Health Risk, Insurance and Optimal Progressive Income Taxation

by Juergen Jung and Chung Tran

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Health Risk, Insurance and Optimal Progressive Income Taxation

Juergen Jung†
Towson University

Chung Tran‡
Australian National University

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Abstract

We study the optimal progressivity of personal income taxes in a general equilibrium overlapping generations model where individuals are exposed to idiosyncratic shocks to health and labor productivity over the lifecycle. Our results—based on a calibration to the US economy—indicate that the presence of health risk and health insurance has a strong effect on the optimal level of tax progressivity. Given the existing non-universal health insurance system in the US, the optimal income tax system is highly progressive in order to provide a sufficient amount of redistribution and social insurance to unhealthy low income individuals. The total welfare gain from optimizing the progressivity level is 5.6 percent in compensating lifetime consumption. The introduction of more comprehensive health insurance systems, such as Medicare for all, leads to large decreases in the optimal level of tax progressivity. When health expenditure risk is not modeled our framework exhibits an optimal income tax system similar to prior literature that abstracts from health risk. These findings highlight the importance of accounting for the unique characteristics of health and health insurance policies when designing optimal income taxes.

JEL: E62, H24, I13

Keywords: Health and income risks, Inequality, Social insurance, Tax progressivity, Suits index, Optimal taxation, General equilibrium.

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†Department of Economics, Towson University, U.S.A (e-mail: jjung@towson.edu)
‡Research School of Economics, Australian National University, Australia (e-mail: chung.tran@anu.edu.au)
1 Introduction

The US income tax system is progressive and plays a key role in shaping the income distribution across households and over time. The optimal taxation literature has investigated optimal progressivity levels in heterogeneous agent models with income uncertainty and incomplete markets (e.g., Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017)). In particular, Heathcote, Storesletten and Violante (2017) find that in their model the optimal income tax system is less progressive than the existing system in the US. What is currently missing from the discussion on optimal tax progressivity is the consideration of health risk and healthy insurance, which have both been recently identified as a prominent source of risk and lifecycle inequality (e.g., Capatina (2015) and De Nardi, Pashchenko and Porapakkarm (2018)).

The purpose of this paper is to revisit the optimal income tax progressivity while taking into account the important effects of health accumulation, health risk, and health insurance.

Specifically, we quantify the optimal level of tax progressivity, within a parametric class, in an incomplete market model where individuals are exposed to both idiosyncratic income and health risks over the lifecycle. We find that the presence of these two types of idiosyncratic risk in combination with incomplete insurance markets strongly affect the redistribution and social insurance role of the progressive income tax system. In an environment with non-universal health insurance, such as the US health insurance system, the optimal income tax system needs to be highly progressive in order to provide a sufficient level of redistribution to unhealthy low income individuals who have limited access to health insurance. More inclusive health insurance systems, such as Medicare for all, lead to large decreases in the optimal level of income tax progressivity. These findings highlight the importance of accounting for health risk and health insurance when characterizing the optimal progressive income tax code.

Our analysis is based on an overlapping generations economy with heterogeneous agents that generates a distribution of income, consumption, health expenditure, and health insurance take-up rates similar to observable US data. Our model has the key ingredients of heterogeneous agent models such as Bewley (1986), Huggett (1993) and Aiyagari (1994) and additionally integrates the Grossman (1972) health capital model. In our Bewley-Grossman framework, health care spending, health accumulation, and buying health insurance are part of the household decision making process. Health affects household consumption through direct and indirect channels. First, the utility of consumption itself is affected by the health status of

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1Our empirical analysis of the Medical Expenditure Panel Survey data indicates similar stylized facts. Panel 1 of Figure 1 shows the coefficient of variation of income is fairly stable before age sixty and rises slightly after retirement; meanwhile, the coefficient for health expenditure is four to five times larger and varies sharply over the lifecycle. Panel 2 indicates that there is a significant gap between the income profile between the two groups. Unhealthy/sick individuals exhibit a much lower income path over the lifecycle. In addition, unhealthy individuals have to devote a larger fraction of their income to health expenditure as can be seen in Panels 3 and 4.

2We model the essential features of the US mixed public and private health insurance system before the Affordable Care Act. Public insurance includes Medicare for the retired population and Medicaid for the poor. The majority of working Americans rely on private health insurance with around 60 percent buying group health insurance via their employers and another 6 percent buying individual health insurance directly from insurance companies. About 50 million Americans did not have health insurance in 2010. Panels 1 and 2 of Figure 4 display the financing sources of health expenditures and the insurance take-up rates over the lifecycle, respectively.
an individual which acts as a utility shifter. Second, health is a co-determinant of labor earnings and therefore affects the household’s ability to earn income. Third, smoothing health over the lifecycle requires healthcare spending, which subsequently reduces funds available for purchasing final consumption goods. The simultaneous presence of both income and health risks shapes the distributions of income, wealth and consumption. In this incomplete markets setting, progressive income taxes and public health insurance serve as policy tools to provide social insurance against income and health risks.

We approximate the US progressive income tax code with a two-parameter polynomial function following Benabou (2002) and determine the optimal progressive income tax system using ex-ante expected utility of a newborn agent in a stationary equilibrium as welfare criterion.\(^3\) In our setting, progressive taxes play a positive role in achieving a more equal distribution of income and welfare as they provide insurance against being born as a low-ability/unhealthy type. They also provide a partial insurance against idiosyncratic income and health shocks over the lifecycle. On the other hand, progressive income taxes distort labor supply and investments in physical capital and health. The optimal level of tax progressivity therefore depends on the trade-offs between welfare gains from insurance and redistribution and the welfare losses from tax distortions.

We calibrate the benchmark model to US data from 2010 and incorporate the lifecycle patterns of shocks to income and health. The model matches US labor supply, asset holdings, consumption, health expenditures, and health insurance take-up rates over the lifecycle. We next use the model to quantitatively explore the optimal level of income tax progressivity.

First, the optimal income tax system is highly progressive and comprises a tax break for income up to $36,400 followed by a jump in the marginal tax rate to 25 percent. The marginal tax rate then increases further to over 40 percent for income above $100,000 and to over 50 percent for income above $200,000. The large zero-tax bracket at the low end of the income distribution is mainly driven by the high demand for social insurance of the low income, unhealthy population who is left out or has limited access to the US health insurance system. The high tax rates at the upper end of the income distribution are required to meet the financing needs of government spending and transfer programs. The optimal tax system in our model has much higher marginal tax rates than the optimal tax systems reported in the literature that largely abstract from modeling health risk and health insurance (e.g., Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017)).

In order to compare the progressivity levels of the different income tax regimes, we follow Suits (1977) and compute a tax progressivity (Suits) index which is a Gini coefficient for income tax contributions by income.\(^4\) The US income tax system in the benchmark model has a Suits index of 0.17. The optimized US tax system is much more progressive with a Suits index of 0.54 which reduces income inequality

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\(^3\)This functional form has two appealing features. First, it provides a close approximation of the US income tax code as demonstrated by Heathcote, Storesletten and Violante (2017). Second, it provides a flexible functional form, nesting a proportional income tax system and a wide variety of both progressive and regressive income tax systems. The two parameters make numerical optimization over the parametric income tax function feasible.

\(^4\)The Suits index varies from +1 (most progressive, the entire tax burden falls on households of the highest income bracket), through 0 for a proportional tax, to −1 (most regressive, the entire tax burden falls on households of the lowest income bracket).
significantly. The after-tax-income Gini coefficient decreases from 0.38 in the benchmark economy to 0.31 after the progressivity level is optimized. Large welfare gains of 5.5 percent of compensating lifetime consumption at the aggregate level are realized when switching the benchmark progressivity level to the optimal progressivity level. This positive welfare outcome is mainly driven by large welfare gains of low income individuals that dominate the welfare losses of the higher income groups.

The mechanisms behind these results are as follows. In an incomplete markets setting with income and health risks, the progressive income tax system is an important policy instrument that redistributes income and supplements the social health insurance system. The latter is a new channel that is missing in prior studies that abstract from modeling health risk and health insurance. In our model, low income individuals are more likely to have poor health than high income individuals because in addition to lacking funds for health investments, they also do not have adequate access to health insurance through the mixed public/private US health insurance system. Many of these individuals are not poor enough to qualify for Medicaid and not rich enough to buy private health insurance on their own or through their employers. This “poor working class” benefits strongly from the optimized tax system in terms of welfare. The zero-tax at the lower end of the income distribution allows these individuals to not only increase their non-medical consumption but also to invest more in health. Indeed, the medical spending of the uninsured increases under the optimal income tax system. These findings emphasize the importance of accounting for health risk and the institutional features of the healthcare system, when studying the optimal design of a progressive income tax system.

In order to isolate the impact of health risk on household heterogeneity and the demand for social health insurance, we consider an economy where health risk is removed from the model. This reduced model is very similar to the models used in previous studies where income shocks are the sole source of risk and agent heterogeneity. Our results indicate that the optimal income tax system with a Suits index of 0.14 is less progressive than the US status quo tax system with a Suits index of 0.17. This finding—the optimal system exhibiting a lower degree of progressivity than the benchmark US income tax system—is similar to findings in Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017). Thus, health risk has an important role in shaping the optimal level of progressivity of the US income tax system. The inclusion of health risk results in much higher progressivity levels in the optimum.

Having established the contribution of the progressive income tax system to social health insurance, we investigate how different designs of health insurance systems interact with the optimal level of income

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5In an incomplete markets setting with income risk only, a progressive income tax system can improve welfare through two channels. First, progressive taxes lead to a more equal post-tax distribution of income and wealth and therefore to a more equitable distribution of household consumption. Second, in the absence of insurance markets, progressive taxes provide partial insurance for idiosyncratic income shocks and can therefore generate more stable lifecycle consumption paths through the redistribution of income from “lucky” high income individuals to “unlucky” individuals who experience negative income shocks.

6Gruber (2008) refers to this group as the “poor working class” whose income is below the median income but above the eligibility thresholds for public health insurance and income transfers.

7While the optimal tax system in our model becomes more similar to Heathcote, Storesletten and Violante (2017) when health risk is removed from the model, important differences in the modeling frameworks remain. Most notably, our framework still includes a deterministic health capital accumulation process as well as elements of the US health insurance system.
tax progressivity. We consider three alternative health insurance scenarios: (i) the US health insurance system after the introduction of the Affordable Care Act (ACA) in 2010, (ii) a system with Medicare for all individuals that we refer to as universal public health insurance (UPHI), and (iii) a system with no health insurance where individuals rely exclusively on self-insurance. When more inclusive health insurance systems (ACA and UPHI) are considered, the optimal level of tax progressivity decreases significantly. The ACA strengthens channels that redistribute resources from healthy, high income types to sicker, low income types through premium subsidies and the expansion of Medicaid. As a result, the post-ACA optimal degree of tax progressivity is lower and the Suits index decreases to 0.50, compared to 0.54 in the optimized system of the pre-ACA era. Under the UPHI scenario, the optimal income tax system becomes even less progressive. With a coinsurance rate of 20 percent, the tax break at the lower end of the income distribution decreases significantly to $26,200, and the marginal tax rates imposed on top earners are much lower at approximately 31 percent for income over $200,000. The Suits index decreases to 0.43 under the UPHI system. Indeed, UPHI reduces the residual demand for social insurance provided by the progressive income tax. If we make UPHI more generous by lowering coinsurance rates, the optimal tax system becomes even less progressive and resembles the one in Heathcote, Storesletten and Violante (2017). Conversely, under the third scenario where all public and private health insurance are eliminated from the model, the optimal level of tax progressivity increases significantly and exhibits a Suits index of 0.59 due to a strong residual demand for social health insurance. In conclusion, the optimal progressive tax schedule varies significantly across the three alternative health insurance designs.

As robustness checks, we relax several modeling assumptions. First, we introduce a new channel of effects through which health directly influences longevity/life expectancy using a similar approach as in Hall and Jones (2007). Second, we study the elasticity of health expenditure and a wider range of risk aversion parameters. Third, we use Epstein-Zin-Weil preferences that use two separate parameters for risk aversion and intertemporal substitution (Epstein and Zin (1989), Epstein and Zin (1991) and Weil (1990)). Fourth, we shut down the health productivity channel through which health affects the labor productivity of workers. Finally, we use a less restricted tax polynomial and allow for government transfers through negative income taxes as in Heathcote, Storesletten and Violante (2017).8 Our main results are qualitatively robust with respect to these changes.

The paper is structured as follows. Section 2 presents the quantitative model. Section 3 describes our calibration strategy. Section 4 describes our experiments and quantitative results. Section 5 is devoted to extension and sensitivity analysis. Section 6 concludes. Appendix A provides stylized facts on health and income over the lifecycle. Appendix B presents a small model highlighting insurance and incentive trade-offs. Appendix C contains the equilibrium definition, computation of the quantitative model and implementation of the ACA.

**Related literature.** In a seminal paper, Varian (1980) shows analytically how social insurance can be

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8Since we explicitly model transfer programs for low income households such as Medicaid and minimum consumption insurance, we restrict the income tax to be non-negative in our benchmark calibration.
provided via a progressive tax system. Building on this insight there exists a large and growing quantitative literature on the optimal design of the progressive income tax code. Examples include Conesa and Krueger (2006) who emphasize the role of income risk, Erosa and Koreshkova (2007), Krueger and Ludwig (2016) and Stantcheva (2017) who consider models of optimal taxation in the presence of endogenous human capital and characterize the optimal interaction between progressive tax and education policies. Chambers, Garriga and Schlenk (2009) who quantify the interactions of progressive taxes and housing policies, McKay and Reis (2016) who study progressive government instruments as automatic stabilization policies, and Heathcote, Storesletten and Violante (2017) who study the optimal degree of progressivity of a tax and transfer system. None of these papers studies progressive income taxes in combination with health insurance policies as our paper does.

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). The Bewley model has been applied widely to quantify the welfare implications of public insurance for idiosyncratic income risk (e.g., Hansen and Imrohoroglu (1992), İmrohoroğlu, İmrohoroğlu and Joines (1995), Golosov and Tsyvinski (2006), Heathcote, Storesletten and Violante (2008), Conesa, Kitao and Krueger (2009) and Huggett and Parra (2010)). This literature focuses on the welfare cost triggered by income/labor productivity risk in an environment without insurance contracts for non-medical consumption. Recently, Capatina (2015) and De Nardi, Pashchenko and Porapakarm (2018) demonstrate that health shocks are another important source of idiosyncratic risk faced by individuals over the lifecycle. In our study we add to this literature by incorporating idiosyncratic health risk, health investment decisions, and insurance policies into a Bewley framework. The presence of health related factors adds a new channel which affects the social insurance role of progressive income taxes.

Our work contributes to a growing macro-public finance literature that focuses on health shocks and healthcare policy. Early studies usually view health shocks as health expenditure shocks (e.g., Palumbo (1999), Jeske and Kitao (2009). Recent studies endogenize health expenditure (e.g., Jung and Tran (2007), Fonseca et al. (2018), Scholz and Seshadri (2013a), Jung and Tran (2016), Yogo (2016), Cole, Kim and Krueger (2019), and Eslami and Karimi (2019)). However, these papers abstract from the social insurance role of progressive income taxes and public health insurance, which is the focus of this paper. The quantitative model presented in this paper shares many features with our previous model in Jung and Tran (2016) but differs in the income tax polynomial, adds health dependent survival, and allows for alternative utility specifications.

There is an analogy to the literature on optimal taxation with human capital which we briefly mentioned above. This literature emphasizes the strong complementarity between progressive taxes and education policies. This literature dates back to an influential paper by Bovenberg and Jacobs (2005) and also see, e.g., Colas, Findeisen and Sachs (2018). Krueger and Ludwig (2016) provide a quantitative analysis of optimal tax and education policies. Our parametric and quantitative model contains a similar fiscal externality as it has a similar modeling approach. Different from theirs, our paper aims to better understand the interaction of health care policies with optimal progressive taxes.
Finally, our paper is connected to the literature on high marginal tax rates for top income earners. Diamond and Saez (2011) advocates for taxing labor earnings at the high end of the distribution at high marginal rates in excess of 75 percent. Badel and Huggett (2015) assess the consequences of increasing the marginal tax rate on US top income earners using a human capital model. Guner, Lopez-Daneri and Ventura (2016) analyze the effectiveness of progressive income tax systems in raising tax revenue and Kindermann and Krueger (2017) show that high marginal labor income tax rates are an effective tool for social insurance in a large-scale stochastic overlapping generations model with optimal marginal tax rates of 90 percent for the top 1 percent earners. Different from these studies, we focus on the optimal marginal tax rates across the entire income distribution. Moreover, we base our analysis on a health capital model where health risk is an additional source of heterogeneity in addition to labor market risk. We also show that very high tax rates at the top are an essential component of the optimal progressive tax system. More importantly, we highlight that such high optimal marginal tax rates at the top are inter-dependent with the marginal tax rates set at the bottom of the income distribution and the government transfer policies already in place.

2 The model

In this section, we formulate a more comprehensive model of the US economy including the healthcare sector following Jung and Tran (2016) and quantify the optimal degree of progressivity of the US income tax system. In addition, we explore how differently designs of a health insurance system affect the optimal tax progressivity.

2.1 Technologies and firms

There are two production sectors in the economy, which are assumed to grow at a constant rate $g$. Sector one is populated by a continuum of identical firms that use physical capital $K_c$ and effective labor services $N_c$ to produce a non-medical consumption good $c$ with a normalized price of one. Firms in the non-medical sector are perfectly competitive and solve the following maximization problem

$$\max_{\{K_c, N_c\}} F(K_c, N_c) - qK_c - wN_c,$$  

(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 $N_m$ to produce medical services $m$ at a price of $p_m$.\footnote{We use exogenous price markups to account for the fact that the medical sector is not perfectly competitive and that not all stakeholders pay the same price for otherwise identical medical services. More details about the price markups used in this study can be found in the calibration section.} Firms in the medical sector maximize

$$\max_{\{K_m, N_m\}} p_m F_m(K_m, N_m) - qK_m - wN_m.$$  

(2)


2.2 Demographics, preferences and endowments

The economy is populated with overlapping generations of individuals who live up to a maximum of $J$ periods. Individuals work for $J_n$ periods and are retired thereafter. Individuals survive each period with age dependent survival probability $\pi_j$.

Deceased agents leave an accidental bequest that is taxed and redistributed equally to the working age population. The population grows exogenously at an annual rate $g^n$. We assume stable demographic patterns, so that age $j$ agents make up a constant fraction $\mu_j$ of the entire population at any point in time. The relative sizes of the cohorts alive $\mu_j$ and the mass of individuals dying in each period $\bar{\mu}_j$ (conditional on survival up to the previous period) can be recursively defined as $\mu_j = \pi_j / (1 + g^n)^{\text{years}} \mu_{j-1}$ and $\bar{\mu}_j = 1 - \pi_j / (1 + g^n)^{\text{years}} \mu_{j-1}$, where $\text{years}$ denotes the number of years per model period.

In each period individuals are endowed with one unit of time that can be used for work $n$ or leisure. Individual utility is denoted by function $u(c,n,h)$ where $u : R^3_{++} \rightarrow R$ is $C^2$, increases in consumption $c$ and health $h$, and decreases in labor $n$. More specifically we use a multiplicative instantaneous utility function of the form

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

where $\bar{h}_j$ is an age dependent fixed cost of working as in French (2005), $\eta$ 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 inter-temporal rate of substitution (or relative risk aversion parameter).

Individuals are born with a specific skill type $\vartheta$ that cannot be changed and that together with their health capital $h_j$ and an idiosyncratic labor productivity shock $\epsilon^n_j$ determines their age-specific labor efficiency $e \left( \vartheta, h_j, \epsilon^n_j \right)$. The transition probabilities for the idiosyncratic productivity shock $\epsilon^n_j$ follow an age-dependent Markov process with transition probability matrix $\Pi^n_j$. An element of this transition matrix is defined as the conditional probability $\Pr \left( \epsilon^n_{i,j+1} | \epsilon^n_{i,j} \right)$, where the probability of next period’s labor productivity $\epsilon^n_{i,j+1}$ depends on today’s productivity shock $\epsilon^n_{i,j}$.

2.3 Health capital

Health capital evolves according to $h_j = \mathcal{H} \left( m_j, h_{j-1}, \delta^h_j, \epsilon^h_j \right)$, where $h_j$ denotes current health capital, $h_{j-1}$ denotes health capital of the previous period, $\delta^h_j$ is the depreciation rate of health capital and $\epsilon^h_j$ is an idiosyncratic health shock. The exogenous health shock $\epsilon^h_j$ follows a Markov process with age dependent transition probability matrix $\Pi^h_j$. Transition probabilities to next period’s health shock $\epsilon^h_{j+1}$ depend on the current health shock $\epsilon^h_j$ so that an element of transition matrix $\Pi^h_j$ is defined as the conditional probability

\(^{10}\text{We extend the benchmark model to include health dependent survival functions in our sensitivity analysis.}

\(^{11}\text{Heathcote, Storesletten and Violante (2017) model government spending in terms of public goods that enter the preferences directly. In their setting, the utility from the consumption of public goods and social insurance are two main channels of welfare gains. In our analysis, we abstract from the former and focus on risk sharing through social insurance programs. We model public spending programs explicitly. Our modeling approach is similar to the one in Conesa and Krueger (2006). However, we take into account both labor productivity and health risks as well as the institutional setup of the US healthcare sector.}
Pr \left( \varepsilon_{j+1}^h | \varepsilon_j^h \right)$. Individuals can buy medical services $m_j$ to improve their health capital. Specifically, the law of motion of health capital follows

\[
h_j = \underbrace{\phi_j m_j^x} + \underbrace{\left( 1 - \delta_j^h \right)} h_{j-1} + \underbrace{\varepsilon_j^h} .
\] (3)

This law of motion is an extension of the deterministic framework in Grossman (1972). The first two components are similar to Grossman (1972) while the third component can be thought of as a random depreciation rate as discussed in Grossman (2000a).\(^{12}\)

2.4 Health insurance and out-of-pocket medical spending

In the benchmark economy we introduce the main features of the US health insurance system before the implementation of the Affordable Care Act in 2010. The health insurance market consists of private health insurance companies that offer two types of health insurance policies: (i) an individual health insurance plan (IHI) and (ii) a tax deductible group health insurance plan (GHI). Individuals are required to buy insurance at a plan specific price (or premium) one period prior to the realization of their health shock in order to be insured in the following period. The insurance policy needs to be renewed each period. By construction, agents in their first period are thus not covered by any insurance. The government provides public health insurance with Medicaid for the poor and Medicare for retirees. To be eligible for Medicaid, individuals are required to pass an income and asset test. The health insurance state $\text{in}_j$ for workers can therefore take on the following values:

\[
\text{in}_j = \begin{cases} 
0 & \text{not insured,} \\
1 & \text{Individual health insurance (IHI),} \\
2 & \text{Group health insurance (GHI),} \\
3 & \text{Medicaid.} 
\end{cases}
\]

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

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

\[
\alpha(m_j) = \begin{cases} 
p_{m_j}^{\text{in}_j} \times m_j, & \text{if } \text{in}_j = 0, \\
p^{\text{in}_j} \times \left( p_{m_j}^{\text{in}_j} \times m_j \right), & \text{if } \text{in}_j > 0 
\end{cases}
\] (4)

\(^{12}\)Arguably, there are shortcomings with this modeling approach as the original model fails a number of empirical tests (e.g., Wagstaff (1986, 1993)). Grossman (2000b) provides a comprehensive 30-year review and clarifies the modeling approach. Recently, Dalgaard and Strulik (2014) suggest an alternative approach to model health using a human frailty index rather than health capital. This setup solves one of the issues in the original Grossman model where health depreciates more (in levels) if an individual has higher health capital. In our model most of the health depreciation comes from idiosyncratic health shocks as opposed to a deterministic (and multiplicative) health depreciation process so that our framework is much less exposed to their critique of Grossman’s health capital concept.
where $0 \leq \rho_{inj} \leq 1$ are the insurance state specific coinsurance rates. The coinsurance rate denotes the fraction of the medical bill that the patient has to pay out-of-pocket.\(^{13}\) A retiree’s out-of-pocket expenditure is $o(m_j) = \rho R \times (p_m^R \times m_j)$, where $\rho R$ is the coinsurance rate of Medicare and $p_m^R$ is the price that a Medicare patient pays for medical services.

**Insurance companies.** Workers are randomly assigned to employers who offer group health insurance (GHI) which is indicated by random variable $\epsilon_{GHI} = 1$. The GHI premium, $\text{prem}_{GHI}$, is tax deductible and group rated so that insurance companies are not allowed to screen workers by health or age. There is a Markov process that governs the group insurance offer probability. It is a function of the individual’s permanent skill type $\vartheta$. Let $Pr\left(\epsilon_{j+1}^{GHI} | \epsilon_j^{GHI}, \vartheta\right)$ be the conditional probability that an agent has group insurance status $\epsilon_{j+1}^{GHI}$ at age $j + 1$ given she had group insurance status $\epsilon_j^{GHI}$ at age $j$. All conditional probabilities for group insurance status are collected in a $2 \times 2$ transition probability matrix $\Pi_{j,\vartheta}^{GHI}$.

If a worker is not offered GHI from her employer, i.e., $\epsilon_{GHI} = 0$, the worker can still buy IHI. However, the worker is subjected to screening so that the IHI premium depends on an individual’s age and health, $\text{prem}_{IHI}(j, h)$, and is not tax deductible.

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

\[(1 + \omega_{j,h}^{IHI}) \mu_j \int \left(1_{[m_j(x_j,h)=1]} (1 - \rho_{IHI}) p_{m}^{IHI} m_j(x_j,h) \right) d\Lambda(x_j) = R \mu_j \int \left(1_{[m_j(x_j,h)=1]} \text{prem}_{j-1,h}^{IHI} \right) d\Lambda(x_{j-1,h}) \tag{5}\]

where $x_{j-1,h}$ is the state vector for cohort age $j$ not containing $h$ since we do not want to aggregate over the health state vector $h$ in this case. The clearing condition for the group health insurances is simpler as only one price, $\text{prem}_{GHI}$, adjusts to balance

\[(1 + \omega_{j,h}^{GHI}) \sum_{j=2}^{J} \mu_j \int \left(1_{[m_j(x_j)=2]} (1 - \rho_{GHI}) p_{m}^{GHI} m_j(x_j) \right) d\Lambda(x_j) = R \sum_{j=1}^{J-1} \mu_j \int \left(1_{[m_j(x_j)=2]} \text{prem}_{j-1}^{GHI} \right) d\Lambda(x_j) \tag{6}\]

where $\omega_{j,h}^{IHI}$ and $\omega_{j,h}^{GHI}$ are markup factors that determine loading costs (fixed costs or profits). Variables $\rho_{IHI}$ and $\rho_{GHI}$ are the coinsurance rates, and $p_{m}^{IHI}$ and $p_{m}^{GHI}$ are the prices for health care services of the two insurance types. The respective left-hand-sides in the above expressions summarize aggregate payments made by insurance companies whereas the right-hand-sides aggregate the premium collections one period prior. Since premiums are invested for one period, they enter the capital stock and we therefore multiply the term with the after tax gross interest rate $R$. The premium markups generate profits which are redistributed in equal (per-capita) amounts of $\pi_{profits}$ to all surviving agents.\(^{14}\)

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\(^{13}\)For simplicity we include deductibles and co-pays into the coinsurance rate.

\(^{14}\)Notice that ex-post moral hazard and adverse selection issues arise naturally in the model due to information asymmetry. Insurance companies cannot directly observe the idiosyncratic health shocks and have to reimburse agents based on the actual observed levels of health care spending. Adverse selection arises because insurance companies cannot observe the risk type of agents and therefore cannot price insurance premiums accordingly. They instead have to charge an average premium that clears the insurance companies’ profit conditions. Individual insurance contracts do distinguish agents by age and health status but not by their health shock.
2.5 Fiscal policy

The government administers various government programs that are financed by a combination of taxes.

**Progressive income taxes.** The government imposes a progressive income tax code on household incomes. The tax schedule is given by a parametric function \( \tilde{\tau}(\tilde{y}) = \tilde{y} - \lambda \tilde{y}^{(1-\tau)} \), where \( \tilde{\tau}(\tilde{y}) \) denotes net tax revenues as a function of pre-tax income \( \tilde{y} \), \( \tau \) is the progressivity parameter, and \( \lambda \) is a scaling factor to match the US income tax revenue. This tax function is fairly general and captures the common cases:

\[
\begin{align*}
(1) \text{ Full redistribution: } & \tilde{\tau}(\tilde{y}) = \tilde{y} - \lambda \text{ and } \tilde{\tau}'(\tilde{y}) = 1 \quad \text{if } \tau = 1, \\
(2) \text{ Progressive: } & \tilde{\tau}(\tilde{y}) = 1 - (1-\tau)\lambda \tilde{y}^{(-\tau)} \text{ and } \tilde{\tau}'(\tilde{y}) > \frac{\tilde{\tau}(\tilde{y})}{\tilde{y}} \quad \text{if } 0 < \tau < 1, \\
(3) \text{ No redistribution (proportional): } & \tilde{\tau}(\tilde{y}) = \tilde{y} - \lambda \tilde{y} \text{ and } \tilde{\tau}'(\tilde{y}) = 1 - \lambda \quad \text{if } \tau = 0, \\
(4) \text{ Regressive: } & \tilde{\tau}(\tilde{y}) = 1 - (1-\tau)\lambda \tilde{y}^{(-\tau)} \text{ and } \tilde{\tau}'(\tilde{y}) < \frac{\tilde{\tau}(\tilde{y})}{\tilde{y}} \quad \text{if } \tau < 0.
\end{align*}
\]

This tax function has a long tradition in public finance (see Musgrave (1959), Kakwani (1977)) and was implemented into a dynamic setting by Benabou (2002) and more recently used in Heathcote, Storesletten and Violante (2017). This tax function is flexible and can be used to model the transfer programs. Note that, Heathcote, Storesletten and Violante (2017) abstract from modeling government transfer programs explicitly, but allow negative income taxes to act as implicit government transfers. We instead model government spending explicitly including Medicaid and Food Stamp programs for low income individuals.

To avoid double counting we impose a non-negative income tax

\[
\tilde{\tau}(\tilde{y}) = \max \left[ 0, \tilde{y} - \lambda \tilde{y}^{(1-\tau)} \right].
\]

This non-negative tax restriction eliminates all government transfers embedded in the progressive tax function. We will relax this restriction in our sensitivity analysis.

**Spending programs.** The government has the following spending programs: social security, social transfers to low income earners, public health insurance, and general government consumption. The social security program operates on a Pay-As-You-Go (PAYG) principle in which the government collects a payroll tax \( \tau_{SS} \) from the working population to finance social security benefits \( t_{SS} \) for retired individuals. The PAYG program is self-financed

\[
\sum_{j=J_w+1}^{J} \mu_j \int t_{SS}^j(x_j) d\Lambda(x_j) = \sum_{j=1}^{J_w} \mu_j \int t_{SS}^j(x_j) d\Lambda(x_j).
\]

In addition, the government provides social insurance through a social transfer program \( T^{SI} \) that guarantees a minimum consumption level. Public health insurance consists of Medicare and Medicaid. Medicare is financed by a Medicare tax \( \text{tax}_{Med}^j \) and premium payments \( \text{prem}^R \) and Medicaid is financed by general tax revenues. In addition, the government needs to finance government consumption \( C_G \) which is exogenous and unproductive. Finally, the government collects accidental bequests from deceased individuals and redistributes them as lump-sum payments \( t_{Beq}^j \) to all surviving working-age individuals.
Balanced budget. The government collects consumption tax revenue at a flat rate, $\tau^C$, and income tax revenue at a progressive rate to balance its budget every period. The government budget constraint is given by

\[
C_G + T^{SI} + \sum_{j=2}^{J_w} \mu_j \int_{1[\ln(x_j)=0]} (1 - \rho^{MAid}) \rho_{m}^{MAid} m_j(x_j) d\Lambda(x_j) + \sum_{j=J_w+1}^{J} \mu_j \int (1 - \rho^R) \rho_{m}^{R} m_j(x_j) d\Lambda(x_j)
= \sum_{j=1}^{J_w} \mu_j \int [c^e c(x_j) + t\tau(x_j)] d\Lambda(x_j) + \sum_{j=J_w+1}^{J} \mu_j \int \text{prem}^R(x_j) d\Lambda(x_j) + \sum_{j=1}^{J_w} \mu_j \int t\tau^M \Lambda d\Lambda(x_j),
\]

where $\rho^{MAid}$ and $\rho^R$ are the coinsurance rate of Medicaid and of the combined Medicare/Medicaid program for the old, respectively.

The government collects and redistributes accidental bequests in a lump-sum fashion to all working-age households

\[
\sum_{j=1}^{J_w} \mu_j \int i_j^{Beq}(x_j) d\Lambda(x_j) = \sum_{j=1}^{J} \tilde{\mu}_j \int a_j(x_j) d\Lambda(x_j),
\]

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

2.6 Household problem

Individuals at age $j \leq J_w$ are workers and thus exposed to labor shocks. Old individuals, $j > J_w$, are retired ($n_j = 0$) and receive pension payments. They do not face labor market shocks anymore. The agent state vector at age $j$ is given by

\[
x_j \in D_j \equiv \begin{cases} 
(a_j, h_j-1, \vartheta, \varepsilon_j^n, \varepsilon_h^j, \text{in}_j) \in R_+ \times R_+ \times R_+ \times R_+ \times R_- \times \mathcal{J}^w & \text{if } j \leq J_w, \ 
(a_j, h_j-1, \vartheta, \varepsilon_h^j, \text{in}_j) \in R_+ \times R_+ \times R_+ \times R_- \times \mathcal{J}^R & \text{if } j > J_w,
\end{cases}
\]

where $a_j$ is the capital stock at the beginning of the period, $h_{j-1}$ is the health state at the beginning of the period, $\vartheta$ is the skill type, $\varepsilon_j^n$ is the positive labor productivity shock, $\varepsilon_h^j$ is a negative health shock, $\text{in}_j$ is the insurance state and $\mathcal{J}^w = \{0, 1, 2, 3\}$ denotes the dimension of the insurance state of workers and $\mathcal{J}^R = \{1\}$ is the sole insurance state for retirees as every retiree is on a combined Medicare/Medicaid program. After the realization of the state variables, agents simultaneously chose from their choice set

\[
\mathcal{C}_j \equiv \begin{cases} 
(c_j, n_j, m_j, a_{j+1}, \text{in}_{j+1}) \in R_+ \times [0, 1] \times R_+ \times R_+ \times \mathcal{J}^w & \text{if } j \leq J_w, 
(c_j, m_j, a_{j+1}) \in R_+ \times R_+ \times R_+ & \text{if } j > J_w,
\end{cases}
\]

where $c_j$ is consumption, $n_j$ is labor supply, $m_j$ are health care services, $a_{j+1}$ are asset holdings for the next period and $\text{in}_{j+1}$ is the insurance state for the next period in order to maximize their lifetime utility. All choice variables in the household problem depend on state vector $x_j$. We suppress this dependence in the
notation to improve readability. The household optimization problem is

\[ V(x_j) = \max \{ u(c_j, n_j, h_j) + \beta \pi J E[V(x_{j+1}) | x_j] \} \text{ s.t.} \]

\[ (1 + \tau^C) c_j + (1 + g) a_{j+1} + o(m_j) + 1_{[j \leq J_n \wedge \text{in}_{j+1} = 1]} \text{prem}^{\text{HII}}(j, h) + 1_{[j \leq J_n \wedge \text{in}_{j+1} = 2]} \text{prem}^{\text{GHI}} + 1_{[j > J_n]} \text{prem}^R \]

\[ = y_j - \text{tax}_j + \tau^S_j, \]

\[ 0 \leq a_{j+1}, 0 \leq n_j \leq 1 \text{ and (3)}. \]

Variable \( \tau^C \) is a consumption tax rate, \( o(m_j) \) is out-of-pocket medical spending depending on insurance type, \( y_j \) is the sum of all income including labor, assets, bequests, and profits. Household income and tax payments are defined as

\[ y_j = 1_{[j \leq J_n]} [\epsilon(\theta, h_j, e^n_j) n_j w + 1_{[j > J_n]} t^S_j + \tau^S_j + \text{tax}^\text{Care}_j], \]

\[ \text{tax}_j = \tilde{\tau}(\tilde{y}_j) + 1_{[j \leq J_n]} (\text{tax}^\text{Soc}_j + \text{tax}^\text{Care}_j), \]

\[ \tilde{y}_j = y_j - a_j - \text{Beq} - 1_{[\text{in}_{j+1} = 2]} \text{prem}^{\text{GHI}} - 0.5 (\text{tax}^\text{SS} + \text{tax}^\text{Med}), \]

\[ \text{tax}^\text{SS}_j = \tau^\text{Soc} \times \min (\tilde{y}_j, e(\theta, h_j, e^n_j) n_j w - 1_{[\text{in}_{j+1} = 2]} \text{prem}^{\text{GHI}}), \]

\[ \text{tax}^\text{Care}_j = \tau^\text{Care} \times (e(\theta, h_j, e^n_j) n_j w - 1_{[\text{in}_{j+1} = 2]} \text{prem}^{\text{GHI}}), \]

\[ t^\text{SI}_j = \max [0, \xi + o(m_j) + \text{tax}_j - y_j]. \]

Indicator function \( 1_{[j \leq J_n]} \) equals one if the individual is of working age and zero otherwise. Variable \( w \) is the market wage rate and \( R \) is the gross interest rate and \( \pi^{\text{profits}} \) denotes profits from insurance companies. Variable \( \tilde{y}_j \) is taxable income, \( \tilde{\tau}(\tilde{y}_j) \) is the progressive income tax payment and \( \text{tax}^\text{SS}_j \) is the social security tax with marginal rate \( \tau^\text{SS} \) that finances the social security payments \( t^\text{SS}_j \). The maximum contribution to social security is \( \tilde{y}_j^{\text{SS}} \). The social insurance payment \( t^\text{SI}_j \) guarantees a minimum consumption level \( \xi \). If social insurance is paid out, then automatically \( a_{j+1} = 0 \), so that social insurance cannot be used to finance savings. For each \( x_j \in D_j \) let \( \Lambda(x_j) \) denote the measure of age- \( j \) agents with \( x_j \in D_j \). Then expression \( \mu_j \Lambda(x_j) \) becomes the population measure of age- \( j \) agents with state vector \( x_j \in D_j \) that is used for aggregation.

3 Calibration

For the calibration we distinguish between two sets of parameters: (i) externally selected parameters and (ii) 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 the external parameters in Table 2. Internal parameters are calibrated so that model-generated data match a given set of targets from US data. These parameters are presented in Table 3. Model generated data moments and target moments from US data are
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: $F_c(K_c, N_c) = A_c K_c^{\alpha_c} N_c^{1-\alpha_c}$ and $F_m(K_m, N_m) = A_m K_m^{\alpha_m} N_m^{1-\alpha_m}$. We set the capital share $\alpha_c = 0.33$, the annual capital depreciation rate at $\delta = 0.1$ and normalize $A_c = 1$ which are 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 Acemoglu and Guerrieri (2008). TFP in the medical sector is calibrated to $A_m = 0.4$ in order to match the size of the medical sector. We abstract from changes in production technologies or other possible causes of excess cost growth in the US health sector.

3.2 Demographics, preferences and endowments

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. The population growth rate for the US was 1.2 percent on average from 1950 – 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.

Parameter $\sigma = 3.0$ and the time preference parameter $\beta = 1.001$ 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 addition, we choose fixed cost of working, $\bar{n}_j$, to match the labor intensity hours per age group. In conjunction with the health productivity parameters $\phi_j$ and $\xi$ from expression (3) these preference weights also ensure that the model matches total health spending and the fraction of individuals with health insurance per age group.

We allow for four permanent skill types $\vartheta$. The permanent skill types are defined as average individual wages for the following wage percentiles 25, 25–65, 65–95, and top 5. The efficiency unit of labor, i.e., labor productivity, evolves over the lifecycle according to

$$e_j(\vartheta, h_j, e^n) = \left(\bar{\vartheta}_j, \vartheta\right)^\chi \times \left(\exp\left(\frac{h_j - \bar{h}_j, \vartheta}{h_j, \vartheta}\right)\right)^{1-\chi} \times e^n \quad \text{for} \quad j = \{1, ..., J_w\},$$

15The calibration strategy is similar to our previous paper Jung and Tran (2016) with adjustments to accommodate the new income tax polynomial, different designs of a health insurance system, endogenous mortality, and alternative utility specifications.

16Previous studies have used capital depreciation rates between 7–10 percent (e.g., 10 percent in Suen (2006) and 7 percent in Zhao (2014)). In our benchmark model the implied investment to output ratio in the steady state is $I = \delta Y = 0.1 \times 2.7 \times 100 = 27$ percent. For a sensitivity check, we also run an experiment with the depreciation rate of 7 percent which implies a lower investment to GDP ratio and a slightly less progressive income tax system. Details are available upon request from the authors.

17We do not attempt to match the labor force participation rate in our model since we are missing important institutional features such as disability early retirement options, unemployment payments, etc.
where $\bar{e}_{j,\vartheta}$ is the average productivity of labor of the $(j, \vartheta)$ types. We estimate $\bar{e}_{j,\vartheta}$ from MEPS data using average wages which results in hump-shaped lifecycle earnings profiles. In addition, labor productivity can be influenced by health. The idiosyncratic health effect on labor productivity 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 idiosyncratic labor productivity shock $\varepsilon^n$ is based on Storesletten, Telmer and Yaron (2004). We discretize this process into a five state Markov process following Tauchen (1986).\textsuperscript{18}

### 3.3 Health capital

We use the health index Short-Form 12 Version 2 ($SF - 12v2$) in MEPS data to measure health capital.\textsuperscript{19} The $SF - 12v2$ includes twelve health measures of physical and mental health. It is widely used to assess health improvements after medical treatments in hospitals. The $SF - 12v2$ is continuous and varies between 0 (worst) and 100 (best).

We first define a space for health capital in the model with a minimum health capital level of $h_{m}^{\text{min}}$ and a maximum health capital level of $h_{m}^{\text{max}}$. We then set the maximum health capital level $h_{m}^{\text{max}}$ and map the health index from MEPS data to the health capital space in the model. Note that, we normalize health capital and health production parameters according to the maximum health level. The lower bound of the health grid $h_{m}^{\text{min}}$ is calibrated.

We classify individual health status into four groups by age-cohort and health capital quartile (i.e., group 1 has health capital in the 25\textsuperscript{th} percentile whereas group 4 has health capital in the top quartile). We assume that individuals in group 1 are in the best health status, so that there is negligibly small or no health shock. Meanwhile, individuals in the other health groups experience negative health shocks. Group 2 experiences a “small” health shock, group 3 experiences a “moderate” health shock, and group 4 suffers from a “large” health shock. The transition probability matrix of health shocks $\Pi^h$ is calculated by counting how many individuals move across health groups between two consecutive years in MEPS data where we also adjust for period length.

In order to measure the magnitudes of health shocks, we compute the average health capital of group, $\bar{h}_{j,d}^i$ with $i = \{1, 2, 3, 4\}$. The average health capital per age group is denoted $\{\bar{h}_{j,d}^1 > \bar{h}_{j,d}^2 > \bar{h}_{j,d}^3 > \bar{h}_{j,d}^4\}$. We measure the shock magnitude in terms of relative distance from an average health state of each group to the average health state of group 1, $\left(\bar{h}_{j,d}^1 - \bar{h}_{j,d}^i\right)$. The vector of shock magnitude in percentage deviation is defined as $\varepsilon_{\text{h7}} = \left\{0, \frac{\bar{h}_{j,d}^2 - \bar{h}_{j,d}^1}{\bar{h}_{j,d}^1}, \frac{\bar{h}_{j,d}^3 - \bar{h}_{j,d}^1}{\bar{h}_{j,d}^1}, \frac{\bar{h}_{j,d}^4 - \bar{h}_{j,d}^1}{\bar{h}_{j,d}^1}\right\}$. This vector is scaled by the maximum health capital level in the model $h_{m}^{\text{max}}$ and used as the shock levels in the model.\textsuperscript{20}

\textsuperscript{18}Ideally, we would propose a structural estimation of the lifecycle profile of efficiency units in combination with the dynamics of health accumulation. However, this approach is computationally too burdensome. We instead calibrate this process based on estimates from previous studies.

\textsuperscript{19}See Ware, Kosinski and Keller (1996) for further details about this health index.

\textsuperscript{20}We acknowledge that this procedure provides approximate estimates for health shocks and relies on ad hoc assumptions. As such it is somewhat similar to the procedure used in Huggett, Ventura and Yaron (2011) who also make exogenous shock
The natural rate of health depreciation $\delta^h_j$ per age group is calculated by focusing on individuals with group insurance and zero health spending in any given year. We then postulate that such individuals did not incur a negative health shock in this period as they could easily afford to buy medical services $m$ to replenish their health due to their insurance status. This allows us to back out the depreciation rate from expression (3).

To the best of our knowledge, there are no suitable estimates for health production processes in equation (3), especially within macro modeling frameworks. 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 calibrate $\xi$ and $\phi_j$ together to match aggregate health expenditures and the medical expenditure profile over age (see Figure 5). We assume a grid of 15 health states for our calibration in order to reduce the computational burden.

### 3.4 Health insurance and out-of-pocket medical spending

**Group Insurance Offers.** MEPS data contain information about whether individuals have received a group health insurance offer from their employer i.e., offer shock $\varepsilon^{GHI} = \{0, 1\}$. The transition matrix $\Pi^h$ with elements $Pr(\varepsilon^{GHI}_{j+1} | \varepsilon^{GHI}_j, \vartheta)$ 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 $\text{prem}^{HH}(j,h)$ will adjust to clear expression (5). Similarly, $\text{prem}^{GHI}$ adjusts to clear expression (6) and the markup profit $\omega^{GHI}$ 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 coinsurance rates of $\gamma^{HH}, \gamma^{GHI}, \gamma^{MAid}$ and $\gamma^{Mcare}$ 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 (2015) we know that prices paid by Medicare and Medicaid are close to 70 percent of the prices paid by private health insurance who themselves pay lower prices than the uninsured due to their market power vis-a-vis health care providers (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 Center for Policy Alternatives assumptions when working with a lifecycle model with endogenous human capital accumulation. That being said, our approach does generate reasonable health shocks as they increase with age and also produce health shock transition probabilities that increase the chance of suffering worse health shocks at higher ages across all health risk types.

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21 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.

22 Since we do not have any data on markup profits per health risk group and age we set $\omega^{HH}_j = 0$.

23 The markup is set to $\omega^{GHI}_j = 0.01$ percent of premium revenue collection which is admittedly a very conservative value for insurance profits.
Based on this information we calculate the markup factors and medical prices for the five insurance types in the model:\(^{24}\)

\[
[p_{m}^{noIns}, p_{m}^{IHI}, p_{m}^{GHI}, p_{m}^{Maid}, p_{m}^{Mcare}] = [1.70, 1.25, 1.10, 1.0, 0.90] \times p_{m}.
\]

3.5 Fiscal policy

**Taxes.** The consumption tax rate, \(\tau_{C}\), is set to 5 percent. We follow Guner, Lopez-Daneri and Ventura (2016) to calibrate the income tax function in the benchmark model. The tax free threshold and progressivity level \(\tau\) are set at $6,000 and 0.053. We calibrate the tax scaling parameter to match the relative size of the government budget so that \(\lambda = 1.095\).

**Social security, Medicare and Medicaid.** In the model, Social Security benefit payments are defined as a function of average labor income by skill type: \(t^{Soc}(\vartheta) = \Psi(\vartheta) \times w \times \bar{L}(\vartheta)\), where \(\Psi(\vartheta)\) is a scaling vector that determines the total size of pension payments as a function of the average wage income 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. The Social Security system is self-financed via a payroll tax of \(\tau_{SS} = 9.4\) percent similar to Jeske and Kitao (2009). The Social Security payroll tax is collected on labor income up to a maximum of $97,500. 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.\(^{25}\) The premium for Medicare is 2.11 percent of per capita GDP as in Jeske and Kitao (2009). The Medicare tax \(\tau_{Mcare}\) is 2.9 percent and is not restricted by an upper limit (see SSA (2007)). 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., \(FPL_{Maid} = 0.7 \times FPL\)), which is the average state eligibility level (Kaiser (2013)) and calibrate the asset test level, \(\bar{a}_{Maid}\), to match the Medicaid take-up rate. Setting the age dependent coinsurance rate for Medicaid \(\gamma_{j}^{Maid}\) to MEPS levels, Medicaid for workers is 0.5 percent of GDP in the model which underestimates Medicaid spending of workers in MEPS.\(^{26}\)

Overall, the model results in total tax revenue of 21.8\% of GDP and residual (unproductive) government consumption of 12 percent. The latter adjusts to clear the government budget constraint (8).

\(^{24}\)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.

\(^{25}\)Our model cannot match the NIPA number because it is calibrated to MEPS data which only accounts for about 65–70 percent of health care spending in the national accounts as discussed in Sing et al. (2006) and Bernard et al. (2012).

\(^{26}\)Overall Medicaid spending in MEPS 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).
3.6 Properties of the benchmark model

Table 4 and Figures 5, 6 and 8 show that the benchmark model matches the relevant elements of the MEPS data quite well. The model closely tracks average medical expenditures by age group (Figure 5, Panel 1) and reproduces the extremely right skewed distribution of health expenditures shown (Figure 5, Panel 2). 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 as shown in Figure 5, Panels 3, 4 and 5 respectively.

The model reproduces the hump-shaped patterns of asset holdings (Figure 6, Panel 1). However, the lack of a formal bequest motive and the presence of health as an alternative investment vehicle for older agents, makes it difficult to match the high levels of asset holdings of the elderly in the data. On the other hand, the model provides a close fit to the average household income over the lifecycle (Figure 6, Panel 2). Retired individuals decrease their consumption faster than in the data which is a result of the low asset holdings of the elderly (Figure 6, Panel 3). The model provides a close fit for the lifecycle pattern of labor supply (Figure 6, Panel 4). Figure 7 displays health accumulation and wage income by health status. The model reproduces the fact that unhealthy individuals follow a lower income path over the lifecycle. Health risk is an important source of lifetime inequality in our model. Figure 8 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 4 compares first moments from the model to data moments from MEPS, CMS, and NIPA.

4 Quantitative analysis

We first quantify the optimal income tax system in the benchmark calibrated economy using a parametric income tax function following Benabou (2002) and Heathcote, Storesletten and Violante (2017). We then analyze quantitatively how the optimal level of tax progressivity changes under different assumptions on health risk and insurance.

4.1 The optimal degree of tax progressivity

The government problem. In order to characterize the optimal level of progressivity in the tax function in this large-scale OLG model with uninsurable idiosyncratic risk and endogenous health spending we follow the Ramsey tradition and restrict the choice dimension of the government similar to Conesa, Kitao and

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27 In their well-known paper, De Nardi, French and Jones (2010) find that no bequest motive is present for individuals in the AHEAD sample of the Health and Retirement Survey. However, in their later paper De Nardi, French and Jones (2016) do identify a bequest motive once they impose a richer institutional setup. In this paper, we explicitly model the major institutions of the US healthcare system as well as important transfer programs. The asset holding pattern in our model is consistent with their latter finding. Recently, Lockwood (2018) demonstrates that life-cycle models with bequests as luxury goods match data better.
We assume that the social welfare function—defined as the ex-ante lifetime utility of an individual born into the stationary equilibrium—depends on the two parameters of the income tax polynomial: 

\[ WF(\lambda, \tau) = \int V(x_{j=1}|\lambda, \tau) \, d\Lambda(x_{j=1}) \]

The government’s objective is to choose the tax parameter values \( \{\lambda, \tau\} \) that maximize the social welfare function taking the decision rules of consumers and firms as well as competitive equilibrium conditions into account. All other policy variables are kept unchanged.

We implement the government problem as a grid-search over values of parameter \( \tau \) while letting the scaling parameter \( \lambda \) adjust to keep the government budget balanced. We fix the level of exogenous government consumption \( C_G \) to the benchmark government consumption level \( \bar{C}_G \). The tax maximization problem can be written as

\[
WF^* = \max_{\{\lambda, \tau\}} \int WF(\lambda, \tau) \text{ s.t.} \\
\sum_{j=1}^{J} \mu_j \int tax_j(\lambda, \tau, x_j) \, d\Lambda(x_j) = \bar{C}_G + T^{SI}(\lambda, \tau) + \text{Medicaid}(\lambda, \tau) + \text{Medicare}(\lambda, \tau) \\
- \tau C_C(\lambda, \tau) - \text{Medicare Prem}(\lambda, \tau) - \text{Medicare Tax}(\lambda, \tau),
\]

where the terms on the right hand side of the constraint are aggregates that depend on the tax parameters due to tax distortions and general equilibrium price effects. The optimal tax policy and the reported welfare results are based on the comparison between two steady states.

The optimal tax progressivity. Figure 9 presents the results of the tax progressivity optimization. The optimal tax function consists of a scaling parameter of \( \lambda^*_{US} = 2.317 \) and a progressivity parameter of \( \tau^*_{US} = 0.237 \), which is much higher than the US benchmark case of \( \tau_{US} = 0.053 \). The optimal tax system is characterized by a tax break for income earners below US$ 36,400 followed by a jump in the marginal tax rate to 25 percent and a steep increase thereafter to top marginal rates of over 40 percent for income above US$ 100,000 and around 50 percent for income above US$ 200,000.

In Panel 1 of Figure 9 we compare the tax burdens of the US benchmark economy to the economy with the optimal tax system. Panels 2, 3 and 4 present the average tax rates per income group, the marginal tax rates and the after-tax income distribution, respectively. For comparison, we also plot the optimal tax progressivity results from Heathcote, Storesletten and Violante (2017) and Conesa and Krueger (2006).

Under the optimal tax system poor and low income individuals pay almost zero taxes, whereas higher-middle and high income individuals pay significantly more than under the current US system. The working poor, who are not at the bottom but below median income level, benefit most from this tax break. The tax burden shifts to individuals in the upper income groups. Overall, the optimal income tax system is significantly more progressive than the current US system.

The optimal income tax in our model is more progressive than the optimal income tax in previous studies.

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\(^{28}\)This paper follows the Ramsey tradition in that we restrict the choices of the government to simple, easily implementable tax policies. Thus the paper is subject to the critique of this approach by the New Dynamic Public Finance literature.

\(^{29}\)Due to our computation constraint we are not able to calculate the welfare changes of generations that live through the transition from the existing tax system to the optimal system in long run. We therefore do not account for potential welfare losses during the transition as well as the issue of how to implement the optimal tax system.
that abstract from endogenous health accumulation and health risk. Heathcote, Storesletten and Violante (2017) use a similar progressive income tax function, but do not impose the non-negative tax restriction. They find a scaling parameter of $\lambda_{HSV}^* = 0.233$ and an optimal progressivity parameter of $\tau_{HSV}^* = 0.084$ which is less than our $\tau_{US}^* = 0.237$. Note that, their perpetual youth model with skill investments is different from our overlapping generations model with health investments. In addition, they do not explicitly track Social Security, Medicare, Medicaid, and minimum consumption insurance. In their model, they include all government spending programs as public goods consumption ($C_G$) into household preferences.

Conesa and Krueger (2006) use an overlapping generations model with a different parametric specification of the tax function based on Gouveia and Strauss (1994). Health risk and institutional details of the US health insurance system are not modeled. Labor productivity shocks are the only source of household heterogeneity. Retirees are not exposed to income shocks after retirement. Their optimal tax function is a proportional tax of 17.2 percent with a fixed deduction of about US$ 9,400. In our model individuals are exposed to both income and health risks during their active work life and to health risk during retirement. We find that the optimal tax function is more progressive with much higher marginal tax rates at the high end of the income distribution (compare panel 3 of Figure 9).

Our result is consistent with the more recent literature on income taxation which also finds high marginal tax rates in the range of 75–90 percent for top income earners (e.g., Diamond and Saez (2011), Badel and Huggett (2015) and Kindermann and Krueger (2017)). In particular, Kindermann and Krueger (2017) show that very high marginal tax rates for the top one percent are primarily driven by the social insurance benefits that these high taxes imply. In their model—in order to match the very high concentration of labor earnings and wealth in the data—households have the opportunity to work for very high wages with very low probability. Then, as a result of precautionary motives, the labor supply of these households is not strongly affected by high marginal taxes. The intuition is that during periods of high labor productivity households work hard and earn the majority of their lifetime income. A similar mechanism is present in our framework as households are exposed to health risk throughout the lifecycle. Precautionary motives are relatively strong in our setting because households face severe health shocks at the end of their life as shown in De Nardi, French and Jones (2010). Labor supply and savings of high skilled households are not strongly affected by high marginal tax rates. From the social welfare perspective it is optimal to impose very high rates on high income households so that the government can provide social insurance against idiosyncratic earnings- and health risk through progressive taxes to low income households that are highly exposed to health spending risk.

In panel 4, we present the income distributions of the US benchmark case with the income distribution of the optimal tax case superimposed. The fraction of the households with income below US$ 40,000 decreases in the optimal tax system; meanwhile, there are more households in with income between US$40,000 and US$120,000. The tax break for income earners below US$ 36,400 is the main driving

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30Permanent earnings ability is not driven by endogenous choices (e.g., education or other forms of human capital accumulation) in our model. Missing this channel potentially under-estimates the distortion of progressive taxes (e.g., Guvenen, Kuruscu and Ozkan (2014) and Badel and Huggett (2015)). Krueger and Ludwig (2016) demonstrate how education policy affects a progressive tax system in general equilibrium.
force. Income inequality decreases after introducing the optimal tax system. The Gini coefficient for after-tax income decreases from 0.38 to 0.31. The decrease in income equality is mainly due to the introduction of a more progressive income tax system as well as general equilibrium effects.

**Suits index.** In order to obtain a better measure of how the level of tax progressivity changes under different tax systems we follow Suits (1977) and construct Lorenz-type tax contribution curves and a tax progressivity (Suits) index. This index is widely used in the empirical public finance and tax policy literature; however, it is rarely used in the macro/public finance literature. Intuitively, the Suits index measures the concentration of aggregate tax contributions by income group. Figure 13 illustrates the tax-income Lorenz curve and its relationship to the Suits index. These Lorenz-type curves for tax contributions of the lowest to highest income group provide an aggregate measure of tax progressivity and the relative tax contributions by income group. The Suits index is in essence a Gini coefficient for tax contribution inequality. It varies from $+1$ (most progressive) where the entire tax burden is allocated to members of the highest income bracket, through 0 for a proportional tax, to $-1$ (most regressive) where the entire tax burden is allocated to members of the lowest income bracket.

Panel 1 in Figure 14 presents the standard Lorenz curve for gross income. Panel 2 displays the Suits curve for income tax contributions by income group. Panel 3 presents the Suits curve for the total tax contribution (progressive income tax and proportional payroll taxes) by income group. As seen in panel 2, the Suits curve for the income tax contribution in the optimal tax system is flatter at the bottom and steeper at the top compared to the benchmark tax system. This indicates that there are significant changes in the allocation of tax burdens across income groups. The Suits index is 0.17 in the benchmark economy. The optimal tax system is more progressive with a Suits index around 0.53.

**Macroeconomic aggregates.** Macroeconomic and welfare effects are summarized in Table 5. In the optimal tax system the government cuts taxes for households with incomes below US$ 60,000 per year and imposes higher taxes on households with incomes higher than that. The tax increases distort individuals’ incentives to save and work. Capital in the non-medical and medical sectors decreases. Weekly hours worked decrease from 29.4 hours to 29.0 hours. These distortions subsequently lead to efficiency losses and lower GDP by about 6 percent.

**Welfare.** The social welfare criterion we use in order to evaluate different progressive income tax systems is steady state ex ante expected utility of a newborn agent. According to our welfare metrics, progressive taxes play a positive role in achieving a more equal distribution of income and welfare as they provide insurance against being born as a low-ability type. They also provide a partial substitute for missing insurance markets against idiosyncratic income and health shocks over the life cycle. On the other hand, the presence of income tax progressivity distorts individuals’ incentives and decisions. A progressive income tax system can result in welfare gains if the distortions caused by the tax system remain relatively small. In order to assess the variation of welfare effects across the income distribution, we compute compensating consumption by permanent income (skill) types. As expected, we find that the welfare effects vary significantly across the four permanent skill types. Workers with medium and high skill levels experience welfare losses, while low skill workers experience welfare gains in the new steady state (see Table 5).
The welfare gains are mainly due to increases in after-tax income and consumption of low skill type agents (see Panels 1 and 2 of Figure 11). Moreover, under the benchmark income tax and health insurance system, unhealthy and low income individuals who have limited access to the health insurance system do not invest enough in their health. When switching to the optimal progressive income tax system, with a wider zero tax range at the lower end of the income distribution, such individuals have more income and are able to improve their consumption and health. Specifically, individuals in the second skill type group, who are mainly poor working class and likely to be among the uninsured, experience increases of consumption and improvements to their health. The medical expenditure of the uninsured increases by 15 percent. Interestingly, the tax break forces some individuals in the lowest skill group out of Medicaid, due to the income and asset tests that determine eligibility for Medicaid. These individuals are slightly worse off in terms of health conditions; however, they are overall still better off as the welfare gains resulting from the increase in consumption are relatively larger (see Panels 2 and 3 of Figure 11).

The tax break at the lower end of the income distribution is essential in providing subsidies (or social health insurance) to the unhealthy low income individuals who previously were without insurance. Exposure to health and income risks is significantly reduced over the lifecycle, as depicted in Figure 10 which shows the coefficient of variation of consumption, medical spending and gross income over the lifecycle. After the implementation of the optimal progressive tax, we observe significant decreases in the fluctuations of consumption, medical spending and income by age group.

The welfare gain for the lowest skill type can be large at up to 21 percent of lifetime consumption whereas welfare losses can amount to 33 percent for the highest income types, as reported in Table 5. Overall, we calculate a net welfare gain of 5.5 percent at the aggregate level when switching to the optimal income tax system. The positive welfare outcome indicates that the welfare gains resulting from improvements in risk sharing and redistribution dominate the welfare losses caused by tax distortions.

4.2 Isolating the role of health risk

In this section we study to what extent the presence of health risk affects the optimal progressivity of the income tax system. We therefore remove the idiosyncratic health shock component from the law of motion of health capital which results in: $h_j = \phi_j m_j^x + \left(1 - \delta_j^h\right) h_{j-1}$. This law of motion of health capital is very similar to the original framework in Grossman (1972) in which health follows a deterministic trend over the lifecycle. In the model, permanent differences and transitory shocks to labor productivity are the only exogenous source of agent heterogeneity, which is similar to the Bewley model in previous studies including Conesa and Krueger (2006). Income differences also drive health capital heterogeneity through health investments.

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31We do abstract from differences as well as changes in household decomposition (e.g., single, married, divorced, children, etc.). so that is likely that we overstate the insurance role of the progressive income tax system since we abstract from intra household self insurance mechanisms such as female labor supply, home care, etc. Krueger and Wu (2019) explore this question in a partial equilibrium model without health. While we think it is worthwhile exploring this question in a model with health, due to computational constraints we leave it for future research.
We re-solve the model with the new law of motion for health capital. The results are summarized in Table 6. There are two income tax systems: (i) the benchmark US income tax system and (ii) the optimal income tax system. We display the optimal progressive tax schedule in Figure 18.

The macroeconomic aggregates of the economy with no health risk are reported in column 2.A of Table 6. GDP in the economy with no health risk is smaller than GDP in the benchmark economy. Since individuals do not face health risk the demand for health insurance is practically eliminated and the private health insurance markets collapses.

The optimal income tax system is the solution of the government maximization problem (13) with the new law of motion of health capital. The new optimal income tax function changes significantly once health risk is eliminated. The optimal tax function now exhibits a tax break for income up to US$ 4,000, a scaling parameter of $\lambda^{*}_{\text{noH-risk}} = 1.091$, and a tax progressivity parameter of $\tau^{*}_{\text{noH-risk}} = 0.085$. As shown in Figure 18, the entire tax function shifts downward and to the left. The marginal tax rates are significantly lower for all households. Overall, the optimal income tax system is much less progressive without health risk in the model. The Suits index for the optimal tax system decreases to 0.14, which is much lower than the 0.53 we calculated for the optimal tax system in the US benchmark model.

The progressive income tax system is an important channel to redistribute income across different earnings ability groups and supplements the health insurance system. The latter is a new channel that exists only in models with health risk. Subsequently, in models without health risk the optimal income tax system is much less progressive. This implies that most of the benefits of highly progressive taxes stem from social health insurance rather than income redistribution.

We next compare the optimal tax system without health risk to the optimal tax system in Heathcote, Storesletten and Violante (2017) which is also a model without health risk. As seen in panel 3 of Figure 18, the optimal income tax function moves closer to the one reported in Heathcote, Storesletten and Violante (2017). Note that in our Bewley-Grossman model without health risk, households are only exposed to income risk similar to Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017). We find that the optimal income tax system is less progressive than the income tax system in the US benchmark calibration. This finding is similar to the results in Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017) that also exhibit a lower level of progressivity in the optimum compared to the current US income tax progressivity.

Thus, our results emphasize the insurance aspect of progressive taxes in the presence of health risk and show that it is important to account for the presence of health risk when analyzing the optimal progressivity level of an income tax system.

### 4.3 Interactions between health insurance and income tax systems

The health insurance system provides a mechanism to insure against health risk and income risk and redistributes income to low income and relatively sicker households. As such the design of the health insurance system will influence the optimal degree of the income tax progressivity. We consider three alternative
health insurance scenarios: (i) the US health insurance system after the introduction of the Affordable Care Act (hereafter, ACA), (ii) a universal public health insurance system (hereafter, UPHI) where the government extends Medicare to all individuals and (iii) no health insurance where we remove all private and public health insurance. Note that under scenarios (i) and (ii) the health insurance system is more inclusive than the benchmark US healthcare system pre 2010. Proposition 1 in Appendix B would therefore suggest less income tax progressivity in the optimum. Conversely, under scenario (iii) the health insurance system provides no social insurance/redistribution so that the optimal income tax system will exhibit a higher degree of progressivity. We use our computational model to quantify this result and stresses the importance of accounting for the interactions between health insurance and income taxes when designing optimal tax policies.

4.3.1 The Affordable Care Act (ACA)

The ACA represents the most significant reform of the US health care system since the introduction of Medicare in 1965. The key policy instruments embedded in the ACA are: (i) an insurance mandate enforced by a penalty of 2.5 percent of taxable income on workers without health insurance, (ii) screening restrictions in IHI markets so that premiums are set independent of health risk, (iii) the introduction of insurance exchanges with premium subsidies which depend on income, (iv) a Medicaid expansion to 133 percent of the Federal Poverty Level and (v) increases in the capital gains tax for individuals with incomes higher than $200,000 per year (or $250,000 for families). We present more details of the implementation in Appendix C.3. As such, the ACA provides a large redistribution program from healthy high income types to sicker low income types as shown in Jung and Tran (2016).

The optimal tax polynomial. We next fix the level of unproductive government consumption $C_G$ at the US benchmark level, turn on all the features of the ACA just described and solve the government maximization problem (13) for the optimal income tax progressivity rate $\tau_{\text{ACA}}^*$. We report the results of this exercise in Table 7, column 3 and Figure 12.

The optimal tax function after the ACA is characterized by a zero tax break up to US$ 30,300, a scaling parameter of $\lambda_{\text{ACA}}^* = 2.117$, and a tax progressivity parameter of $\tau_{\text{ACA}}^* = 0.222$. The optimal tax progressivity level $\tau_{\text{ACA}}^*$ is slightly smaller than $\tau_{\text{US}}^* = 0.237$ in the benchmark case prior to the ACA.33

Figure 12 compares the two optimal tax systems: one before ACA and one after ACA. As seen in panel 3, the optimal marginal tax schedule shifts left after introducing the ACA. This indicates that the fixed deduction is smaller and the marginal tax rates are larger for each income group which implies less progressivity overall as measured by the Suits index. Households with annual income around $35,000 would have to pay taxes in the ACA case whereas before they were not taxed at all. The ACA provides a significant redistribution of wealth from healthy high income types to sicker low income types through subsidies and the expansion of Medicaid. The government factors in the redistribution that is introduced

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32 In the model we use a flat payroll tax on individuals with incomes higher than $200,000.
33 This is also highlighted by Proposition 1 in our small model.
by the ACA when it optimizes the income tax code. As a result, the new optimal tax system with the ACA is less progressive than before. The Suits index is slightly smaller at 0.50, compared to 0.53 in the US benchmark case.

**Aggregates and welfare.** Columns \([2a]\) and \([2b]\) of Table 7 display the macroeconomic aggregates and welfare outcomes after implementing the ACA with the benchmark income tax system and then the optimal income tax system, respectively. The ACA indeed extends health insurance coverage, but reduces both aggregate output and welfare. This result is consistent with the finding in Jung and Tran (2016). Replacing the US tax system with the optimal tax system reduces aggregate output further, but it improves welfare. The underlying mechanism behind the positive welfare outcome is similar to the baseline analysis. The welfare gain for the lowest skill type is larger, up to 21 percent of lifetime consumption and the welfare loss the highest income types is also larger, up to 35 percent. Overall, there is still a net welfare gain of 2.25 percent at the aggregate level when switching to the optimal income tax with the ACA as the welfare gains resulting from better risk sharing and redistribution still dominate the welfare losses caused by tax distortions.

### 4.3.2 Universal public health insurance (UPHI)

We next consider an experiment in which the government extends public health insurance to all individuals. The out-of-pocket health expenditure is given by

\[
o(m_j) = \rho \times (p_m \times m_j)
\]

Specifically, we assume that the coinsurance rate is \(\rho = 0.2\) which is identical to the calibrated value of Medicare in the US benchmark version of the model. The structural parameters for preferences, technologies, labor productivity and health shocks are identical to the US calibration. We also maintain social security, consumption floor insurance, government consumption and taxes as in the benchmark model. However, we eliminate all private insurance programs in the model. The UPHI system is self-financed by a payroll tax. We then search for the tax progressivity parameter that maximizes welfare of a newborn individual.

We report the macroeconomic aggregates and welfare outcomes after introducing the UPHI program in column \([3.1]\). Output and welfare decrease significantly due to the introducing the UPHI system. The fiscal distortions caused by tax increases needed to finance the UPHI program are the main driver of these results. As before, we consider a switch from the US income tax progressivity to the optimal tax progressivity and report the macroeconomic and welfare effects in column \([3.1b]\) of Table 7. We display the optional income tax schedule in Figure 15.

**Macroeconomic aggregates.** The presence of UPHI and the higher taxes needed to finance it both distort the incentives to save and work. Weekly hours worked decrease from 29.4 hours in the benchmark model to 27.1 hours. Since the UPHI system subsidizes health care consumption, the sectoral production structure and the allocation of capital and labor across sectors changes as more resources move into the healthcare sector. Capital in the non-medical sector decreases by 14 percent while capital in the medical sector remains almost unchanged. Human capital decreases by more than 11 percent in the non-medical sector and increases by 3.8 percent in the medical sector. Output in the non-medical sector drops by 10.5
percent while output in the medical sector increases by 2.9 percent. These distortions lead to significant efficiency losses and lower GDP of about 10 percent.

**The optimal income tax polynomial.** The optimal tax function under the UPHI system includes a zero tax break for incomes up to US$ 26,200, a scaling parameter of $\lambda_{UPHI} = 1.567$, and a tax progressivity parameter of $\tau_{UPHI} = 0.140$. UPHI provides (social) health insurance for all types of individuals in the economy.

The poor working class, who are not covered by insurance under the pre-ACA US healthcare system, are now covered by the UPHI system. As a result, the demand for social insurance provided through the progressive income tax system decreases and therefore the optimal degree of progressivity decreases as well. This is again consistent with our result from Proposition 1. The optimal tax schedule shifts down toward zero as shown in Figure 15. The income threshold that remains tax free decreases to US$ 26,200, which is much smaller than the previous threshold of US$ 36,400 in the benchmark model. The marginal income tax rates are also lower. The rates imposed on incomes above US$ 200,000 are reduced to 35 percent, compared to around 50 percent under the optimal tax system in the benchmark US model. This reduction is mainly driven by a relatively smaller need for tax revenue from the top end of the income distribution. Thus, the expansion of public (social) health insurance significantly reduces the demand for social insurance provided through the progressive income tax system. The Suits index of the optimal tax system in this environment decreases to 0.4.

Interestingly, this new optimal income tax function moves toward the optimal ones in Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017). This may not be surprising. The introduction of UPHI reduces the individual exposure to health shocks dramatically which makes the model’s incentive structure more similar to previous studies that abstract from health risk and health insurance.

**Welfare.** The introduction of the UPHI system results in heterogeneous welfare outcomes. The lowest skill type experiences large welfare gains, but all other income groups experience welfare losses. The overall effect is negative. The net welfare loss is $-5.13$ percent of compensating lifetime consumption. The welfare gains are the result of improved risk sharing and more income redistribution. However, they are dominated by the welfare losses from tax distortions. Switching to the optimal progressive income tax system mitigates the negative welfare effects caused by the introduction of a UPHI system. However, the overall effect is still negative compared to the baseline US insurance system.

This finding indicates that the social insurance role of the income tax system interacts with the social insurance role of the public health insurance system. The optimal design of a progressive income tax system depends on the nature of the public health insurance system. This result highlights the importance of considering a broader notion of a social insurance system that includes both progressive income taxes and public health insurance.

**Lower coinsurance rates.** Arguably, in the UPHI system with a 20 percent coinsurance rate individuals are still exposed to a significant amount of health expenditure risk as they pay 20 percent of their health expenditures out-of-pocket. We next consider an alternative design of a UPHI system with lower coinsurance rates. We find that a more generous UPHI system with a lower coinsurance rate extends (social) health
insurance to additional low income individuals thus reducing the need for high progressivity in the income tax code in order to achieve welfare improving re-distribution. In order to demonstrate this effect, we report the results for the UPHI system with a coinsurance rate of 4 percent in column [3.2] of Table 7 and Figure 16.\(^{34}\) In this setting, the optimal income tax system is characterized by a zero tax break for incomes up to US$ 6,061, a scaling parameter of \(\lambda_{UPHI}^* = 1.117\), and a tax progressivity parameter of \(\tau_{UPHI}^* = 0.07\). We find that this new optimal income tax function is less progressive than the one found in Heathcote, Storesletten and Violante (2017). However, they are quite close, as can be seen in panel 3 of Figure 16.

Thus, the optimal level of tax progressivity is strongly affected by the design of the health insurance system. When the expansion of public health insurance reduces households’ exposure to health expenditure shocks, the optimal tax system becomes less progressive and looks more similar to the optimal progressivity levels reported in previous studies such as Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017).

### 4.3.3 No health insurance

We next consider an economy in which the health insurance system is completely removed. In this setting, individuals exclusively rely on their own income to cover health expenditures, i.e., self-insurance. The OOP health expenditure is therefore given by: \(o(m_j) = p_m \times m_j\). The model again inherits the structural parameter values for preferences, technologies, labor productivity profiles and health shocks from the US calibration. All fiscal policies including social security, consumption floor insurance, general government consumption and taxes are kept at US levels. However, the entire health insurance system, public and private insurance, is eliminated. We then search for the optimal income tax progressivity rate \(\tau_{noHI}^*\) that solves the government maximization problem (13) with no health insurance. We report the macroeconomic and welfare effects in column 4 of Table 8. For comparison, we also repeat the US benchmark steady state values in column 1 and the optimal progressive tax schedule in Figure 17.

Without health insurance individuals rely entirely on private savings and labor income to cover their healthcare costs. That is, individuals are more exposed to health expenditure shocks, especially at the end of the lifecycle. They therefore work longer and save more in order to self-insure against health expenditure shocks. These precautionary motives raise capital accumulation and labor supply at the aggregate level, which subsequently leads to a large expansion of the economy. As reported in column [4a], output increases by 7 percent compared to the benchmark economy. Without health insurance, consumption of non-medical goods increases by 6.1 percent whereas consumption of medical goods decreases by 7 percent.

The optimal tax function for the no insurance case has a zero tax break up to incomes of US$ 42,400, a scaling parameter of \(\lambda_{noHI}^* = 2.681\), and a tax progressivity parameter of \(\tau_{noHI}^* = 0.266\). The optimal tax schedule shifts upward toward zero as shown in Figure 17. The zero tax income threshold increases further,\(^{34}\)In our model with endogenous health spending, an equilibrium with free healthcare (i.e., a zero coinsurance rate) is not feasible. A completely free healthcare system requires very high taxes that result in decreases in labor supply. The effective zero price for healthcare leads to a very high demand that cannot be met on the supply side with the given technology and supply of capital and labor.
compared to the threshold of US$ 36,400 in the benchmark model. The marginal income tax rates are also higher. The rates imposed on incomes above US$ 200,000 are around 50 percent. These increases are due to a relatively larger demand for tax revenue from the top end of income distribution to balance the government budget after further cutting taxes for individuals at the lower end of income distribution.

Thus, turning off the health insurance system increases the demand for social insurance/redistribution through the progressive income tax system. As a consequence, the optimal income tax system is more progressive in this setting. The Suits index increases to 0.59, which is higher than 0.57 in the baseline analysis. This quantitative result is consistent with Proposition 2 which states that as health insurance becomes less generous, the optimal progressivity level increases as more redistribution needs to be provided through the tax system.

4.3.4 Negative income taxes

In our benchmark model, we use the two parameter specification from Benabou (2002) but impose a non-negative tax restriction to remove any transfer components embedded in the tax function.\(^{35}\) In this section, we remove this restriction and use the original specification of \(\hat{\tau}(\hat{y}) = \hat{y} - \hat{\lambda}(1-\tau)\). Under this new tax system, households are able to receive government transfers in the form of negative taxes in addition to Medicaid and consumption insurance.

The optimal tax schedule under this scenario is characterized by tax progressivity parameter \(\tau_{\text{negIncTax}}^* = 0.180\) and scaling parameter \(\hat{\lambda}_{\text{negIncTax}}^* = 1.808\) as can be seen from case 3 in Table 8. We also report total taxes, the average tax rate and the marginal tax rates by income in Figure 17. The optimal marginal tax rates are negative for households with very low income. This implies that poor households receive transfers from the government via the tax system in addition to government transfers such as the minimum consumption insurance, Medicaid and Social Security. The tax payments become positive only when taxable income is above US$ 28,300. The marginal tax rates are around 20 percent when household income reaches US$ 30,000. Households with incomes above US$ 100,000 and US$ 200,000 face marginal tax rates of over 35 percent and 42 percent, respectively. Compared to the baseline results, the marginal tax rates are substantially lower when negative taxes are allowed. The entire tax function moves downward and to the left. The households at the bottom of the income distribution receive transfers through negative tax rates, while the households at the top pay less in taxes under the new optimal tax system.

This result implies that such negative taxes strongly affect the shape of the optimal progressive tax function, especially tax rates for top income individuals. Heathcote, Storesletten and Violante (2017) consider a similar parametric specification when quantifying the optimal level of tax progressivity in the US. Interestingly, we find that the optimal progressive income tax system in our setting moves toward the optimal tax system in Heathcote, Storesletten and Violante (2017). However, the optimal tax system is still more progressive in our model. The main reason is due to differences in the modeling approach. In our Bewley-

\(^{35}\)Since our benchmark model explicitly accounts for major public transfer programs already we keep transfers out of the progressive income tax function.
Grossman model, we model both health and income risk as sources of agent heterogeneity. In addition, we explicitly model all main social transfer programs in the US, including Food Stamps, Social Security, Medicaid, and Medicare. None of these programs are explicitly modeled in Heathcote, Storesletten and Violante (2017).

5 Extensions and robustness checks

In this section we analyze the robustness of our results under different modeling assumptions, including health-dependent survival rates, different elasticities of health expenditure, the absence of health effects on labor productivity, different degrees of risk aversion, and Epstein-Zin-Weil preferences. We provide results for these cases in Table 9.

5.1 Health-dependent survival rates

In the Grossman health capital model health affects household decision making and welfare through three main channels: (i) health has a direct impact on the utility flow from consumption and leisure (utility channel); (ii) health can change the available work time and labor productivity which subsequently affects income (income channel); and (iii) health affects survival probabilities (longevity channel). One limitation of our benchmark model is that we abstract from the third channel in order to lower the computational burden. Health in the benchmark model has no direct effect on survival probabilities. There is a concern that, if health-dependent survival rates were allowed, households would have stronger incentives to invest in health to extend their lifetime which could influence the design of the optimal progressive income taxes as it creates a stronger fiscal externality. The extent to which the optimal level of tax progressivity will change with endogenous survival probabilities will depend on how strongly health affects the survival rates.

In this section, we therefore add the survival channel and allow health to influence the survival rates of the retired individuals. We follow Hall and Jones (2007) and Zhao (2014) and assume that the survival probability function, \( \pi(h) \), has the form of the cumulative distribution function of a Weibull distribution \( \pi(h) = 1 - \frac{1}{e^\varphi h^\theta} \) for \( h > 0, \varphi > 0 \) and \( \theta > 0 \). The Bellman equation is given by

\[
V(x_j) = \max \left\{ \left\{ (u(c_j, n_j, h_j, b)) + \beta \pi_j(h_{j+1})E[V(x_{j+1}) | x_j] \right\} s.t. \right. \\
\left. \left( 1 + \tau C \right)c_j + (1 + g)a_{j+1} + o(m_j) + 1_{[j>J]} \right] \text{prem} = y_j - tax_j + t_j^{SI}, \tag{14} \]

and \( 0 \leq a_{j+1}, \) and \( n_j = 0 \). Our newly recalibrated matches data from the US as well as US survival rates from 2010. We then apply the model to search for the optimal progressive income tax system that maximizes the social welfare criteria.\(^{37}\)

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\(^{36}\)Survival rates of working age individuals are very high in general and the restriction simplifies our calibration strategy significantly.

\(^{37}\)This modeling approach is similar to the one in Hall and Jones (2007), Suen (2006) and Zhao (2014). Note that in a standard CRRA utility function, the level of utility would be negative when the coefficient of relative risk aversion is larger than one.
We find that the optimal progressivity parameter with endogenous survival rates is $\tau^*_US = 0.1925$ with a scaling parameter of $\lambda^*_US = 1.933$. The marginal tax rate is zero for income earners below US$ 32,324. Compared to the benchmark model with exogenous survival probabilities we now find that the optimal policy is slightly less progressive. The self protection possibility through health investments creates an additional investment payoff for health investments so that less redistribution is needed from the income tax system as agents have an additional option to take care of themselves. However, the optimal income tax system still exhibits a higher level of tax progressivity than the US benchmark tax system. When the health insurance system is reformed to extend Medicare to all individuals the optimal income tax system becomes less progressive and the zero tax rate threshold moves to US$ 20,203 as can be seen from the last column in Table 9. As such our results are qualitatively similar to the results from the benchmark model where health does not affect survival rates. Thus, inclusion of an additional channel through which health affects survival does not change our main finding that the presence of health risk in an environment with incomplete of health insurance amplifies the social insurance role of progressive income taxes.

5.2 Elasticity of health expenditure

In our endogenous health model, health expenditure is responsive to changes in after-tax income, health insurance and the price of medical care. In this section, we reduce the elasticity of health expenditures with respect to price and income changes. To do so, we introduce an alternative functional form for preferences in which there is a time cost associated with medical consumption, similar to Jung and Tran (2016)

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

where $\eta_m \geq 0$ is a parameter that controls the utility cost of the procurement of medical services. If $\eta_m = 0$, there is no direct time cost associated with healthcare investments to produce health capital. If $\eta_m > 0$, the procurement of medical services imposes a time cost as it reduces leisure time in the preferences.

We specifically consider the case with $\eta_m = 1.0$ as the second case in Table 9. Our new simulation results indicate that the optimal tax function results in a progressivity parameter of $\tau^*_US = 0.1925$ and an associated scaling parameter of $\lambda^*_US = 1.838$. The optimal tax system is characterized by a tax break for income earners below US$ 30,303 and a jump in the marginal tax rate. The optimal income tax system is again more progressive than the current US income tax code and the Suits index increases from 0.17 to 0.36. This is less progressive than the result in the benchmark model in Section 4.1. This makes sense as in this setup, high medical spending triggers a large utility time cost so that the distribution of medical spending has less variation in this setup so that a lower level of redistribution through the tax system is optimal. Overall though the result is qualitatively similar to our baseline analysis with a higher elasticity of medical spending. A similar result holds for the UPHI case that again exhibits a lower degree of optimal

When survival rates do not depend on health, the level of period utility flow does not matter. However, when extending life becomes a choice, the level of utility is not irrelevant anymore. For instance, agents would prefer a shorter life if the level of utility is negative. To avoid this problem, we follow Hall and Jones (2007) and add a positive constant $b$ into the utility function.
progressivity and zero tax threshold of US$ 18,183. Both cases confirm that even when health expenditure is less elastic, progressive income taxes are still an important source of social insurance, especially when the health insurance system is fragmented and incomplete.

5.3 No health effect on labor productivity

In our benchmark model we explicitly model a health component in the wage process (the second channel of health effects). We now examine the quantitative role of that channel. We do so by setting the value of parameter \( \chi \) in expression (12) to 1, while keeping all other parameters of the model unchanged. Removing the health influence on labor productivity, labor efficiency units evolve stochastically over the lifecycle according to: 

\[ e_j(\vartheta, \epsilon^n) = \bar{e}_{j,\theta} \times \epsilon^n \quad \text{for} \quad j = \{1, \ldots, J_w\}. \]

Labor efficiency units are now similar to the previous literature (e.g., Storesletten, Telmer and Yaron (2004) and Conesa, Kitao and Krueger (2009)). With this modeling assumption, there is no explicit component of health in the wage process and the income channel of health effects is removed. Note that, since households still have health in their preferences, the utility channel of health is still at work. Health investments and insurance are still endogenous choices and appear in household budget constraint. We re-calibrate the model and repeat the previous experiments. The optimal tax system is significantly more progressive than the benchmark US tax system and the zero tax thresholds increases to US$ 38,385. When UPHI is introduced to replace the US health insurance system, the optimal and benchmark income tax system are very close and the optimal zero tax threshold decreases to US$ 4,041. The tax progressivity parameter and Suits index increase slightly from 0.053 and 0.18 in the benchmark tax system to 0.24 and 0.53 in the optimal tax system, respectively. Thus, as more social health insurance is provided via a more inclusive health insurance system that covers everyone, there will be less demand for the social insurance role of the progressive income tax system. This result highlights the important implications of modeling health risk together with the available insurance options on the optimal design of a system of progressive income taxes.

5.4 Alternative values of risk aversion

We next explore the sensitivity of the model dynamics to alternative values of risk aversion parameter \( \sigma \) in cases [4A] and [4B] in Table 9. We recalibrate the model with \( \sigma = 2 \) and again with \( \sigma = 4 \). For each case we then simulate the model and search for the optimal progressive income tax code using the same welfare objective as before. In an economy model with lower values of risk aversion (\( \sigma = 2 \)) than in the benchmark calibration (\( \sigma = 3 \)), the optimal tax function consists of a progressivity parameter of \( \tau_{US}^* = 0.1862 \) and a scaling parameter of \( \lambda_{US}^* = 1.891 \) which implies a zero tax threshold of US$ 32,324. That is, the optimal income tax system is more progressive than the US tax system in the model with low risk aversion. When a universal public health insurance system is introduced, the optimal level of tax progressivity is reduced as before. The result is robust to higher values of risk aversion (\( \sigma = 4 \)) as well as the optimal progressivity is
quite similar. We conclude that overall our findings are robust within the considered range of risk-aversion parameter values.

5.5 Epstein-Zin-Weil preferences

In this section we use Epstein-Zin-Weil preferences (Epstein and Zin (1989), Epstein and Zin (1991), and Weil (1990)) which allow for separate parameters for the intertemporal elasticity of substitution and risk aversion. Standard Von Neumann-Morgenstern preferences constrain the coefficient of relative risk aversion to be the reciprocal of the elasticity of intertemporal substitution. The recursive preferences can be written as

\[
V(x_j) = \max \left\{ (1 - \beta) \left( \left( \frac{1 - l_j \cdot \xi_j}{(1 + m)^{\eta \cdot m}} \right)^{1 - \eta} \right)^{1 - \sigma} + \beta \pi_j (h_{j+1}) \left( E \left[ V(x_{j+1})^{1 - \gamma} | x_j \right] \right) \right\}^{1 - \sigma},
\]

where \(\sigma\) is the inverse of the elasticity of intertemporal substitution and \(\gamma\) is the coefficient of relative risk aversion. We recalibrate the benchmark model with \(\sigma = 1.3\), \(\gamma = 3\) and \(\beta = 0.966\). We use the new benchmark model and search for the optimal progressive income tax code. As reported in Table 9 the optimal progressive income tax system is more progressive under the pre-Obamacare health insurance system. After introducing UPHI the optimal income tax system becomes less progressive than the US benchmark tax system as before. Interestingly, the level of progressivity is lower than under the benchmark US system. However, our main conclusion is robust with respect to switching to Epstein-Zin-Weil preferences as the optimal tax system exhibits a higher level of progressivity than the US benchmark and the optimal system under the UPHI program exhibits a much lower level of progressivity.

6 Conclusion

In this paper we study the optimal level of progressivity of an income tax system in a model where individuals are exposed to idiosyncratic health and income shocks in an incomplete markets setting. In our framework the distributions of consumption, income and wealth are determined by exogenous earnings risk, health risk and equilibrium conditions. We demonstrate that the presence of health risk in combination with incomplete insurance markets introduces a new channel that significantly affects the role of the progressive income tax system. In particular, given the institutional features of the US health insurance system the optimal income tax system exhibits higher levels of progressivity than the current tax system in order to provide a sufficient amount of redistribution and social insurance to individuals who are likely exposed to bad health and low income.

Our results highlight that the progressive income tax plays a key role in shaping the income distribution across households. Income inequality decreases under the optimal system as measured by after-tax income Gini coefficients. A fundamental tax reform that switches the current US tax system to the optimal tax system results in large welfare gains. However, the welfare effects are asymmetric. The poor and lower-
middle income households gain because of lower taxes whereas high income earners suffer from higher taxes. This suggests that implementing such a reform would be a political challenge. More importantly, our results indicate that the optimal level of tax progressivity is highly dependent on the type of health insurance system in place and the interaction between income and health risks over the lifecycle. Overall, the presence of health risk significantly amplifies the social insurance/redistribution role of the progressive income tax system.

Our results differ from previous studies that found much lower levels of optimal tax progressivity (e.g., see Conesa and Krueger (2006) and Heathcote, Storesletten and Violante (2017)). This difference is mainly attributed to the presence of the additional source of uncertainty, that is health risk, and institutional features of the health insurance system in our framework. When health expenditure risk is reduced/eliminated, the optimal income tax system becomes more similar to the optimal systems reported in previous studies based on models with only income risk.

This paper only focuses on a progressive income tax system. However, there are broader questions that can be investigated with our framework. For example, a switch from a progressive income tax to a progressive consumption tax is an interesting case. Analyzing the optimal design of the whole tax and transfer system in this environment is another possible avenue to investigate. In addition, bequest motives and transition dynamics are left for future research.
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Figure 1: Health status, income, and out-of-pocket (OOP) health expenditure.
Self-Reported Health Status reports 5 levels of health status: 1. excellent, 2. very good, 3. good, 4. fair, or 5. poor. We use SRHS to construct a binary “healthy” index. An individual is considered to be in good health or “healthy”, if his/her SRHS is either excellent, very good, or good; and “sick/unhealthy”, if otherwise. OOP expenditure in 2009 US dollars.
Figure 2: Health status over the lifecycle
MEPS provides two measures of health status: the Short-Form 12 Version 2 (SF12v2) and Self-Reported Health Status (SRHS). SF12v2 is computed using the scores of twelve questions on physical and mental health. SF12v2 ranges from 0 to 100, where a zero score indicates the lowest level of health measured by the scales and 100 indicates the highest level of health. Panels 1 and 2 report the mean and standard deviation of the SF12v2 index. SRHS reports 5 levels of health status: 1. excellent, 2. very good, 3. good, 4. fair, or 5. poor. We use SRHS to construct a binary “healthy” index. An individual is considered to be in good health, i.e., “healthy”, if his/her SRHS is either excellent, very good, or good; and “unhealthy” otherwise. Panel 3 reports the fraction of healthy individuals over life time. The two measures of health status show that health depreciates over the life cycle.
Figure 3: **Total health expenditure by health state.**

Health expenditures are low early in life because of high initial health capital and low health risk and subsequently health expenditures rise as individuals are exposed to more frequent and larger health shocks. On average, individuals in their twenties spend about $1,500 per year on healthcare whereas older individuals in their fifties spend about $4,000 per year. Once individuals are older than 50, health expenditures rise very fast on average. The highest expenditures are incurred by the very old and amount to approximately $10,000 on average per year. Panels 3 and 4 in Figure 3 compare the lifecycle patterns of total health expenditures by health status in levels and as fraction of income. There is a large gap between the spending patterns of the healthy and sick. The sick group spends significantly more over the lifecycle.
Figure 4: **Health financing and insurance take up rates.**


The fraction of health expenditure financed by private insurance and Medicaid decreases with age, whereas the fraction of health expenditures financed by out-of-pocket funds increases moderately. Around the retirement age of 65 there is a big shift in the magnitude of financing from private insurance toward public insurance including Medicare, Veteran’s benefits, and other state run insurance plans. Employer-based group health insurance policies (GHI) cover only around 60 percent of the working-age population while individual-based health insurance policies (IHI) cover less than 6 percent. A large number of healthy and young individuals do not have health insurance, either by choice or by circumstance. The fraction of the uninsured is highest among young workers below 35. Medicaid picks up less than 10 percent of workers by covering low income individuals. About 25 percent of the working population are without health insurance.
Figure 5: **Health expenditure and insurance take-up**
Model vs. data from MEPS 2000-2009
Figure 6: Moment matching using PSID 1984-2007 and CPS 1999-2009
Blue lines are model generated data moments and black dotted lines are PSID data in Panel 1 and 2 and CPS data in Panel 3.

Figure 7: Moment matching using MEPS 2000-2009
Blue dots are model generated data moments and green dots lines are from PSID data.
Figure 8: **Moment matching using MEPS 2000-2009**
Blue dots are model generated data moments and green dots lines are from PSID data.
Figure 9: The optimal income taxes in the benchmark calibrated economy

Progressive income taxes of the pre-ACA benchmark case are based on Guner, Lopez-Daneri and Ventura (2016) that uses the tax polynomial introduced in Benabou (2002). The Conesa and Krueger (2006) case is based on a model without health shocks and health insurance and uses a tax polynomial based on Gouveia and Strauss (1994). The optimal tax function consists of a tax break up to US$ 36,400, a scaling parameter of $\lambda^* = 2.317$, and a tax progressivity parameter of $\tau^* = 0.237$. 
Figure 10: Change in the coefficient of variation by age group after introducing the optimal progressive income tax.

We report the difference in the coefficient of variation of variable $x$ by age group: $\text{CV}(x\text{-optimal}) - \text{CV}(x\text{-US benchmark})$ where $x$ is either consumption, medical spending or gross income.
Figure 11: **Changes after introducing the optimal progressive income tax system**

We express the difference in percentage changes of average values per income group from optimizing taxes in the benchmark economy.
Figure 12: The optimal income tax systems before and after the ACA
Progressive income taxes of the pre-ACA Benchmark case are based on Guner, Lopez-Daneri and Ventura (2016) and use the tax polynomial introduced in Benabou (2002). The red-circled line is the optimal tax without the ACA and the green-triangle line is the optimal tax with the ACA. The optimal tax function after the ACA is characterized by a tax break up to US$ 30,000, a scaling parameter of $\lambda^* = 2.117$, and a tax progressivity parameter of $\tau^* = 0.222$. 
Figure 13: **Lorenz curves and Suits Index for the income taxes**

The Tax Lorenz-type curve and Suits index measure the degree of dis proportionality between pretax income and tax contributions by means of a relative concentration curve. The Suits index is essentially a Gini coefficient for tax contributions by income group. It varies from +1 (most progressive) where the entire tax burden is allocated to households of the highest income bracket, through 0 for a proportional tax, and to −1 (most regressive) where the entire tax burden is allocated to households of the lowest income bracket.
Figure 14: **Income and Income Tax Lorenz Curves**

Panel [1] presents Lorenz curves of taxable income (pre-ACA Benchmark). Panel [2] presents Suits curves of progressive income taxes based on Suits (1977) and Panel [3] presents Suits curves of total taxes, that is consumption taxes, progressive income taxes, and payroll taxes for social security and Medicare. For the ACA case total taxes also include a new tax on investment income of high income earners and penalties for being uninsured. Panel [4-6] present the cases with the ACA.

Progressive income taxes of the pre-ACA Benchmark case are based on Guner, Lopez-Daneri and Ventura (2016) and use the tax polynomial introduced in Benabou (2002). The ACA case uses the same tax structure as the pre-ACA Benchmark case.
Figure 15: The optimal income tax system after introducing a universal public health insurance (UPHI) system with a coinsurance rate of 20 percent

Progressive income taxes of the pre-ACA Benchmark case are based on Guner, Lopez-Daneri and Ventura (2016) and use the tax polynomial introduced in Benabou (2002).

The red-circled line is the US optimal tax benchmark case without the ACA and the purple line with triangle markers is the optimal tax with UPHI. The optimal tax function consists a tax break up to US$ 26,200, a scaling parameter of $\lambda^* = 1.567$, and a tax progressivity parameter of $\tau^* = 0.140$. 
Figure 16: The optimal income tax system after introducing a universal public health insurance (UPHI) system with a coinsurance rate of 4 percent.

[1] The red dotted line is the optimal benchmark case (i.e., a tax break up to US$ 36,400, $\lambda^* = 2.317$, and $\tau^* = 0.237$).

[2] The purple line with triangle markers is the optimal tax function of the UPHI system with a 20 percent coinsurance rate (i.e., a tax break up to US$ 26,200, $\lambda^* = 1.567$, and $\tau^* = 0.140$).

[3] The orange line with x-markers is the optimal tax function of the UPHI system with a 4 percent coinsurance rate (i.e., a tax break up to US$ 6,061, $\lambda^* = 1.117$, and $\tau^* = 0.07$).

Figure 17: Sensitivity analysis of optimal taxes

[0] The red-circle line is the optimal tax without the ACA (i.e., a tax break up to US$ 36,400, $\lambda^* = 2.317$, and $\tau^* = 0.237$).

[1] The blue squares line is the optimal tax without any health insurance contracts (i.e., a tax break up to US$ 42,400, $\lambda^* = 2.681$ and $\tau^* = 0.266$).

[2] The purple-x line is the optimal tax structure allowing for negative taxes (i.e., a tax break up to US$ 28,300, $\lambda^* = 1.808$ and $\tau^* = 0.180$).

[3] The green starred line is the optimal tax without any idiosyncratic health shocks.
Figure 18: **No health shock case**

[1] The blue solid line is the US tax case.

[2] The green line with star markers is the optimal tax case for the no health shock version (i.e., a tax break up to US$ 4,041, $\lambda^* = 1.090$, and $\tau^* = 0.085$).

### Table 1: 2017 Marginal tax rates in the US

<table>
<thead>
<tr>
<th>Marginal Tax Rate</th>
<th>Single Taxable Income</th>
<th>Married Filing Jointly</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>$0 - $9,325</td>
<td>$0 - $18,650</td>
</tr>
<tr>
<td>15%</td>
<td>$9,326 - $37,950</td>
<td>$18,651 - $75,900</td>
</tr>
<tr>
<td>25%</td>
<td>$37,951 - $91,900</td>
<td>$75,901 - 153,100</td>
</tr>
<tr>
<td>28%</td>
<td>$91,901 - $191,650</td>
<td>$153,101 - $233,350</td>
</tr>
<tr>
<td>33%</td>
<td>$191,651 - $416,700</td>
<td>$233,350 - $416,700</td>
</tr>
<tr>
<td>35%</td>
<td>$416,7001 - $418,400</td>
<td>$416,701 - $470,700</td>
</tr>
<tr>
<td>39.6%</td>
<td>$418,401+</td>
<td>$470,700+</td>
</tr>
<tr>
<td>Parameter Description</td>
<td>Parameter Values</td>
<td>Source</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Maximum periods alive</td>
<td>$J = 15$</td>
<td></td>
</tr>
<tr>
<td>Periods working</td>
<td>$J_w = 9$</td>
<td></td>
</tr>
<tr>
<td>Population growth rate</td>
<td>$n = 1.2%$</td>
<td>CMS 2010</td>
</tr>
<tr>
<td>Years modeled</td>
<td>$years = 75$</td>
<td>from age 20 to 95</td>
</tr>
<tr>
<td>Total factor productivity</td>
<td>$A_c = 1$</td>
<td>Normalization</td>
</tr>
<tr>
<td>Growth rate</td>
<td>$g = 2%$</td>
<td>NIPA</td>
</tr>
<tr>
<td>Capital share in production</td>
<td>$\alpha_c = 0.33$</td>
<td>Kydland and Prescott (1982)</td>
</tr>
<tr>
<td>Capital in medical services prod.</td>
<td>$\alpha_m = 0.26$</td>
<td>Donahoe (2000)</td>
</tr>
<tr>
<td>Capital depreciation</td>
<td>$\delta = 10%$</td>
<td></td>
</tr>
<tr>
<td>Health depreciation</td>
<td>$\delta_{h,j} = [0.6% - 2.13%]$</td>
<td>MEPS 1999/2009</td>
</tr>
<tr>
<td>Survival probabilities</td>
<td>$\pi_j$</td>
<td>CMS 2010</td>
</tr>
<tr>
<td>Health Shocks</td>
<td></td>
<td>Technical Appendix</td>
</tr>
<tr>
<td>Health transition prob.</td>
<td></td>
<td>MEPS 1999/2009</td>
</tr>
<tr>
<td>Productivity shocks</td>
<td></td>
<td>Technical Appendix</td>
</tr>
<tr>
<td>Productivity transition prob.</td>
<td></td>
<td>MEPS 1999/2009</td>
</tr>
<tr>
<td>Group ins. transition prob.</td>
<td></td>
<td>Technical Appendix</td>
</tr>
<tr>
<td>Price for med. care: uninsured</td>
<td>$\nu_{\text{noIns}} = 0.7$</td>
<td>MEPS 1999/2009</td>
</tr>
<tr>
<td>Price markup for IHI insured</td>
<td>$\nu_{\text{IHI}} = 0.25$</td>
<td>Shatto and Clemens (2015)</td>
</tr>
<tr>
<td>Price markup for GHI insured</td>
<td>$\nu_{\text{GHI}} = 0.1$</td>
<td>Shatto and Clemens (2015)</td>
</tr>
<tr>
<td>Price markup for Medicaid</td>
<td>$\nu_{\text{Maid}} = 0.0$</td>
<td>Shatto and Clemens (2015)</td>
</tr>
<tr>
<td>Price markup for Medicare</td>
<td>$\nu_{\text{Mcare}} = -0.1$</td>
<td>Shatto and Clemens (2015)</td>
</tr>
<tr>
<td>Coinsurance rate: IHI in %</td>
<td>$\gamma_{\text{IHI}} \in [22, 46, 49, 50, 53, 52, 50]$</td>
<td>MEPS 1999/2009</td>
</tr>
<tr>
<td>Coinsurance rate: GHI in %</td>
<td>$\gamma_{\text{GHI}} \in [33, 33, 33, 34, 36, 36, 45, 50]$</td>
<td>MEPS 1999/2009</td>
</tr>
<tr>
<td>Medicare premiums/GDP</td>
<td>$2.11%$</td>
<td>Jeske and Kitao (2009)</td>
</tr>
<tr>
<td>Medicaid coins. rate in %</td>
<td>$\gamma_{\text{Maid}} \in [11, 14, 17, 16, 17, 18, 20, 22]$</td>
<td>Center for Medicare and Medicaid Services (2005)</td>
</tr>
<tr>
<td>Public coins. rate retired in %</td>
<td>$\gamma^R = 20$</td>
<td>Center for Medicare and Medicaid Services (2005)</td>
</tr>
<tr>
<td>IHI markup profits</td>
<td>$\omega_{\text{IHI}} = 0$</td>
<td>No data</td>
</tr>
<tr>
<td>Payroll tax Social Security:</td>
<td>$\tau_{\text{Soc}} = 9.4%$</td>
<td>IRS</td>
</tr>
<tr>
<td>Consumption tax:</td>
<td>$\tau^c = 5.0%$</td>
<td>Mendoza, Razin and Tesar (1994)</td>
</tr>
<tr>
<td>Payroll tax Medicare:</td>
<td>$\tau_{\text{Med}} = 2.9%$</td>
<td>SSA (2007)</td>
</tr>
<tr>
<td>Progressivity parameter</td>
<td>$\tau = 0.053$</td>
<td>Guner, Lopez-Daneri and Ventura (2016)</td>
</tr>
<tr>
<td>The tax break threshold</td>
<td>US$ 6,050</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2: External parameters**

These parameters are based on our own estimates from MEPS and CMS data as well as other studies.
Parameters Description | Parameter Values | Calibration Target | Nr.M.
--- | --- | --- | ---
Relative risk aversion | $\sigma = 3.0$ | to match $\frac{K}{Y}$ and $R$ | 1
Pref. of consumption vs. leisure | $\eta = 0.43$ | to match labor supply and $\frac{p \times M}{Y}$ | 1
Pref. of consumption/leisure 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
GHI markup profits | $\omega_{\text{GHI}} = 0.01$ | to match GHI take-up | 1
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
Fixed time cost of labor | $\bar{n}_j \in [0.0 - 0.7]$ | to match labor participation | 9
Minimum health state | $h_{\text{min}} = 0.01$ | to match health spending | 1
Asset test level | $d_{\text{Medicaid}} = \$150,000$ | to match Medicaid take-up | 1
Total number of internal parameters | | | 44

Table 3: **Internal parameters**

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

<table>
<thead>
<tr>
<th>Moments</th>
<th>Model</th>
<th>Data</th>
<th>Source</th>
<th>Nr.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical expenses HH income</td>
<td>17.6%</td>
<td>17.07%</td>
<td>CMS communication</td>
<td>1</td>
</tr>
<tr>
<td>Workers IHI</td>
<td>5.6%</td>
<td>7.2%</td>
<td>MEPS 1999–2009</td>
<td>1</td>
</tr>
<tr>
<td>Workers GHI</td>
<td>61.1%</td>
<td>62.2%</td>
<td>MEPS 1999–2009</td>
<td>1</td>
</tr>
<tr>
<td>Workers Medicaid</td>
<td>9.6%</td>
<td>9.2%</td>
<td>MEPS 1999–2009</td>
<td>1</td>
</tr>
<tr>
<td>Capital output ratio: $K/Y$</td>
<td>2.7%</td>
<td>2.6 – 3</td>
<td>NIPA</td>
<td>1</td>
</tr>
<tr>
<td>Interest rate: $R$</td>
<td>4.2%</td>
<td>4%</td>
<td>NIPA</td>
<td>1</td>
</tr>
<tr>
<td>Size of Social Security/$Y$</td>
<td>5.9%</td>
<td>5%</td>
<td>OMB 2008</td>
<td>1</td>
</tr>
<tr>
<td>Size of Medicare/$Y$</td>
<td>3.1%</td>
<td>2.5 – 3.1%</td>
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<td>Figure 5</td>
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<td>IHI insurance take-up profile</td>
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<td>Figure 5</td>
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<td>Figure 5</td>
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<td>Average labor hours</td>
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<td>Figure 6</td>
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<td>Total number of moments</td>
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Table 4: **Matched data moments**

We choose internal parameters so that model generated data matches data from MEPS, CMS, and NIPA.
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<td>B. Optimal Tax System</td>
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</tr>
<tr>
<td>Capital (K_m)</td>
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<td>Weekly hours worked</td>
<td>29.40</td>
<td>29.03</td>
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<td>Workers insured (%)</td>
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<tr>
<td>Medicaid (%)</td>
<td>9.56</td>
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<td>5.08</td>
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<tr>
<td>Wage rate (w)</td>
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<tr>
<td>Gini (Total income)</td>
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<tr>
<td>Gini (Net income)</td>
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<td>0.31</td>
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<tr>
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<td>0.237</td>
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<td>The tax break threshold (US$)</td>
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<td>Scaling parameter (λ)</td>
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<tr>
<td>• Income Group 3</td>
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<td>• Income Group 4 (High)</td>
<td>0</td>
<td>−31.84</td>
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</tr>
</tbody>
</table>

Table 5: **Macroeconomic and welfare effects when switching from the benchmark US tax system to the optimal progressive income tax system.**

Column 1 shows steady state results of the benchmark economy based on the current US income tax system and a pre-ACA health insurance system. Column 2 shows steady state results for an identical economy with a welfare maximizing progressive tax system. Numbers in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are normalized with values of the benchmark case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual with respect to consumption levels in the benchmark.
### Table 6: Health risk and optimal tax progressivity.

This table presents steady state results in the model economies with no health risk. Column 1 shows steady state results of the benchmark economy based on the current US income tax system and a pre-ACA health insurance system. Column 2 shows the results for an economy without idiosyncratic health shocks. Sub-column A. US-Tax shows the US income tax system with no health risk and sub-column B. Opt-Tax shows the optimal income tax system with no health risk. Numbers in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are normalized with values of the benchmark case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual with respect to consumption levels in the benchmark.

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<td>128.65</td>
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<td>78.59</td>
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<td>2.25</td>
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<tr>
<td>Medicaid (%)</td>
<td>9.56</td>
<td>2.38</td>
<td>2.25</td>
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<td>Interest rate (r in %)</td>
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<td>0.46</td>
<td>0.46</td>
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<tr>
<td>Gini (Net income)</td>
<td>0.38</td>
<td>0.39</td>
<td>0.38</td>
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<tr>
<td>Suits index (Income tax)</td>
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<td>0.09</td>
<td>0.14</td>
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<td>-5.66</td>
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<td>+19.61</td>
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<td>96.61</td>
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<td>99.59</td>
<td>99.62</td>
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<td>NA</td>
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</tr>
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<td>-35.17</td>
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Table 7: Health insurance systems and optimal tax progressivity.

Column 1 shows steady state results of the benchmark economy based on the US income tax system and a pre-ACA health insurance system. Column 2 shows the US health insurance system with the implementation of the ACA. Column 3 and 4 show results with Universal Public Health Insurance with a 20 or 4 percent coinsurance rate, respectively. For each case, sub-column A. US-Tax denotes the US income tax system and sub-column B. Opt-Tax shows the optimal income tax system. The ACA and the UPHI systems are financed by a payroll tax $\tau^v$. Data in rows marked with the % symbol are either fractions in percent or tax rates in percent. All other rows are normalized with values of the benchmark case. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn.
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<td>99.92</td>
<td>88.65</td>
</tr>
<tr>
<td>Med. consumption (M)</td>
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<td>92.92</td>
<td>100.04</td>
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<td>0</td>
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<td>7.19</td>
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<tr>
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<td>4.37</td>
<td>5.07</td>
<td>5.38</td>
</tr>
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<td>98.55</td>
</tr>
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<td>Gini (Total income)</td>
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<td>0.44</td>
<td>0.41</td>
<td>0.44</td>
<td>0.45</td>
</tr>
<tr>
<td>Gini (Net income)</td>
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<td>0.39</td>
<td>0.33</td>
<td>0.38</td>
<td>0.34</td>
</tr>
<tr>
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<td>0.17</td>
<td>0.53</td>
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<td>3.36</td>
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<td>+27.71</td>
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<td>+5.65</td>
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<td>0.04</td>
<td>-31.14</td>
<td>-0.11</td>
<td>-30.73</td>
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</tbody>
</table>

Table 8: The optimal income tax system in economies with no health insurance.

This table presents steady state results in the model economies with no health insurance or negative income tax allowed. Column 1 shows steady state results of the benchmark economy based on the current US income tax system and a pre-ACA health insurance system. Column 2 shows steady state results of an economy without any health insurance. A. US-Tax shows the US income tax system with no health insurance and sub-column B. Opt-Tax shows the optimal income tax system with no health insurance. Numbers in rows marked with the % symbol are either fractions in percent or tax rates in percent. The other rows are normalized with values of the benchmark case. Each column presents steady-state results. CEV values are reported as percentage changes in terms of lifetime consumption of a newborn individual with respect to consumption levels in the benchmark.
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>0.053</td>
<td>0.237</td>
<td>0.053</td>
<td>0.14</td>
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<td>0.108</td>
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<td>1.095</td>
<td>1.08</td>
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<td>$38,385</td>
<td>$6,061</td>
<td>$4,041</td>
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<tr>
<td>Suits index (Income tax)</td>
<td>0.18</td>
<td>0.53</td>
<td>0.12</td>
<td>0.14</td>
</tr>
</tbody>
</table>


Table 9: Optimal progressive income tax systems under different modeling assumptions.


text:

A. Data and stylized facts

A.1 Data

We use data from the Panel Study of Income Dynamics (PSID) and the Medical Expenditure Panel Survey (MEPS) 1999–2009 for our estimation and calibration.

**PSID.** We use eight waves of the Panel Study of Income Dynamics (PSID) in combination with the wealth surveys of 1984, 1989, 1994, 1999, 2000, 2003 and 2005 to estimate the initial asset profiles and labor hours for agents in our benchmark model. We use variable Sx16, which is the sum of all asset value types net of debt value and home equity (x refers to wave) and drop values above $800,000. All values are converted to 2009 dollars using the PCE chain price index.

**MEPS.** We use MEPS from 1999 to 2009 for estimation of health related variables. MEPS provides a nationally representative survey about health care use, health expenditures, health insurance coverage as well as demographic data on income, health status, and other socioeconomic characteristics. The original household component of MEPS was initiated in 1996. Each year about 15,000 households are selected and interviewed five times over two full calendar years. MEPS groups individuals into Health Insurance Eligibility Units (HIEU). We do abstract from family size effects and concentrate on adults aged 20–91 who are the head of the household. We supplement some health expenditure data with data we received from the Centers for Medicare and Medicaid Service, Office of the Actuary because MEPS is not a representative sample of the retired population. We remove individuals with income less than $500. If we only keep individuals with observations in two consecutive years, we are left with 131,121 head-of-HIEU/year observations.

We calculate population weighted health expenditure profiles, as well as Markov transition probability matrices for income shocks, health shocks, and employer matching shocks. All dollar values are denominated in 2009 dollars using the Personal Consumption Expenditures (PCE - chain price) index for monetary measures. All distributional statistics for income are calculated for working age individuals between age 20–65. Summary statistics are presented in Table 10. We document key facts on medical expenditure over the lifecycle using MEPS data in our empirical paper Jung and Tran (2014).

A.2 Stylized facts

In order to motivate the role of health factors we document some stylized facts on health status, health expenditures, insurance, health financing and income over the lifecycle using data from the Medical Expenditure Panel Survey (MEPS).

**Health status.** Due to human biology, health status is highly correlated with age. The literature has used various proxy measures for health status. MEPS provides two measures: Short-Form 12 Version 2 (SF-12v2) and Self-Reported Health Status (SRHS). SF-12v2 ranges from 0 to 100, where a zero score

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SF-12v2 includes twelve different health measures about physical and mental health and is available as a physical health index as well as a mental health index. Both indices use the same variables to construct the index but the physical health index
<table>
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<th>Std.Err.</th>
<th>Obs.</th>
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</tr>
<tr>
<td>Female</td>
<td>44.6%</td>
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<tr>
<td>Person total income</td>
<td>$39,976</td>
<td>$271</td>
<td>131,121</td>
</tr>
<tr>
<td>Hourly wage</td>
<td>$20.0</td>
<td>$0.12</td>
<td>85,149</td>
</tr>
<tr>
<td>Health expenditure</td>
<td>$4,203</td>
<td>$54.85</td>
<td>131,121</td>
</tr>
<tr>
<td>Health capital (4.56 – 74.38)</td>
<td>49.48</td>
<td>0.07</td>
<td>112,672(∗)</td>
</tr>
<tr>
<td>No insurance</td>
<td>21.1%</td>
<td>0.003</td>
<td>91,538(**)</td>
</tr>
<tr>
<td>Workers on individual health insurance(IHI)</td>
<td>7.2%</td>
<td>0.001</td>
<td>91,538</td>
</tr>
<tr>
<td>Workers on group health insurance (GHI)</td>
<td>62.17%</td>
<td>0.004</td>
<td>91,538</td>
</tr>
<tr>
<td>Workers with GHI offer</td>
<td>63.07%</td>
<td>0.003</td>
<td>91,538</td>
</tr>
<tr>
<td>Workers on Medicaid/Public</td>
<td>9.60%</td>
<td>0.002</td>
<td>91,538</td>
</tr>
<tr>
<td>Coinsurance IHI</td>
<td>0.50</td>
<td>N/A</td>
<td>4,646(∗∗*)</td>
</tr>
<tr>
<td>Coinsurance GHI</td>
<td>0.32</td>
<td>0.002</td>
<td>42,186</td>
</tr>
<tr>
<td>Coinsurance Medicaid</td>
<td>0.17</td>
<td>N/A</td>
<td>10,855</td>
</tr>
<tr>
<td>Coinsurance Medicare</td>
<td>0.31</td>
<td>N/A</td>
<td>28,381</td>
</tr>
</tbody>
</table>


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

indicates the lowest level of health measured by the scales and 100 indicates the highest level of health. SRHS has 5 levels: 1. excellent, 2. very good, 3. good, 4. fair, or 5. poor. We use the SRHS to construct a binary “healthy” index. An individual is considered to be in good health or healthy if the health status measure is either excellent, very good, or good. This classification is standard in the literature.

Figure 2 displays these two measures over the lifecycle. Panel 1 presents the physical component of SF-12v2 index. Young individuals start at a relatively high level of health. The level of health consistently decreases as an individual ages. The “healthy” index Panel 3 of Figure 2 follows a similar pattern. Moreover, we calculate standard deviations of the health status measure over the lifecycle. Panel 2 shows that the variations in health status are relatively small when young and become larger at the end of the lifecycle. This implies that individuals become more exposed to health risks as they get older.

Health expenditure. Figure 3 reports the distribution and lifecycle patterns of health expenditures, expressed in 2009 US dollars. Individual health expenditures (exclusive insurance premium payments) are relatively low at young ages but increase significantly from age 50 onward (Panel 2). This is mainly driven by depreciation of health over the lifecycle. On average, individuals in their twenties spend about $1,500 per year on healthcare whereas older individuals in their fifties spend about $4,000 per year. Once they pass age 50, health expenditures rise very fast on average. The highest expenditures are incurred by the very old

puts more weight on variables measuring physical health components and the mental health index puts more weight on variables measuring mental health components. Ware, Kosinski and Keller (1996) provides more details on the construction of the SF-12v2 index. We use the physical component of SF-12v2 as an indicator for health status in this study.
and amount to approximately $10,000 on average per year. Panels 3 and 4 compare the lifecycle patterns of total health expenditures by health status in levels and as fraction of income. There is a large gap between the spending patterns of the healthy and sick. The sick group spends significantly more over the lifecycle.

**Health financing.** The US health insurance system is a mixed system where public health insurance programs target the retired population (Medicare) and the poor (Medicaid). The majority of working individuals obtain private health insurance via their employers (Employer-based group health insurance, or GHI from here onward). Panels 1 and 2 of Figure 4 display the financing sources of health expenditures and the insurance take-up rates over the lifecycle, respectively. Private insurance reimbursements and out-of-pocket payments are the two major funding sources for medical spending of the working age population. The fraction of health expenditure financed by private insurance and Medicaid decreases with age, whereas the fraction of health expenditures financed by out-of-pocket funds increases moderately. Around the retirement age of 65 there is a big shift in the magnitude of financing from private insurance toward public insurance including Medicare, Veteran’s benefits, and other state run insurance plans.

Despite the many different types of insurances, about 50 million Americans did not have health insurance in 2010. Employer-based group health insurance policies (GHI) cover only around 60 percent of the working-age population while individual-based health insurance policies (IHI) cover less than 6 percent. A large number of healthy and young individuals do not have health insurance, either by choice or by circumstance. The fraction of the uninsured is highest among young workers below 35. Medicaid picks up less than 10 percent of workers by covering low income individuals. Consequently, about 25 percent of the working population are without health insurance. Gruber (2008) points out the modal uninsured person is a member of the working poor class. Members of this class have income below median income but above the federal poverty level and are therefore not eligible for Medicaid.

**Health risk and income gap.** Figure 1 presents coefficients of variation for health expenditures and income and the age-profiles of income and out-of-pocket health expenditure for the unhealthy/sick and healthy groups. Panel 2 indicates that there is a significant gap between the income profile between the two groups. Unhealthy/sick individuals exhibit a much lower income path over the lifecycle. This indicates that bad health conditions significantly reduce lifetime income. In addition, unhealthy individuals have to devote a larger fraction of their income to health expenditure. Panels 3 and 4 of Figure 1 present average OOP health expenditure in levels and as fractions of average income for healthy and unhealthy types. On average, the share of OOP health expenditures as fraction of income is less than 8 percent. However, this fraction varies across health states and age. The unhealthy/sick group not only spends more on healthcare in levels but also as fraction of their income, 15 percent on average. Even though Medicare and Medicaid are the main sources of health financing for the elderly, they still pay a significant amount OOP because of co-pays and coinsurance rates. This implies that the US health insurance system fails to fully insure unhealthy Americans against health expenditure risks.

Panel 1 of Figure 1 reports the coefficients of variation for income and health expenditures over the lifecycle. The coefficient of variation for income is fairly stable at around 0.9 before age sixty and rises slightly after retirement. However, the coefficient of variation for health expenditure is four to five times
larger and varies sharply over the lifecycle. It is largest in the young age of 20 to 30. Note that health expenditures are relatively low for young individuals but so is income. This indicates that health expenditure risk can be significant for young individuals who are often credit constrained in addition to having low income.

The stylized facts imply a strong association between health risk and lifetime inequality in the US (e.g., see De Nardi, Pashchenko and Porapakkarm (2018)). This is partly due to the design of the US health insurance system that lets many young individuals opt out of health insurance or does not provide sufficient financial support to help cover premium payments for individuals who simply cannot afford it. The Affordable Care Act was implemented in 2010 to address some of these perceived shortcomings.

The level of access to health insurance has implications for the social insurance role of the progressive income tax system. To better understand these facts we formulate a simple two period model with medical spending and health insurance in Appendix A. We analytically illustrate that the optimal income tax system is more progressive as individuals become more exposed to income inequality and medical costs.

From these qualitative results we conclude that accounting for health risk and health insurance has consequences for the design of an optimal progressive income tax system. In a more general framework, the optimal level of tax progressivity depends on many more model fundamentals such as preferences, endowments, technologies, the evolution of health risks over the lifecycle, and the institutional features of the existing health insurance system. In the next section, we develop a quantitative model and quantify the various economic channels affecting the efficacy of the income tax system.

B Simple two-period model

We clarify some of the determinants of optimal income tax progressivity in a simple model with medical spending and health insurance. We consider a two period overlapping generations model with low and high skilled households and a government. Every period a new cohort of young agents of size one is born. In the first period agents work and earn labor income based on their skill type. Agents retire in the second period and face deterministic health expenditures. A typical agent’s budget constraint in the first period is: 
\[ c_i^1 + s_i^1 = (1 - P_i^1)(1 - \tau^i)w^i + T^i, \]
where \(w^i\) is the skill-specific wage rate, \(c_i^1\) and \(s_i^1\) are consumption and savings in period 1, \(T^i\) is the lump-sum transfer and \(\tau^i\) is the labor income tax rate. The second period budget constraint can be written as: 
\[ c_i^2 = R s_i^1 - \rho^i m^i, \]
where \(c_i^2\) is consumption, \(R\) is the interest rate, \(m^i\) is total health expenditure, \(\rho^i\) is the coinsurance rate and \(\rho^i m^i\) is out-of-pocket health expenditure.

**Household problem.** At the beginning of period 1, a typical household makes decisions about consumption, labor supply and savings to maximize her expected utility. Let \(\hat{\Gamma} = \{w^i, R, m^i, \tau^i, T^i, \rho^i\}\) and \(V^i(\hat{\Gamma})\) denote the state variable vector and the value function, respectively. The household optimization
problem is given by

\[ V^i(\hat{\Gamma}) = \max_{c^i_1, l^i_1, c^i_2, s^i_1} \left\{ u(c^i_1) + \theta v(l^i_1) + \beta u(c^i_2) \right\} \]

\[ \text{s.t.} \]

\[ c^i_1 + s^i_1 = (1 - l^i_1) (1 - \tau^i) w^i + T^i \text{ and } c^i_2 = R s^i_1 - \rho^i m^i, \]

where \( n^i_1 = (1 - l^i_1) \) is labor supply when young. It is assumed that the utility function \( u(c) \) is a concave function with \( u_c > 0, v_l > 0, u_h > 0, \) and \( u_{cc} < 0 \). The F.O.Cs for the household problem is given by

\[ u(c^i_1) = \frac{\theta}{w} v_l (l^i_1) \] and \[ u(c^i_1) = R \beta u(c^i_2). \]

The optimal decision rules are \( c^*_1 = g^i_1(\hat{\Gamma}), l^*_1 = g^i_1(\hat{\Gamma}), \)

\[ s^*_1 = g^s(\hat{\Gamma}) \] and \( c^*_2 = g^c(\hat{\Gamma}). \)

**Government problem.** The government sets up a tax and transfer system that aims to redistribute income from high to low income agents. The government budget constraint is given by

\[ \sum_{i=1}^{I} \tau^i (1 - l^i_1) w^i = \sum_{i=1}^{I} T^i, \]

where \( I \) is a number of skill types. The problem to be solved by the central decision-makers is taken to be that of finding a maximum of a social welfare function, by appropriate choice of tax parameters and subject to the constraint that the government’s budget must balance. The social welfare function \( SW \) is the sum of all individual welfare functions, \( SW = \sum_{i=1}^{I} V^i(\hat{\Gamma}). \)

This is an utilitarian social welfare criterion where the society’s total, unweighted, expected utility is maximized. Generally, the government problem is written as

\[ \max_{\tau^i, T^i} \left\{ \sum_{i=1}^{I} V^i(\hat{\Gamma}) \right\} \text{ st. } \sum_{i=1}^{I} \tau^i (1 - l^i_1) w^i = \sum_{i=1}^{I} T^i, \]

where \( \tau^i, T^i \) are individual-specific taxes and transfers, respectively. The Lagrange for the government problem is

\[ L = \max_{\tau^i, T^i} \left\{ \sum_{i=1}^{I} V^i(\hat{\Gamma}) + \Lambda \left( \sum_{i=1}^{I} \tau^i (1 - l^i_1) w^i - \sum_{i=1}^{I} T^i \right) \right\}, \]

where \( \Lambda \) is a Lagrangian multiplier. The FOCs are

\[ \frac{\partial L}{\partial T^i} = \sum_{i=1}^{I} \frac{\partial V^i(\hat{\Gamma})}{\partial T^i} - \Lambda = 0, \]

\[ \frac{\partial L}{\partial \tau^i} = \sum_{i=1}^{I} \frac{\partial V^i(\hat{\Gamma})}{\partial \tau^i} - \Lambda \left(1 - l^i_1\right) w^i = 0. \]

**Log-preference example.** We consider a log-form of preferences, \( V = \ln c_1 + \theta \ln l_1 + \beta \ln c_2. \) The household decision rules are given by \( c^i_1 = \frac{1}{1 + \beta + \theta} \hat{\Gamma}, \)

\[ c^i_2 = \frac{1}{1 + \beta + \theta} R \hat{\Gamma}, \]

\[ l^i_1 = \frac{\theta}{1 + \beta + \theta} \hat{\Gamma}, \]

\[ w^i = \frac{\theta}{1 + \beta + \theta} \hat{\Gamma}, \]

where \( \hat{\Gamma} = (1 - \tau^i) w^i \) and \( \hat{\Gamma} = (1 - \tau^i) w^i + T^i - \frac{\rho^i m^i}{R} \) are the after tax wage and net wealth, respectively. The indirect utility is \( V^i(\hat{\Gamma}) = B^i + (1 + \beta + \theta) \ln \left[ (1 - \tau^i) w^i + T^i - \frac{\rho^i m^i}{R} \right] - \theta \ln \left[ (1 - \tau^i) w^i \right]. \)
For simplicity we consider two household types, low and high skills. There is an income gap between these two groups as high skill agents are more productive and have higher wage rate, \( w^H > w^L \). The government aims to narrow the income gap by redistributing income from high to low skill agents. It runs a progressive income tax system that taxes high income agents relatively more and redistribute more to low income agents, \( \tau^L \leq \tau^H \) and \( T^L \geq T^H \). The government budget constraint is given by \( \tau^L (1-l^L_1) w^L + \tau^H (1-l^H_1) w^H = T^L + T^H \). The social welfare function is \( SW = V^L + V^H \). Accordingly, the government problem can be written as

\[
\max_{\tau^L, \tau^H, T^L, T^H} \left\{ V^L + V^H \right\}
\quad \text{s.t.}
\quad T^L + T^H = \tau^L (1-l^L_1) w^L + \tau^H (1-l^H_1) w^H.
\]

We consider a non-linear tax and transfer system in which the government allows a tax break and transfer to the low skill agents, \( \tau^L = 0 \) and \( T^L > 0 \), while taxing income and giving no transfer to the high skill agents, \( \tau^H > 0 \), and \( T^H = 0 \). The government problem then simplifies to

\[
SW = \max_{\tau^H, T^L} \left\{ V^L + V^H \mid \text{s.t. } T^L = \tau^H (1-l^H_1) w^H \right\}
\]

Taking the FOCs yields the equilibrium condition

\[
\frac{\partial V^L}{\partial T^L} (1-l^H_1) w^H = -\frac{\partial V^H}{\partial \tau^H}.
\]

Expressing health expenditures in terms of income, we have \( m^L = \gamma^L w^L \) and \( m^H = \gamma^H w^H \), where \( \gamma^L \) and \( \gamma^H \) are health expenditures as fractions of labor income, the FOC becomes

\[
\frac{(1+\beta) \left( \frac{1 - \tau^H - \rho^H \gamma^H}{1 - \tau^H} \right) w^H}{(1 - \rho^L \gamma^L) w^L + \tau^H \frac{1+\beta}{1+\beta+\theta} \left( \frac{1 - \tau^H - \rho^H \gamma^H}{1 - \tau^H} \right) w^H} = \frac{(1+\beta+\theta)}{1 - \tau^H} - \frac{\theta}{1 - \tau^H}.
\]

Normalizing the coinsurance rate for the high skill agents to \( \rho^H = 0 \), i.e., health expenditures of the high skill agents are fully covered by the health insurance system, the expression simplifies to

\[
\tau^H = \left( \frac{1+\beta+\theta}{2+2\beta+\theta} \right) \left( 1 - \left( \frac{\rho^L \gamma^L}{R} \right) \frac{w^L}{w^H} \right).
\]

The tax and transfer system is progressive as high income households pay higher tax rate, \( \tau^H > \tau^L \). The above equation describes the link between the optimal top tax rate and income inequality, \( \frac{w^H}{w^L} \), health expenditure as fraction of income for the low income (skill) agents, \( \gamma^L \), and the coinsurance rate \( \rho^L \) for the low income (skill) agents. Low skill agents have limited access to the health insurance system, so they
have to pay a coinsurance rate $\rho^L > 0$. Our analytical model has implications for the optimal design of a progressive income tax system.

**Proposition 1.** The optimal income tax system is more progressive if the income gap between low and high skill households is larger.

**Proof.** The partial derivative of expression (16) with respect to the wage ratio is

$$\frac{\partial \tau^H}{\partial \left( \frac{w^L}{w^H} \right)} = -\left( \frac{1 + \beta + \theta}{2 + 2\beta + \theta} \right) (1 - \rho^L \gamma^L) < 0$$

because both $0 < \rho^L < 1$, $0 < \gamma^L < 1$.

**Proposition 2.** The optimal income tax system is more progressive if low income (skill) households face a relatively higher coinsurance rate.

**Proof.** The partial derivative of expression (16) with respect to the coinsurance rate of the low income agent is

$$\frac{\partial \tau^H}{\partial \rho^L} = \left( \frac{1 + \beta + \theta}{2 + 2\beta + \theta} \right) \frac{\gamma^L}{R} \left( \frac{w^L}{w^H} \right) > 0.$$
The firm first order conditions hold in both sectors

\[
\begin{align*}
w &= F_{N_c}(K_c, N_c) = p_m F_{m,N_m}(K_m, N_m), \\
q &= F_{K_c}(K, N) = p_m F_{m,K_m}(K_m, N_m), \\
R &= q + 1 - \delta, \\
\end{align*}
\]

(c) Markets clear

\[
\begin{align*}
K &= K_c + K_m = \sum_{j=1}^{J} \mu_j \int (a(x_j)) \, d\Lambda(x_j) + \sum_{j=1}^{J} \tilde{\mu}_j a_j(x_j) \, d\Lambda(x_j), \\
N &= N_c + N_m = \sum_{j=1}^{J} \mu_j \int e_j(x_j) n_j(x_j) \, d\Lambda(x_j), \\
\end{align*}
\]

(d) The aggregate resource constraint holds

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

(e) The government programs (7) and (8) clear

(f) The accidental bequest redistribution program clears

\[
\sum_{j=1}^{J} \mu_j \int t_{j}^{\text{Beq}}(x_j) \, d\Lambda(x_j) = \sum_{j=1}^{J} \tilde{\mu}_j a_j(x_j) \, d\Lambda(x_j),
\]

(g) The private insurance system, expressions (5) and (6), clears

(h) 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.

C.2 Computation of the quantitative model

We parameterize the model and use a standard grid search algorithm to solve for an equilibrium.

State space. The size of the model state space is \( (a_j, h_{j-1}, \vartheta, e^l_j, e^h_j, e^{GHI}_j, i_{nj}) = (100 \times 15 \times 4 \times 5 \times 4 \times 2 \times 4) \times 9 + (100 \times 15 \times 4 \times 4) \times 6 = 8.784 \times 10^6 \) points. The first part is the state space for workers and the second part in the sum is the state space for retirees. The 100 point asset gridspace is unevenly spaced. A higher density of gridpoints is assigned to lower asset levels where the curvature of the optimal savings policy function is more pronounced. The model is not sensitive to adding more asset gridpoints. The health grid is solved on 15 possible health states. Extending the health states further is computationally prohibitive as the number of overall gridpoints is already large at 8.78 million and we are not able to extend the state
space any further in any dimension at this point. This also prohibits us from solving for transition solutions when we switch policy regimes. In order to solve for the transition dynamics we would need to extend the model state space by at least $2 \times J$ which would amount to around 150 million points. Unfortunately, this vastly exceeds our computing capacity at this point.

**Solution algorithm.** We first guess a price vector, then solve the household problem backwards on the state variable grid, then aggregate the economy and solve for a new price vector using firm first order conditions then update the price vector and repeat all the steps until the price vector converges. We do not use Euler Equations or interpolation techniques to solve the model as the budget constraints exhibits kinks due to some of the discrete choices in the model. Here is a more detailed summary:

1. Guess initial price vector $\{w, q, R, p_m\}$ and $\{\text{prem}^{GHI}, \text{prem}^{IHI}_{j, h}\}$

2. Solve the household problem backwards for $\{c_j(x_j), n_j(x_j), a_{j+1}(x_j), m_j(x_j), \text{in}_{j+1}(x_j)\}_{j=1}^J$

3. Aggregate savings into capital, labor supply, insurance take up for $GHI$ and $IHI$

4. Use firm first order conditions from the two sectors to calculate the share of capital and labor for both sectors and solve for new prices: $w, q, R, p_m$

5. Use insurance company profit conditions to solve for premiums $\{\text{prem}^{GHI}, \text{prem}^{IHI}_{j, h}\}$

6. Use the government budget constraint to solve for residual government consumption: $C^g$

7. Repeat from step 2 with new prices until prices converge

**Algorithm 1:** Grid search steady state solution algorithm

The most challenging part in our calibration exercise is to match the insurance take-up rates over the lifecycle since the health insurance markets are very sensitive to general equilibrium price adjustments in premiums and can easily lead to adverse selection spirals if prices are updated too aggressively. The algorithm is implemented on a multi-core server in parallel Fortran using the OpenMP standard.

### C.3 ACA model implementation

The following features of the ACA are explicitly modeled. First, we introduce a penalty of 2.5 percent of taxable income on workers without health insurance which enters the budget constraint as: $\text{penalty}_{j} = \mathbb{I}_{\text{ins}_{j+1} = 0} \times 0.025 \times \tilde{y}_j$, where $\mathbb{I}_{\text{ins}_{j+1} = 0}$ is an indicator variable equal to one if the household choose to not buy health insurance. We abstract from penalties on employers. Second, we do not allow IHI companies to screen their clients anymore. The price setting in GHI and IHI markets is now similar, except for the fact that IHI premiums are not tax deductible. Third, workers who are not offered insurance from their employers are eligible to buy health insurance through insurance exchanges at subsidized rates that depends on the premium, taxable income, and the federal poverty level subsidy $\text{FPL-Maid}_{j} \left(\text{prem}^{IHI}_{j}, \tilde{y}_{j}, \text{FPL-Maid}\right)$. 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 \( j \). The exact specification of the subsidy is:

\[
\text{subsidy}_j = \begin{cases} 
\max\left(0, \text{prem}_j^{\text{IHI}} - 0.03\tilde{y}_j\right) & \text{if } 1.33 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 1.5 \text{ FPL}_{\text{Maid}}; \\
\max\left(0, \text{prem}_j^{\text{IHI}} - 0.04\tilde{y}_j\right) & \text{if } 1.5 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 2.0 \text{ FPL}_{\text{Maid}}; \\
\max\left(0, \text{prem}_j^{\text{IHI}} - 0.06\tilde{y}_j\right) & \text{if } 2.0 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 2.5 \text{ FPL}_{\text{Maid}}; \\
\max\left(0, \text{prem}_j^{\text{IHI}} - 0.08\tilde{y}_j\right) & \text{if } 2.5 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 3.0 \text{ FPL}_{\text{Maid}}; \\
\max\left(0, \text{prem}_j^{\text{IHI}} - 0.095\tilde{y}_j\right) & \text{if } 3.0 \text{ FPL}_{\text{Maid}} \leq \tilde{y}_j < 4.0 \text{ FPL}_{\text{Maid}}. 
\end{cases}
\]

Fourth, the ACA expands the Medicaid eligibility threshold to 133 percent of the FPL and removes the asset test. After the reform is implemented all individuals with incomes lower than 133 percent of the FPL will be enrolled in Medicaid. Fifth, the reform is financed by increases in capital gains taxes for individuals with incomes higher than $200,000 per year (or $250,000 for families). In the model we use a flat payroll tax on individuals with incomes higher than $200,000 denoted \( \text{tax}_{j}^{\text{ACA}} \) in the new household budget constraint with the ACA

\[
\left(1 + \tau^C\right)c_j + (1 + g)a_{j+1} + o^W(m_j) + 1_{[\text{in}_{j+1}=1]}\text{prem}_j^{\text{IHI}} + 1_{[\text{in}_{j+1}=2]}\text{prem}_j^{\text{GHI}} = y_j + r_j^s - \text{tax}_j - 1_{[\text{in}_{j+1}=0]}\text{penalty}_j + 1_{[\text{in}_{j+1}=1]}\text{subsidy}_j - \text{tax}_{j}^{\text{ACA}}.
\]