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# Aging and Health Financing in the US: A General Equilibrium Analysis\*

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## Abstract

We quantify the effects of population aging on the US healthcare system. Our analysis is based on a stochastic general equilibrium overlapping generations model of endogenous health accumulation calibrated to match pre-2010 U.S. data. We find that population aging not only leads to large increases in medical spending but also a large shift in the relative size of public vs. private insurance. Without the *Affordable Care Act* (ACA), aging itself leads to a 36.6 percent increase in health expenditures by 2060 and a 5 percent increase in GDP which is driven by the expansion of the healthcare sector. The *group-based health insurance* (GHI) market shrinks, while the *individual-based health insurance* (IHI) market and Medicaid expand significantly. Additional funds equivalent to roughly 4 percent of GDP are required to finance Medicare in 2060 as the elderly dependency ratio increases. The introduction of the ACA increases the fraction of insured workers to 99 percent by 2060, compared to 81 percent without the ACA. This additional increase is mainly driven by the further expansion of Medicaid and the IHI market and the stabilization of the GHI market. Interestingly, the ACA reduces aggregate health care spending by enrolling uninsured workers into Medicaid which pays lower prices for medical services. Overall, the ACA adds to the fiscal cost of population aging mainly via the Medicare and Medicaid expansion.

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**Keywords:** Population aging, calibrated general equilibrium OLG model, health expenditures, Medicare & Medicaid, Affordable Care Act 2010, Grossman model of health capital, endogenous health spending and financing.

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# 1 Introduction

Unlike many other developed nations, the US has a mixed public/private health insurance system, where public health insurance (Medicare and Medicaid) covers retirees and low income individuals and private health insurance covers most of the working population (see Figure 1). This system leaves over 45 million Americans without health insurance. In addition, the U.S. health care system is the most expensive in the world. National health expenditure reached 17.7 percent of GDP in 2010 according to a study by the Centers for Medicare and Medicaid Services (Keehan et al. (2011)). The increase in health care costs at rates greater than the rate of GDP growth causes concerns about the long-term solvency of the health insurance system and the adverse fiscal effects of financing Medicare and Medicaid. The situation is made worse by projected population aging that in the near-term will increase the fraction of the elderly population who, on average, spends more on health care and rely more heavily on Medicare and Medicaid (see Figure 2).

The aging of the US population over the next 50 years provides a challenge for the US health insurance system (e.g., see NRC (2012) and Lee (2014)). It is now clear that the fiscal problems created by Medicare/Medicaid are already larger in magnitude relative to Social Security as reported in Figure 3 based on a report by the Congressional Budget Office (CBO (2016)). In March 2010 the Obama administration introduced a comprehensive health reform at the federal level via the *Affordable Care Act* (ACA). The reform encompasses many objectives including solving the problem of the uninsured and promoting universal health insurance coverage, fixing the Medicare program and controlling health care cost. This legislation is still in the process of being implemented. Critics maintain that the reform is underfunded and will drive up health care prices and health care premiums. When population aging accelerates in years to come the adverse effects of the ACA could be even more severe.

The long-term fiscal outlook in the US is sensitive to assumptions about how health care spending will respond to the ACA as reported in CBO (2013, 2014, 2016). Auerbach and Gale (2013) point out that the long-term fiscal gap in the federal government budget ranges between 6.1 percent and 9 percent of GDP, depending on the assumed growth rate of health care expenditures. The behavioral responses to the changes in demographics and insurance markets are critically important to understand how health expenditures will grow. However, none of these health-related behaviors are depicted in CBO's reported projections as their models do not consider the micro foundations of health spending and financing over the lifecycle. The current paper aims to fill this gap and focuses on two issues. First, we quantify the effects of population aging on healthcare spending and financing in the US. Second, we assess the implications of the ACA reform in this aging context.

We address these questions using a general equilibrium, overlapping-generations model calibrated to mimic the behavior of US households. Most importantly, we develop an analytical framework with micro foundations in which the demand for medical services and the demand for health insurance are endogenously derived from a household optimization problem together with consumption, labor supply, and savings. Our framework combines a stochastic dynamic

general equilibrium overlapping generations model with incomplete markets and heterogeneous agents (e.g., see Huggett (1996)) with the Grossman health capital model (Grossman (1972a)) and then adds idiosyncratic health shocks. The model includes institutional details of the public health insurance system and distinguishes between private employer provided group insurance (GHI) and private individual health insurance (IHI).

We calibrate the model to US data before the ACA reform. The primary data sources are the Medical Expenditure Panel Survey, data from the National Health Expenditure Accounts, as well as population projections by CMS/OACT. The benchmark model matches lifecycle patterns of insurance take-up rates, health expenditures, the labor supply, consumption and asset accumulation as well as important macroeconomic aggregates. Our model also captures adverse selection and ex-post moral hazard effects as we explicitly model the insurance take-up choice and health care spending decisions of US households. More importantly, since the model is a general equilibrium model, it accounts for the price feedback effects that naturally arise as a consequence of the demographic shift and the introduction of the ACA. In terms of general equilibrium models, our model is among the most institutionally detailed platforms in existence to investigate the pre- and post-ACA states of the U.S. economy. The model extends our previous framework in Jung and Tran (2016) by altering the demographic structure in the model to mimic the process of population aging.

We next apply the model to study the effects of changes in the population age composition and analyze the implications of the ACA. Our results can be summarized as follows. First, without the ACA population aging leads to large increases in medical spending as well as output growth effects due to increased capital accumulation. We also observe large increases in the size of government spending programs for the retired population. Aging alone, without the ACA, leads to an increase in aggregate health expenditures of almost 37 percent which in turn causes a 50 percent increase in the size of Medicare. The additional investments into health capital by households trigger a large expansion of the healthcare sector which leads to an overall increase of GDP of about 5 percent when solving the model with 2060 demographics.

In addition, aging reduces the fraction of workers in the group based health insurance (GHI) market while it increases the fraction of workers in the individual based health insurance (IHI) market and Medicaid. Overall, the expansion of the IHI-market and Medicaid insurance dominates the reduction in the GHI insurance so that the overall insurance take-up rate for workers increases from 77 percent to 81 percent. This increase in insurance take-up of the working population goes hand in hand with lower overall premiums for the working age population as individuals, in anticipation of longer life-spans, maintain their health a higher levels but also more individuals are treated under government programs.

With the ACA in place, aging causes a smaller increase in the level of health expenditures by 35 percent, compared to 37 percent by 2060 in an economy without the ACA. Thus, the ACA on net, reduces overall health expenditures by as much as 2 percent. Moreover, the ACA reform strengthens the positive effects of aging on the overall insurance take-up rate of the working population. The ACA reform increases the fraction of insured workers to 99 percent

for all demographic profiles that we tested. This expansion in take-up is mainly driven by the expansion of Medicaid and IHI and the stabilization of the GHI market. Without the ACA this percentage stays consistently below 86 percent.

The ACA reduces health care spending by shifting uninsured workers who pay a high price for medical services into Medicaid which pays much lower prices. Premiums in the individual health care market (IHI) rise as a result of the subsidies. However, aging itself leads to more individuals eligible for government programs which still results in a net decrease of private insurance premiums despite the ACA. The ACA adds to the fiscal cost of population aging mainly via the expansion of Medicaid.

**Related Literature.** Our work is connected to different branches of the quantitative macroeconomics and health economics literature. First, our paper contributes to the large literature on the economics of aging (see Wise (2005) and Bloom, Canning and Fink (2010) and De la Croix (2013) for an overview). In the context of dynamic lifecycle models Auerbach and Kotlikoff (1987) are probably the first to include fertility rates into a large-scale deterministic framework. Follow up contributions (Faruqee (2002), Kotlikoff, Smetters and Walliser (2007) and others) have used either deterministic frameworks or stochastic frameworks (De Nardi, Imrohoroğlu and Sargent (1999), Kitao (2014) and Nishiyama (2015)) to analyze the effects of aging on household decision making and pensions. Recently, Braun and Joines (2015) and Kitao (2015) quantify the fiscal cost of population aging in Japan, while Nishiyama (2015) analyzes the effects of aging in the U.S. None of these papers have addressed the effects of aging on the healthcare system, which is the focus of this paper.

Our paper is related to the literature on incomplete markets macroeconomic models with heterogeneous agents as pioneered by Bewley (1986) and extended by Huggett (1993) and Aiyagari (1994). A number of studies address health risk and precautionary savings within dynamic household optimization frameworks (e.g., Kotlikoff (1988), Levin (1995), Hubbard, Skinner and Zeldes (1995) and Palumbo (1999)). These studies commonly assume exogenous health expenditure shocks. More recent contributions to this literature have incorporated exogenous health expenditure shocks into large-scale dynamic general equilibrium models which are then used to evaluate the macroeconomic effects of health insurance reforms (e.g., Jeske and Kitao (2009) and Pashchenko and Porapakkarm (2013)). Unlike these studies our model is based on the micro-foundations of health capital accumulation in the spirit of Grossman (1972a) which endogenizes decisions on health care and insurance. That is, we are able to account for the two-way interaction between insurance status and health expenditures which is an important determinant of the behavioral response (i.e., ex-post moral hazard) arising from changes in the demographic factors as well as from the ACA reform. This novel extension allows us to analyze out the consequences of population aging in a new dynamic general equilibrium model that fully accounts for the interactions between health spending and financing.

There is a growing literature that extends lifecycle models to include both medical and non-medical consumption and analyze the determinants of rising health care cost in the US including technological progress, economic growth and Social Security (e.g., see Suen (2006),

Hall and Jones (2007), Fonseca et al. (2013), Ozkan (2014) and Zhao (2014)). Similarly, we analyze the effects of aging on health care cost and health financing. We demonstrate that the health insurance system affects the rise of health care cost and vice versa. Finally, this paper is related to our previous work in Jung and Tran (2016) where we extend the Grossman framework and analyze the long-run effects of the Affordable Care Act (ACA) without aging. In this paper, we extend our previous work and analyze whether aging mitigates or amplifies the effects of the ACA.

The structure of the paper is as follows: Sections 2 and 3 present a description and calibration of the model. Section 4 presents model results grouped into (i) the effects of aging absent health reform and (ii) the ACA reform in combination with the effects of aging. Section 5 concludes.

## 2 The Model

The model builds on the existing integrated modeling framework in Jung and Tran (2016) which includes a stochastic dynamic general equilibrium overlapping generations model with incomplete markets and heterogeneous agents (e.g., Imrohoroglu, Imrohoroglu and Joines (1995) and Huggett (1996)) and the Grossman health capital model (Grossman (1972a)) augmented with idiosyncratic health shocks. The overlapping generations feature recognizes that people at different stages in their lives may have different needs and priorities that are likely to affect the overall performance of the economy. Intra-cohort heterogeneity of agents incorporates other important differences among individuals and institutions. The Grossman health capital model combined with idiosyncratic health shocks postulates that individual health is much like a capital asset that appreciates or depreciates in value over the course of an individual's lifetime. Our framework specifies a household sector, a production sector for final consumption goods, a production sector for medical services, a health insurance sector and a government sector.

### 2.1 Technologies and Firms

The economy consists of two separate production sectors. 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 are perfectly competitive and solve the following maximization problem

$$\max_{\{K, L\}} \{F(K, L) - qK - wL\}, \quad (1)$$

taking the rental rate of capital  $q$  and the wage rate  $w$  as given. Capital depreciates at rate  $\delta$  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

$$\max_{\{K_m, L_m\}} \{p_m F_m(K_m, L_m) - qK_m - wL_m\}. \quad (2)$$

The price  $p_m$  is a base price for medical services. The price for health care paid by households is  $p_j^{in_j} = (1 + \nu^{in_j}) p_m$  where the markup factor  $\nu^{in_j}$  depends on a household's insurance state. This markup will generate a profit for medical care providers, denoted Profit<sup>M</sup>. Profits are redistributed in equal amounts to all surviving individuals.

## 2.2 Demographics

The economy is populated with overlapping generations of individuals who live to a maximum of  $J$  periods. Individuals work for the first  $J_1$  periods and then retire for  $J - J_1$  periods. In each period individuals of age  $j$  face the exogenous survival probability  $\pi_j$ . Deceased individuals leave an accidental bequest which is taxed and redistributed equally to all individuals alive. The population grows exogenously at an annual net rate  $n$ . We assume stable demographic patterns, so that age  $j$  individuals make up a constant fraction  $\mu_j$  of the entire population at any point in time.<sup>1</sup> The relative sizes of the cohorts alive  $\mu_j$  and the mass of individuals dying  $\tilde{\mu}_j$  in each period (conditional on survival up to the previous period) can be recursively defined as  $\mu_j = \frac{\pi_j}{(1+n)^{years}} \mu_{j-1}$  and  $\tilde{\mu}_j = \frac{1-\pi_j}{(1+n)^{years}} \mu_{j-1}$ , where *years* denotes the number of years per model period.

## 2.3 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,  $u(c, l, h)$  where  $u : R_{++}^3 \rightarrow R$  is  $C^2$ , increases in consumption  $c$  and health  $h$ , and decreases in labor  $l$ .<sup>2</sup> Individuals are born with a specific skill type  $\vartheta$  that cannot be changed over their lifecycle and that together with their health state  $h_j$  and an idiosyncratic labor productivity shock  $\varepsilon_j^l$  determines their age-specific labor efficiency unit  $e(\vartheta, h_j, \varepsilon_j^l)$ . The transition probabilities for the idiosyncratic productivity shock  $\varepsilon_j^l$  follow an age dependent Markov process with transition probability matrix  $\Pi^l$ . Let an element of this transition matrix be defined as the conditional probability  $\Pr(\varepsilon_{i,j+1}^l | \varepsilon_{i,j}^l)$ , where the probability of next period's labor productivity  $\varepsilon_{i,j+1}^l$  depends on today's productivity  $\varepsilon_{i,j}^l$ .<sup>3</sup>

## 2.4 Health Capital and Healthcare Expenditures

**Health Capital.** Similar to Grossman (1972a) health capital is a function of last period's health capital  $h_{j-1}$ , the amount of medical spending in the current period  $m_j$ , the health depreciation rate  $\delta^h$  and an exogenous idiosyncratic health shock  $\varepsilon_j^h$  which can be expressed as

$$h_j = \mathcal{H}(m_j, h_{j-1}, \delta^h, \varepsilon_j^h). \quad (3)$$

<sup>1</sup>We discuss how changing the demographic structure can mimic population aging in Section 4.1.

<sup>2</sup>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 model in Grossman (1972a).

<sup>3</sup>We abstract from the link between health and life time so that health capital has no effect on 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.

The exogenous health shock follows a Markov process with age dependent transition probability matrix  $\Pi_j^h$ . Transition probabilities to next period's health shock  $\varepsilon_{j+1}^h$  depend on the current health shock  $\varepsilon_j^h$  so that an element of transition matrix  $\Pi_j^h$  is defined as the conditional probability  $\Pr(\varepsilon_{j+1}^h | \varepsilon_j^h)$ .

**Healthcare Expenditure.** An individual'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  $in_j$ .<sup>4</sup> An individual with insurance only pays a fraction  $\gamma$  of her medical expenditures. The out-of-pocket health expenditure is defined as

$$o(m_j) = \begin{cases} p_m^{in_j} \times m & \text{if } in_j = 0 \\ \gamma_j^{in_j} (p_m^{in_j} \times m_j) & \text{if } in_j > 0 \end{cases} \quad (4)$$

where  $0 \leq \gamma_j^{in_j} \leq 1$  are the insurance type specific as well as age dependent coinsurance rates.

## 2.5 Insurance Sector

We model various aspects of the US health insurance system. In the private health insurance markets, there are two types of insurance policies available for working age individuals, an individual health insurance plan (IHI) and a group health insurance plan (GHI). In order to be covered by insurance, individuals have to buy insurance one period prior to the realization of the health shock. The insurance policy needs to be renewed each period.<sup>5</sup> IHI can be bought by any individual for an age and health dependent premium denoted,  $\text{prem}^{\text{IHI}}(j, h)$ . GHI can only be bought by workers who are (randomly) matched with an employer that offers GHI which is indicated by random variable  $\varepsilon^{\text{GHI}} = 1$ . The GHI premium,  $\text{prem}^{\text{GHI}}$ , is tax deductible and insurance companies are not allowed to screen workers by health or age.<sup>6</sup> If a worker is not offered group insurance from the employer, i.e.  $\varepsilon^{\text{GHI}} = 0$ , 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.

The Markov process that governs the group insurance offer probability is a function of the permanent skill type  $\vartheta$ . Let  $\Pr(\varepsilon_{j+1}^{\text{GHI}} | \varepsilon_j^{\text{GHI}}, \vartheta)$  be the conditional probability of an individual's group insurance status at age  $j + 1$  given the individual's group insurance status at age  $j$ . We collect all conditional probabilities for group insurance status in the transition probability

<sup>4</sup>We only model discretionary health expenditures. Given the same magnitude of health shocks  $\varepsilon_j^h$ , a richer individual will therefore 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 etc.). In such cases a poor individual could still incur large health care costs. However, it is not unreasonable to assume that a rich person will outspend a poor person even under these circumstances.

<sup>5</sup>Agents in their first period are thus not covered by any insurance by construction.

<sup>6</sup>An employer can only force a worker to take the plan if the employer pays 100 percent of the premiums or if the worker agreed to take the plan as part of an employment or union agreement. Many GHI plans are not fully subsidized by the employer. If a worker chooses to opt out and buy an individual plan the worker forgoes the employer subsidy as well as the tax deductibility of the insurance premium. However, for a young low-risk worker a cheap individual plan may still be a better option than a GHI plan from an employer. (compare also: <http://healthcoverageguide.org/affordable-care-act/additional-issues/employee-rules-and-rights/>)



matrix  $\Pi_{j,\vartheta}^{\text{GHI}}$  which has dimension  $2 \times 2$  for each permanent skill type and age group.

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 test. Let  $in_j$  denote the health insurance status at age  $j \leq J_w$ :

$$in_j = \begin{cases} 0 & \text{if No insurance,} \\ 1 & \text{if Individual health insurance IHI,} \\ 2 & \text{if Group health insurance GHI,} \\ 3 & \text{if Medicaid.} \end{cases}$$

After retirement,  $j > J_1$ , all individuals are covered by a combined Medicare/Medicaid program for which they pay premium  $\text{prem}^R$ .

For simplicity we abstain from modeling insurance companies as profit maximizing firms and simply allow for a premium markup  $\omega$  to cover loading costs. Since insurance companies in the individual market screen customers by age and health, we impose a separate clearing condition for each age-health type  $(j, h)$  :

$$\begin{aligned} & (1 + \omega_{j,h}^{\text{IHI}}) \mu_j \int \left[ 1_{[in_j(x_{j,h})=1]} (1 - \gamma_j^{\text{IHI}}) p_m^{\text{IHI}} m_{j,h}(x_{j,h}) \right] d\Lambda(x_{j,-h}) \\ &= R \mu_{j-1} \int \left( 1_{[in_{j,h}(x_{j-1,h})=1]} \text{prem}^{\text{IHI}}(j-1, h) \right) d\Lambda(x_{j-1,-h}), \quad \text{for } j = \{2, \dots, J_1\} \end{aligned} \quad (5)$$

where  $x_{j,h}$  is the state vector not containing  $h$ . The clearing condition for the GHI company is

$$\begin{aligned} & (1 + \omega^{\text{GHI}}) \sum_{j=2}^{J_1} \mu_j \int \left[ 1_{[in_j(x_j)=2]} (1 - \gamma^{\text{GHI}}) p_m^{\text{GHI}} m_j(x_j) \right] d\Lambda(x_j) \\ &= R \sum_{j=1}^{J_1-1} \mu_j \int \left( 1_{[in_{j+1}(x_j)=2]} \text{prem}^{\text{GHI}} \right) d\Lambda(x_j), \end{aligned} \quad (6)$$

where  $\omega_{j,h}^{\text{IHI}}$  and  $\omega^{\text{GHI}}$  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 individuals buy the individual health insurance policy,  $1_{[in_j(x_j)=2]}$  is an indicator function equal to unity whenever individuals buy the group insurance policy,  $\text{prem}^{\text{IHI}}$  and  $\text{prem}^{\text{GHI}}$  are the insurance premiums,  $\gamma^{\text{IHI}}$  and  $\gamma^{\text{GHI}}$  are the coinsurance rates, and  $p_m^{\text{IHI}}$  and  $p_m^{\text{GHI}}$  are the prices for health care services for the two insurance types. The premium markups generate profits that are redistributed in equal amounts to all surviving individuals.

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

have to charge an average premium that clears the insurance companies' profit condition.<sup>7</sup>

## 2.6 Household Problem

**Workers.** Individuals at age  $j \leq J_1$  are workers. They are exposed to labor market risk. The state vector of a worker is defined as  $x_j = (a_j, h_{j-1}, \vartheta, \varepsilon_j^l, \varepsilon_j^h, \varepsilon_j^{GHI}, in_j)$ , where  $a_j$  is the capital stock at the beginning of the period,  $h_{j-1}$  is the health state at beginning of the period,  $\vartheta$  is the skill type,  $\varepsilon_j^l$  is a positive labor productivity shock,  $\varepsilon_j^h$  is a negative health shock,  $\varepsilon_j^{GHI}$  is the employer matching indicator that determines whether an individual is able to purchase GHI, and  $in_j$  is the insurance state at the beginning of the period. Note that,  $x_j \in D_W \equiv R_+ \times R_+ \times \{1, 3\} \times R_+ \times R_- \times \{0, 1\} \times \{0, 1, 2, 3\}$ .

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

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

*s.t.*

$$\begin{aligned} & (1 + \tau^C) c_j + (1 + g) a_{j+1} + o(m_j) + 1_{\{in_{j+1}=1\}} \text{prem}^{\text{IHI}}(j, h) + 1_{\{in_{j+1}=2\}} \text{prem}^{\text{GHI}} \\ & = y_j^W - \text{tax}_j + t_j^{\text{SI}}, \\ & 0 \leq a_{j+1}, 0 \leq l_j \leq 1, \text{ and (3)}, \end{aligned}$$

where

$$\begin{aligned} y_j^W &= e(\vartheta, h_j, \varepsilon_j^l) \times l_j \times w + R(a_j + t^{\text{Beq}}) + \text{profits}, \\ \text{tax}_j &= \tilde{\tau}(\tilde{y}_j^W) + \text{tax}_j^{\text{SS}} + \text{tax}_j^{\text{Mcare}}, \\ \tilde{y}_j^W &= y_j^W - a_j - t^{\text{Beq}} - 1_{[in_{j+1}=2]} \text{prem}^{\text{GHI}} - 0.5(\text{tax}_j^{\text{SS}} + \text{tax}_j^{\text{Med}}), \\ \text{tax}_j^{\text{SS}} &= \tau^{\text{Soc}} \times \min(\bar{y}_{\text{SS}}, e(\vartheta, h_j, \varepsilon_j^l) \times l_j \times w - 1_{[in_{j+1}=2]} \text{prem}^{\text{GHI}}), \\ \text{tax}_j^{\text{Mcare}} &= \tau^{\text{Mcare}} \times (e(\vartheta, h_j, \varepsilon_j^l) \times l_j \times w - 1_{[in_{j+1}=2]} \text{prem}^{\text{GHI}}), \\ t_j^{\text{SI}} &= \max[0, \underline{c} + o(m_j) + \text{tax}_j - y_j^W]. \end{aligned}$$

Variable  $\tau^C$  is a consumption tax rate,  $o(m_j)$  is out-of-pocket medical spending depending on insurance type,  $y_j^W$  is the sum of all income including labor, assets, bequests, and profits. Variable  $w$  is the market wage rate,  $R$  is the gross interest rate,  $t_j^{\text{Beq}}$  denotes accidental bequests,  $\text{tax}_j$  is total taxes paid, and  $t_j^{\text{SI}}$  is social insurance (e.g., food stamp programs). Taxable income is denoted  $\tilde{y}_j^W$  which is composed of wage income and interest income on assets, interest earned

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<sup>7</sup>Individual insurance contracts do distinguish individuals by age and health status but not by their respective health shock.

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 the Social Security paid on wage income below  $\bar{y}_{ss}$  (i.e., \$106,800 in 2010) and  $tax_j^{Mcare}$  for Medicare. Individuals can only buy IHI or GHI if they have sufficient funds to do so.<sup>8</sup> Individuals are eligible for Medicaid if their income  $\tilde{y}_j^W$  is below the federal poverty line  $y^{FPL}$ . The social insurance program  $t_j^{SI}$  guarantees a minimum consumption level  $\underline{c}$ . If social insurance is paid out then automatically  $a_{j+1} = 0$  and  $in_j = 3$  (Medicaid) so that social insurance cannot be used to finance savings and private health insurance.

**Retirees.** Old individuals,  $j > J_1$  are retired from the labor market and receive pension payments. The only remaining idiosyncratic shock for retirees is the health shock  $\varepsilon_j^h$ . Retirees are also eligible for Medicare and do not buy any more private health insurance. The state vector of a retiree therefore collapses to  $x_j = (a_j, h_{j-1}, \varepsilon_j^h) \in D_R \equiv R_+ \times R_+ \times R_-$  and the household problem is:

$$V(x_j) = \max_{\{c_j, m_j, a_{j+1}\}} \left\{ u(c_j, h_j) + \beta \pi_j E \left[ V(x_{j+1}) \mid \varepsilon_j^h \right] \right\} \quad (8)$$

*s.t.*

$$(1 + \tau^C) c_j + (1 + g) a_{j+1} + \gamma^{Mcare} \times p_m^{Mcare} \times m_j + \text{prem}^{Mcare} = R \left( a_j + t_j^{\text{Beq}} \right) - tax_j + t_j^{\text{Soc}} + t_j^{\text{SI}},$$

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

where

$$\begin{aligned} tax_j &= \tilde{\tau}(\tilde{y}_j^R), \\ \tilde{y}_j^R &= t_j^{\text{Soc}} + r \times (a_j + t_j^{\text{Beq}}) + \text{profits}, \\ t_j^{\text{SI}} &= \max \left[ 0, \underline{c} + \gamma^{Mcare} \times p_m^{Mcare} \times m_j + tax_j - R \left( a_j + t_j^{\text{Beq}} \right) - t_j^{\text{Soc}} \right]. \end{aligned}$$

Variable  $t_j^{\text{Soc}}$  are pension payments and  $\tilde{y}_j^R$  is total taxable income of a retired person. For each  $x_j \in D_j$  let  $\Lambda(x_j)$  denote the measure of age  $j$  individuals with  $x_j \in D_j$ . The fraction  $\mu_j \Lambda(x_j)$  then denotes the measure of age- $j$  individuals with  $x_j \in D_j$  with respect to the entire population of individuals in the economy.

## 2.7 Government

The government taxes consumption at rate  $\tau^C$  and income at a progressive tax rate. The government finances a social insurance program  $T^{\text{SI}}$  (e.g., foodstamps), Medicaid, as well as exogenous government consumption  $G$ . Government spending  $G$  is unproductive.

Since health insurance for the old in the model is a combination of Medicare and Medicaid, we make it part of the general budget constraint. The government uses a Medicare payroll tax

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<sup>8</sup>In their last working period, workers will not buy private insurance anymore because they become eligible for Medicare when retired.

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

$$\begin{aligned}
& G + \sum_{j=1}^J \mu_j \int t_j^{\text{SI}}(x_j) d\Lambda(x_j) + \overbrace{\sum_{j=2}^{J_1} \mu_j \int (1 - \gamma^{\text{MAid}}) p_m^{\text{MAid}} m_j(x_j) d\Lambda(x_j)}^{\text{Medicaid for workers}} \\
& + \underbrace{\sum_{j=J_1+1}^J \mu_j \int (1 - \gamma^{\text{Mcare}}) p_m^{\text{Mcare}} m_j(x_j) d\Lambda(x_j)}_{\text{Medicare/Medicaid for retirees}} \\
& = \sum_{j=1}^J \mu_j \int [\tau^C c(x_j) + \text{tax}_j(x_j)] d\Lambda(x_j) + \sum_{j=J_1+1}^J \mu_j \int \text{prem}^{\text{Mcare}}(x_j) d\Lambda(x_j) \\
& + \sum_{j=1}^{J_1} \mu_j \int \text{tax}_j^{\text{Mcare}}(x_j) d\Lambda(x_j),
\end{aligned} \tag{9}$$

where  $\gamma^{\text{MAid}}$  is the coinsurance rate of Medicaid,  $p_m^{\text{MAid}}$  is the price of medical services for individuals on Medicaid,  $\gamma^{\text{Mcare}}$  is the coinsurance rate for individuals on Medicare and  $p_m^{\text{Mcare}}$  is the price for medical services for the retired. In addition, the government runs a pay-as-you-go Social Security program which is self-financed via a payroll tax so that

$$\sum_{j=J_1+1}^J \mu_j \int t_j^{\text{Soc}}(x_j) d\Lambda(x_j) = \sum_{j=1}^{J_1} \mu_j \int \text{tax}_j^{\text{SS}}(x_j) d\Lambda(x_j) \tag{10}$$

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

$$\sum_{j=1}^{J_1} \mu_j \int t_j^{\text{Beq}}(x_j) d\Lambda(x_j) = \sum_{j=1}^J \int \tilde{\mu}_j a_j(x_j) d\Lambda(x_j), \tag{11}$$

where  $\mu_j$  and  $\tilde{\mu}_j$  denote the surviving and deceased population at age  $j$  in time  $t$ , respectively.

We provide a definition of equilibrium in Appendix Section 6.1.

### 3 Parameterization and Estimation

We present a brief description of the calibration of the model.<sup>9</sup> In our calibration strategy, we distinguish between two sets of parameters, *externally* selected parameters and *internally* calibrated parameters. *Externally* selected parameters are estimated independently from our model and are either based on our own estimates using data from the Medical Expenditure Panel Survey (MEPS) or estimates provided by other studies. We summarize these external parameters in Table 4. *Internal* parameters are calibrated so that model-generated data match a given set of targets from U.S. data. These parameters are presented in Table 5. Model

<sup>9</sup>More details of our calibration strategy and the solution algorithm can be found in Jung and Tran (2016).

generated data moments and target moments from U.S. data are juxtaposed in Table 6.

### 3.1 Technologies and Firms

We impose a Cobb-Douglas production technology using physical capital and labor as inputs for the final goods and the medical sector respectively:  $F(K, L) = AK^\alpha L^{1-\alpha}$  and  $F_m(K_m, L_m) = A_m K_m^{\alpha_m} L_m^{1-\alpha_m}$ . We set the capital share  $\alpha = 0.33$  and the annual capital depreciation rate at  $\delta = 0.1$ , which are both similar to standard values in the calibration literature (e.g., Kydland and Prescott (1982)). The capital share in production in the health care sector is lower at  $\alpha_m = 0.26$  which is based on Donahoe (2000) and our own calculations. We abstract from changes in production technologies or other possible causes of excess cost growth in the US health sector.

### 3.2 Demographics

One model period is defined as 5 years. We model households from age 20 to age 95 which results in  $J = 15$  periods. The annual conditional survival probabilities, supplied by CMS, are adjusted for period length.<sup>10</sup> 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.

### 3.3 Endowments and Preferences

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

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

where  $c$  is consumption,  $l$  is labor supply,  $\bar{l}_j$  is the age dependent fixed cost of working as in French (2005),  $m$  is the amount of medical services,  $\eta$  is the intensity parameter of consumption relative to leisure,  $\kappa$  is the intensity parameter of health services relative to consumption and leisure, and  $\sigma$  is the inverse of the intertemporal rate of substitution (or relative risk aversion parameter).

Fixed cost of working is set in order to match labor hours per age group. Parameter  $\sigma = 3.5$  and the time preference parameter  $\beta = 1.025$  to match the capital output ratio and the interest rate. The intensity parameter  $\eta$  is 0.43 to match the aggregate labor supply and  $\kappa$  is 0.89 to match the ratio between final goods consumption and medical consumption. In conjunction with the health productivity parameters  $\phi_j$  and  $\xi$  from expression (13) these preference weights also ensure that the model matches total health spending and the fraction of individuals with health insurance per age group.

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<sup>10</sup>CMS projections.

**Labor Productivity.** The effective quality of labor supplied by workers

$$e = e_j(\vartheta, h_j, \varepsilon^l) = (\overline{wage}_{j,\vartheta})^\chi \times \left( \exp\left(\frac{h_j - \bar{h}_{j,\vartheta}}{\bar{h}_{j,\vartheta}}\right) \right)^{1-\chi} \times \varepsilon^l \text{ for } j = \{1, \dots, J_1\}, \quad (12)$$

has two components. We model 4 permanent skill types  $\vartheta$  whose average hourly wages  $\overline{wage}_{j,\vartheta}$  are estimated from MEPS data and result in hump shaped lifecycle earnings profiles. The four permanent skill types are defined as average individual wages per wage quartile. In addition, the quality of labor can be influenced by health. Since variable  $\overline{wage}_{j,\vartheta}$  already reflects the productivity of the average health among the  $(j, \vartheta)$  types, the idiosyncratic health effect is measured as deviation from the average health  $\bar{h}_{j,\vartheta}$  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. Finally, the third component is an idiosyncratic labor productivity shock  $\varepsilon^l$  and is based on Storesletten, Telmer and Yaron (2004). We discretize this process into a five state Markov process following Tauchen (1986).

### 3.4 Health Capital

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

$$h_j = \mathcal{H}(m_j, h_{j-1}, \delta_j^h, \varepsilon_j^h) = \underbrace{\phi_j m_j^\xi}_{\text{Investment}} + \underbrace{(1 - \delta_j^h) h_{j-1}}_{\text{Trend}} + \underbrace{\varepsilon_j^h}_{\text{Disturbance}}. \quad (13)$$

The first component is a health production function that uses healthcare services  $m$  as inputs to produce new quantities of health capital. The second component represents natural health deterioration over time. Depreciation rate  $\delta_j^h$  is the per period health depreciation of an individual of age  $j$ . Finally, the third component represents a random but age-dependent health shock. 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.

We use the health index Short-Form 12 Version 2 ( $SF - 12v2$ ), an index that is widely used to assess health improvements after medical treatments in hospitals, as a measure of health capital.<sup>11</sup> The health capital grid in the model has a maximum health capital level of  $h_m^{max} = 3.5$ . All other health shock and health production parameters are then normalized with this value. The lower bound of the health grid  $h_m^{min}$  is calibrated. We allow for 15 health states on this grid.

The natural rate of health depreciation  $\delta_j^h$  per age group is calculated by focusing on indi-

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<sup>11</sup>The  $SF - 12v2$  includes twelve health measures of physical and mental health. See Ware, Kosinski and Keller (1996) for further details about this health index.

viduals 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 allows us to back out the depreciation rate from expression (13).

We then separate individuals into four risk groups by age-cohort and health capital quartile (e.g., Group 1 has health capital in the 25<sup>th</sup> percentile, 4 has health capital in the top quartile). We then assume that group 1 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 two experiences a “small” health shock, group 3 experiences a “moderate” health shock, and group 4 suffers from a “large” health shock. The average health capital per age group is denoted  $\{\bar{h}_{j,d}^{max} > \bar{h}_{j,d}^2 > \bar{h}_{j,d}^3 > \bar{h}_{j,d}^4\}$ . We next express the shock magnitudes as percentage deviations from the maximum health state, so that the shock vector is:  $\varepsilon_j^{h\%} = \left\{0, \frac{\bar{h}_{j,d}^2 - \bar{h}_{j,d}^{max}}{\bar{h}_{j,d}^{max}}, \frac{\bar{h}_{j,d}^3 - \bar{h}_{j,d}^{max}}{\bar{h}_{j,d}^{max}}, \frac{\bar{h}_{j,d}^4 - \bar{h}_{j,d}^{max}}{\bar{h}_{j,d}^{max}}\right\}$ . 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  $\Pi^h$  is calculated by counting how many individuals move across risk groups between two consecutive years in MEPS data where we also adjust for period length.

We are not aware of any precise estimates for parameters  $\phi_j$  and  $\xi$  in expression (3). A recent empirical contribution by Galama et al. (2012) finds weak evidence for decreasing returns to scale which implies  $\xi < 0$ . In our paper we allow  $\phi_j$  to be age-dependent and calibrate  $\xi$  and  $\phi_j$  together to match aggregate health expenditures and the medical expenditure profile over age (see Figure 4).

### 3.5 Insurance Sector

**Group Insurance Offer.** MEPS data contain information about whether individuals have received a group health insurance offer from their employer i.e., offer shock  $\varepsilon^{GHI} = \{0, 1\}$ .<sup>12</sup> The transition matrix  $\Pi^h$  with elements  $\Pr(\varepsilon_{j+1}^{GHI} | \varepsilon_j^{GHI}, \vartheta)$  depends on the permanent skill type  $\vartheta$ . We then count how many individuals with a GHI offer in year  $j$  are 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 set premiums according to a person’s age and health status. Premiums  $\text{prem}^{\text{IHI}}(j, h)$  will adjust to clear expression (5). Age and health dependent markup profits  $\omega_{j,h}^{\text{IHI}}$  are calibrated to match the IHI take-up rate by age group. Similarly,  $\text{prem}^{\text{GHI}}$  adjusts to clear expression (6) and the markup profit  $\omega^{\text{GHI}}$  is calibrated to match the insurance take-up rate of GHI. The coinsurance rate is defined as the fraction of out-of-pocket health expenditures over total health expenditures. Coinsurance rates therefore include deductibles and copayments. We use MEPS data to estimate

<sup>12</sup>We use OFFER31X, OFFER42X, and OFFER53X where the numbers 31, 42, and 53 refer to the interview round within the year (individuals are interviewed five times in two years). We assume that an individual was offered GHI when either one of the three variables indicates so.

coinsurance rates of  $\gamma^{\text{IHI}}$ ,  $\gamma^{\text{GHI}}$ ,  $\gamma^{\text{MAid}}$  and  $\gamma^{\text{Mcare}}$  for individual, group, Medicaid and Medicare insurance, respectively.

**Price of Medical Services.** The base price of medical services  $p_m$  is endogenous as we model the production of medical services via expression (2). According to Shatto and Clemens (2011) we know that reimbursement rates of Medicare and Medicaid are close to 70 percent of the price paid by private health insurance who themselves pay lower prices than the uninsured due to their market power (see Phelps (2003)). Various studies have found that uninsured individuals pay an average markup of 60 percent or more for prescription drugs as well as hospital services (see *Playing Fair, State Action to Lower Prescription Drug Prices* (2000), Brown (2006), Anderson (2007), Gruber and Rodriguez (2007)). Based on this information we pick the following markup factors for the five insurance types in the model:

$$[p_m^{\text{noIns}}, p_m^{\text{IHI}}, p_m^{\text{GHI}}, p_m^{\text{MAid}}, p_m^{\text{Mcare}}] = [0.70, 0.25, 0.10, 0.0, -0.10] \times p_m.$$

When the experiments are run, this relative pricing structure is held constant so that Medicaid and Medicare remain the programs that pay the lowest prices for medical services. Thus, providers are assumed to not being able to renegotiate reimbursement rates.

### 3.6 Government

**Pensions.** In the model, Social Security transfers are defined as a function of average labor income by skill type:  $t^{\text{Soc}}(\vartheta) = \Psi(\vartheta) \times w \times \bar{L}(\vartheta)$ , 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.

**Medicare and Medicaid.** According to data from CMS (Keehan et al. (2011)) the share of total Medicaid spending on individuals older than 65 is about 36 percent. Adding this amount to the total size of Medicare results in public health insurance payments to the old of 4.16 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.<sup>13</sup> The premium for Medicare is 2.11 percent of per capita GDP as in Jeske and Kitao (2009).

According to MEPS data, 9.2 percent of working age individuals are on some form of public health insurance. We therefore set the Medicaid eligibility level in the model to 70 percent of the FPL (i.e.,  $\text{FPL}_{\text{MAid}} = 0.7 \times \text{FPL}$ ), which is the average state eligibility level (Kaiser (2013)) and calibrate the asset test level,  $\bar{a}_{\text{MAid}}$ , to match the Medicaid take-up rate.<sup>14</sup> All model experiments that expand the Medicaid program are percentage expansions based on the model threshold,  $\text{FPL}_{\text{MAid}}$ . Setting the age dependent coinsurance rate for Medicaid  $\gamma_j^{\text{MAid}}$  to MEPS levels, Medicaid for workers is 0.5 percent of GDP in the model which underestimates Medicaid

<sup>13</sup>Our model cannot match the NIPA number because it is calibrated to MEPS which 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)).

<sup>14</sup>Compare Remler and Glied (2001) and Aizer (2003) for additional discussions of Medicaid take-up rates.



spending of workers in MEPS.<sup>15</sup>

**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 Social Security system is self-financed via a payroll tax of  $\tau^{SS} = 9.4$  percent similar to 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 tax  $\tau^{\text{Mcare}}$  is set to 2.9 percent and is not restricted by an upper limit (see *Social Security Update 2007* (2007)). Finally, the consumption tax rate is set to 5.0 percent (Mendoza, Razin and Tesar (1994) report 5.67 percent). Overall, the model results in total tax revenue of 21.8% of GDP and residual (unproductive) government consumption of 12 percent.

### 3.7 Model Performance

Figures 4, 5 and 6 and Table 6 in the Appendix show that the benchmark model matches the relevant and necessary elements of the MEPS data quite well.

**Medical Expenditures and Insurance Take-Up.** The model closely tracks average medical expenditures by age group (Figure 4, Panel 1) and reproduces the distribution of health expenditures quite well (Figure 4, Panel 2 and 3). Overall, the model generates total health expenditures of 12 percent of GDP. In addition, the model matches the insurance take-up percentages of IHI, GHI and Medicaid by age group (Figure 4, Panels 4, 5 and 6 respectively).

**Income, Consumption and Labor Supply.** The model provides a close fit to average household income over the lifecycle (Figure 5, Panel 1). Retired individuals decrease their consumption faster than in the data which is a result of the low asset holdings of the elderly (Panel 2). The model reproduces the hump-shaped patterns of asset holdings. However, the lack of a formal bequest motive in the model generates a shift in asset holdings from retirees to the working age population. Finally, the model provides a close fit for the lifecycle pattern of labor supply (Panel 3).

**Income Distribution and Macroeconomic Aggregates.** Figure 6 compares the model income and wage distribution to data from MEPS. The model matches the lower and upper tails of the income distribution with around 12 percent individuals with income below 133 percent of the Medicaid eligibility level (MaidFPL). Finally, Table 6 summarizes first moments that the model matches from aggregate MEPS, CMS, and National Income data.

## 4 Policy Experiments and Results

In this section we conduct a number of policy experiments to understand the effects of population aging on the health insurance system and the effects of the ACA reform in combination with

<sup>15</sup>Overall Medicaid spending in MEPS, workers and retirees, accounts for about 0.95 to 1.02 percent of GDP according to Sing et al. (2006), Keehan et al. (2011) and Bernard et al. (2012).

population aging.

#### 4.1 The Effects of Aging without the ACA Reform

We start from the benchmark economy in 2010 and adjust the survival probabilities in the model to match the demographic structure of the US population based on CMS/OACT population forecasts in Figure 7. We then fix the particular demographic structure in a given year and resolve the model for a new steady state leaving all other parameters at their benchmark levels.<sup>16</sup>

We report the main results in Table 1. In particular, the second column in Table 1 presents the steady state results when the population age structure is fixed to projections for 2020. We then repeat this procedure using the predicted demographic structures of the years 2030, 2040, 2050 and 2060 and repeatedly solve for steady states. “Updating” the age profile of the economy in this way essentially creates a larger share of older individuals in the model by appropriately increasing individual survival probabilities. This allows us to identify the long-run effects of having more and more older individuals in the economy without explicitly solving for the entire transition path from year 2010 to 2060 and beyond.

	<b>Benchmark: 2010</b>	[1] 2020	[2] 2030	[3] 2040	[4] 2050	[5] 2060
GDP:	100.00	105.50	101.73	101.20	103.86	105.27
Health capital: $H$	100.00	110.06	111.48	110.85	112.55	114.44
Consumption: $C$	100.00	104.18	97.30	95.17	97.33	97.90
Med. quantity: $M$	100.00	118.28	131.61	138.26	141.15	144.13
Med. spend.: $p_m M$	100.00	114.58	125.73	132.31	134.35	136.95
M. sp.: no Ins	100.00	69.87	80.90	100.27	85.66	84.96
M. sp.: IHI	100.00	170.05	131.16	98.14	131.46	134.75
M. sp.: GHI	100.00	106.41	98.16	95.45	99.84	100.56
M. sp.: Maid	100.00	110.78	118.26	121.58	119.21	120.93
M. sp.: Old	100.00	132.48	166.84	181.55	184.92	190.45
M. sp.: $p_m M / \text{GDP} \%$	12.69	13.78	15.68	16.59	16.41	16.50
IHI in %:	6.43	13.06	10.71	7.39	10.04	10.70
GHI in %:	61.02	62.56	60.05	56.96	59.29	59.27
Medicaid in %:	9.78	10.20	11.56	12.01	11.39	11.42
WorkersInsured %:	77.23	85.81	82.33	76.36	80.71	81.39
Medicare in %:	17.68	21.74	26.21	27.01	26.76	27.42
Consumption tax: $\tau^C \%$	5.00	7.21	10.59	12.10	12.08	12.43
Soc. sec. tax: $\tau_{SS} \%$	9.38	12.19	15.61	16.23	16.04	16.58
Medicare tax: $\tau_{Med} \%$	2.90	2.90	2.90	2.90	2.90	2.90

Table 1: **The Effects of Population Aging without ACA.**

Data in rows marked with % are either fractions in percent or tax rates in percent. The other rows are indexes with 2010 benchmark levels equal to 100. Each column presents steady-state results based on population profiles predicted for the given year.

When conducting this type of experiment, crucial assumptions about government policies

<sup>16</sup>We focus on the steady state analysis due to computational constraints. We are not able to solve for the full transition paths where all economic variables evolve endogenously with changing demographic structures.

need to be made. Medicare will grow if we assume that the policymaker does not change any of the parameters for Medicare and needs to be financed in a certain way. We need to make assumptions about how the government treats programs like Medicare/Medicaid in reaction to an increased share of elderly individuals in order to calculate a new steady state equilibrium. We proceed in the following way.

We fix the Medicare payroll tax at the benchmark level of 2.9 percent. As the number of the old cohorts increases, Medicare spending will grow. Since Medicare is part of the overall budget constraint (compare expression (9)) we adjust the consumption tax rate to cover the extra resources needed for Medicare/Medicaid of the old. Social Security, on the other hand, is self-financing in the benchmark model (compare expression (10)) so that an increase in Social Security spending (due to a larger share of retired cohorts) is met by an increase in the Social Security payroll tax  $\tau_{SS}$ .

**Health Insurance Coverage.** The results show a stable fraction of insured workers through 2060 at around 81 percent. The fraction of workers covered by IHI increases from 6.4 percent in 2010 to almost 11 percent in 2060. At the same time, the number of workers in GHI decreases. These alternate outcomes in IHI and GHI markets are caused by the difference in the premium adjustment process in the two markets. IHI market premiums are charged according to risk type (i.e., age and health capital in the model). The longer lifespans make health investments more desirable. As a consequence IHI markets grow as the various insurance pools (by risk type) become healthier overall so that premiums drop. In addition as health becomes more desirable, due to the longer lifespans, health insurance becomes more desirable as well as it helps to insure against large health shocks at higher ages that individuals are now more likely to experience. As a result, the take-up of IHI grows.

The situation is different for GHI markets. GHI do not price discriminate by age and health capital. As the population ages, the GHI pool is composed of more of the older, high-risk, types. GHI premiums will therefore increase. Despite the fact that insurance itself becomes more desirable overall, the increase in the GHI premiums causes some of the younger low risk types to drop out as can be seen in Panel [2] of Figure 8. Overall this leads to a slight decrease in the GHI take-up rates compared to the benchmark economy with 2010 demographic profiles. We also observe an increase in the fraction of workers insured by Medicaid from 9.8 percent with 2010 age profiles to 11.4 percent with 2060 age profiles. This increase has to do with the fact that the Medicaid eligibility threshold, i.e. the Federal Poverty Level, is pegged to median income in the model. Since median income increases so does the threshold. As a consequence more individuals become eligible for Medicaid. Finally, the growing fraction of retirees in the population generates an increase in the fraction of the population on Medicare from 18 percent with 2010 age structure up to 27 percent with the age structure predicted for 2040 and above.

There is a decrease, down to 76 percent, in the fraction of insured workers in 2040. The main reason for this is that the 2040 demographic profile weighs the population most heavily towards retirees (compare Figure 7). This has repercussions on the insurance markets of the working-age population. The change in the demographics of 2040 causes an unusually large

drop in IHI market share. As can be seen in Panel [1] of Figure 8, there is an expansion in the IHI take up rates between 25 and 40 ages but a decrease in the IHI take-up rates in the 40 to 55 age range. The overall reduction of the higher risk working population leads to the shrinking of the IHI market. In addition, the shrinking of the risk sharing pool of the working population causes an increase in GHI premiums. This effect leads to some of the younger low-risk workers dropping out of the GHI markets as depicted in Panel [2] of Figure 8. Overall, the participation in the GHI market decreases due to higher premiums. A fraction of the lower risk population that chooses to exit the GHI markets moves into Medicaid. This subsequently leads to a small extension of Medicaid coverage across all working ages.

**Health Spending.** The increased proportion of retirees, who face larger health shocks, in the future also generates a substantial increase in medical spending. Aggregating the entire sector we find that the level of health spending increases 15 percent with 2020 demographics and 37 percent with 2060 demographics, compared to 2010. Medical spending for the uninsured and Medicaid participation rates move roughly in line with the sector aggregate. Some of the largest effects of aging manifest in insurance premiums in private insurance markets which tend to fall as we recalculate equilibria using population projections that point further into the future. Premiums of IHI generally fall around 4 percent when compared to the benchmark.

**Fiscal Cost.** Aging results in large fiscal costs associated with age-related government spending programs. The tax implications are as expected. The Social Security tax rate increases from 9.4 percent with 2010 demographics to 16.6 percent with 2060 demographics in order to keep the PAYG Social Security system in balance. Overall, in response to the change in age-related government spending, total tax revenue as a share of GDP rises from 22 percent with 2010 demographics up to 30 percent with 2060 demographics if we keep the fraction of government consumption as percent of GDP at the benchmark level of 2010. This increase is predominantly driven by the growth of Medicare/Medicaid as well as Social Security.

**Aggregate Variables.** The aggregate implications of aging center around two main developments. First, the average worker is becoming older and is thus earning a higher level of labor income. Second, the older households also hold more assets which generates a larger capital stock for the production sector. The first feature dominates the results with 2020 demographics. We observe a 5.7 percent rise in capital stock used for non-medical services production, a 21 percent rise in capital stock used for medical services production, and a 6.4 percent rise in consumption. After 2020 the demographics continue to slide to a point where the growth in the number of retirees dominates the growth in the working age population. This can be seen by the slight drop in most of the aggregates between 2020 and 2040. Only the medical sector continues to increase, and this is due to the effects described earlier.

Aging has fairly standard effects on resource prices. The decline in the proportion of working age households restricts the supply of labor and increases wages. At the same time, older households hold more assets/capital which increases the supply of capital and decreases interest rates. We find that aging increases wages by about 1.5 percent and interest rates decrease when comparing the economy with 2010 demographics to steady states calculated based on 2060

demographics.

We also observe a large shift in the consumption patterns of households. Households reduce spending on general household consumption and significantly increase the consumption of medical services. This can lead to sizable growth effects. As individuals start to invest not only in physical capital but also into their health (capital) due to the longer lifespans, the large growth in the medical sector leads to an overall growth of GDP of over 5 percent with 2060 demographics. This growth channel is the result of modeling health investments as part of the household decision problem. This channel is therefore not operational in models that abstract from health investments or models that treat health care spending as exogenous shocks to the household budget.

## 4.2 The Effects of Aging in Combination with the Affordable Care Act

In March 2010 the Obama administration introduced a comprehensive health reform at the federal level via the *Affordable Care Act* (ACA). The reform is intended to be a serious effort toward solving the problem of the uninsured and promoting universal health insurance coverage. From an economic point of view, the most notable features of the ACA are those measures intended to correct partial market failures in the insurance markets which will allow more individuals to participate in the insurance markets. Intuitively, the reform has two key features: (i) an insurance mandate enforced by penalties and subsidies, and (ii) an expansion of Medicaid. The former is a market based approach that relies on new regulation of private health insurance markets, while the latter is a government based approach that relies on extending existing public insurance. Most of the reform is financed by taxes on higher income individuals which add an element of wealth redistribution.<sup>17</sup>

In this section we analyze the effects of population aging and the ACA reform. In order to calculate these effects, we first change the population profiles using projections from CMS/OACT for the depicted target years as in the previous section. We then fix the population structure for a specific target year and then re-solve for a new steady state including the ACA features discussed in the previous section for that target year. Table 2 provides the effects of aging under the ACA in levels, normalized to the benchmark values in 2010. This is similar to the normalization in Table 1 where we discussed aging without the ACA.

In order to isolate the net effects of the ACA reform in an aging economy we differentiate Table 1 from Table 2. That is, for each variable we present

$$\frac{(\text{Table 2: Aging \& ACA in year } t) - (\text{Table 1: Aging only in year } t)}{(\text{Table 1: Aging only in year } t)} \times 100$$

Table 3 presents the net difference between an aging economy with and without the ACA reform in terms of percent of the steady state outcomes without the reform for any given target year.

We focus our discussion on the differential impact of the ACA reported in Table 3.

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<sup>17</sup>See Appendix B for a detailed description of how the ACA is implemented in our model.

	<b>Bench:2010</b>	ACA - [1] 2020	[2] 2030	[3] 2040	[4] 2050	[5] 2060
GDP:	100.00	104.15	100.44	100.10	102.69	104.08
Health capital: $H$	100.00	110.22	111.63	110.99	112.68	114.57
Consumption: $C$	100.00	101.44	94.62	92.69	94.79	95.35
Med. quantity: $M$	100.00	120.37	133.37	139.90	142.86	145.79
Med. spend.: $p_m M$	100.00	113.20	123.63	129.09	131.92	134.52
M. sp.: no Ins	100.00	17.10	18.45	18.41	18.56	18.88
M. sp.: IHI	100.00	209.54	191.74	189.41	195.26	195.35
M. sp.: GHI	100.00	106.48	99.65	98.75	101.46	101.87
M. sp.: Maid	100.00	202.12	196.87	196.91	201.43	204.96
M. sp.: Old	100.00	132.49	166.86	181.62	185.00	190.51
M. sp.: $p_m M / \text{GDP} \%$	12.69	13.79	15.61	16.36	16.30	16.40
IHI in %:	6.43	21.71	21.14	20.98	21.05	20.94
GHI in %:	61.02	61.70	61.18	61.11	61.13	60.93
Medicaid in %:	9.78	16.10	16.92	17.12	16.99	17.20
WorkersInsured %:	77.23	99.52	99.24	99.22	99.17	99.07
Medicare in %:	17.68	21.74	26.21	27.01	26.76	27.42
Consumption tax: $\tau^C \%$	5.00	7.68	11.16	12.68	12.60	12.87
Soc. sec. tax: $\tau_{SS} \%$	9.38	12.25	15.69	16.35	16.14	16.70
Medicare tax: $\tau_{Med} \%$	2.90	2.90	2.90	2.90	2.90	2.90
Payroll tax: $\tau^V \%$	0.00	1.33	1.38	1.38	1.36	1.36

Table 2: **The Effects of Population Aging with ACA.**

Data in rows marked with % are either fractions in percent or tax rates in percent. The other rows are indexes with 2010 benchmark levels equal to 100. Each column presents steady-state results based on population profiles predicted for the given year.

**Health Insurance Coverage.** The long-run impact of the ACA changes quite significantly with the population age structure. Solving the model with the 2060 population-age structure, we find that the net impact of the ACA reform is a 18 percent rise in worker insurance take-up (see Table 3). We report the effects of aging on the insurance take-up rates with and without the ACA in Figure 10. The participation rates in specific types of insurance are significantly affected by the ACA. However, the impact (compare the results with the 2020 population-age structure) is almost entirely an increase in Medicaid and IHI participation. Meanwhile, participation in GHI is relatively constant around 60 percent over the duration of the simulation whether or not we introduce the ACA. This is in direct contrast to our earlier results in Section 4.1 where the effect of aging decreased the take-up rates of GHI because the insurance pool became older and therefore ultimately more risky. The ACA stabilizes the GHI market as it imposes a mandate that effectively eliminates the negative effects from adverse selection. We can also see this in Figure 9 where we show the health insurance take-up rates over the lifecycle for 2060 with and without the ACA. Panel [1] shows that the ACA induces more individuals to participate in the IHI markets. Panel [2] very clearly shows how the ACA keeps younger low-risk cohorts in the GHI markets (dotted line) compared to a situation without the ACA where some of the young low-risk types leave the GHI market (solid green line). The expansion of Medicaid to individuals

	% $\Delta$ ACA - [1] 2020	[2] 2030	[3] 2040	[4] 2050	[5] 2060
% $\Delta$ : GDP:	-1.29	-1.27	-1.09	-1.12	-1.14
% $\Delta$ : Health capital: $H$	0.15	0.13	0.12	0.12	0.12
% $\Delta$ : Consumption: $C$	-2.63	-2.75	-2.61	-2.61	-2.60
% $\Delta$ : Med. quantity: $M$	1.77	1.34	1.18	1.21	1.15
% $\Delta$ : Med. spend.: $p_m M$	-1.20	-1.66	-2.43	-1.81	-1.78
% $\Delta$ : M. sp.: no Ins	-75.53	-77.20	-81.63	-78.33	-77.78
% $\Delta$ : M. sp.: IHI	23.22	46.19	92.99	48.53	44.97
% $\Delta$ : M. sp.: GHI	0.07	1.51	3.45	1.62	1.30
% $\Delta$ : M. sp.: Maid	82.46	66.48	61.96	68.97	69.49
% $\Delta$ : M. sp.: Old	0.01	0.01	0.04	0.04	0.03
% $\Delta$ : M. sp.: $p_m M$ / GDP %	0.01	-0.06	-0.23	-0.11	-0.11
% $\Delta$ : IHI in %:	8.65	10.42	13.60	11.02	10.24
% $\Delta$ : GHI in %:	-0.85	1.13	4.16	1.84	1.66
% $\Delta$ : Medicaid in %:	5.91	5.36	5.11	5.60	5.78
% $\Delta$ : WorkersInsured %:	13.71	16.91	22.86	18.46	17.68
% $\Delta$ : Consumption tax: $\tau^C$ %	0.47	0.57	0.58	0.52	0.44
% $\Delta$ : Soc. sec. tax: $\tau_{SS}$ %	0.07	0.08	0.11	0.10	0.11
% $\Delta$ : Medicare tax: $\tau_{Med}$ %	0.0	0.0	0.0	0.0	0.0
% $\Delta$ : Payroll tax: $\tau^V$ %	1.33	1.38	1.38	1.36	1.36

Table 3: **The Net Effects of the ACA.**

Difference table expressed as percentage change of the no-ACA steady state to the ACA steady state for a given demographic structure. The numbers therefore represent the net effects of the ACA in the context of population aging as the comparison benchmark is not the 2010 steady state anymore but the steady state solved with the demographic structure of the target decade without the ACA.

with income below 133 percent of the  $FPL_{Maid}$  significantly increases the Medicaid take-up rates over the lifecycle in steady states calculated using the 2060 population profile. Overall, the ACA is able to stabilize the market shares of IHI, GHI and Medicaid for all demographic environments between 2010 and 2060 as can also be seen in Figure 10.

**Health Spending.** The effects of the ACA on healthcare spending vary greatly depending on the scope of the analysis. At the sector level, aggregate health spending drops by a small percentage. With 2020 demographics we observe a decrease of 2.9 percent compared to the case without the ACA. This decrease in health spending due to the ACA shrinks to about 1.8 with 2060 demographics. This decrease is brought on by the movement of uninsured individuals into insurance markets where prices paid for medical services are lower. Dis-aggregating medical spending further we find a substantial increase in spending from both Medicaid and IHI participants. The Medicaid increase is caused by expanding the eligibility income thresholds whereas the increase in IHI spending is triggered by shifts in spending types within IHI. The subsidies make it possible for high risk types to enter into IHI contracts so that overall spending of IHI types as a group is higher. As we switch into more distant population profiles, the increase in Medicaid spending stays relatively constant around 70 percent. At the same time IHI spending increases 109.6 percent with 2010 demographics and levels out at 45 percent with

2060 demographics.

On the flip side, we observe a large drop in the spending by the uninsured due to the ACA. Using the 2020 age structure the ACA decreases the medical spending of the uninsured by 83 percent. This of course has to do with the fact that the total number of uninsured workers is much lower under the ACA. Only 0.5 percent of workers are uninsured under the ACA with 2020 demographics (compare Table 2) as opposed to 14 percent of workers without the ACA and 2020 demographics (compare column 2 in Table 1). As the population ages, the ability of the ACA to insure additional workers diminishes. Using 2060 demographics we calculate that the ACA only adds a net of 18 percent of workers into insurance as opposed to 22.3 percent under 2010 demographics. In an economy with an older age structure more individuals are covered by Medicare, so that the effect of the ACA, which in our model primarily affects the working age cohorts, is weaker.

We calculate large changes in insurance premiums over time with the introduction of the ACA. Aging does not appear to play a big role in premium changes. We find IHI premiums increase about 20 percent and GHI premiums fall about 25 percent. These effects remain fairly constant across all simulations.

**Fiscal Cost.** The tax implications are as expected. Given a small drop in household income and no drop in health spending, we find a rise in the key tax rates that finance the health sector and government consumption. The introduction of the ACA is primarily financed by a payroll tax which is 1.25 percent with 2010 demographics and 1.4 percent with 2060 demographics. The consumption tax is the residual tax that clears the government budget and specifically finances the expansion of Medicare (due to the larger share of elderly in the economy) as well transfers that are tied to the overall size of GDP (e.g., government consumption is a fixed fraction of GDP). The consumption tax rate increases by 0.67 percent with 2010 demographics due to the negative growth effects of the ACA and subsequently increases to 12.9 percent (a net increase of 7.9 percent over the benchmark of 5 percent) with 2060 demographics when more tax revenue is required to fund Medicare. The other tax rates and sources of revenue remain relatively stable over the duration of the simulation compared to the results without the ACA reform.

**Aggregate Variables.** The ACA causes tax distortions which lead to decreases of GDP of 1.2 percent using the 2010 population-age structure. The effect on GDP is relatively stable as we “age” the cohorts (compare the 1.1 percent drop in column [5] of Table 3. This decrease in GDP is partly caused by a redistribution of capital between the two sectors. Capital in the non-medical sector decreases by about 1.0 percent across all simulations, whereas capital in the medical sector increases by about 2 percent. Human capital follows a similar trend. These changes in capital persist when solving the model with a higher percentage of older cohorts (i.e. 2020, 2030, etc.), though at muted levels. One of the explanations for this shift is the increase in the consumption tax rate which increases the relative price of consumption compared to medical consumption. In addition, the negative income effect at the aggregate level caused by the drop in GDP further lowers consumption. Overall, we observe a 2.6 percent drop in consumption due to the ACA that is not really affected by the share of the elderly. Given the decrease in



capital we find the fairly standard effects on resource prices. The results show small effects on labor hours. Thus, we find trivial changes in wages due to the ACA across all simulations.

## 5 Conclusion

In this paper we develop a realistic overlapping generations, general-equilibrium model with endogenous health capital and evaluate the effects of population aging on the U.S. health care system. The general equilibrium approach that we propose is essential to capture the dynamics between health accumulation, health spending, health insurance and the remaining portfolio decisions of U.S. households. Our results indicate that population aging leads to large increases in medical expenditures and induces workers to join IHI markets and Medicaid. The ACA reform reduces adverse selection problems that are prevalent in private health insurance markets and increases the fraction of insured workers further. A combination of population aging and the ACA reform causes large increases in the level of health expenditures, by 34.5 percent. However, this effect is almost entirely explained by aging. The ACA, on net, reduces overall health expenditures by as much as 2.9 percent, depending on the particular age structure that we use to solve the model.

Our model concentrates on selected components of the ACA. Important limitations to our modeling approach are discussed next. First, the model does not include a provision for differential treatment of the Medicaid expansion by U.S. states. In addition, some states have used a §1115 demonstration application approved by the Centers for Medicare and Medicaid Services to expand coverage of low income individuals using Medicaid funds as premium assistance for marketplace qualified health plans. Funding private insurance subsidies from Medicaid funds is not without controversy as arguments have been made that a direct expansion of Medicaid may be more cost effective (CBO, 2012). Our modeling framework can be extended to shed some light on this issue.

A further limitation of the current model is that the relative pricing structure of health care services is fixed exogenously. However, all prices do increase/decrease according to a base (production) price that the model generates endogenously. This modeling choice is an ad hoc approximation of differential pricing by providers with market power. Relaxing this assumption could shed some light on how competition in the health insurance market is affected by the ACA as well as aging. In addition, we currently do not account for the possibility that providers may refuse to treat Medicare/Medicaid patients if the prices that these programs pay decrease strongly. This assumption also drives the simulated decrease in overall medical expenditures triggered by the ACA. Allowing for profit maximization on the provider side is a possible extension that could address this issue. Finally, we do not model possible innovations in the healthcare sector that could lead to cost savings or improvements in health production. We leave these issues for future research.

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## 6 Appendix

### 6.1 Appendix A: Definition of Recursive Equilibrium

Given the transition probability matrices  $\{\Pi_j^l, \Pi_j^h, \Pi_j^{\text{GHI}}\}_{j=1}^J$ , the survival probabilities  $\{\pi_j\}_{j=1}^J$  and the exogenous government policies  $\{tax(x_j), \tau^C, \text{prem}^R, \tau^{SS}, \tau^{\text{Mcare}}\}_{j=1}^J$ , a competitive equilibrium is a collection of sequences of distributions  $\{\mu_j, \Lambda_j(x_j)\}_{j=1}^J$  of individual household decisions

$\{c_j(x_j), l_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^J$ , aggregate stocks of physical capital and effective labor services  $\{K, L, K_m, L_m\}$ , factor prices  $\{w, q, R, p_m\}$ , markups  $\{\omega^{\text{IHI}}, \omega^{\text{GHI}}, \nu^{\text{in}}\}$  and insurance premiums  $\{\text{prem}^{\text{GHI}}, \text{prem}^{\text{IHI}}(j, h)\}_{j=1}^J$  such that:

(a)  $\{c_j(x_j), l_j(x_j), a_{j+1}(x_j), m_j(x_j), in_{j+1}(x_j)\}_{j=1}^J$  solves the consumer problem (7) and (8),

(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

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

(d) the aggregate resource constraint holds

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

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

(f) the budget conditions of the insurance companies (5) and (6) 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.

## 6.2 Appendix B: The Model Implementation of the Affordable Care Act

We discuss the specific implementation of each of the elements of the reform that we have included into our model simulation.

**Medicaid Expansion.** The ACA expands the Medicaid eligibility threshold to 133 percent of the FPL and removes the asset test.<sup>18</sup> After the reform is implemented all individuals with incomes lower than 133 percent of the  $FPL_{\text{Maid}}$  will be enrolled in Medicaid.

**Subsidies.** 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 according to

$$subsidy_j = \begin{cases} \max\left(0, \text{prem}_j^{\text{IHI}} - 0.03\tilde{y}_j\right) & \text{if } 1.33 FPL_{\text{Maid}} \leq \tilde{y}_j < 1.5 FPL_{\text{Maid}}, \\ \max\left(0, \text{prem}_j^{\text{IHI}} - 0.04\tilde{y}_j\right) & \text{if } 1.5 FPL_{\text{Maid}} \leq \tilde{y}_j < 2.0 FPL_{\text{Maid}}, \\ \max\left(0, \text{prem}_j^{\text{IHI}} - 0.06\tilde{y}_j\right) & \text{if } 2.0 FPL_{\text{Maid}} \leq \tilde{y}_j < 2.5 FPL_{\text{Maid}}, \\ \max\left(0, \text{prem}_j^{\text{IHI}} - 0.08\tilde{y}_j\right) & \text{if } 2.5 FPL_{\text{Maid}} \leq \tilde{y}_j < 3.0 FPL_{\text{Maid}}, \\ \max\left(0, \text{prem}_j^{\text{IHI}} - 0.095\tilde{y}_j\right) & \text{if } 3.0 FPL_{\text{Maid}} \leq \tilde{y}_j < 4.0 FPL_{\text{Maid}}. \end{cases} \quad (14)$$

The subsidies ensure that the premiums that an individual pays at the health insurance exchange for IHI will not exceed a certain percentage of her taxable income  $\tilde{y}_j$  at age  $j$ .

**Penalties.** Private health insurance is compulsory for all workers. Workers who do not have health insurance face a tax penalty of 2.5 percent of their income which enters the budget constraint as<sup>19</sup>:

$$penalty_j = 1_{[ins_{j+1}=0]} \times 0.025 \times \tilde{y}_j,$$

where  $1_{[ins_j=0]}$  is an indicator variable equal to one if the household has no health insurance. We abstract from employer penalties in the model.

**Screening.** The reform puts new restrictions on the price setting and screening procedures of insurance companies. In the model we do not allow for screening in the IHI market anymore, so that the price setting in group and individual markets is now identical except for the fact that group insurance premiums are still tax deductible.

**Financing.** The reform bill is financed by increases in payroll taxes for individuals with incomes higher than \$200,000 per year (or \$250,000 for families).<sup>20</sup> In the model we use a flat income tax on individuals with incomes higher than \$200,000.

<sup>18</sup>The model does not use actual the FPL to assess Medicaid eligibility in the benchmark (pre-reform) economy as this would grossly overstate the percentage of the population currently on Medicaid as discussed in the calibration section. Instead, we calculate a ‘‘Medicaid eligibility’’ federal poverty level,  $FPL_{\text{Maid}}$ , to match the percent of the population that is currently on Medicaid according to MEPS data.

<sup>19</sup>We do not model exemptions from the penalty for certain low income and high risk groups.

<sup>20</sup>We do not account for the various other sources that are used to generate additional revenue in order to pay for the reform (e.g., funds from Social Security, cuts to Medicare, funds from student loans, taxes on ‘‘Cadillac’’ insurances, taxes on medical devices and others).

Summarizing, we can write the new household budget constraint with the ACA as

$$(1 + \tau^C) c_j + (1 + g) a_{j+1} + o^W(m_j) + 1_{\{in_{j+1}=1\}} \text{prem}^{\text{IHI}} + 1_{\{in_{j+1}=2\}} \text{prem}^{\text{GHI}} \\ = y_j + t_j^{\text{SI}} - \text{tax}_j - 1_{\{in_{j+1}=0\}} \text{penalty}_j + 1_{\{in_{j+1}=1\}} \text{subsidy}_j - \text{tax}_j^{\text{ACA}}.$$

### 6.3 Appendix C: Tables and Figures

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	$\pi_j$	CMS 2010
- Health Shocks	Technical Appendix	MEPS 1999/2009
- Health transition prob.	Technical Appendix	MEPS 1999/2009
- Productivity shocks	see Section 3	MEPS 1999/2009
- Productivity transition prob.	Technical Appendix	MEPS 1999/2009
- Group ins. transition prob.	Technical Appendix	MEPS 1999/2009
- Price for medical care for uninsured	$\nu^{\text{noIns}} = 0.7$	MEPS 1999/2009
- $M$ price markup for IHI insured	$\nu^{\text{IHI}} = 0.25$	Shatto and Clemens (2011)
- $M$ price markup for GHI insured	$\nu^{\text{GHI}} = 0.1$	Shatto and Clemens (2011)
- $M$ price markup for Medicaid	$\nu^{\text{Maid}} = 0.0$	Shatto and Clemens (2011)
- $M$ price markup for Medicare	$\nu^{\text{Mcare}} = -0.1$	Shatto and Clemens (2011)
- Coinsurance rate: IHI in %	$\gamma_j^{\text{IHI}} \in [22, 46, 48, 49, 50, 53, 52, 50]$	MEPS 1999/2009
- Coinsurance rate: GHI in %	$\gamma_j^{\text{GHI}} \in [33, 33, 33, 34, 36, 36, 45, 50]$	MEPS 1999/2009
- Medicare premiums/GDP	2.11%	Jeske and Kitao (2010)
- Medicaid coinsurance rate in %	$\gamma_j^{\text{Maid}} \in [11, 14, 17, 16, 17, 18, 20, 22]$	Center for Medicare and Medicaid Services (2005)
- Public coinsurance rate retired in %	$\gamma^R = 20$	Center for Medicare and Medicaid Services (2005)

Table 4: **External Parameters.**

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



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 $\tau^{soc}$	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 5: **Internal Parameters.**

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

Moments	Model	Data	Source	Nr.M.
- Medical expenses HH income	17.6%	17.07%	CMS communication	1
- Workers IHI	5.6%	7.2%	MEPS 1999/2009	1
- Workers GHI	61.1%	62.2%	MEPS 1999/2009	1
- Workers Medicaid	9.6%	9.2%	MEPS 1999/2009	1
- Capital output ratio: $K/Y$	2.7	2.6 – 3	NIPA	1
- Interest rate: $R$	4.2%	4%	NIPA	1
- Size of Social Security/ $Y$	5.9%	5%	OMB 2008	1
- Size of Medicare/ $Y$	3.1%	2.5 – 3.1%	U.S. Department of Health (2007)	1
- Payroll tax Social Security: $\tau^{Soc}$	9.4%	10 – 12%	IRS	1
- Consumption tax: $\tau^C$	5.0%	5.7%	Mendoza et al. (1994)	1
- Payroll tax Medicare: $\tau^{Med}$	2.9%	1.5 – 2.9%	SocialSecurity Update (2007)	1
- Medical spend. profile	Figure 4	Figure 4	MEPS 1999/2009	15
- IHI insurance take-up profile	Figure 4	Figure 4	MEPS 1999/2009	8
Total number of moments				34

Table 6: **Matched Data Moments.**

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

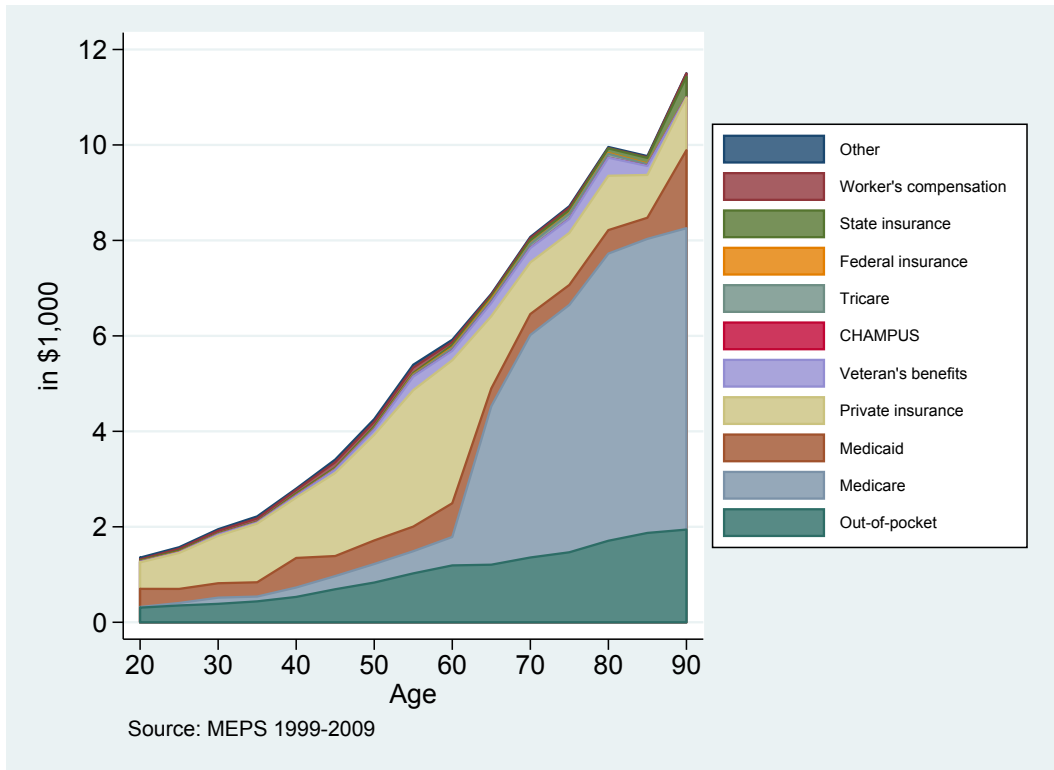


Figure 1: **Health Spending over the Lifecycle by Financing Source.**

We present average health spending per 5-year age cohort based on MEPS 1999-2009. We break down health spending by spending source. Spending values are inflation adjusted to 2009-dollar values.

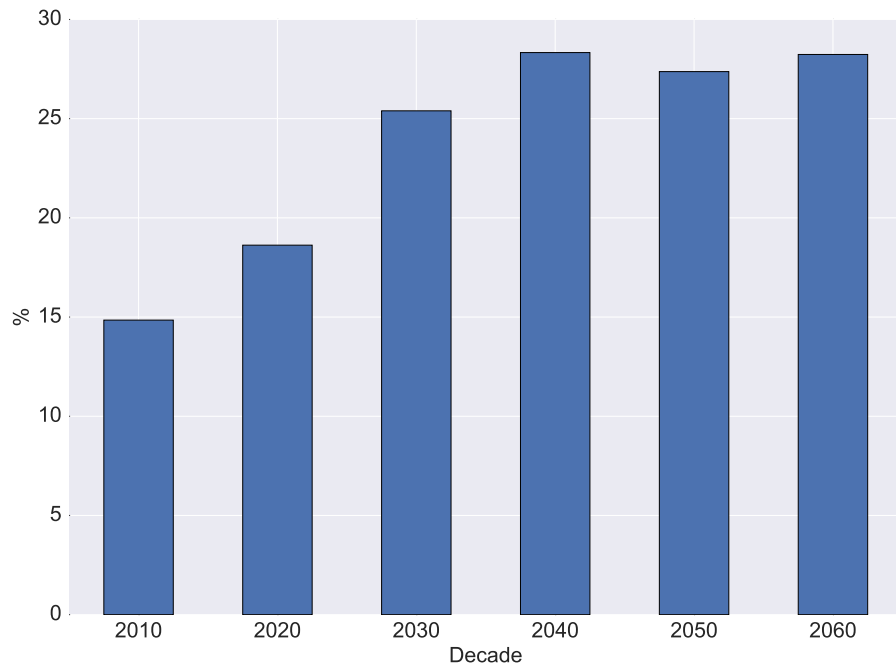


Figure 2: **Old Age Dependency Ratios over Time.** (Source: CMS/OACT)  
 The old age dependency ratio is defined as the population older than 65 divided by the workforce of 20-64 year olds.

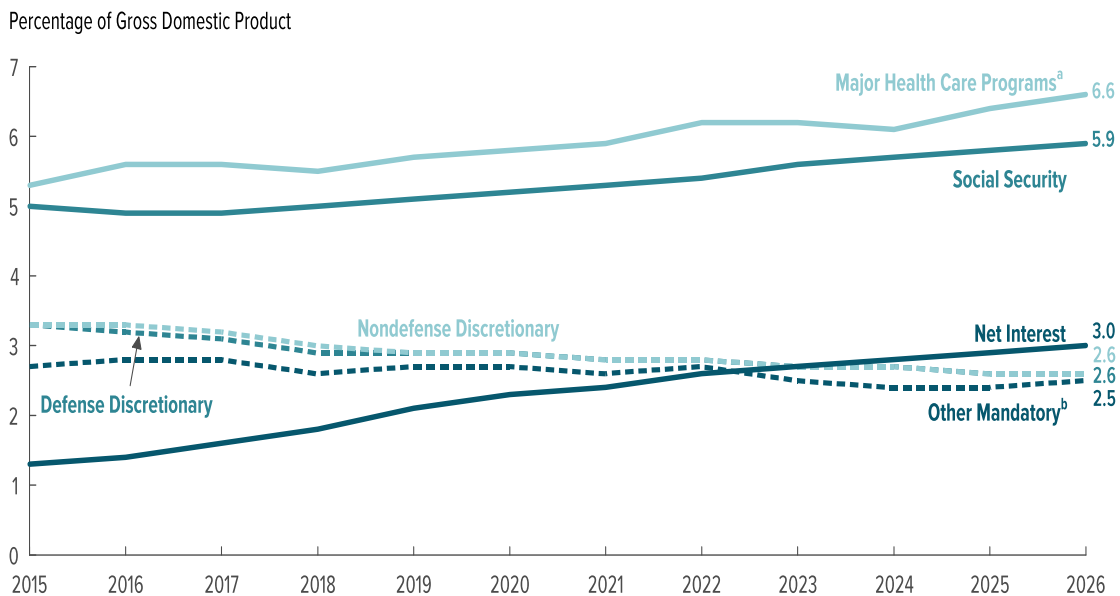


Figure 3: **CBO Projections of Government Spending.** (Source:CBO (2016))  
 a. Consists of Medicare, Medicaid, the Children’s Health Insurance Program and subsidies for health insurance purchased through exchanges and related spending.  
 b. All mandatory spending other than that for the major health care programs and Social Security.

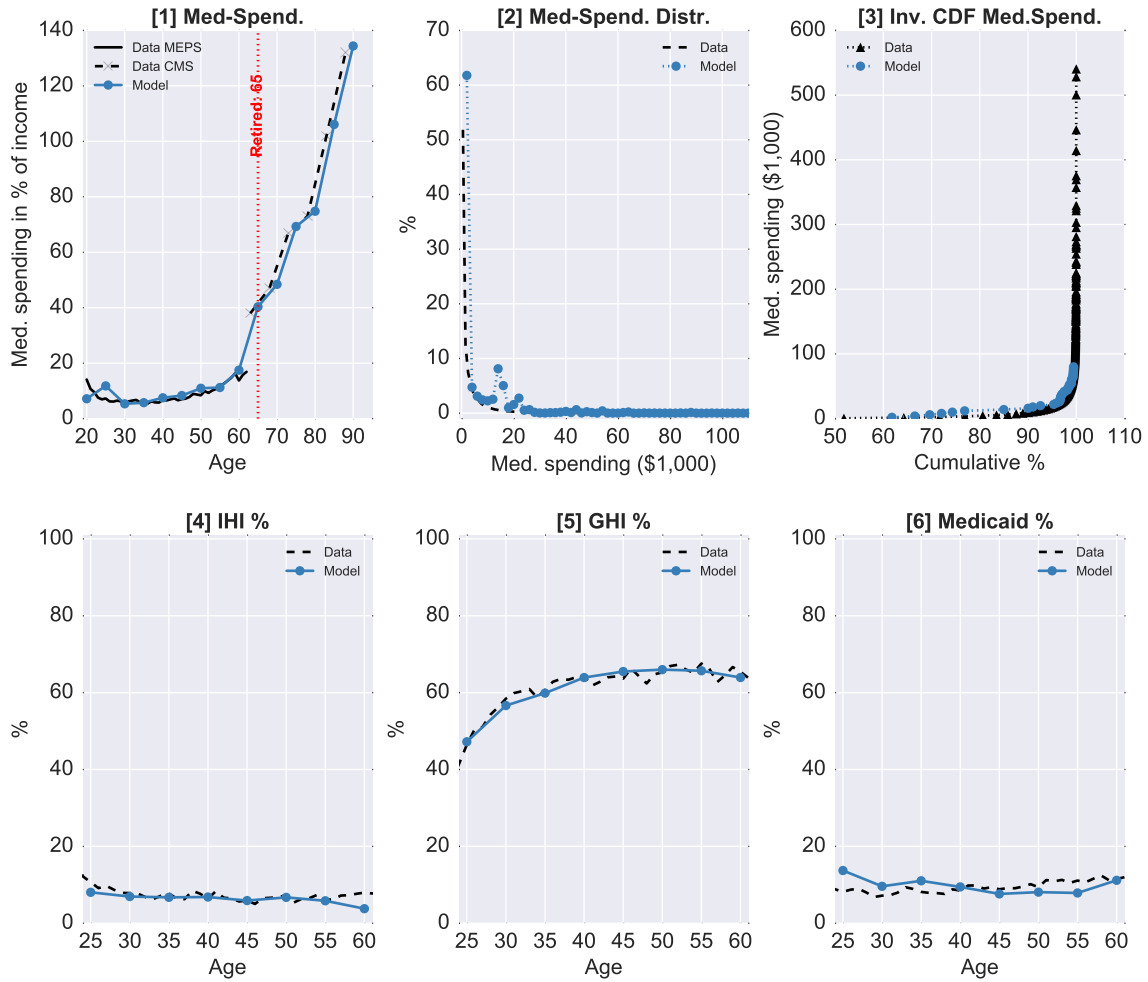


Figure 4: **Moment Matching using MEPS Data 2000-2009.**

Blue lines are model generated data moments and black dotted lines are MEPS data. Panel [1] depicts the percentage of average medical spending as percent of total household income of a 5-year age-cohort. Panel [2] shows the health expenditure distribution of heads of households from MEPS vs. model generated health spending. Panels [3-4] show the fraction of individual, group and Medicaid insurance for the working age population.

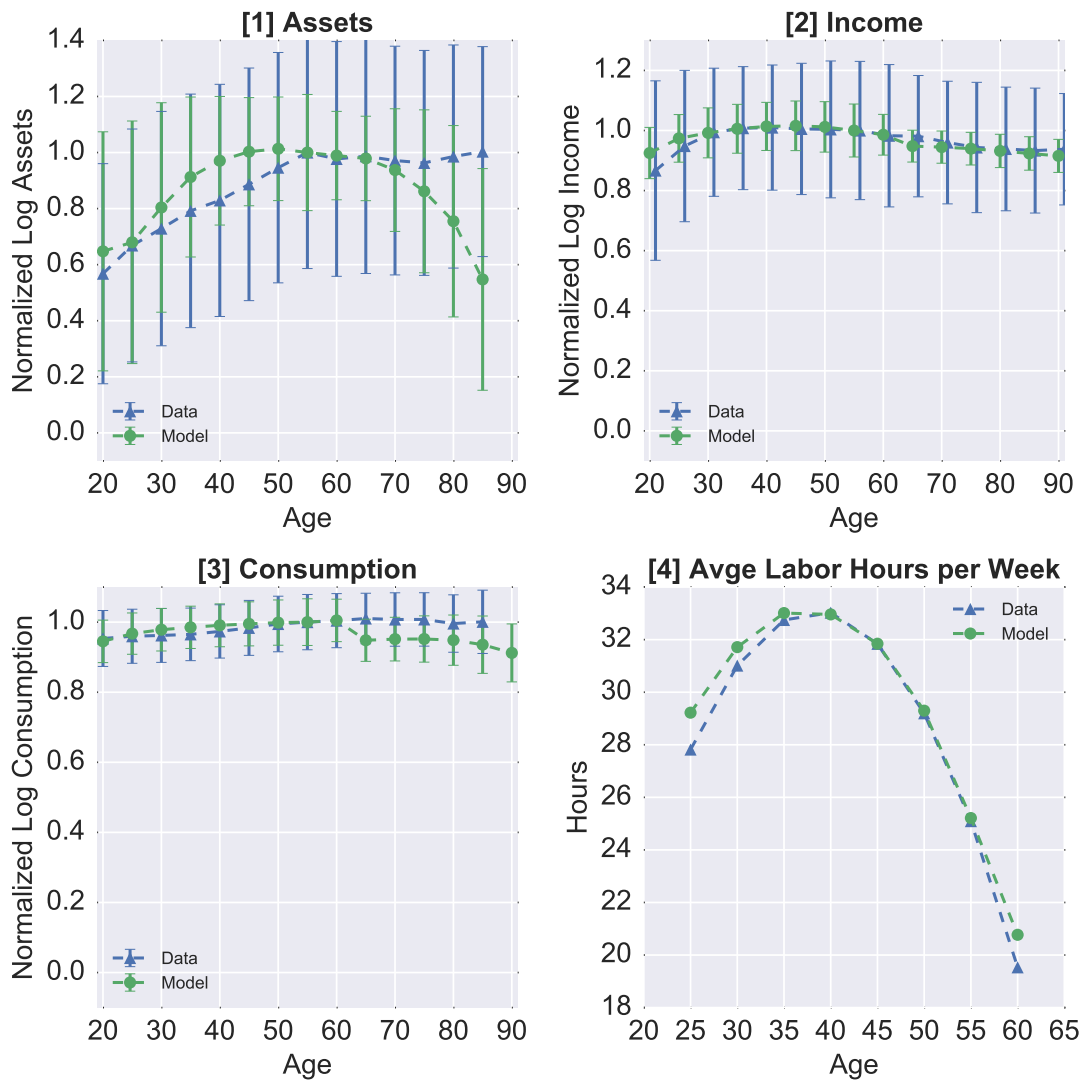


Figure 5: **Model vs. Data.**

Average lifecycle profiles normalized to values from the age 55 cohort. The vertical lines in panels [1]-[3] are standard deviations of log-values. Asset data in Panel [1] is from PSID 1984-2007. Income data for panel [2] is from MEPS 2000-2009. Consumption data in panel [3] is from CEX 1980-2007. Data on weekly work-hours by age-cohort in panel [4] is from CPS 1999-2007.



Figure 6: **Moment Matching using MEPS 2000-2009.**  
 Blue dots are model generated data moments and green dots lines are from PSID 1984-2007.

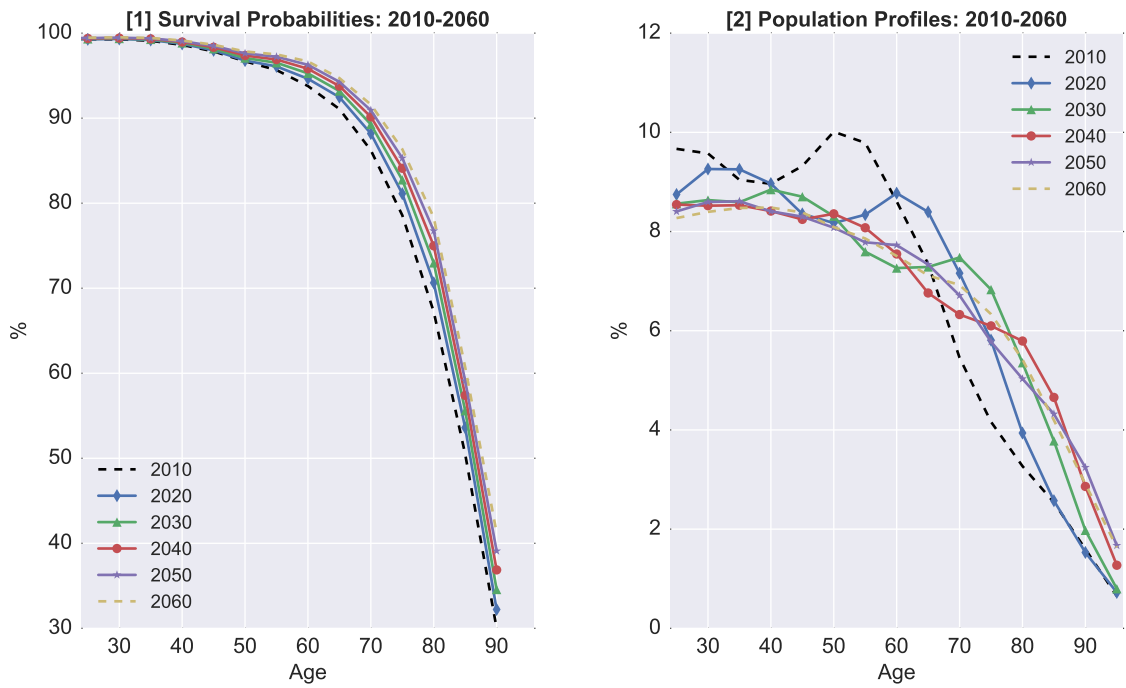


Figure 7: **Survival Probabilities and Cohort Sizes from 2010-2060.**

The average projected survival probabilities for each decade from 2010-2060 in panel [1] and the relative cohort sizes for each decade from 2010-2060 in panel [2] were both attained via personal communication from CMS/OACT. We observe that both survival probabilities and the fraction of older cohorts increase over time.

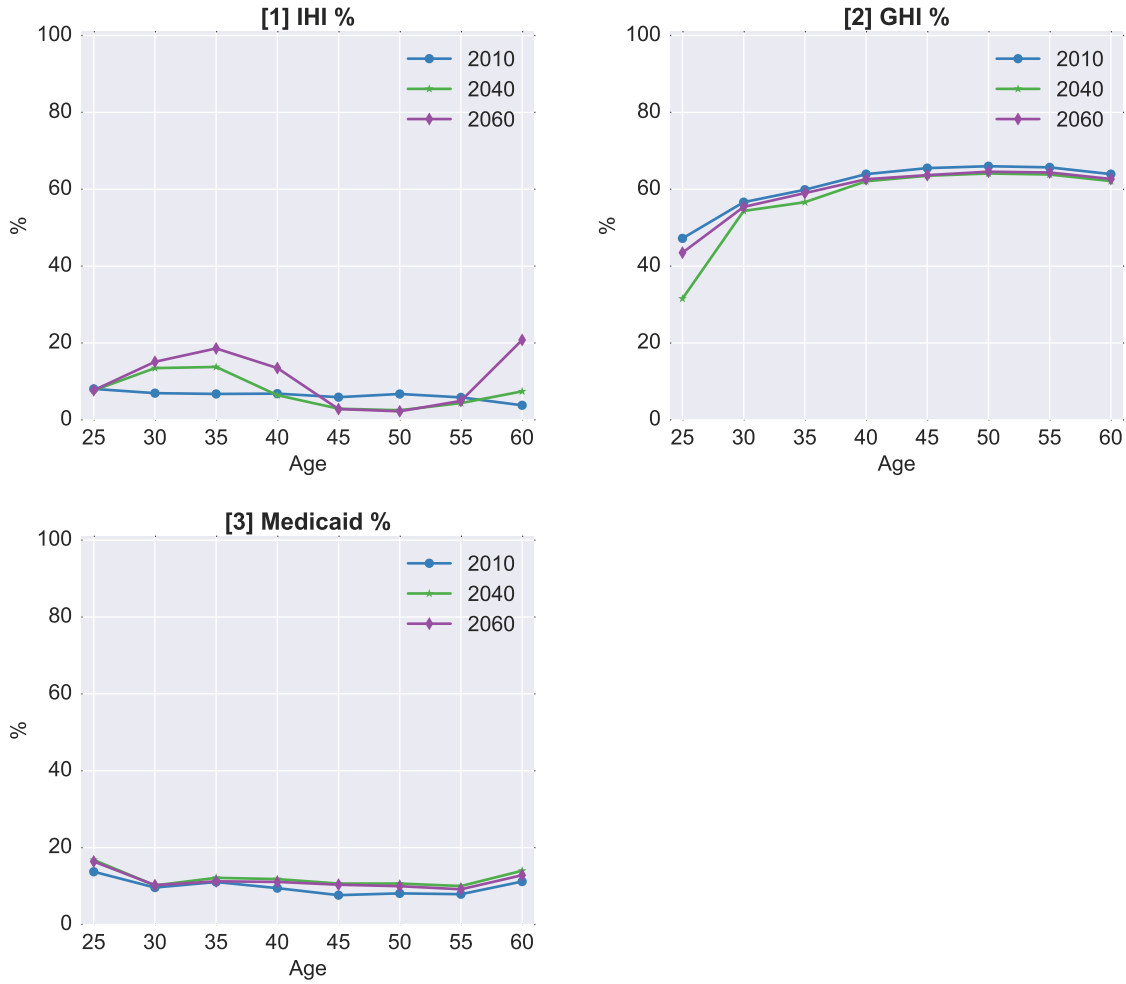
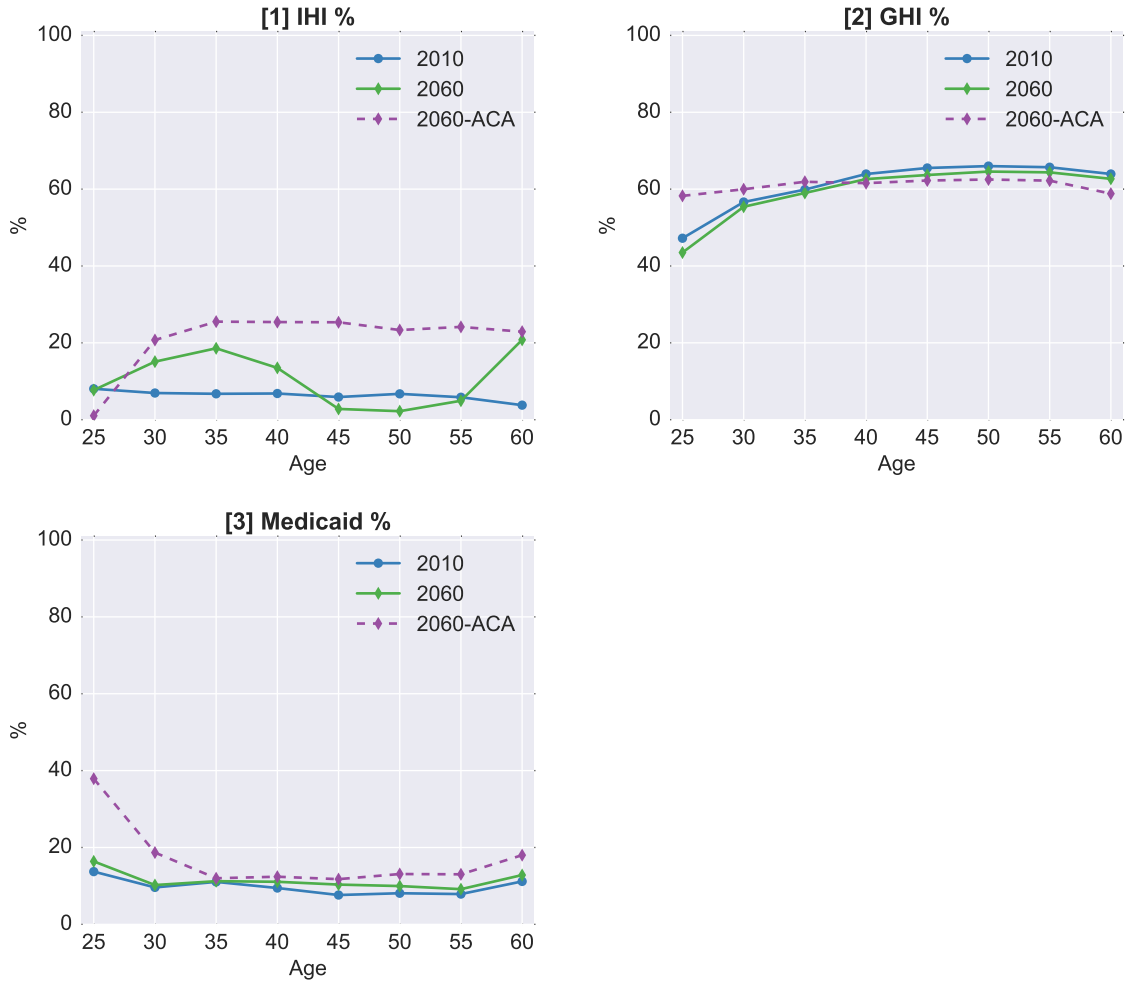


Figure 8: **Insurance Take-Up: Aging.**

We present insurance take-up rates over the lifecycle by insurance type using population profiles from 2010, 2040 and 2060. Panel [1] presents the insurance take-up rates of individual health insurance (IHI), panel [2] present the insurance take-up rates for group health insurance (GHI) and panel [3] presents the take-up rates for Medicaid.





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Figure 9: **Insurance Take-Up: Aging + ACA.**

We present insurance take-up rates over the lifecycle by insurance type using population profiles from 2010 and 2060. In addition, we present the take-up rates with 2060 profiles with the ACA fully implemented (dotted line). Panel [1] presents the insurance take-up rates of individual health insurance (IHI), panel [2] present the insurance take-up rates for group health insurance (GHI) and panel [3] presents the take-up rates for Medicaid.

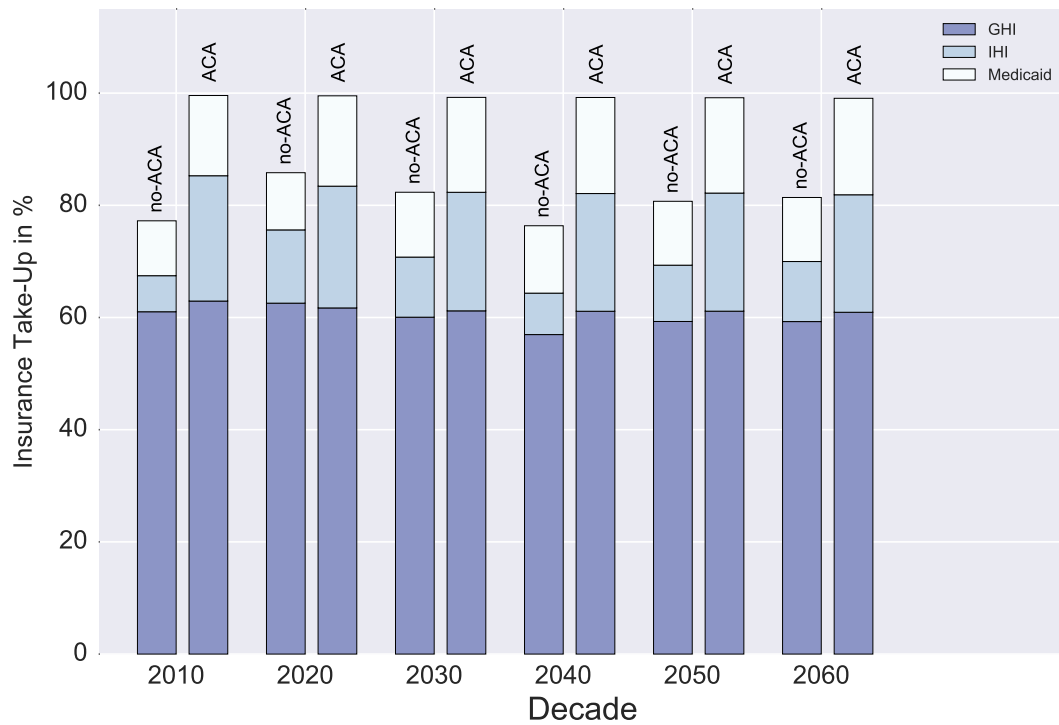


Figure 10: **Insurance Take-up of Workers by Insurance Type over Time.**

We present the decomposition of insurance coverage type of workers based on different demographic structures using projections of the US population by CMS/OACT. The insurance take-up rates are steady state results that we calculate holding the demographic structure fixed at the projected population levels for each decade.