the insurance premium is tax deductible. In addition, the government runs a PAYG Social Security program which is self-financed via a payroll tax so that

$$\sum_{j=J_1+1}^J \mu_j \int t_j^{\text{SS}}(x_j) d\Lambda(x_j) = \sum_{j=1}^{J_1} \mu_j \int \text{tax}_j^{\text{SS}}(x_j) d\Lambda(x_j). \tag{11}$$

Accidental bequests are redistributed in a lump-sum fashion to working-age households

$$\sum_{j=1}^{J_1} \mu_j \int t_j^{\text{Beq}}(x_j) d\Lambda(x_j) = \sum_{j=1}^J \tilde{\mu}_j \int a_j(x_j) d\Lambda(x_j), \tag{12}$$

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

3.8. Recursive equilibrium

Given transition probability matrices $\{\Pi_j^l, \Pi_{j,\vartheta}^{\text{GHI}}\}_{j=1}^{J_1}$ and $\{\Pi_j^h\}_{j=1}^J$, survival probabilities $\{\pi_j\}_{j=1}^J$ and exogenous government policies $\{\text{tax}(x_j), \tau^{\text{C}}, \text{prem}^{\text{R}}, \tau^{\text{SS}}, \tau^{\text{Med}}\}_{j=1}^J$, a competitive equilibrium is a collection of sequences of distributions $\{\mu_j, \Lambda_j(x_j)\}_{j=1}^J$ of individual household decisions $\{c_j(x_j), l_j(x_j), a_{j+1}(x_j), m_j(x_j), \text{in}_{j+1}(x_j)\}_{j=1}^J$, aggregate stocks of physical capital and effective labor services $\{K, L, K_m, L_m\}$, factor prices $\{w, q, R, p_m\}$, markups $\{\omega^{\text{IHI}}, \omega^{\text{GHI}}, v^{\text{in}}\}$ and insurance premiums $\{\text{prem}^{\text{GHI}}, \text{prem}^{\text{IHI}}(j, h)\}_{j=1}^J$ such that

- (a) $\{c_j(x_j), l_j(x_j), a_{j+1}(x_j), m_j(x_j), \text{in}_{j+1}(x_j)\}_{j=1}^J$ solves the consumer problems (5) and (7),
- (b) the firm first order conditions hold in both sectors

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

- (c) markets clear

$$\begin{aligned}
K + K_m &= \sum_{j=1}^J \mu_j \int a(x_j) d\Lambda(x_j) + \sum_{j=1}^{J_1} \tilde{\mu}_j \int a_j(x_j) d\Lambda(x_j) \\
& + \sum_{j=1}^{J_1} \mu_j \int (1_{[\text{in}_{j+1}=2]}(x_j) \times \text{prem}^{\text{IHI}}(j, h) + 1_{[\text{in}_{j+1}=3]}(x_j) \times \text{prem}^{\text{GHI}}) d\Lambda(x_j), \\
L + L_m &= \sum_{j=1}^{J_1} \mu_j \int (e_j(x_j) \times l_j(x_j)) d\Lambda(x_j),
\end{aligned}$$

(d) the aggregate resource constraint holds¹⁴

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

(e) the government programs clear so that (11), (10), and (12) hold,

(f) the profit conditions of the insurance companies (8) and (9) hold, and

(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.

4. Parameterization, estimation and calibration

We parameterize the model and use a standard numeric algorithm to solve for an equilibrium.¹⁵ For the calibration we distinguish between two sets of parameters that we refer to as *external* and *internal* parameters. *External* parameters are estimated independently from our model and either based on our own estimates using data from MEPS, CMS, or estimates provided by other studies. We summarize these external parameters in Appendix B, Table 9. *Internal* parameters are calibrated so that model-generated data match a given set of targets from U.S. data. These parameters are presented in Appendix B, Table 10. Model generated data moments and target moments from U.S. data are juxtaposed in Appendix B, Table 11.

4.1. Demographics

One period is defined as 5 years. Households are economically active from age 20 to age 95 which results in $J = 15$ periods. The annual conditional survival probabilities are taken from U.S. life-tables in 2010 and adjusted for period length.¹⁶ The population growth rate for the U.S. was 1.2 percent on average from 1950 to 1997 according to the Council of Economic Advisors (1998). In the model the total population over the age of 65 is 17.7 percent which is very close to the 17.4 percent in the census.

4.2. Endowments and preferences

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

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

where c is consumption, l is labor supply, \bar{l}_j is the age dependent fixed cost of working as in French (2005), η is the intensity parameter of consumption relative to leisure, κ is the intensity parameter of health services relative to consumption and leisure, and σ is the inverse of the intertemporal rate of substitution. Cobb–Douglas preferences are widely used in the macroeconomic literature (e.g., see Heathcote et al., 2008), as they are consistent with a balanced growth path, irrespective of the choice for σ . Palumbo (1999), French (2005), De Nardi et al. (2010) and French and Jones (2011) use similar setups where health status is a shifting factor in preferences.

Fixed cost of working is set in order to match labor hours per age group. Parameter σ is set to 3.0 and the time preference parameter β is set to 1.0 to match the capital output ratio and the interest rate. It is understood that in a general equilibrium model every parameter affects the equilibrium value of all endogenous variables to some extent. Here we associate parameters with those equilibrium variables that are the most directly affected (quantitatively). The intensity parameter η is 0.43 to match the aggregate labor supply and κ is 0.75 to match the ratio between final goods consumption and medical consumption. In conjunction with the health productivity parameters ϕ_j and ξ from expression (14) these preference weights also ensure that the model matches total health spending and the health insurance take-up rate for each age group.

¹⁴ If we used the marked up prices $p_m^{inj}(x_j)$ for medical services on the left hand side we would need to include the profits from medical providers on the right hand side.

¹⁵ We first guess a price vector, then backward solve the household problem using these prices, then aggregate the economy and solve for a new price vector using firm first order conditions. We then update the price vector and repeat all the steps until the price vector converges. The algorithm is implemented on a multi-core server in parallel FORTRAN.

¹⁶ CMS/OACT provided the life-tables.

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

$$e = e_j(\vartheta, h_j, \epsilon^l) = (\overline{wage}_{j,\vartheta})^\chi \times \left(\exp\left(\frac{h_j - \bar{h}_{j,\vartheta}}{\bar{h}_{j,\vartheta}}\right) \right)^{1-\chi} \times \epsilon^l \text{ for } j = \{1, \dots, J_1\}, \quad (13)$$

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

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

The third component is an idiosyncratic labor productivity shock ϵ^l and is based on [Storesletten et al. \(2004\)](#). We specify $\log(\epsilon_{t+1}^l) = \omega_t + \epsilon_t$ and $\omega_t = \beta_0 \times \omega_{t-1} + v_t$, where $\epsilon_t \sim N(0, \sigma_\epsilon^2)$ is the transitory component and ω is the persistent component of the labor shock ϵ^l . The error term in the second equation follows a normal distribution, $v_t \sim N(0, \sigma_v^2)$. [Storesletten et al. \(2004\)](#) estimate $\beta_0 = 0.935$, $\sigma_\epsilon^2 = 0.01$ and $\sigma_v^2 = 0.061$. We then discretize the labor shocks into a five state Markov process following [Tauchen \(1986\)](#) so that the magnitude of the labor shocks are $\epsilon^l \in \{4.41; 3.51; 2.88; 2.37; 1.89\}$.

4.3. Health capital

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

$$h_j = i\left(m_j, h_{j-1}, \delta_j^h, \epsilon_j^h\right) = \overbrace{\phi_j m_j^\xi}^{\text{Investment}} + \overbrace{(1 - \delta_j^h) h_{j-1}}^{\text{Trend}} + \overbrace{\epsilon_j^h}^{\text{Disturbance}}. \quad (14)$$

The first component is a health production function that uses health services m as inputs to produce new quantities of health capital. The second component measures the natural health deterioration over time. Depreciation rate δ_j^h is the per period health depreciation of an individual of age j . The third component represents a random and age dependent health shock. This law of motion for health is widely used in the Grossman health capital literature. The first two components are used in the original deterministic analysis of [Grossman \(1972a\)](#). The third component can be thought of as a random depreciation rate as discussed in [Grossman \(2000\)](#). Calibrating the law of motion for health is non-trivial for two reasons. First, there is no consensus on how to measure health capital. Second, to the best of our knowledge, suitable estimates for health production processes within macro modeling frameworks do not exist.

MEPS contains two possible sources of information on health status that could serve as a measure of health capital: self-reported health status and the health index Short-Form 12 Version 2 (SF-12v2).¹⁷ Many previous studies use the former as a proxy for health capital and health shocks (e.g., [De Nardi et al., 2010](#) use self-reported health status reported in AHEAD data from the Health and Retirement Study). However this measure is very subjective and not directly comparable between two individuals with different age. The definition of “excellent” health may mean something entirely different for a 20 or 60 year old individual, respectively. The SF-12v2 is a more objective measure of health. This index is widely used in the health economics literature to assess health improvements after medical treatments in hospitals. For this reason, we use the SF-12v2 as measure for health capital in our model.

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

Health depreciation rates. We next approximate the natural rate of health depreciation δ_j^h per age group. We calculate the average health capital \bar{h}_j per age group of individuals with group insurance and zero health spending in any given year. We then postulate that such individuals did not incur a negative health shock in this period as they could easily afford to buy medical services m to replenish their health due to their insurance status. This means that for those individuals the smoothing and shock component in expression (14) disappears as $\epsilon_j^h = 0$ and $m_j = 0$. The average law of motion of

¹⁷ The SF-12v2 includes twelve health measures of physical and mental health. There are two versions of this index available, one for physical health and the other for mental health. Both indices use the same health measures to construct the index but the physical health index puts more weight on variables measuring physical health components (compare [Ware et al., 1996](#) for further details about this health index). For this study we use the physical health index.

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

Health shocks. For each age cohort j we separate individuals into four risk groups: group 1, whose health capital levels fall into the 25th percentile of age j individuals, group 2 whose health capital levels fall between the 25th and the 50th percentile, group 3 falls between the 50th and the 75th percentile, and group 4 whose health capital is in the top quartile. We then assume that group 4 experiences no health shock, so that this group's average health capital defines the maximum health capital $\bar{h}_{j,d}^{\max}$ (where subscript d indicates that this variable is calculated from MEPS data). Group 3 experiences a “small” health shock, group 2 experiences a “moderate” health shock, and group 1 suffers from a “large” health shock. The averages of health capital per age group are denoted $\bar{h}_{j,d}^{\max} > \bar{h}_{j,d}^3 > \bar{h}_{j,d}^2 > \bar{h}_{j,d}^1$. We next express the shock magnitudes as percentage deviations from the maximum health state in the data, so that the shock vector is: $\epsilon_j^{h\%} = \left\{ 0, \frac{\bar{h}_{j,d}^3 - \bar{h}_{j,d}^{\max}}{\bar{h}_{j,d}^{\max}}, \frac{\bar{h}_{j,d}^2 - \bar{h}_{j,d}^{\max}}{\bar{h}_{j,d}^{\max}}, \frac{\bar{h}_{j,d}^1 - \bar{h}_{j,d}^{\max}}{\bar{h}_{j,d}^{\max}} \right\}$. This vector is then multiplied with the maximum health capital level in the model h_m^{\max} to calculate the shock levels in the model. The transition probability matrix of health shocks Π^h is calculated by counting how many individuals move across risk groups between two consecutive years in MEPS data.¹⁸ We smooth the transition probabilities and adjust for period length which results in increasing probabilities of more severe health shocks over the lifecycle.

The health production technology. Grossman (1972b) and Stratmann (1999) estimate positive effects of medical services on measures of health outcomes. However, we are not aware of any precise estimates for parameters ϕ_j and ξ in expression (1). A recent empirical contribution by Galama et al. (2012) finds weak evidence for decreasing returns to scale which would imply that $\xi < 0$. In our paper we allow ϕ_j to be age-dependent and calibrate ξ and ϕ_j together to match aggregate health expenditures and the medical expenditure profile over age.

4.4. Technology and firms

According to NIPA the economy grows at the exogenous growth rate $g = 2$ percent. We impose a standard Cobb–Douglas production technology that uses physical capital and labor as inputs to produce a final consumption good according to $F(K, L) = AK^\alpha L^{1-\alpha}$. The medical sector uses $F_m(K_m, L_m) = A_m K_m^{\alpha_m} L_m^{1-\alpha_m}$. We set the capital share of production α to 0.33 and the annual capital depreciation rate at $\delta = 0.1$, which are both standard values in the calibration literature (e.g., Kydland and Prescott, 1982). The capital share in production in the health care sector is set lower at $\alpha_m = 0.26$ (based on Donahoe, 2000 and our own calculations). The base price of medical services p_m is an equilibrium outcome.

4.5. Insurance sector

Group insurance offer. MEPS contains information about whether agents have received a group health insurance offer from their employer so that offer shock $\epsilon^{GHI} = \{0, 1\}$ where 0 indicates no offer and 1 indicates a group insurance offer. MEPS contains three variables that indicate whether an individual was offered health insurance by her employer in a specific year. An individual was offered group health insurance when either one of the three variables indicates so. Since the probability of a GHI offer will be highly correlated with income, we also condition on the skill type ϑ of an individual when constructing the transition matrix $\Pi_{j,\vartheta}^{GHI}$ with elements $\Pr(\epsilon_{j+1}^{GHI} | \epsilon_j^{GHI}, \vartheta)$. That is, for each skill type we count the fraction of individuals with a GHI offer in year j , that is still offered group insurance in $j + 1$. We smooth the transition probabilities and adjust for the five-year period length.

Insurance premiums and coinsurance rates. Insurance companies in the individual markets screen their customers and price discriminate according to age and health status. Age and health dependent markup profits $\omega_{j,h}^{IHI}$ are calibrated to match the IHI take-up rate over the lifecycle. Similarly, the markup profit ω^{GHI} is calibrated to match the insurance take-up rate of GHI.¹⁹ We define the coinsurance rate as the fraction of out-of-pocket health expenditures over total health expenditures, so that our coinsurance rates include deductibles and copayments. We use MEPS data to estimate coinsurance rates in percent as $\gamma^{IHI} = [22, 46, 48, 49, 50, 53, 52, 50]$ and $\gamma^{GHI} = [33, 33, 33, 34, 36, 36, 45, 50]$ for individual and group insurance respectively. The coinsurance rates are age-dependent and increase significantly over age.²⁰

¹⁸ An alternative approach would use equation (14) directly to calculate the size of the health shocks. However, in order to do this in a consistent way we would require a panel data set over 15 years. MEPS is a rotating panel that only allows for one-year lags as it switches survey respondents every two years.

¹⁹ In the GHI we allow for lower premiums for the two youngest age cohorts in order to match the relatively high take-up rates despite the very low probability of adverse health shocks. Without this “minor” discrimination, GHI premiums would be too high and not enough young low risk types would buy into it to match the take-up rate in the data.

²⁰ Individuals in their first period are by definition uninsured, so that only 8 coinsurance rates are required to solve this model with 9 working periods.

Price of medical services. Since we model the production of medical services, the base price of medical services p_m is endogenous. Shatto and Clemens (2011) report that the reimbursement rates of Medicare and Medicaid are close to 70 percent of the price that private health insurances pay for comparable health care services. Furthermore, various studies have found that uninsured individuals pay over 50 percent higher prices for prescription drugs as well as hospital services than insured individuals (e.g., Anderson, 2007; Gruber and Rodriguez, 2007).²¹ According to Brown (2006) the national average is a markup of around 60 percent. Large group insurance companies are able to operate at lower average fixed costs and will also be able to negotiate lower prices for health care services (see Phelps, 2003). Based on this information and assuming that Medicaid reimbursement levels result in zero provider profits, we pick the following markup factors $\nu^{\text{noIns}} = 0.7$, $\nu^{\text{IHI}} = 0.25$, $\nu^{\text{GHI}} = 0.1$, $\nu^{\text{Maid}} = 0.0$ and $\nu^{\text{Mcare}} = -0.1$ so that prices are:

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

4.6. Government

Pensions. In the model, social security transfers are defined as a function of skill type and average labor income. Let $\bar{L}(\vartheta)$ and $w \times \bar{L}(\vartheta)$ denote the average effective human capital and the average wage income per skill type. Let $t^{\text{Soc}}(\vartheta) = \Psi(\vartheta) \times w \times \bar{L}(\vartheta)$ be pension payments, where $\Psi(\vartheta)$ is a scaling vector that determines the total size of pension payments by skill type. Total pension payments amount to 4.1 percent of GDP, similar to the number reported in the budget tables of the Office of Management and Budget (OMB) for 2008.

Public health insurance for the old. We use data from CMS (Keehan et al., 2011) and calculate that the share of total Medicaid spending that is spent on individuals older than 65 is about 36 percent. Adding this amount to the total size of Medicare results in a combined total of 4.16 percent of GDP of public health insurance reimbursements for the old. Since MEPS only accounts for about 65–70 percent of health care spending in the national accounts (see Sing et al., 2006 and Bernard et al., 2012) we target a size of 3.0 percent of GDP. Given a coinsurance rate of $\gamma^R = 0.20$, the size of the combined Medicare/Medicaid program in the model is 3.1 percent of GDP.²² We fix the premium for Medicare as 2.11 percent of per capita GDP as in Jeske and Kitao (2009).

Medicaid. According to Kaiser (2013), 16 states have Medicaid eligibility thresholds below 50 percent of the FPL, 17 states have eligibility levels between 50 and 99 percent, and 18 states have eligibility levels that exceed 100 percent of the FPL. In addition, state regulations vary greatly with respect to the asset test of Medicaid. Second, many individuals who are eligible for Medicaid are either unaware or unwilling to enroll because of social stigma and access costs (Remler et al., 2001 and Aizer, 2003). We do not account for these effects in our model as all agents are fully informed and rational. Using the FPL directly would grossly overstate the Medicaid population in the model.

According to MEPS data, 9.2 percent of working age individuals are on some form of public health insurance. In order to match the fraction of the working age population covered by Medicaid we keep the Medicaid eligibility level to 70 percent of the FPL ($FPL_{\text{Maid}} = 0.7 \times FPL$), that is the state average level, and calibrate the asset test level, \bar{a}_{Maid} .

All model experiments that expand the Medicaid program are therefore percentage expansions based on the model threshold, FPL_{Maid} . The size of Medicaid for workers is about 1.46 percent of GDP according to national accounts data but Medicaid spending in MEPS only accounts for about 0.95 to 1.02 percent of GDP according to Keehan et al. (2011), Sing et al. (2006) and Bernard et al. (2012). Again, based on MEPS data we set the age dependent coinsurance rate for Medicaid to $\gamma_j^{\text{Maid}} = [11, 14, 17, 16, 17, 18, 20, 22]$ which results in a Medicaid size for workers of 0.5 percent of GDP in the model.

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

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

where \tilde{y} is taxable income. The parameter estimates for this tax polynomial are $a_0 = 0.258$, $a_1 = 0.768$ and $a_2 = 0.031$.

The Medicare tax τ^{Mcare} is set to 2.9 percent. Medicare payroll taxes are 2×1.45 percent on all earnings split in employer and employee contributions (see Social Security Update 2007, 2007). The social security system is self-financed via a payroll tax of $\tau^{\text{SS}} = 9.4$ percent. The Old-Age and Survivors Insurance Security tax rate of 10.6 percent that has been used by Jeske and Kitao (2009) in a similar calibration. The social security payroll tax is collected on labor income up to a maximum of \$97,500. The Medicare payroll tax does not face such a restriction.

Finally, the consumption tax rate is set to 5.0 percent (Mendoza et al. (1994) report 5.67 percent). The model results in total tax revenue of 21.8% of GDP and residual (unproductive) government consumption of 12 percent.

²¹ An anonymous referee pointed out that part of the markup for uninsured individuals may be intended to cover incomplete repayment. However, we do not model incomplete repayment.

²² The focus of the analysis is on working age individuals and since we do not distinguish health spending categories (e.g., prescription drugs, inpatient care, outpatient care, nursing home care, etc.) separately tracking Medicare and Medicaid for the retired cohorts would only convolute the model unnecessarily.

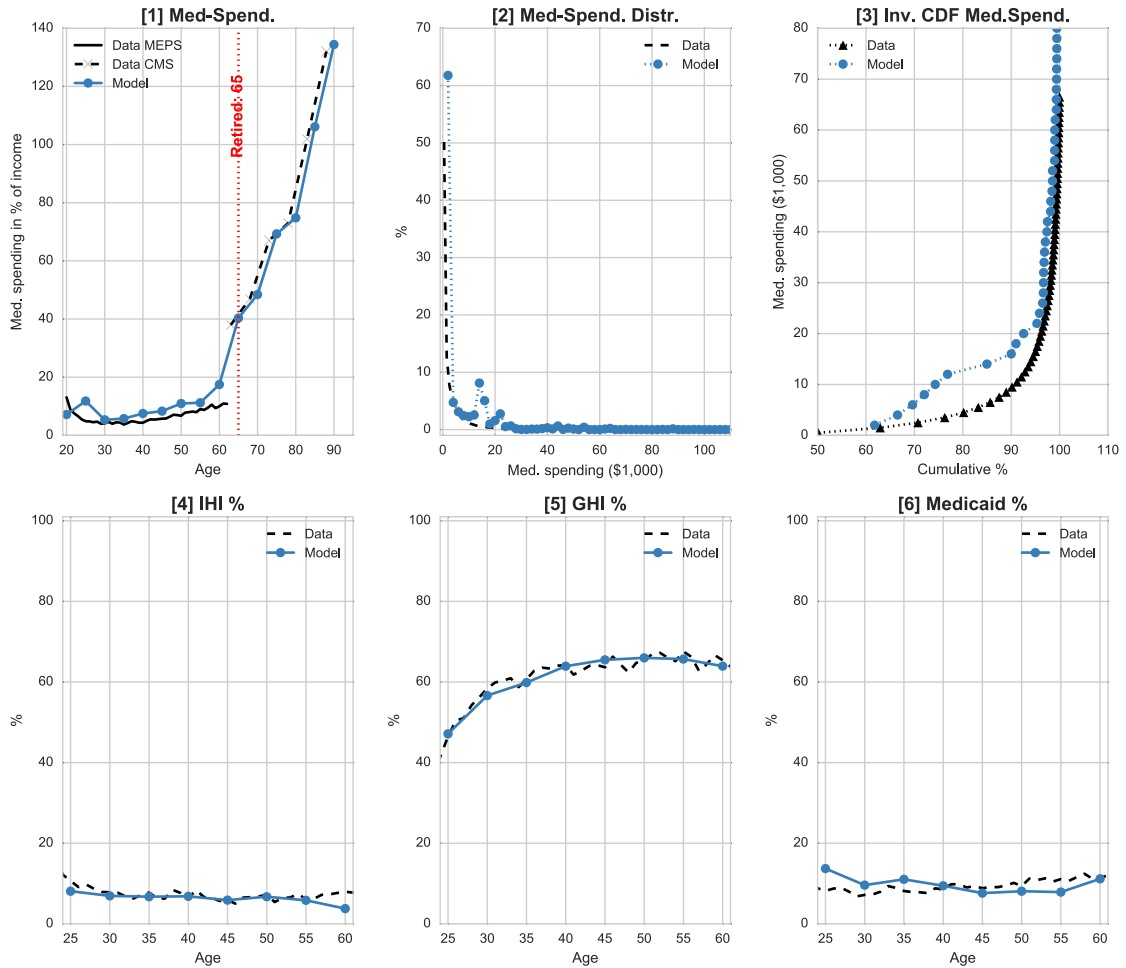


Fig. 1. Model vs. MEPS-Data. Health expenditure and insurance take-up rates over the lifecycle. Panel [1] depicts average medical spending over average income per age group. The numbers of the retired cohorts are inflated using additional data from CMS/OACT to adjust for the known under-reporting of medical spending in MEPS. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

4.7. Benchmark model performance

In order to provide a convincing simulation environment the model has to be able to reproduce the stylized facts in the data before the implementation of the ACA in 2010. This section presents how well the model matches the lifecycle profiles of health expenditures, insurance take-up rates, labor supply, as well as aspects of the US income distribution and important macro-aggregates from data. Figs. 1, 2, and 3 and Table 11 summarize the model output.

Medical expenditures. Panel 1 of Fig. 1 compares health expenditure profiles as fraction of income with MEPS data for heads of households. Our model generates total medical expenditures of 17.6 percent of gross household income which matches data provided by CMS. MEPS under reports spending on health care (Bernard et al., 2012). We therefore adjust the MEPS based spending data of the retired cohorts upward using data received via personal communication from the CMS-Office of the Actuary. Our model then produces health expenditures of 12.69 percent of GDP which is quite similar to the one reported in Pashchenko and Porapakkarm (2013) but still lower than the reported health spending figures in the National Health Expenditure Accounts (NHEA) in 2009. In addition, our model reproduces the distribution of health expenditures as seen in panel 2 and panel 3 of Fig. 1.²³ The partial equilibrium medical services demand elasticity with respect to the coinsurance rate is -0.15 which is close to estimates from microeconomic studies that report around -0.2 (e.g., see Manning et al., 1987).

Insurance take-up ratio. Panels 4, 5 and 6 of Fig. 1 plot the lifecycle profiles of insurance take-up rates for individual health insurance (IHI), group health insurance (GHI) and Medicaid of the working age population. Young agents with low

²³ It should be noted that the model targets augmented MEPS data whereas panels 2 and 3 (dotted blue lines) show the distribution of medical spending based on MEPS data only.

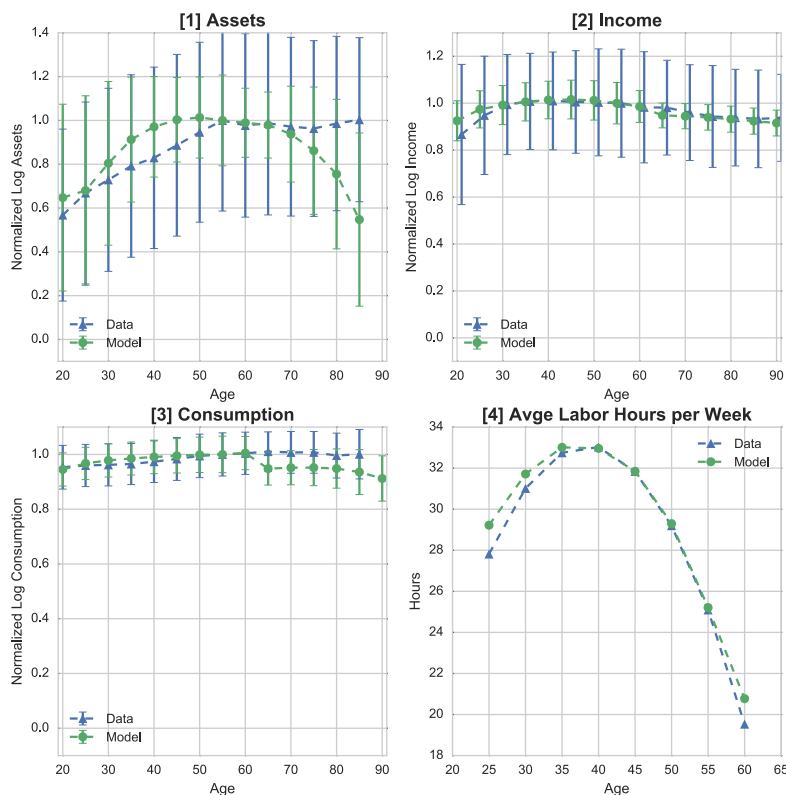


Fig. 2. Model vs. Data. Average lifecycle profiles normalized at age 55 values. The vertical lines in panels [1]–[3] are standard deviations of log-values.

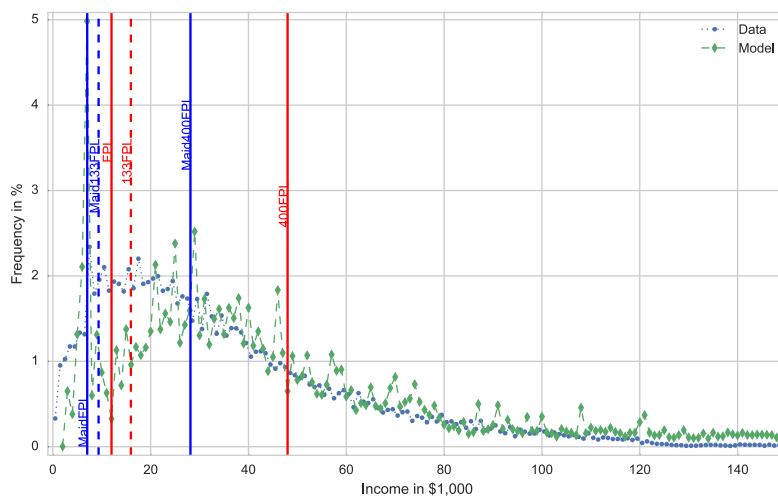


Fig. 3. Income Distribution. Model vs. MEPS data 1999–2009. ACA subsidy eligibility thresholds are denoted Medicaid. The federal poverty level is denoted FPL.

income are less likely to buy private health insurance compared to middle aged agents at the peak of their lifecycle earnings ability. Young individuals face lower health risk and are less willing to buy private health insurance than older individuals who are both, more willing (i.e. they face higher expected negative health shocks) and more able to buy health insurance. The model slightly overstates the take-up rate of Medicaid among young agents.

Assets, consumption and labor supply. Fig. 2 presents the lifecycle profiles of asset holdings, income, consumption and labor supply. The model reproduces the hump-shaped patterns of lifecycle asset holdings from CPS data, non-medical consumption from CEX data and labor supply from MEPS data. The model does not match the asset position of older households

very well. This is a common issue with models that endogenize health spending (Yogo, 2009) and do not incorporate a bequest motive (De Nardi, 2004).²⁴

Income distribution. Fig. 3 provides a summary of the income distribution compared to data from MEPS. Our benchmark model matches the lower and upper tails of the income distribution with around 14.8 percent of individuals having income below the FPL vs. 16.4 percent in MEPS.

Aggregates. The benchmark model reproduces many important macroeconomic aggregates in the U.S. data. Table 11 compares model moments with first moments from MEPS, CMS, and NIPA data.

5. Quantitative results

In this section we apply the model to quantify the effects of the ACA on insurance take-up rates, medical spending, macro aggregates and welfare. We first isolate the quantitative importance of each policy component. In section 5.1, we start from the benchmark pre-ACA equilibrium and then introduce each policy separately and then solve for a new long-run equilibrium (i.e., steady state) with this reform component in place. In addition, in all reforms, we hold the share of government spending as a percent of GDP constant.²⁵ In section 5.2 we quantify the overall effect of the ACA when all three policy components are allowed to interact. We then explore alternative (counterfactual) designs of the ACA and provide sensitivity analysis of our results in section 5.3.

5.1. Isolating the effects of the ACA

Table 1
The effects of the insurance mandate with penalties.

	Benchmark	Penalty in % of individual income				
		(a) 1.0%	(b) 2.5%	(c) 5%	(d) 10%	(e) 15%
Workers insured (%):	77.23	88.49	97.24	98.21	99.05	99.24
• IHI (%)	6.43	16.29	21.18	22.22	23.43	23.92
• GHI (%)	61.01	65.81	67.75	68.56	69.38	69.80
• Medicaid (%)	9.78	6.39	8.31	7.42	6.23	5.52
IHI average premium	100.00	111.71	114.78	113.98	113.14	113.27
GHI premium	100.00	73.62	68.91	67.63	65.97	65.18
Med. services (units)	100.00	99.70	99.78	99.65	99.08	98.81
Med. services spending (\$)	100.00	96.43	95.94	95.69	95.06	94.80
Med. spending/GDP (%)	12.69	12.46	12.12	12.06	11.95	11.89
Penalty/GDP (%)	0.0	0.00	0.05	0.08	0.10	0.12
GDP	100.00	100.27	100.45	100.64	100.93	101.12
Welfare: CEV (%)	0.00	−0.40	−0.46	−0.63	−0.78	−0.99

5.1.1. Insurance mandate with penalty

According to the ACA, workers who do not have health insurance by February 2014 face a tax penalty of up to 2.5 percent of their income. This insurance mandate enforced by penalties is probably the most controversial policy of the ACA. In order to understand the role of the penalty we consider an experiment in which only the penalty will be introduced while all other features of the ACA are ineffective. We then compare the pre-ACA benchmark equilibrium to equilibria where the mandate is enforced by penalties of 1, 2.5, 5, 10, and 15 percent of gross income in Table 1.²⁶

The mandate is expected to induce more of the young and healthy individuals to participate in the private health insurance markets. Intuitively, the penalties are an implicit income tax for the uninsured who face a higher marginal income tax rate in case they do not buy health insurance. Penalties thereby alter the trade-off between the costs and benefits of health insurance. Working age individuals, especially the young and healthy, face a higher cost of not participating in the health insurance markets. Young workers have low income and face low risk of getting sick and therefore tend to be very sensitive to changes in insurance premiums. If more healthy workers participate in the health insurance market, improved risk-sharing will drive down premiums. Private health insurance becomes more affordable for low income individuals who can then also join the pool. Indeed, we observe a big increase in the fraction of healthy agents in their 20–30s in the GHI

²⁴ In models with exogenous health spending a bequest motive is not required to match the asset distribution of the old as exogenous spending risk generates stronger precautionary motives (Braun et al., 2015; Kopecky and Koreschkova, 2014).

²⁵ Alternatively, we could fix government spending at the level of the benchmark pre-ACA steady state. However, we believe it is more realistic to assume that if an economy shrinks in the long-run, its level of government spending will also decrease. The same argument can be made for a growing economy.

²⁶ The ACA also introduces a mandate that requires firms with more than 50 full-time employees to provide health insurance. In this paper we only consider individual insurance mandates.

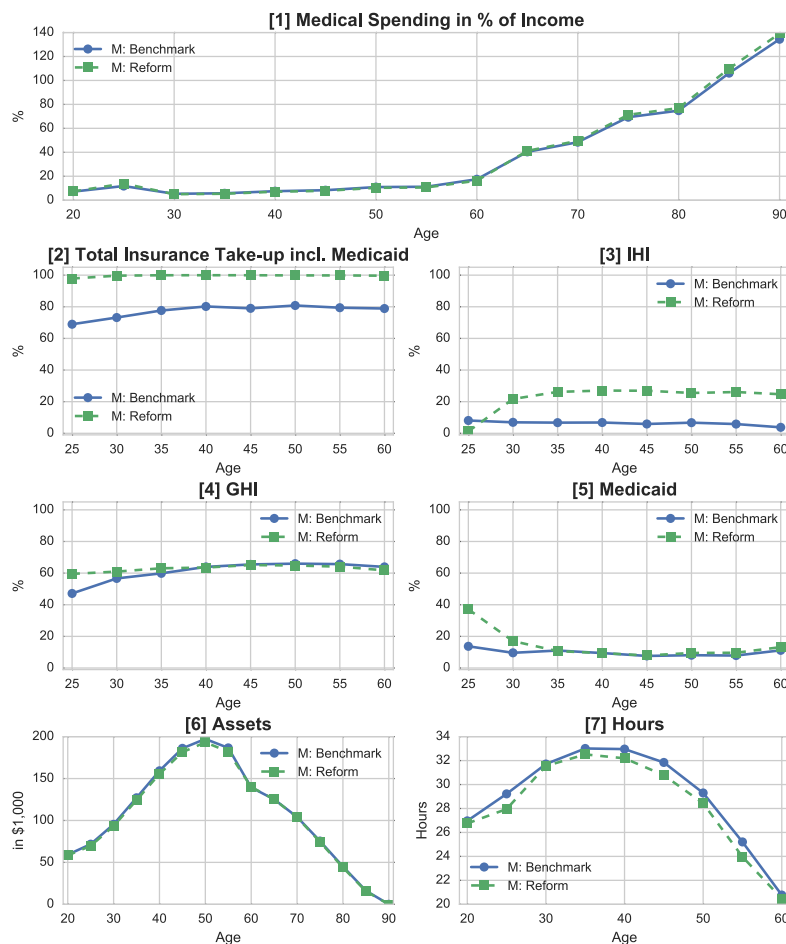


Fig. 4. Effects of the ACA. Benchmark profiles compared to equilibrium profiles with ACA.

program, while a fraction of agents in their 40–60s moves into IHI after penalties are introduced. As a result the coverage rate of the GHI market increases as the average GHI premium decreases.²⁷ The penalty increases the take-up rates of IHI as well. However, since IHI charges premiums based on health and age, the average premium in IHI markets increases as more high risk types enter the pool. High risk types were previously priced out of the insurance market which is a typical adverse selection result. Overall, a high enough penalty can result in universal insurance coverage at the expense of creating welfare losses measured as compensating consumption equivalents.²⁸

As we increase the magnitude of the penalties we observe that most of the increase in coverage is driven by the expansion of private health insurance markets, while the coverage of Medicaid declines slightly due to crowding out. More specifically, a 2.5 percent penalty, which is the benchmark level in the ACA (see column (b) 2.5% in Table 1), increases the fraction of insured workers from 77.23 percent in the pre-ACA economy to 97.24 percent in the post-ACA economy. The largest share of this expansion is due to more young individuals picking up IHI, the fraction of which jumps from 6.43 to 21.18 percent. In addition, more low risk types join the GHI policies so that premiums in GHI markets drop significantly. The GHI market expands modestly by about 6 percent.

The expansion of the private health insurance markets draws individuals out of Medicaid and causes a small decline in Medicaid coverage by 1.4 percent. More aggressive penalty rates of 5, 10 and 15 percent lead to even higher private insurance take-up rates while the Medicaid take-up decreases further as shown in columns (c) to (e) in Table 1. Even though the Medicaid rules are unchanged in these experiments, individuals optimally adjust their asset holdings, so that they can be eligible for Medicaid. This mechanism is highlighted in Hubbard et al. (1995). We indeed observe a fraction of

²⁷ The effects are qualitatively similar to those shown in panels 3 and 4 of Fig. 4. Graphs are available in the supplemental appendices.

²⁸ We calculate compensating equivalent variation (CEV) in consumption as a fraction of pre-reform lifetime consumption that has to be added or subtracted in each period to make a newborn individual indifferent between the pre-ACA steady state and the new steady state after the ACA reform. A negative CEV reflects a welfare decrease, a positive CEV reflects a welfare gain due to policy changes.

Table 2

The effects of insurance exchanges with premium subsidies.

	Benchmark	IHI subsidies relative to ACA (%)			
		(a) 100%	(b) 110%	(c) 120%	(d) 130%
Workers insured (%):	77.23	87.40	87.90	88.19	88.49
• IHI (%)	6.43	15.04	15.56	15.94	16.29
• GHI (%)	61.01	65.62	65.73	65.77	65.81
• Medicaid (%)	9.78	6.75	6.61	6.47	6.39
IHI average premium	100.00	118.03	117.33	116.93	116.42
GHI premium	100.00	80.65	79.74	79.12	78.62
Med. services (units)	100.00	99.59	99.58	99.57	99.56
Med. services spending (\$)	100.00	97.91	97.84	97.81	97.76
Med. spending/GDP (%)	12.69	12.47	12.46	12.46	12.46
Subsidy/GDP (%)	0.0	0.50	0.53	0.57	0.61
GDP	100.00	99.63	99.60	99.56	99.53
Welfare: CEV (%)	0.00	0.58	0.64	0.67	0.70

high risk agents in their 50–60s move out of GHI and into Medicaid. The spillover effects from the expansion of Medicaid contributes to lowering the average GHI premium.

Interestingly, we observe decreases in the quantity of medical services (in units) demanded. In general, the expansion of insurance coverage induces higher demand for medical services as it reduces the effective price of medical services for the previously uninsured (substitution effect). On the other hand, the penalties result in adverse effects on disposable income as individuals now either pay the penalty or the premium (negative income effect). In addition, the purchase of medical services is an equilibrium outcome that depends on the interaction between supply and demand. Since we observe a small contraction in the medical services sector that is accompanied by an overall increase in the base price of medical services, the negative income effects dominate slightly so that the overall quantity of medical services demanded decreases.

We find that almost universal coverage can be reached with a penalty of about 10 percent. Penalties higher than that only modestly increase the take-up rate but tend to generate larger welfare losses, especially among low skill types. This result indicates that the introduction of penalties greatly reduces adverse selection in private health insurance markets. However, the penalty policy is regressive as now fewer low income individuals benefit from Medicaid.

5.1.2. Insurance exchanges with premium subsidies

According to the ACA, workers who are not offered insurance from their employers and whose income is between 133 and 400 percent of the FPL are eligible to buy health insurance at insurance exchanges at subsidized rates. This feature of the ACA is designed to make health insurance more affordable for low income workers whose income is above the Medicaid eligibility threshold and who currently do not have access to GHI from their employer. In order to isolate the role of the insurance exchanges with premium subsidies, we again compare the pre-ACA steady state (Benchmark column in Table 2) to a steady state with insurance exchanges for IHI and premium subsidies set at ACA levels (compare column (a) in Table 2). We next calculate a steady state with 10 percent larger premium subsidies relative to the standard subsidies (see column 110% in Table 2), followed by even larger increases of 20 and 30 percent. Note that all other features of the ACA are inactive, including penalties and the Medicaid expansion.

Subsidies at ACA levels increase the coverage rates of IHI and GHI insurance from 6.43 to 15.04 percent and from 61.01 to 65.62 percent, respectively and decrease the fraction of workers covered by Medicaid from 9.78 to 6.75 percent. As the subsidies get larger, the coverage via Medicaid drops further while the coverage via IHI expands. However, the expansion of IHI markets is relatively small. The subsidies have only a small indirect effect on the GHI insurance market and take-up stays almost constant for subsidy rates larger than 100 percent of ACA rates (compare columns (b)–(d) in Table 2).

Premium subsidies by themselves result in much smaller insurance take-up rates than the previously analyzed equilibria with penalties. This result is in line with empirical evidence reported in Gruber and Washington (2005) who also find that subsidies have a very small effect on insurance take-up but tend to induce people to buy more expensive health insurance. In addition, the tax distortions associated with the subsidies reduce aggregate income, causing the level of the Medicaid threshold to decrease so that many low income households drop out of Medicaid. Since these low income households do not benefit from the subsidies (which only become effective for income levels above 133 percent of the FPL_{Maid}), they stay out of insurance. Some of the high risk types that previously bought GHI are now better off buying into IHI with the help of subsidies. On other hand, the subsidy policy induces more low risk individuals in their 20–30s to join the GHI scheme. This lowers premiums in the GHI markets and leads to a slight expansion of the GHI market.

The decrease in Medicaid coverage is the result of changes in incentives to save and accumulate wealth because of the availability of subsidies. In our model the prospect of low future earnings or high out-of-pocket medical expenditure shocks influences the saving behavior even if the individual never actually encounters bad health or labor productivity shocks. Before the ACA reform, the Medicaid program with asset-based means-testing discouraged agents with low expected

lifetime income from saving (e.g., see [Hubbard et al., 1995](#)). In our model, agents have three options to insure against health risk: (i) decrease asset holdings and work effort to become eligible for Medicaid, (ii) buy private health insurance, or (iii) self-insure via increased savings.

Low asset holdings reduce the ability to self insure and expose individuals more to labor productivity shocks. Some individuals with income between 0.7 of the FPL (the baseline number) and 133 percent of the FPL (the subsidy floor) therefore opt to buy private health insurance even as they save more and accumulate more wealth. We find that capital accumulation is higher when the subsidies are introduced in our framework. This makes the Medicaid income test more stringent. As a consequence, more agents fail to pass the Medicaid asset test so that the number of individuals on Medicaid declines. We observe a similar mechanism and outcome when penalties are introduced.

The purchase of medical services and medical spending falls due to a mechanism similar to the one described in the previous section. Output also drops slightly as the subsidy rate increases. In terms of welfare we observe welfare gains when the subsidy is introduced. The redistributive effect is quite strong as the reform redistributes wealth collected from a payroll tax of up to 0.61 percent from a very small fraction of high income workers to a much larger group of low income workers.

Table 3
The effects of the Medicaid expansion.

	Benchmark	Medicaid expansion (% of FPL _{Maid})			
		(a) 133%	(b) 150%	(c) 200%	(d) 300%
Workers insured (%):	77.23	80.28	81.91	85.12	87.23
• IHI (%)	6.43	6.56	6.96	6.47	5.70
• GHI (%)	61.01	59.27	58.07	55.45	50.19
• Medicaid (%)	9.78	14.45	16.89	23.20	31.34
IHI average premium	100.00	99.19	97.42	98.36	95.68
GHI premium	100.00	99.33	98.39	97.23	98.07
Med. services (units)	100.00	101.00	101.51	102.66	103.51
Med. services spending (\$)	100.00	100.30	100.32	100.25	99.97
Med. spending/GDP (%)	12.69	12.85	12.92	13.13	13.39
ACA payroll tax (%)	0.0	0.36	0.62	1.37	2.13
GDP	100.00	99.00	98.54	96.84	94.69
Welfare: CEV (%)	0.00	−0.38	−0.62	−2.41	−4.97

5.1.3. Medicaid expansion

The ACA expands the Medicaid eligibility threshold uniformly to individuals with income below 133 percent of the FPL.²⁹ The primary goal of the Medicaid expansion is to cover individuals whose income is below the subsidy threshold to prevent a coverage gap as low income individuals would then face penalties for being uninsured. The expansion of Medicaid can potentially crowd-out some segments of the private health insurance markets as it provides an alternative insurance option for low income individuals. On the other hand, the expansion can have positive effects on private health insurance markets that can result in lower premiums if bad income shocks and large negative health shocks are strongly correlated. In this case private health insurance markets can retain the low risk types (i.e., cream-skimming) while Medicaid draws in the costly high risk types. This will lower premiums in private insurance markets which in turn attracts additional low risk types. The overall effect of expanding Medicaid depends on how these effects play out.

In order to isolate the effects of the Medicaid expansion, we consider an experiment in which we implement the expansion of the Medicaid program to 133 percent of the FPL_{Maid} while ignoring all other elements of the ACA. We then compare alternative expansion levels of 150, 200, and 300 percent of the FPL_{Maid} and report the results in [Table 3](#).

Expanding Medicaid eligibility to individuals with income below 133 percent of the FPL_{Maid} increases the Medicaid take-up rate by 4.7 percent (from 9.78 percent to 14.45 percent, column (a) in [Table 3](#)). The fraction of workers insured by IHI increases slightly by about 0.13 percent while the fraction of workers on GHI declines by 1.7 percent. This result indicates that the crowding-out effect dominates the cream-skimming effect in the GHI market but not in the IHI market. Interestingly, the average premium in the IHI and GHI markets both drop when Medicaid expands. The average IHI premium decreases between 2 and 5 percent and the average GHI premium decreases between 0.5 and 2 percent. This indicates that the expansion of Medicaid attracts low income individuals with bad health from the private insurance markets. This drives down the average medical cost in the private insurance pool and lowers the average premium.

Overall, the private health insurance markets lose a combined market share of about 1.74 percent. The net effect of newly insured workers is therefore only a 3 percent increase so that the overall coverage increases to 80.28 percent when

²⁹ Currently only about 50 percent of all States in the US participate in this expansion.

Medicaid expands to 133 of the FPL_{Maid} . When allowing Medicaid to expand to 150 percent of the FPL_{Maid} , the insurance coverage of workers increases to up to 81.91 percent despite further losses in market share for GHI. As Medicaid expands further to 300 percent of the FPL_{Maid} , the insurance coverage rate increases further to 87.23 percent.

Medical spending in levels increases slightly but output drops due to tax distortions. Health spending as a fraction of GDP increases slightly by 0.16 percent. The Medicaid expansion causes a tax distortion which has implications for output and welfare. The Medicaid expansion to 133 percent of the FPL_{Maid} comes at a cost of a new payroll tax of 0.36 percent on high income earners. The realized loss in output is about 1 percent of GDP, which lowers welfare of high income earners.

On the other hand, Medicaid is a means-tested social insurance program that targets low income individuals. The expansion subsequently improves risk sharing and results in redistribution effects that are welfare improving for the relatively large group of low income earners. Finally, the Medicaid expansion entices low income types to move away from self insurance via savings which also adds to the decrease in capital accumulation. Overall, negative income effects dominate positive welfare effects when Medicaid expands to 133 percent of the FPL_{Maid} , so that we observe an overall welfare loss. As the Medicaid program expands further, the tax distortions become more severe and the welfare losses become larger.

Table 4
The general and partial equilibrium effects of the ACA reform.

	Benchm.	The ACA reform	
		(a) General Equ.	(b) Partial Equ.
Workers insured (%):	77.23	99.58	97.95
• IHI (%)	6.43	22.29	22.15
• GHI (%)	61.01	62.91	60.63
• Medicaid (%)	9.78	14.38	15.18
Medical services (units)	100.00	101.87	103.07
Med. services spending (\$)	100.00	96.95	98.59
Med. spending/GDP (%)	12.69	12.45	n/a
IHI average premium	100.00	118.05	100.00
GHI premium	100.00	65.64	100.00
ACA payroll tax (%)	0.00	1.24	0.00
GDP	100.00	98.77	n/a
Capital (K_c)	100.00	98.89	99.45
Capital (K_m)	100.00	102.49	104.72
Weekly hours worked	29.22	28.50	28.05
Health (H)	100.00	100.14	100.25
Consumption (C)	100.00	97.41	99.04
Welfare: CEV (%)	0.00	−1.70	+4.06

5.2. The overall effects of the ACA

We next evaluate the general equilibrium effects of the entire ACA reform with (i) penalties for the uninsured; (ii) subsidies to buy IHI for income earners between 133 and 400 percent of the FPL_{Maid} ; (iii) an expansion of the eligibility threshold for Medicaid to 133 percent of the FPL_{Maid} and no more asset tests for Medicaid; and (iv) no more screening by health status in IHI markets (i.e., age screening only). We again compare pre-ACA steady states (Benchmark) to the steady states calculated under two different reform settings: (a) a general equilibrium setting in which all prices adjust in order to satisfy market clearing conditions, (b) a partial equilibrium setting in which all prices are kept unchanged at the initial steady state levels. The results are summarized in Table 4.

Health insurance take-up rates. General equilibrium results are presented in column (a) of Table 4. If all prices are free to adjust in order to clear all markets, the ACA leads to a 22 percent increase of health insurance coverage of the working age population (first row of column (a)). This increase is mainly driven by the expansion of IHI coverage which increases from 6.43 percent to 22.29 percent and by the expansion of Medicaid from 9.78 to 14.38 percent. Fig. 4 presents the change in the take up-rates of the different insurance types over the lifecycle. The ACA induces or allows workers who are 50 and older to participate in the IHI markets; meanwhile, the Medicaid expansion significantly increases the insurance take-up rate of young workers below 30. The ACA has a different effect on the GHI markets. As depicted in panel 4 of Fig. 4, we observe a shift in the age structure in the GHI market. First, there is a significant increase in the take-up rates among young and low risk types because of the penalties and subsidies. Second, there is a small decline in the take-up rates of old and high risk types because they move into Medicaid. Overall, the coverage rate of the GHI market increases by 2 percent and GHI premiums drop significantly by 35 percentage points as more low risk types move into GHI.

Comparing the partial equilibrium outcome of column (b) in Table 4, we observe that the reform increases the fraction of workers with health insurance significantly. This expansion is driven by the increase in the number of workers insured by IHI (from 6 to 22 percent) and by an increase in the number of workers insured by Medicaid (from 10 to 15 percent). The

Table 5

Welfare effects by health state and income group. Health states are measured at the beginning of the period.

Health capital	Skill 1 (low)	Skill 2	Skill 3	Skill 4 (high)
$h = 15$ (healthy)	1.02	−1.79	−3.91	−4.10
$h = 14$	1.13	0.56	−2.69	−3.59
$h = 13$	1.51	1.71	−2.57	−3.47
$h = 12$	2.02	2.65	−2.51	−3.38
$h = 11$	2.13	2.85	−1.79	−3.32
$h = 10$	2.00	2.85	−1.64	−3.21
$h = 9$	2.39	3.28	−1.44	−3.09
$h = 8$	2.78	3.93	−1.11	−2.95
$h = 7$	3.31	4.83	−0.59	−2.76
$h = 6$	4.26	6.24	0.08	−2.37
$h = 5$	6.09	8.03	1.12	−1.82
$h = 4$	8.05	11.62	2.49	−1.03
$h = 3$	10.93	14.84	4.30	0.37
$h = 2$	15.93	18.50	5.82	1.25
$h = 1$ (sick)	24.00	23.72	8.90	2.08

share of the GHI market decreases slightly since premiums are held constant and premium reductions due to alleviating adverse selection are not realized in the partial equilibrium setting. Overall, the reform increases the fraction of insured workers to 98 percent. Note that in this reform setting, prices are not free to adjust to clear markets. We can interpret these as pure demand side or “first round” partial-equilibrium effects that can either be amplified or diminished by price substitution and income effects that are provided by the general equilibrium analysis above.

Medical consumption and spending. We observe an increase in the traded quantity of medical services of 1.87 percent (compare row five of Table 4). This result indicates that changes in the insurance market structure result in significant effects on medical consumption. Note that the demand for medical services and the demand for health insurance are endogenously determined from a utility optimization problem. Thus, ex-post moral hazard and adverse selection problems are present in our model. This allows us to capture the two-way relation between medical consumption and financing over the lifecycle.

Interestingly, despite the increase in health insurance coverage and medical consumption we do observe a drop in the level of health expenditures. In our general equilibrium model this result is driven by two forces: (i) a negative income effect and (ii) a move of a group of individuals that pays a high price for medical services (i.e., the uninsured) into a program that pays the lowest price for medical services (i.e., Medicaid). Medicaid patients, as a group, pay a lower price for medical services than the uninsured.³⁰ Since after the implementation of the ACA, a large group of uninsured individuals moves into Medicaid, the overall spending level decreases by 3 percent.

One assumption in our model is of course that providers cannot refuse to treat Medicare or Medicaid patients, so that these “cost savings” are always fully realized in the model but may potentially be unattainable in the real world where providers might try to renegotiate Medicare/Medicaid reimbursement levels. Since the economy shrinks, the drop in medical spending levels barely factors in when comparing medical spending as a fraction of GDP. If the low prices that Medicaid currently pays can be maintained and if providers do not refuse to treat Medicaid patients, then the shifting of uninsured individuals into Medicaid is an effective cost containment tool.

Aggregate variables. In the model, the government imposes a new flat payroll tax on individuals with incomes higher than \$200,000 per year to finance the ACA. The general equilibrium result shows that this new tax has to be about 1.2 percent in the long-run in order to be able to finance the expansion of Medicaid as well as the subsidies (see row 9 of column (a) in Table 4). The new Medicaid arrangement, together with the new tax, distorts individuals’ incentives to save and work. Capital in the non-medical sector decreases while capital in the medical sector production increases. Overall, weekly hours worked decrease from 29.22 hours to 28.50 hours, a decrease of 2.5 percent. This is consistent with a recent CBO study (CBO, 2014, p. 127) that attributes a loss of 2.3 million jobs due to decreases in labor supply to the ACA. These distortions subsequently lead to efficiency losses and lower GDP by about 1.2 percent in our model.

Welfare. The ACA improves risk sharing across agents and redistributes income from low to high health risk types as well as from high to low skill types, all of which can result in welfare gains. To understand how the welfare effects vary across agent types, we compute compensating consumption by health and permanent income type in Table 5. As expected, we find that the welfare effects vary significantly across health capital and skill types. High skill workers with good health (see the top right corner of Table 5) experience welfare losses, while low skill workers in bad health (see the bottom left corner of Table 5) experience welfare gains in the new steady state. The welfare gain for the lowest skill type can be large at up to 24 percent of life-time consumption whereas welfare losses can amount to 4.1 percent for high income types.

³⁰ An extreme example of this gap in the price tag faced by the two groups would be a comparison of the relatively low Medicaid reimbursement levels and the chargemaster prices billed to uninsured individuals in emergency room situations.

At the aggregate level we observe welfare losses of 1.70 percent (see the last row of column (a) in Table 4). This indicates that the welfare losses caused by the fiscal distortions dominate the welfare gains resulting from better risk sharing and redistribution. In addition, some of the welfare losses can be attributed to the penalties that disproportionately hurt low income groups and counter the positive welfare effects of subsidies and the Medicaid expansion that target the very same type of individual (compare Table 1 and the negative welfare results in the last row). More importantly, we identify substantial differences between partial equilibrium and general equilibrium welfare outcomes. When we keep market prices unchanged in the partial equilibrium setting, we find that the ACA results in significant welfare gains of 4.06 percent (see last row of column (b) in Table 4). In this case tax distortions are not fully realized via general equilibrium price adjustments, so that none of the negative income effects are accounted for in the welfare calculations.

5.3. Extensions and sensitivity analysis

Table 6

The general equilibrium effects of the ACA with time cost of medical consumption ($\eta_m > 0$).

	The ACA reform		
	$\eta_m = 0$	$\eta_m = 0.5$	$\eta_m = 1.0$
P.E. coinsurance elasticity in pre-ACA eqm.	−0.15	−0.06	−0.007
Workers insured (%):	99.58	99.64	98.97
• IHI (%)	22.29	22.36	22.29
• GHI (%)	62.91	63.58	63.07
• Medicaid (%)	14.38	13.71	14.40
Medical services (units)	101.87	101.21	100.19
Med. services spending (\$)	96.95	96.65	95.48
Med. spending/GDP (%)	12.45	11.68	11.56
ACA payroll tax (%)	1.24	0.93	0.76
GDP	98.77	98.93	98.97
Welfare: CEV (%)	−1.70	−0.37	+0.53

5.3.1. Ex-post moral hazard and welfare

In this section, we consider an alternative functional form for preferences. We assume a time cost of medical consumption in preferences as follows

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

where $\eta_m \geq 0$ is a parameter that controls the utility cost of the procurement of medical services. The benchmark setting $\eta_m = 0$ imposes no direct time cost of medical consumption. If $\eta_m > 0$ then the procurement of medical services imposes a time cost as it reduces leisure time in the preferences. This makes the demand for medical services less elastic.

In the benchmark experiment we have discussed how the ACA results in significant increases in consumption of medical services due to an ex-post moral hazard effect. In order to minimize this effect so that our results become comparable to previous studies with exogenous health expenditure shocks, we next consider two alternative cases with parameter values $\eta_m = 0.5$ and $\eta_m = 1.0$. For each case we recalibrate the benchmark model and then introduce the ACA reform into the new version of the model with lower health care demand elasticities. We report the partial equilibrium health care demand elasticities with respect to the coinsurance rate as well as the effects of the ACA for these cases in Table 6.

The effect on insurance coverage and the aggregate effects are quite similar across all three experiments. We find that the response of health care demand to the ACA reform becomes smaller as the value of η_m increases. In particular, when $\eta_m = 1.0$ the ACA reform only leads to an increase in consumption of medical services (units) by about 0.19 percent. This implies that the demand for medical services is quite inelastic, so that the ex-post moral hazard effect triggered by more insurance via the ACA is effectively suppressed in this setting. Interestingly, we now find aggregate welfare gains of 0.53 percent of CEV as opposed to welfare losses when moral hazard effects are more pronounced (i.e., the cases with $\eta_m = 0$ or $\eta_m = 0.5$). Note that this setup does not allow for a complete elimination of the ex-post moral hazard effect; however, we can mimic a general equilibrium setting in which the ex-post moral hazard effect is marginalized. The opposing welfare outcomes indicate that the ex-post moral hazard effect matters for the overall welfare result. The underlying mechanism works mainly through the tax distortion channel. When the ex-post moral hazard effect is very small the financing needs of the reform are much smaller. The smaller tax that is now necessary to finance the reform – a 0.76 percent payroll tax on high income households vs. 1.24 percent in the experiment with moral hazard – creates smaller distortions in the economy. The ACA, in this case, generates overall welfare gains.

Table 7

The general equilibrium effects of the ACA reform. Government consumption adjusts to finance the reform, so that the tax distortions are minimized.

	Benchm.	ACA: payroll tax	ACA: G adjusts
Workers insured (%):	77.23	99.58	99.57
• IHI (%)	6.43	22.29	22.42
• GHI (%)	61.01	62.91	63.14
• Medicaid (%)	9.78	14.38	14.01
Medical services (units)	100.00	101.87	102.37
Med. services spending (\$)	100.00	96.95	97.51
Med. spending/GDP (%)	12.69	12.45	12.46
GDP	100.00	98.77	99.31
Welfare: CEV (%)	0.00	−1.70	+2.92

The positive welfare effect in the setting with $\eta_m = 1$ is consistent with findings in the literature analyzing the welfare effect of the ACA in models with exogenous health expenditure shocks that do not account for the increase in medical spending triggered by the insurance take-up expansion (e.g., see [Pashchenko and Porapakarm, 2013](#)). This result highlights the importance of accounting for moral hazard and general equilibrium price adjustments when conducting a comprehensive long-run assessment of a reform of such complexity.

5.3.2. Reducing government consumption to finance the ACA

In the benchmark ACA reform described earlier a flat income tax on high income earners is the financing instrument. We next investigate a tax neutral reduction of exogenous government consumption G . In this case the government keeps tax rates unchanged and simply adjusts the level of government consumption to finance the extra spending caused by Medicaid and IHI subsidies. The results are summarized in [Table 7](#).

This experiment eliminates any distortionary effects caused by new or higher taxes and therefore allows for an estimate of the pure fiscal cost of the reform absent any of the tax distortions. This experiment reveals how the insurance mandate with fines and premium subsidies affects individuals' optimal portfolio choice independent of distortionary effects triggered by changes in the tax system.

The increases in government spending from the premium subsidy program and Medicaid expansion are relatively small and very close to the results of the earlier benchmark reform. Contrary to the earlier results where a payroll tax financed the reform, this reform results in welfare gains of about 2.9 percent despite efficiency losses and shows how detrimental distortionary taxes are for welfare (see last row in [Table 7](#)). The intuition behind the positive welfare outcome is simple. As the government does not have to impose a new tax to finance the expansion of the public health insurance system, the reform is practically “free” and positive insurance effects will determine the overall welfare outcome.

5.3.3. Screening in IHI markets and the Medicaid asset test

The ACA prevents insurers in the IHI markets from price discrimination by health state. In addition, the reform completely removes the asset test for Medicaid eligibility. [Table 8](#) presents the effects of these two elements, implemented in isolation, on market outcomes: column [2] – IHI without screening by health but age screening still active, column [3] – IHI with no screening by age and health, and column [4] – Medicaid without an asset test.

Only allowing for age screening decreases the IHI take-up significantly from 6.4 percent to 3 percent. If we remove the ability to screen by age and health completely without introducing measures to support IHI markets, then IHI markets collapse (see column [3] in [Table 8](#)). An adverse selection spiral can be observed and low risk types begin to leave the IHI markets which are now forced to charge an average premium of the entire risk pool. This in turn increases the premium in the IHI market and leads to a further exodus of low risk types. Premiums eventually rise high enough so that the entire IHI market collapses and no single agent buys IHI anymore. The GHI market, which is also not allowed to screen, is partly protected by tax deductibility of insurance premiums which keeps the market viable.

We next simulate a scenario where screening is allowed, but the asset test for Medicaid eligibility is abolished (see column [4] in [Table 8](#)). In this experiment, the Medicaid eligibility is simply based on the income test of the benchmark economy (i.e., income less than $FPL_{\text{Maid}} = 0.7 \times FPL$ qualifies for Medicaid). As expected, the share of Medicaid increases by about 2 percent as low income but high asset households now qualify for Medicaid. The slight expansion of Medicaid crowds out GHI slightly but barely affects IHI. A negative income effect can be observed as output drops due to tax distortions caused by the larger Medicaid program. Since the negative welfare losses caused by the tax distortions and the efficiency losses dominate the welfare gains associated with redistributive/social insurance function of the Medicaid expansion we again observe a negative welfare outcome.

5.3.4. Alternative values of preference parameters

In this section we explore the sensitivity of the model dynamics to alternative calibration values of key preference parameters including risk aversion and the preference weights on consumption, leisure and health. For each change in a

Table 8

The role of screening in IHI markets and the Medicaid asset test.

	[1] Benchmark	[2] IHI health Screening-off	[3] IHI all Screening-off	[4] Medicaid Asset test-off
Workers insured (%):	77.23	70.56	60.18	77.86
• IHI (%)	6.43	3.08	0.00	6.25
• GHI (%)	61.01	57.45	50.77	60.32
• Medicaid (%)	9.78	10.03	9.41	11.23
Med. services (units)	100.00	98.88	98.56	101.88
Med. services spending (\$)	100.00	99.25	100.76	101.45
Med. spend./GDP (%)	12.69	12.60	12.79	12.91
GDP	100.00	99.97	99.97	99.73
Welfare: CEV (%)	0.00	−0.94	−1.03	−1.11

preference parameter we re-calibrate the pre-ACA steady state (Benchmark). We then simulate the ACA reform again and compare the reform outcome across calibration specifications. We find that our results are stable with respect to changes in the selected preference parameters.³¹

6. Conclusion

Confronted with an ever increasing number of uninsured Americans and health expenditures exceeding 17 percent of GDP, President Obama signed the *Affordable Care Act* in early 2010. In this paper we develop an overlapping generations, general-equilibrium model with endogenous medical spending and health insurance choice and evaluate the long-run macroeconomic and welfare effects of the ACA. The methodology that we propose is novel and necessary to capture the dynamics of health accumulation, health spending, health insurance and the remaining optimal portfolio decisions of U.S. households.

Our results indicate that the reform reduces the severity of adverse selection problems that are partly responsible for the large number of uninsured individuals in private health insurance markets. The reform leads to high insurance take-up rates for workers. In order to finance the reform the government has to either introduce a 1.24 percent payroll tax on individuals with incomes above \$200,000 or cut government spending by about 1 percent of GDP. The reform triggers a 2 percent increase in medical services consumption, a small increase in the aggregate health stock, a decrease in labor supply and capital stock due to tax distortions, and decreases in steady state output of up to 1.2 percent. The penalties are more effective in increasing the insurance take-up rates. The subsidies that help low income workers buy IHI are less successful in achieving high coverage rates but are welfare improving due to redistribution effects. The expansion of Medicaid crowds out the private health insurance markets. Finally, we find that ex-post moral hazard effects and general equilibrium price effects that incorporate tax distortions are crucial in determining the overall welfare outcomes.

Our paper contributes to a growing literature that uses macroeconomic models to examine issues pertaining to health care spending. Our quantitative analysis is informative for academics and policymakers as it merges aspects of health economics, macroeconomics, and public finance to shed light on the macro and welfare effects of a health care reform. Our model can be extended to address a wide range of other related issues including long-term care and long-term care insurance, health-related behavior, as well as aging. We leave these extensions for future work.

Appendix A. ACA model implementation

A.1. Household problem

We next including penalties for not having health insurance and premium subsidies for IHI into the model. Suppressing state vector x_j in order to not clutter the notation, the household budget constraint changes to

$$\begin{aligned}
 & (1 + \tau^c) c_j + (1 + g) a_{j+1} + o^w(m_j) + 1_{\{in_{j+1}=1\}} \text{prem}^{\text{IHI}} + 1_{\{in_{j+1}=2\}} \text{prem}^{\text{GHI}} \\
 & = y_j + t_j^{\text{SI}} - \text{tax}_j - 1_{\{in_{j+1}=0\}} \text{penalty}_j + 1_{\{in_{j+1}=1\}} \text{subsidy}_j - \text{tax}_j^{\text{ACA}},
 \end{aligned}$$

³¹ The results of these experiments are reported in the Supplementary Online Appendix.

where

$$\text{subsidy}_j = \begin{cases} \max \left(0, \text{prem}_j^{\text{IHI}} - 0.03 \tilde{y}_j \right) & \text{if } 1.33 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 1.5 \text{ FPL}_{\text{Maid}}, \\ \max \left(0, \text{prem}_j^{\text{IHI}} - 0.04 \tilde{y}_j \right) & \text{if } 1.5 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 2.0 \text{ FPL}_{\text{Maid}}, \\ \max \left(0, \text{prem}_j^{\text{IHI}} - 0.063 \tilde{y}_j \right) & \text{if } 2.0 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 2.5 \text{ FPL}_{\text{Maid}}, \\ \max \left(0, \text{prem}_j^{\text{IHI}} - 0.08 \tilde{y}_j \right) & \text{if } 2.5 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 3.0 \text{ FPL}_{\text{Maid}}, \\ \max \left(0, \text{prem}_j^{\text{IHI}} - 0.095 \tilde{y}_j \right) & \text{if } 3.0 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 4.0 \text{ FPL}_{\text{Maid}}, \text{ and} \end{cases}$$

$$\text{penalty}_j = 0.025 \times \tilde{y}_j. \quad (15)$$

Variable \tilde{y}_j is individual gross income as defined in expression (6). Premium subsidies are regulated so that an individual's spending on health insurance does not exceed a certain percentage of her overall income. This percentage threshold increases with the income of an individual. A person who is at the lower end of the income distribution is not supposed to spend more than 3 percent of her income on health insurance. This threshold increases to 9.5 percent for individuals that are closer to the eligibility upper bound of 400 percent of the FPL. The subsidies defined in expression (6) ensure that premium spending stays within the defined range as specified in the ACA (Consult [Fernandez \(2014\)](#) for further details). In the model we use a flat payroll tax on individuals with incomes higher than \$200,000 in order to finance the ACA. The additional tax term is defined as: $\text{tax}_j^{\text{ACA}} = \tau^V \times \tilde{y}_j$ if $\tilde{y}_j \geq \$200,000$.

A.2. Insurance system

Private insurance companies. The ACA prevents IHI companies from screening by health, so that only an average premium, $\text{prem}_j^{\text{IHI}}$, per age group can be charged. The new zero profit conditions for IHI for each age group can be written as

$$\begin{aligned} & (1 + \omega_j^{\text{IHI}}) \mu_j \int [1_{\{in_j(x_j)=1\}}] (1 - \gamma_j^{\text{IHI}}) p_m^{\text{IHI}} m_{j,h}(x_{j,h}) d\Lambda(x_j) \\ & = R \mu_{j-1} \int (1_{\{in_{j,h}(x_{j-1})=1\}} \text{prem}_{j-1}^{\text{IHI}}) d\Lambda(x_{j-1}), \quad \text{for } j = \{2, \dots, J_1\}. \end{aligned}$$

The new government budget constraint is³²

$$\begin{aligned} & G + \sum_{j=1}^J \mu_j \int t_j^{\text{SI}}(x_j) d\Lambda(x_j) + \sum_{j=2}^{J_1} \mu_j \int (1 - \gamma^{\text{MAid}}) p_m^{\text{MAid}} m_j(x_j) d\Lambda(x_j) \\ & + \sum_{j=J_1+1}^J \mu_j \int (1 - \gamma^R) (p_m^R m_j(x_j)) d\Lambda(x_j) + \sum_{j=1}^{J_1-1} \mu_j \int 1_{\{in_{j+1}(x_j)=1\}} \text{subsidy}(x_j) d\Lambda(x_j) \\ & = \sum_{j=1}^J \mu_j \int [\tau^C c(x_j) + \text{tax}_j(x_j)] d\Lambda(x_j) + \sum_{j=J_1+1}^J \mu_j \int \text{prem}^R d\Lambda(x_j) \\ & + \sum_{j=1}^{J_1} \mu_j \int \tau^{\text{Med}} \left(e(h_{j-1}(x_j), \epsilon_j^l) l_j(x_j) w - 1_{\{in_{j+1}(x_j)=2\}} \text{prem}^{\text{GHI}} \right) d\Lambda(x_j) \\ & + \sum_{j=1}^{J_1} \mu_j \int \text{tax}_j^{\text{ACA}}(x_j) d\Lambda(x_j) + \sum_{j=1}^{J_1-1} \mu_j \int 1_{\{in_{j+1}(x_j)=0\}} \text{penalty}(x_j) d\Lambda(x_j). \end{aligned}$$

³² We hold coinsurance rates γ_j^{IHI} constant at pre-ACA levels. Since the ACA implements minimum coverage thresholds for the subsidized plans, the increase in the IHI premiums in the model is a lower bound as is the financing need for subsidies of IHI contracts sold at the insurance exchanges. We would like to thank an anonymous referee for pointing out this issue.

Appendix B. Calibration tables

Table 9

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

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

Table 10

Internal parameters. We choose these parameters in order to match a set of target moments in the data.

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

Table 11

Matched data moments. We choose internal parameters so that model generated data matches data from MEPS, CMS, and NIPA.

Moments	Model	Data	Source	Nr.M.
– Medical expenses as % of HH income	17.6%	17.07%	CMS communication	1
– Workers IHI	5.6%	7.2%	MEPS 1999/2009	1
– Workers GHI	61.1%	62.2%	MEPS 1999/2009	1

(continued on next page)

Table 11 (continued)

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

Appendix C. Supplementary material

Supplementary material related to this article can be found online at <http://dx.doi.org/10.1016/j.red.2016.02.002>.

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