European Economic Review 166 (2024) 104755

Contents lists available at ScienceDirect

European Economic Review

journal homepage: www.elsevier.com/locate/eer

Financing universal health care: Premiums or payroll taxes?[☆]

Hans Fehr[a,b,c,*], Maria Feldman[d]

[a] University of Wuerzburg, Germany
[b] Netspar, The Netherlands
[c] CESifo, Germany
[d] BearingPoint, Germany

ARTICLE INFO

JEL classification:
C68
D91
H55
J24

Keywords:
Stochastic general equilibrium
Overlapping generations
Endogenous health

ABSTRACT

This paper presents a stochastic overlapping generations model with endogenous health investment to study the transition from the existing hybrid health insurance system in Germany towards a uniform system, financed by either funded or unfunded premiums or payroll taxes.

Our simulation results highlight the insurance properties of payroll taxes, but also their cost in terms of labor supply distortions and moral hazard. We find that compulsory deductibles decrease aggregate welfare in Germany, although they reduce moral hazard and increase private health investment. Reform models with premiums also induce precautionary behavior and increase labor supply, but at the same time increase exposure to productivity risk. Since the introduction of a funded system is costly for transitional cohorts, unfunded premiums provide the highest efficiency gains in our framework.

1. Introduction

Developed countries of the Western world spend a substantial amount of their income and wealth on health care. Health expenditure is projected to outpace GDP growth in the future due to demographic pressures, medical progress, changes in morbidity, and individual health demand. The need to address these increasing costs has led to a growing debate about the reform and financing of the health care system in many countries.

Levels of cost coverage and financing methods of health care differ a lot even among Western countries. On the one hand, the U.S., Switzerland, and the Netherlands mainly rely on private health care financed by individual premiums, either funded or unfunded. On the other hand, most other European countries have adopted payroll taxes as the main financing source for their health care expenditures. Payroll taxes are considered to be more equitable, as they spread the financial burden across all working individuals. However, this method also distorts the labor-leisure choice, putting pressure on the ageing workforce. Individual premiums do not distort labor supply, but instead increase the labor income risk exposure of the insured. This trade-off between risk sharing and distortive effects is a key issue in the debate over health care financing. In addition to the financing methods, the share of health

☆ **Acknowledgement**: Earlier versions of this paper were presented at the 27th International Conference Computing in Economics and Finance 2021 (virtual), the 14th Workshop on Dynamic Macroeconomics 2021 in Vigo, the Annual Meeting of the Verein für Socialpolitik 2021, the 17th Vienna Macroeconomics Workshop 2022, the Conference on Aging and Healthcare in the Macroeconomy in Santa Barbara 2022, the Midwest Macroeconomics Meeting Fall 2022 and university seminars in Munich, Groningen, Dallas and Frankfurt. We would like to thank the participants at those conferences and seminars for their feedback and especially Juan Carlos Conesa, Timothy Kehoe, Finn Kydland, Alexander Ludwig, Vegard Nygaard, Nick Pretnar, and Victor Rios-Rull for their detailed discussions and comments that helped to improve the paper. Finally, we would like to thank the editor Peter Rupert, and two referees who provided detailed comments and suggestions to a previous version of the paper.

* Correspondence to: University of Wuerzburg, Sanderring 2, 97070 Wuerzburg, Germany.
E-mail address: hans.fehr@uni-wuerzburg.de (H. Fehr).

https://doi.org/10.1016/j.euroecorev.2024.104755
Received 9 February 2023; Received in revised form 22 March 2024; Accepted 13 May 2024
Available online 20 May 2024

care cost that is covered by the government varies considerably among countries. This leads to an ongoing debate about how much should be financed by whom and how.

This paper develops a dynamic stochastic equilibrium model with overlapping generations where households choose their optimal labor supply, ordinary consumption, health investment, and savings facing productivity, health, and longevity risks along their life cycle. While productivity shocks reduce income from work, health shocks reduce the work capacity and induce costs that are at least partly borne by public and/or private health care. Households may invest in health capital (Grossman, 1972) to benefit from increased future health, time endowment, and longevity. This allows us to quantify moral hazard problems related to insurance provision and to generate differences in life expectancy across and within cohorts.

The model is applied to analyze reforms in the German health care system. Germany has one of the highest total health expenditures among OECD countries, accounting for 11.7 percent of GDP in 2019. The current system is characterized by the coexistence of public statutory health insurance (SHI) and private health insurance (PHI). Employees with earnings below the income threshold are compulsorily insured in the public system, while self-employed, civil servants, and high-income employees are privately insured. The SHI is financed through a payroll tax and offers a standard treatment quality, the PHI is funded by risk-related premiums and offers higher treatment quality at higher cost. The system therefore favors specific employment types and high-income households leading to proposals for establishing a uniform health care system financed either by premiums or payroll taxes.

The present paper aims to evaluate these reform proposals concerning their induced intra- and intergenerational income redistribution, as well as the implied overall efficiency effects. Starting from an initial long-run equilibrium that features the existing health care system, reforms are introduced without announcement and the full transition path to the new steady state is computed together with the individual welfare changes and an aggregated welfare measure. Our simulation results indicate that universal payroll financing provides insurance against productivity and health shocks, which may even compensate for the induced labor supply distortions. However, this comes at the expense of higher moral hazard costs and a loss in life expectancy for those previously privately insured due to the lower treatment quality. The latter also applies to universal premium financing, although it would induce greater individual health investment. Universal funded private insurance provides better treatment quality, which leads to higher life expectancies, but the higher costs induce an overall welfare loss. Finally, we find that compulsory deductibles would reduce aggregate welfare in Germany, although they increase private health investment. Overall, the results of the model provide valuable insights into the trade-off's as well as the potential distributional and welfare consequences of various health care reform proposals.

Our study is related to the extensive literature which allows for heterogeneity in income and health shocks over the life cycle. Mostly this literature focuses on the situation in the U.S., where some public health care is provided to retirees, additional private health care is not mandatory for all, and health costs coverage is low. Out-of-pocket medical expenditures are therefore potentially an important driver of precautionary savings. Palumbo (1999) provides one of the first approaches to estimate preference parameters in a life cycle model where the health status affects consumption utility while the future health status and costs are uncertain. Comparing the model predictions with actual consumption data clearly showed that including health uncertainty in the pure life-cycle model allows us to explain the observed consumption and savings behavior of the elderly much better than before. Follow-up studies by De Nardi et al. (2010) or Capatina (2015) apply better data on how medical expenses rise by age and income and discuss more channels (besides medical expenses) through which the health status affects individuals. An extended version of the life cycle model in De Nardi et al. (2010) already allows households to choose optimally between medical goods and ordinary consumption goods. Capatina (2015) also includes important features of the relationship between Medicare and private health care in the U.S.

However, a detailed analysis of the economic effects of health care reforms required a more comprehensive approach. Jeske and Kitao (2009), as well as Attanasio et al. (2010), develop some early general equilibrium models with heterogeneous agents that analyze the impact of health care reforms on the macro-economy and household welfare. Later studies highlight the individual health care choice when social insurance programs such as Medicaid and a minimum consumption floor crowd out the demand for private insurance. Hsu and Lee (2013) focus on the crowding-out effect on precautionary savings and private health care when a universal health care system is introduced. Quite similar to us they also address the trade-off between risk reductions and tax distortions of different financing methods. Pashchenko and Porapakkarm (2013) as well as Hansen et al. (2014) study the implications of the "Patient Protection and Affordable Care Act" (ACA) signed in 2010 by President Obama while Zhao (2017) discusses the linkages between the public and the private U.S. health care system. Feng and Zhao (2018) even argue that differences in the health care systems may explain part of the observed differences in employment rates between the U.S. and European countries. Like our paper, Conesa et al. (2018) distinguish between short-run and long-run effects by considering the transition between steady states. They also derive an aggregate welfare measure to evaluate each reform proposal.

Our approach is related to all these studies, but due to the institutional setting of the German health care system all households are compulsory insured and cost coverage is much higher than in the U.S. Consequently, the policy debate focuses more on labor supply distortions and moral hazard problems. Therefore, we follow recent work by Jung and Tran (2016), Jung et al. (2017), Halliday et al. (2019) as well as He et al. (2021) and model the individual health investment decision that determines life expectancy and improves productivity. Health care provision may distort such investments similar to labor supply. Similar to Frankovic and Kuhn (2019) we assume that households differ in their ability to produce health to generate different life expectancies. This is especially important in Germany, where privately insured people are healthier than those covered by public insurance.

The next section describes the main characteristics of the German health care system. Then we present the simulation model as well as its calibration of the initial steady state equilibrium. Section five explains the considered reform options and the respective simulation results followed by some conclusions.

2. The German health care system

In contrast to most European countries, Germany features not a uniform but a dual health insurance system, distinguishing between statutory health insurance and private health insurance. Health coverage is compulsory for everyone in Germany. In 2021, approximately 88 percent of the population was covered under statutory health insurance, roughly 10.5 percent were privately insured and the remaining fraction received health care through specific governmental schemes.

Individuals with an income below the insurance threshold of € 62,550 per year (2020), along with their non-working family members, as well as recipients of social assistance, are members of the SHI system. Self-employed and individuals with an annual income above that threshold can keep SHI voluntarily. While those without income do not contribute to health insurance, employed individuals contribute 14.6 percent of their income up to a contribution ceiling of € 56,224 per year (2020), plus an additional premium of approximately 1 percent of their income. These contributions are paid into a health insurance fund together with tax-financed federal subsidies. Then the fund redistributed resources to health insurance companies depending on the number and health profile of their insured members. The insurance providers operate on a pay-as-you-go basis, meaning that currently received contributions are used for immediate cost coverage. The SHI provides basic benefits that are regulated by law, but many additional services (i.e. dental cleaning, ultrasound, etc.) have to be paid out-of-pocket. When billing a benefit funded by SHI, the value of the services is expressed in points. The monetary value of these points is determined quarterly, based on the total amount of services provided during the quarter and the available funds. This leads to income uncertainty for providers, who do not bill the patient, but the respective health insurance company.

Individuals with income above the insurance threshold are eligible to join private health insurance. PHI benefits are also regulated by law but are more flexible than in the SHI. Individuals can be rejected, and different deductibles can be offered in this context. After the contract is signed, the insured individual is entitled to the agreed-upon benefits during the working phase as long as his earnings are above the threshold, and during retirement. If the income falls below the threshold, the insured person must rejoin the SHI but can retain the entitlement in case of a later return to the PHI. In contrast to SHI, PHI premiums are calculated individually and risk-based. Factors such as age and pre-existing conditions are taken into account to assess individual risks. The PHI operates a funded system, where each generation finances its expected lifetime costs. This means that premiums at younger ages are typically higher than the realized costs while the rising costs at older ages are financed by premiums and the reserves accumulated before. In 2019 the capital stock of private insurers amounted to roughly € 303 bn or (roughly) 9 percent of GDP, see Appendix B.

The pricing of services in the PHI is also based on point values, but the monetary value of points is predetermined. The service fee is then calculated by multiplying the point value with an adjustment factor, which can rise to 3.5, reflecting the effort of the doctor. For that reason, providing medical services to privately insured is more attractive than to SHI insured. In contrast to the SHI, the billing is directly issued to the patient, who initially covers the costs and then seeks reimbursement from his PHI provider. Individuals with private health insurance therefore typically receive faster and better medical care than those covered by the SHI, which also partly explains why they are healthier than the latter ones.[1]

This should suffice to explain the institutional structure of public and private health care in Germany.

3. The model economy

This section describes our simulation model which tries to capture the central elements of the above-described system. To reduce the complexity of the model, we do not allow for an individual insurance choice for those employees above the opt-out threshold, since this would require considering dependent household members in our model. Instead, we distinguish two subgroups within a cohort that are covered either by the SHI or the PHI. PHI members are typically above the income threshold, but even in case they fall temporarily below the threshold they would retain the PHI. Our simplification may be justified by the fact that we focus on the consequences of financing systems.

3.1. Demographics

We consider an economy populated by J overlapping generations. At the beginning of each period t a new generation is born where we assume a population growth rate n. When individuals enter the economy at age $j = 1$, they are assigned to a subgroup $\theta \in \mathcal{S} = \{\theta_1, \theta_2\}$, which may be interpreted as an education level. This assignment determines their skill class for labor productivity and their health care system in the benchmark. In addition to the skill level, all households receive an identical initial endowment of health capital $\bar{h} \in \mathcal{H} = [0, \infty]$.[2] The latter will either depreciate due to health shocks $\zeta \in \mathcal{F} = \{0, -\upsilon\}$ and regular age-dependent depreciation δ_j^h or improve due to individual health investments m during the lifetime. The health capital stock h_j at age j determines the conditional survival probability $\psi(h_j)$ from age j to age $j+1$ with the property $\psi(h_J) = 0$. In addition to health shocks, households

[1] Treatment differences between the private and the public health insurance and their consequences are analyzed by Kriwy and Mielck (2006), Schneider and Schneider (2012) or Stauder and Kossow (2017). A more detailed description of the German health care system is provided by Karlsson et al. (2016) or Wasem et al. (2018).

[2] De Nardi et al. (2023) argue that mainly the innate heterogeneity in health types explains differences in health outcomes over the life cycle in the U.S. Our assumption may be justified by the fact that German men aged 18–29 rate their health very similar independent of their educational background, see Appendix B. Despite that, we also report model results with different initial health capital in Appendix D, which generates different health transitions. Our main qualitative results remain valid in such a model with heterogeneous health types.

also start with initial labor productivity $\bar{\eta} \in \mathcal{E}$ and then receive transitory labor productivity shocks until they retire at age j_R and start to live from their pensions and savings. Pension benefits are determined by so-called earning points $ep \in \mathcal{P} = [0, \infty]$ that are accumulated when working in the market.

Consequently, agents are characterized by the state vector

$$z = (j, a, h, ep, \theta, \eta, \zeta) \in \mathcal{Z} = \mathcal{J} \times \mathcal{A} \times \mathcal{H} \times \mathcal{P} \times \mathcal{S} \times \mathcal{E} \times \mathcal{F}$$

where $a \in \mathcal{A} = [0, \infty]$ denotes assets held at the beginning of age $j \in \mathcal{J} = \{1, \dots, J\}$. Assets are initially zero and restricted throughout the whole life cycle to be greater or equal to zero, i.e. agents might be liquidity-constrained. To distinguish low- and high-skilled individuals (who may have different health insurances) we also define the state space for the two sub-groups as

$$z_i = (j, a, h, ep, \theta_i, \eta, \zeta) \in \mathcal{Z}_i \qquad \text{with} \qquad i = 1, 2.$$

Similarly, the state space for a specific cohort j of subgroup i is defined by $\mathcal{Z}_{ji} = \mathcal{A} \times \mathcal{H} \times \mathcal{P} \times \mathcal{E} \times \mathcal{F}$.

Health and productivity shocks that agents receive throughout their lifetime follow a finite-state Markov process. Therefore, households know their current productivity and health shock at the beginning of each period but have to make expectations about next period shocks when making individual consumption and labor supply decisions.

In each period t the population cohort is then fragmented into subgroups $\phi_t(z)$, according to the initial distribution at age $j = 1$ as well as mortality processes, current health and productivity shocks, and optimal household decisions. Let $X_t(z)$ be the corresponding cumulated measure to $\phi_t(z)$. We abstract from health shocks in the initial period, hence

$$\int_{\mathcal{E}} \mathrm{d}X_t(z_{11}) = \varpi \qquad \text{and} \qquad \int_{\mathcal{E}} \mathrm{d}X_t(z_{12}) = 1 - \varpi \qquad \text{with} \qquad z_{1i} = (1, 0, \bar{h}, 0, \theta_i, \bar{\eta}, 0) \tag{1}$$

must hold where ϖ denotes the fraction of low-skilled households insured in the SHI system. The fractions of the two skill classes have to add up to the normalized newborn cohort size of unity. Let $\mathbf{1}_{k=x}$ be an indicator function that returns 1 if $k = x$ and 0 if $k \neq x$. Then, the law of motion of the measure of households is

$$\phi_{t+1}(z^+) = \int_{\mathcal{Z}_{ji}} \frac{\psi(h(z))}{1+n} \cdot \mathbf{1}_{a^+=a(z)} \cdot \mathbf{1}_{h^+=h(z)} \cdot \mathbf{1}_{ep^+=ep(z)} \cdot \pi(\eta^+|\eta) \cdot \pi^h(\zeta^+|h, \zeta) \, \mathrm{d}X_t(z), \tag{2}$$

where $\pi(\cdot)$ and $\pi^h(\cdot)$ denote the transition probabilities for productivity and health shocks from one period to the next, respectively and "+" indicates next periods' values.

In the following, we will omit the state indices z and the period index t for every variable whenever possible. Agents and variables are then only distinguished according to the age j.

3.2. Household behavior

Individuals have preferences over streams of consumption c_j and leisure ℓ_j and their stock of health capital h_j

$$\mathbb{E}\left[\sum_{j=1}^{J} \beta^{j-1} \left(\Pi_{i=1}^{j-1} \psi(h_i)\right) u(c_j, \ell_j, h_j)\right] \qquad \text{with} \qquad \psi(h_j) = 1 - \exp(\omega_1 h_j^{\omega_2}), \tag{3}$$

where β denotes the subjective discount factor. The age-specific survival function $\psi(h_j)$ depends on health capital and the values of ω_1 and ω_2 determine the respective impact. With $\omega_1 < 0$ the choice of $\omega_2 \in [0; 1]$ determines how strong the survival probability decreases with decreasing health capital. Since the health stock h_j typically decreases with age, the probability of dying increases with age. If the health capital is completely depleted at $h_j = 0$, the individual will surely die, i.e. $\psi(0) = 0$. A higher health capital increases the probability of survival, i.e. $\psi(\infty) = 1$.

The preference function is based on Halliday et al. (2019), who assume a Cobb–Douglas specification for consumption and leisure and a CES specification between the consumption-leisure aggregate and health:

$$u(c_j, \ell_j, h_j) = \left[\chi [c_j^{\mu} \ell_j^{1-\mu}]^{1-\frac{1}{\nu}} + (1-\chi) h_j^{1-\frac{1}{\nu}}\right]^{\frac{1}{1-\frac{1}{\nu}}}. \tag{4}$$

Each period, the total time endowment of unity is split between leisure, working (l_j) and sick time $s(h_j)$

$$\ell_j + l_j + s(h_j) = 1 \qquad \text{with} \qquad s(h_j) = \exp(-\xi h_j), \tag{5}$$

i.e. sick time increases over the life cycle, when health capital decreases.[3]

During their working periods, labor productivity depends on a deterministic age profile of earnings ς_j, the fixed productivity effect θ that is drawn at the beginning of the life cycle, and a transitory component η_j that evolves stochastically over time with an autoregressive structure of degree 1, i.e.

$$\eta_{j+1} = \rho \eta_j + \epsilon_{j+1} \qquad \text{with} \qquad \epsilon_{j+1} \sim N(0; \sigma_\epsilon^2) \qquad \text{and} \qquad \eta_1 = \bar{\eta}. \tag{6}$$

[3] Consequently, health affects the allocation of time as opposed to labor productivity as in Jung and Tran (2016), which is in line with Grossman (1972), Capatina (2015) or Halliday et al. (2019).

Given that, an individual's gross labor income y_j is defined by the wage rate w and the individual's productivity $e_j := \varsigma_j \cdot \exp(\theta+\eta_j)$ for effective hours worked multiplied by the hours effectively worked, i.e.

$$y_j = \begin{cases} we_j l_j & \text{if} \quad j < j_R \quad \text{and} \\ 0 & \text{if} \quad j \geq j_R. \end{cases}$$

The accumulated earning points depend on the relative income position $y_j/\bar{y}$ of the worker at age $j \leq j_R$. Since the ceiling for pension contributions $\hat{y}^p$ is fixed at the double of average income $\bar{y}$, agents could collect earning points per year up to a maximum of $\hat{y}^p/\bar{y} = 2$, i.e.

$$ep_{j+1} = ep_j + \min[y_j/\bar{y}; 2]. \tag{7}$$

At the mandatory retirement age j_R, labor productivity falls to zero and households receive a pension benefit that is computed as a product of the accumulated earning points at retirement ep_{j_R} and the so-called "actual pension amount" which is modeled as a fraction κ of average income:[4]

$$pen_j = ep_{j_R} \times \kappa\bar{y} \qquad \forall \quad j \geq j_R. \tag{8}$$

Consequently, the pension system in Germany is closely linked to taxes and benefits, so that labor market shocks during employment are fully transmitted into retirement. This induces precautionary behavior and health investments in later ages.[5]

Health capital accumulation is given by

$$h_{j+1} = (1-\delta_j^h)h_j + g(m_j, hc_j) + \zeta_j \qquad \text{with} \quad \frac{\partial g}{\partial m_j} > 0, \frac{\partial g}{\partial hc_j} > 0. \tag{9}$$

Individual health capital depreciates at the age-specific rate δ_j^h and may decrease due to a shock ζ_j (see Eq. (10)). The shock could be any illness or injury that causes a large reduction of health capital such as a stroke, heart attack, or a hip fracture. Following Picone et al. (1998), 177), the health shock takes the following distribution

$$\zeta_{j+1} = \begin{cases} 0 & \text{with prob. } \pi^h(h_j, \zeta_j) \\ -\upsilon & \text{with prob. } 1-\pi^h(h_j, \zeta_j). \end{cases} \tag{10}$$

The probability $\pi^h(h_j, \zeta_j)$ of experiencing a shock in the future increases with declining health and in the presence of an existing shock. This relationship, similar to the one in Picone et al. (1998), is described by the following function:

$$\pi^h(h_j, \zeta_j) = \frac{\exp(1 + d_0 h_j + d_1 \zeta_j)}{1 + \exp(1 + d_0 h_j + d_1 \zeta_j)}, \tag{11}$$

Next, the health production function $g(\cdot)$, which generates the heterogeneity in health behavior and health accumulation between the two insurance types needs to be specified. As in Jung et al. (2017) or Halliday et al. (2019) it is assumed that the health status could be improved by private health investment m_j and insurance-financed health care hc_j.[6] To make sure that both effects are independent we set

$$g(m_j, hc_j(u)) = \lambda_3(\theta)(\lambda_1 - \lambda_2\zeta_j)m_j^{\varepsilon_j} + \lambda_4(u)\sqrt{hc_j(u)} \quad \text{where} \quad \lambda_i > 0, \;\; \text{and} \quad u = SHI, PHI,$$

so that the marginal products of both expenditures are positive and decrease with higher expenditure levels. When the agent experiences no health shock (i.e. when $\zeta_j = 0$), the marginal product of private health investment is lower than when a health shock occurs (i.e. when $\zeta_j = -\upsilon$), see Picone et al. (1998).

Agents may increase their health capital by (mostly preventive) health investments m_j. These contain expenditures that may improve health but are usually not a direct response to health deterioration, i.e. not prescribed curative care, infrequent vaccinations and screening, costs of sports activities, and healthy food consumption. The effectiveness of m_j on the health production function depends on various factors. High-skilled individuals are more productive in this regard, as they generally have more knowledge how to apply the medical products. We represent this relationship through the skill-class-specific parameter λ_3. This parameter is higher for high-skilled individuals compared to low-skilled individuals, so that $\lambda_3(\theta_1) < \lambda_3(\theta_2)$.

In contrast, health care costs hc_j are direct responses to a health shock that causes a specific, immediate need. If an agent is hit by a shock, the (curative) health costs are defined by

$$hc_j(u) = \Lambda(u)(\varphi_0 + \varphi_1 j + \varphi_2 j^2), \tag{12}$$

which are (at least in the initial equilibrium) fully reimbursed by the insurance. The function hc_j depends on the age of individuals since treatments become more complex and expensive with increasing age. In addition, the cost function is multiplied by $\Lambda(u), u =$

[4] The adjustment factor for early and late retirement is neglected in the model.

[5] See Schneider and Winkler (2021) for a recent analysis of moral-hazard effects with annuitized retirement wealth and Zhao (2014) for possible spill-overs between pensions and health care in the US.

[6] In the U.S. models a fraction of total health care demand is typically covered by the insurance system. But this does not reflect the German insurance system that provides basic benefits after a health shock. Individual health investment in our model represents all additional health care expenditures that have to be paid out-of-pocket.

SHI, PHI which reflects the cost difference between statutory and private health insurance. As explained in Section 2, privately insured will typically receive more treatments that are billed at higher rates than those under the SHI. The last parameter $\lambda_4(u)$ depends on the health care provider and reflects the fact that the PHI offers a better treatment quality (i.e. faster access to health care services, etc.) in case of illness, i.e. $\lambda_4(PHI) > \lambda_4(SHI)$.

In order to isolate risk aversion from intertemporal substitution, we follow the approach of Epstein and Zin (1991) and write the households optimization problem during the working phase in a recursive form as

$$\begin{aligned} V(z_j) &= \max_{c_j,\ell_j,m_j,a_{j+1}} \left\{ u(c_j,\ell_j,h_j)^{1-\frac{1}{\gamma}} + \beta\psi(h_j)\mathbb{E}_j\left[V(z_{j+1}|\eta_j,\zeta_j)^{1-\varrho}\right]^{\frac{1-\frac{1}{\gamma}}{1-\varrho}} \right\}^{\frac{1}{1-\frac{1}{\gamma}}} \quad \text{s.t.} \\ a_{j+1} &= (1+r)a_j + y_j + b_j - T_p(y_j) - T_h(y_j) - T(\tilde{y}_j) - \vartheta hc_j - p(m_j + c_j) \\ & c_j \geq 0,\ m_j, a_{j+1} \geq 0, \end{aligned} \tag{13}$$

together with the constraints (5), (6), (7), (9) and (10). The expectation operator $\mathbb{E}_j$ in Eq. (13) is with respect to the stochastic processes of η and ζ. The parameter ϱ defines the risk aversion coefficient while γ denotes the intertemporal elasticity of substitution. When households enter retirement, their leisure consumption is determined by their remaining healthy time (i.e. $\ell_j = 1 - s(h_j)$) and their budget constraint changes to

$$a_{j+1} = \underbrace{(1+r)a_j + pen_j - T_h(pen_j) - T(\tilde{y}_j) - \vartheta hc_j}_{x_j} + tr_j - p(m_j + c_j) \quad \text{with} \quad tr_j = \max[p\underline{c} - x_j, 0].$$

Consequently, retirees receive pensions pen_j but no bequest. Instead, they may be eligible for government transfers tr_j that guarantee a minimum consumption level $\underline{c}$.

According to the budget constraint, future assets a_{j+1} are derived from current assets (including interest), gross income from labor y_j and accidental bequests b_j net of payroll taxes $T_p(\cdot)$ and health care contributions (or lump-sum health premiums) $T_h(\cdot)$, income taxes $T(\cdot)$ (with taxable income $\tilde{y}_j$), co-payment for health care costs ϑhc_j and expenditures for health investment and ordinary consumption.[7] Consumer prices include consumption taxes, so that $p = 1 + \tau^c$ with τ^c denoting the respective tax rate. Expenditures must be non-negative and the borrowing constraint must hold. As already explained above, pension contributions are subject to a contribution ceiling $\hat{y}^p$, i.e.

$$T_p(y_j) = \tau^p \min[y_j, \hat{y}^p].$$

Similarly, contributions of SHI members are also subject to a contribution ceiling $\hat{y}^h$. In contrast, PHI members pay an individual premium q_j^{ip} which may depend on age. Consequently,

$$T_h(y_j) = \begin{cases} \tau^h \min[y_j, \hat{y}^h] & \text{for SHI members} \\ q_j^{ip} & \text{for PHI members.} \end{cases}$$

Our model abstracts from annuity markets. Therefore, private assets of all agents who died are aggregated and then distributed uniformly among all working-age cohorts $i < j_R$, i.e.

$$b_i = [N(1+n)]^{-1} \int_{\mathcal{Z}} (1 - \psi(h(z)))(1 + r_{t+1})a_{j+1}(z)\mathrm{d}X_t(z)$$

where N denotes the number of all working agents.

3.3. The production sector

The production sector is populated by large firms that hire capital K and effective labor L on perfectly competitive factor markets to produce a single good according to the Cobb–Douglas production technology

$$Y_t = \Phi K_t^\alpha L_t^{1-\alpha},$$

with α denoting the capital share in production. Φ is a technology parameter used to normalize wages in the initial equilibrium to unity. Capital is rented from households through an intermediary at the riskless rate and depreciates over time again with depreciation rate δ. Factor prices are determined competitively by marginal productivity conditions, i.e.

$$w_t = (1-\alpha)\Phi\left(\frac{K_t}{L_t}\right)^\alpha \tag{14}$$

$$r_t = \alpha\Phi\left(\frac{L_t}{K_t}\right)^{1-\alpha} - \delta. \tag{15}$$

[7] Note that in Germany the same VAT rate is applied to medical and non-medical goods and we abstract from different production technologies.

3.4. Government sector

The government sector in our model is split into a general government and a public pension and health care system, where each budget is closed separately. While the budget of the general government is balanced by the consumption tax each period, the pension and health care budgets are balanced by the respective contribution rates or health premiums.

General government. In each period t the general government issues new debt $(1+n)B_{G,t+1}-B_{G,t}$ and collects income and consumption taxes to finance public consumption G, transfers Tr_t as well as interest payments on its debt, i.e.

$$(1+n)B_{G,t+1} - B_{G,t} + T_{y,t} + \tau_t^c(C_t + M_t) = G + Tr_t + r_t B_{G,t}, \tag{16}$$

where C_t and M_t define aggregate consumption and health investment, while $T_{y,t}$ denotes the revenues of income taxation. In the initial long-run equilibrium we specify the debt-to-output ratio B_G/Y as well as the public consumption-to-output ratio G/Y and adjust the consumption tax rate τ^c endogenously to balance the budget. During the transition, the debt level is kept constant, and public consumption is fixed per capita.

Concerning taxable income $\tilde{y}_t$ we assume that contributions to public pensions and health care are completely exempted from taxation while pension benefits are fully taxed.[8] The resulting income is then further reduced in order to account for income splitting of married partners, work-related allowances, etc. (see below). Then we apply the progressive tax code of 2020 (including the solidarity surcharge τ^z of 5.5 percent), so that

$$T_{y,t} = \int_{\mathcal{Z}} T(\tilde{y}(z))\mathrm{d}X_t(z) = (1+\tau^z)\int_{\mathcal{Z}} T_{18}(\tilde{y}_j(z))\mathrm{d}X_t(z).$$

Pension system. The pension system pays old-age benefits and collects payroll contributions at a rate τ^p from labor income below the contribution ceiling $\hat{y}^p$. Pensions are zero before the retirement age, i.e. we do not consider early retirement. Given the aggregate pension contribution base PCB_t and aggregate benefits PB_t in period t, the contribution rate balances the budget so that

$$\tau_t^p PCB_t = PB_t, \tag{17}$$

where

$$PCB_t = \int_{\mathcal{Z}} \min[y(z), \hat{y}_t^p]\mathrm{d}X_t(z) \quad \text{and} \quad PB_t = \int_{\mathcal{Z}} pen(z)\mathrm{d}X_t(z_j).$$

Statutory health insurance (SHI). Households insured in the public system have to pay contributions to the SHI on their labor or pension income below the contribution ceiling $\hat{y}_t^h$. Similar to public pensions, the contribution rate τ_t^h balances the SHI budget, so that

$$\tau_t^h HCB_t = SHC_t \tag{18}$$

where

$$HCB_t = \int_{\mathcal{Z}_1} \min[y(z_1) + pen(z_1), \hat{y}_t^h]\mathrm{d}X_t(z_1) \quad \text{and} \quad SHC_t = (1-\vartheta)\int_{\mathcal{Z}_1} hc(z_1)\mathrm{d}X_t(z_1)$$

define the contribution base and (social) health costs in period t which are not covered by co-payments of the insured population group.

Private health insurance (PHI). Privately insured households born in period t pay premiums q_t^{ip} to the insurance system throughout their lifetime which balances the expected present value of their lifetime health costs. Therefore we need to distinguish between the *aggregate* private health costs in period t PHC_t and the present value of expected *individual* health costs of a newborn in period t IHC_t:

$$PHC_t = (1-\vartheta)\int_{\mathcal{Z}_2} hc(z_2)\mathrm{d}X_t(z_2) \quad \text{and} \quad IHC_t = (1-\vartheta)\int_{\mathcal{Z}_2} R_{jt} hc(z_2)\mathrm{d}X_{t+j-1}(z_2),$$

where $R_{jt} = \left[\Pi_{i=1}^{j-1}(1+r_{t+i})\right]^{-1}$ defines the discount rate. PHI premiums q_t^{ip} of a newborn in period t are then defined by

$$q_t^{ip} ICB_t = IHC_t \quad \text{where} \quad ICB_t = \int_{\mathcal{Z}_2} R_{jt}\mathrm{d}X_{t+j-1}(z_2) \tag{19}$$

denotes the individual contribution base, i.e. the discounted sum of expected lifetime periods for a privately insured. Since at younger ages, premiums are typically higher than respective health costs, the PHI accumulates an assets stock $A_{p,t+1}$, which is invested on the capital market:

$$(1+n)A_{p,t+1} = (1+r_t)A_{p,t} + \int_{\mathcal{Z}_2} q_{t-j+1}^{ip}\mathrm{d}X_t(z_2) - PHC_t. \tag{20}$$

These assets increase initially over the life cycle of a specific cohort and then decrease to zero again.

[8] Actually, the deferred taxation of pensions will be fully implemented in 2035. However, this complication is neglected in the model.

3.5. Individual and aggregate welfare calculation

To assess the welfare effect of a specific policy reform we follow the literature, e.g. Jeske and Kitao (2009) or Halliday et al. (2019), and compute the consumption equivalent variation (CEV) for each agent. The CEV measures the percentage change in consumption in every state of the world that has to be given to (or taken from) an agent to make him indifferent between remaining in the initial equilibrium and moving to the situation after the reform has taken place. If $V_0(z)$ and $V_1(z)$ measure the utility of household z in the initial equilibrium and the reform period, the required transfer $v_1(z)$ is defined by

$$V_1(j, a + v_1(z), h, ep, \theta, \eta, \zeta) = V_0(z).$$

Note that positive v's constitute welfare losses from a given reform, relative to the status quo. We convert the aggregate transfers of a specific cohort (and insurance type) into a constant consumption stream $\bar{c}_{ji}$ for the remaining lifetime:

$$\bar{c}_{ji}(1 + r_0)\left(1 - (1 + r_0)^{j-J}\right)/r_0 = \int_{\mathcal{Z}_{ji}} v_1(z_{ji})\mathrm{d}X_1(z_{ji}).$$

The CEV measure is then derived by dividing the computed annuity by the respective consumption value c_{ji0} from the initial equilibrium, i.e.

$$CEV_{ji} = -\frac{\bar{c}_{ji}}{c_{ji0}} \times 100.$$

Similarly, aggregate welfare is computed as the present discounted value of all transfers[9]

$$W = \int_{\mathcal{Z}} v_1(z)\mathrm{d}X_1(z) + \sum_{t=2}^{\infty}\left(\frac{1+n}{1+r_0}\right)^{t-1}\int_{S\times\mathcal{E}} v_t(z_{1i})\mathrm{d}X_t(z_{1i}),$$

where $v_t(z_{1i})$ measure the transfers to the newborn cohort of subgroup i in period t. As before we turn the aggregate welfare measure into an annuity stream over the whole transition path and the new long-run equilibrium and express the size of the annuity as a percent of initial aggregate consumption C_0, i.e.

$$CEV = -\frac{W(r_0 - n)}{C_0(1 + r_0)} \times 100.$$

3.6. Equilibrium

Given public tax and social policy $\{G, B_G, T18(\cdot), \tau^c, \tau^h, \vartheta, \hat{y}^h, \tau^p, \hat{y}^p, \kappa\}$ and private insurance policy $\{\vartheta, q^{ip}\}$ $\forall$ t, a recursive equilibrium path is a set of value functions $V(z)$, household decision rules $c(z)$, $l(z)$, $m(z)$, $a^+(z)$, distribution of unintended bequest $b(z)$, measures of households $\phi_t(z)$, relative prices of labor and capital w_t, r_t such that the following conditions are satisfied $\forall$ t:

1. households' decision rules solve the households decision problems (13) subject to the respective constraints;
2. factor prices are competitive, i.e. (14) and (15) hold;
3. individual and aggregate behavior are consistent:

$$\begin{aligned} L_t &= \int_{\mathcal{Z}} \varsigma_j \exp(\theta + \eta) l(z)\,\mathrm{d}X_t(z) \\ A_{t+1} &= \int_{\mathcal{Z}} a^+(z)\,\mathrm{d}X_t(z) \\ C_t &= \int_{\mathcal{Z}} c(z)\,\mathrm{d}X_t(z) \\ M_t &= \int_{\mathcal{Z}} m(z)\,\mathrm{d}X_t(z) \\ Tr_t &= \int_{\mathcal{Z}} tr(z)\,\mathrm{d}X_t(z) \end{aligned}$$

4. the laws of motion (1) and (2) for the measure of households hold;
5. unintended bequests satisfy

$$\int_{\mathcal{Z}} b(z)\mathrm{d}X_{t+1}(z) = \int_{\mathcal{Z}} (1 - \psi(h(z)))(1 + r_{t+1})a^+(z)\mathrm{d}X_t(z); \tag{21}$$

6. the budgets of the general government (16), the public pension and the health care systems (17) and (18) are balanced;
7. private insurance contributions are equal to expected costs (19) and the private health care budget (20) is balanced.

[9] For simplicity we describe here the situation in the small open economy, although the benchmark calculations are in a closed economy.

Table 1
Key parameter values of the benchmark model.

Symbol	Definition	Value	Source/Target
Demographics			
J	Maximum life span	16	Age 95–99
j_R	Retirement age	10	Age 65–69
ϖ	Fraction of households in SHI	0.9	See Appendix B
n	Growth rate (annual)	0.0055	Calibrated
Household preferences			
γ	Intertemporal elasticity of substitution	0.5	Halliday et al. (2019)
ϱ	Risk aversion coefficient	2.0	Common value
ν	Intratemporal elasticity of substitution	0.1	Halliday et al. (2019)
μ	Consumption coefficient	0.4	Halliday et al. (2019)
χ	Weight of consumption/leisure utility	0.65	Calibrated
β	Time discount factor (annual)	0.98	Calibrated
Labor productivity			
$\{\varsigma\}_{j=1}^{j_R-1}$	Age-efficiency profile		Fehr et al. (2013)
ρ	AR(1) correlation	0.96	Fehr et al. (2013)
σ_ϵ^2	Transitory variance	0.03	Calibrated
σ_θ^2	Skill variance	0.8	Calibrated
Health stock accumulation and health costs			
δ_j^h	Depreciation rate (annual)	$[0.0025 - 0.035]$	Jung et al. (2017)
υ	Health shock value	2.0	Picone et al. (1998)
d_0, d_1	Health shock probability (h_j, ζ_j)	0.1, 0.4	Calibrated (SMM)
φ_0, φ_1	Health costs coefficients	0.04, 0.034	Calibrated
φ_2		−0.0011	
$\Lambda(u)$	Health expenditures parameter (SHI, PHI)	1.05, 1.34	Calibrated (SMM)
ξ	Sick time coefficient	0.61	Calibrated (SMM)
ω_1, ω_2	Survival probability	−0.77, 0.89	Calibrated (SMM)
λ_1, λ_2	Health production	2.9, 2.4	Calibrated (SMM)
$\lambda_3(\theta)$	Health production (low/high skilled)	(0.9, 1.1)	Calibrated (SMM)
$\lambda_4(u)$	Health production (SHI/PHI insured)	(0.1, 0.7)	Calibrated (SMM)
ε_j	Health production elasticity	$[0.5, \dots, 2.0, \dots, 0.3]$	Hall and Jones (2007)
Production sector			
α	Capital share	0.34	See Appendix B
δ	Capital depreciation rate (annual)	0.053	See Appendix B
Policy parameters			
ϑ	Co-insurance rate	0.00	Specified
G/Y	Public consumption-to-output ratio	0.172	See Appendix B
B_G/Y	Debt-to-output ratio	0.75	See Appendix B
κ	Pension accrual rate	0.061	See text
$\underline{c}$	Consumption floor	$0.1\bar{y}$	See text

8. the capital market clears, i.e.

$$A_t + A_{P,t} = K_t + B_{G,t} + B_{F,t},$$

with net foreign assets $B_{F,t} = 0$ in the closed economy;

9. the goods market clears, i.e.

$$Y_t = C_t + (1+n)K_{t+1} - (1-\delta)K_t + G + M_t + SHC_t + PHC_t + NX_t,$$

with net exports $NX_t = 0$ in the closed economy.

4. Calibration and the initial equilibrium

This section describes the parametrization of the model. This is a two-stage process, where we first specify specific parameter values estimated outside the model and then calibrate further parameters by matching the moments of our model to the data. Our SMM solution algorithm is presented in Appendix C. The aim is to match the German economy in the year 2019/20 with the initial equilibrium. However, since our theoretical model structure reflects specific assumptions (i.e. closed economy, no public transfers for income redistribution, etc.), we need to adjust the original German GDP data to generate target moments from the data. These calculations are reported in detail in Appendix B. Table 1 summarizes the parameter values used for our benchmark model, while Table 2 compares the targeted moment conditions in the (adjusted) data and those generated by the model.

Table 2
Model solution and targets for Germany 2020 (in % of GDP).

Variable	Model	Target[a]
Demographics		
Dependency ratio (65+/20-64)	0.35	0.37
Life expectancy at birth	79.4/84.0	79.1/84.8
at retirement	19.3/23.1	19.6/23.2
Expenditures on GDP		
Private consumption	50.5	49.2
Government consumption	17.2	17.2
Gross investment	23.2	23.4
SHI/PHI health spending	7.0/1.1	7.5/1.1
Private health investment	1.1	1.6
Capital stock, labor market and income		
Capital-output ratio	435.3	380.0
PHI capital-output ratio	11.0	10.0
Working time (in %)	31.5	33.0
Gini (gross labor income)	0.46	0.46
Top 10% share (in %)	42.4	37.1
Bottom 50% share (in %)	19.5	19.0
Interest rate p.a. (in %)	2.9	2.6
Health indicators (in %)		
Fraction of sick 20–24	11.3	11.2
Fraction of sick 55–59	17.7	17.3
Fraction of sick average	17.0	15.3
Sick time 25–29	12.1	4.0
Sick time 55–59	30.0	10.6
Sick time average	19.7	7.2
Health costs - income ratio	8.9	8.2
Government indicators		
Labor income tax revenue	10.3	10.2
Consumption tax revenue	8.7	10.4
Consumption tax rate (in %)	16.9	–
Interest costs	1.7	2.0
Pension benefits	8.9	10.2
Pension contribution rate (in %)	17.4	18.6
SHI contribution rate (in %)	15.9	15.6
PHI premium (in € p.m.)	268	300

[a] See the documentation and calculations in Appendix B.

Model period and time endowments: The model period is 5 years. An individual enters the labor market at the real-time age of 20. Therefore, the model period $j = 1$ corresponds to ages 20–24 and maximum age $J = 16$ corresponds to ages 95–99. Mandatory retirement at model period $j_R = 10$ is therefore at age 65–69. As already discussed above, about 10 percent of the population in Germany are members of private health care. Consequently, the fraction of those insured in the public system ϖ is set to 0.9. The growth rate n in our model includes productivity growth and population growth. Without immigration, the latter is even negative while hourly productivity decreased from an average of 1.7 percent in the period 1995–2005 to 0.8 percent in the period 2005–2016, see Elstner et al. (2018, 9). Our value of 0.55 percent is in line with these figures and also generates a realistic dependency ratio (see Table 2).

Sick time: The health status affects the time available for work, leisure, and lifespan. Hereby ξ is specified to generate an average working time in total time endowment of a third. Note that Table 2 reports that the resulting average sick days in the model are much higher than those in the data. However, this seems to be justified since the data only accounts for those sick days when visiting a doctor during working time.

Utility: In our benchmark calibration of the utility function (4) we combine a value of $\gamma = 0.5$ for the intertemporal elasticity of substitution and $\varrho = 2.0$ for risk aversion. These values are also applied by Halliday et al. (2019) and are widely used as a starting point in the literature. The intratemporal elasticity ν is used by Halliday et al. (2019) and also helps to match a realistic level of health investments. Similarly, the consumption weight μ is similar to the value used by Halliday et al. (2019) and helps to match an average fraction of working time (see below). The weight χ of the consumption-leisure aggregate is calibrated to match the consumption share in output. Finally, the time discount factor β is calibrated to generate a realistic capital-to-output ratio. Due to

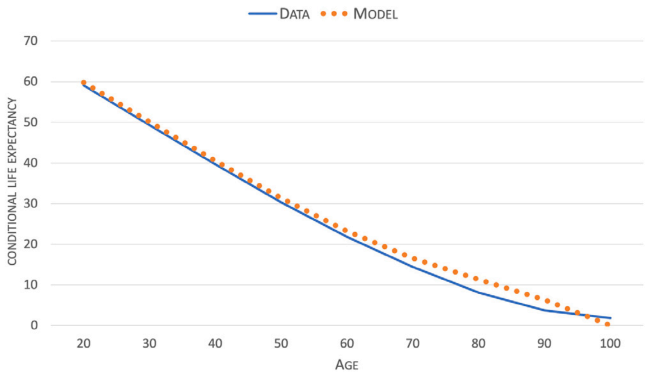


Fig. 1. Conditional LE in the model and in the data.

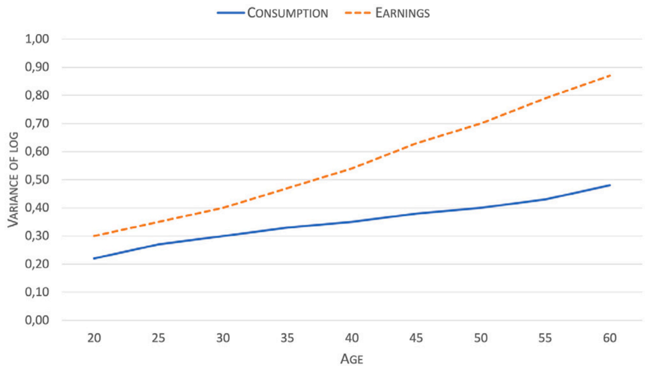


Fig. 2. Variance of logs over the life cycle.

the preference formulation from Epstein and Zin (1991), utility is positive, so households always want to live longer, see Rosen (1988).

Life expectancy: The ω_i's in the survival function (3) are calibrated to match a realistic life expectancy at birth and retirement. Fig. 1 below compares the resulting conditional life expectancy in the model with those from the German mortality Table 2018/2020.

Productivity: Individual labor productivity is determined by the deterministic age-efficiency profile ς_j, the skill level $\theta_i = \pm\sigma_\theta$, and the idiosyncratic productivity shock η. The age-efficiency profile for Germany was estimated by Fehr et al. (2013), we only aggregate the annual figures over five years. Similarly, the persistence parameter ρ of the AR(1) process is taken from that study. The variances of the white noise term σ_ϵ^2 of the idiosyncratic component η and the skill variance σ_θ^2 are then calibrated to match the variances of log income at the beginning and the end of the employment phase reported in Storesletten et al. (2004, 613). The continuous process is discretized using a Rouwenhorst method with five states, see Fehr and Kindermann (2018, 344f.).

Fig. 2 shows the variance of the logarithm of labor earnings and consumption over the working period in the initial equilibrium. The income variance rises from 0.3 to 0.9 and the consumption variance from 0.25 to 0.45. As shown in Table 2, our approach generates the Gini-coefficient and realistic pre-tax income shares for 2020.

Health capital: With respect to the health accumulation process we need to pin down first the initial health capital $\bar{h}$ and the depreciation rate δ_j^h. We normalize the initial health status to $\bar{h} = 10.0$ and assume an (inverse) exponential relationship $\delta_j^h = 1 - \exp(-0.012j)$ to arrive at the (annual) depreciation rates reported in Table 1 above, which are roughly in line with those derived in Picone et al. (1998) or those computed with U.S. health data reported in Jung et al. (2017).[10] The parameters d_0, d_1 in the health shock function (11) are calibrated to generate realistic fractions of ill agents over the life cycle, see Table 2. A higher health capital stock reduces the probability of a health shock and a shock in the previous period increases the respective probability in the current

[10] Due to health depreciation, agents also invest in health even if they experience no health shocks over the life cycle.

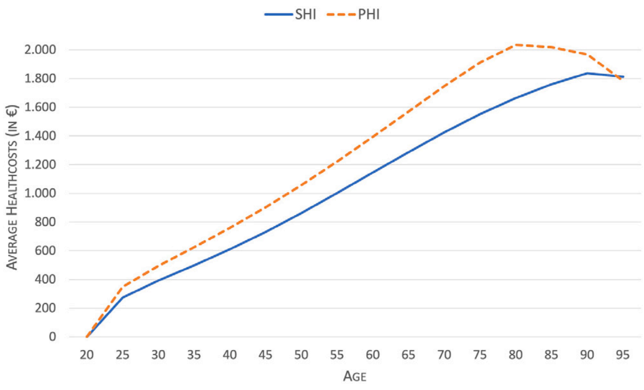


Fig. 3. Average expected health costs over the life cycle.

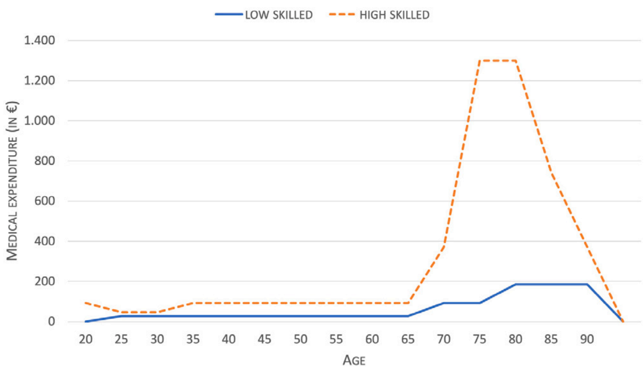


Fig. 4. Health investment over the life cycle.

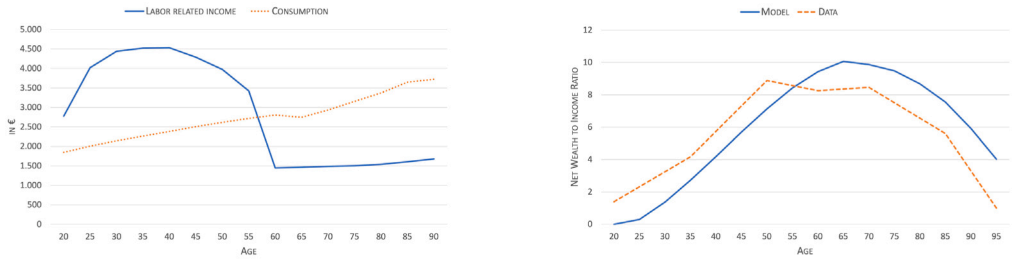
period. The value of the shock at $\upsilon = 2$ is taken from Picone et al. (1998) and generates a realistic trajectory of health depreciation in terms of survival probabilities and health care costs.

Health production: Following Hall and Jones (2007, 58) the elasticity of health status with respect to the health investment ε_j is hump-shaped. Values rise from 0.5 at young ages to 2.0 around retirement and then decrease again to 0.3. The calibration of the λ_i's can be found in Appendix C.

Health costs: The three free parameters φ_i in the health cost function (12) are calibrated to match the profile of SHI health costs relative to average income as reported in Appendix B. To capture the difference in cost structures between the two health care types reported in Appendix B and to match the health care expenditures relative to GDP we multiply the cost profile by $\Lambda(u)$ which is 1.05 and 1.34 for the SHI and PHI, respectively. Table 2 shows that we match the average health costs to income ratio almost perfectly. The resulting *expected* per-capita cost profiles are displayed in Fig. 3, where the difference in the two profiles reflects the PHI markup and the reduced sickness probability of the privately insured.

Fig. 4 shows the private health investment over the life cycle for the two skill types. At young ages, households invest in health to reduce sick time and to work more. At older ages, they invest to increase utility and extend their life span. As it turns out, both skill types invest very little in health during their employment years since they first build up savings to self-insure against income shocks. After retirement especially the high-skilled increase health investment since better health generates utility and extends their life span. This is consistent with the investment motives discussed by Grossman (1972) and Halliday et al. (2019). It is consistent with the data which shows much higher expenditures in rehabilitation facilities at older ages, see Appendix B. The resulting difference in life expectancy of the two insurance types reported in Table 2 matches the data reported in Appendix B quite well.

Turning to the production parameters and the government policy, the capital share as well as the depreciation rate are computed from 2020 German GDP data in Appendix B. For simplicity, we abstract from any co-payments for private health investments in the benchmark simulation. The shares of public consumption as well as public debt relative to GDP are computed in Appendix B. The pension accrual rate κ yields a replacement rate for an average pensioner of 48 percent. This is roughly in line with the current practice, it also generates a realistic benefit to GDP ratio and contribution rate (see lower part of Table 2). We apply the German income tax code of the year 2020 to labor and pension income, i.e. the marginal tax rate schedule rises after a basic allowance from 14 to 42 (or 45) percent plus the solidarity surcharge. To generate a realistic income tax revenue, income net of insurance



(a) Labor income and consumption (b) Assets in Model and Data

Fig. 5. Labor income, consumption and assets over the life cycle.

contributions is further reduced by 20 percent, i.e.

$$\tilde{y}_j = 0.8[y_j + pen_j - T_p(\cdot) - T_h(\cdot)].$$

The consumption floor $\underline{c}$ is set at 10 percent of average earnings. This level is below the social assistance level in Germany and produces hardly any budgetary cost in the initial equilibrium.[11] The consumption tax rate is then used to balance the budget. While we abstract from any redistributive transfers and neglect other tax revenues, the resulting revenue and consumption tax rate is quite realistic, see the discussion in Appendix B. Even more important in the present context is the fact that the modeling of health care shocks and costs yields a quite realistic SHI contribution rate and PHI premium.

To solve the model numerically, a micro- and a macroeconomic solution method is distinguished. The former solves a two-stage optimization problem described in detail in Appendix A. The latter follows the Gauss–Seidel iteration procedure to compute equilibrium prices and quantities. For more information on the computational approach see Fehr and Kindermann (2018, 505f.). Fig. 5 shows the dynamics over the life cycle of labor income and consumption in Fig. 5(a) and the relation between assets and average income in Fig. 5(b). The consumption and income profiles are very consistent with the data reported by Fehr et al. (2013, 99) while the asset profile on the right is close to the German profile for 2017 reported by ECB (2020, 6).

5. Simulating policy reforms

Various reform proposals for the German health care system have been made in the past. They can be distinguished by the implied financing (pay-as-you-go or funded), the individual contribution calculation (per-capita premiums, wage-related, income-related, or risk-related), the compulsory membership structure (coverage for specific social groups or universal) and the specific regulations for the phase-out of the existing system. In this section, we will focus on the following reforms:[12]

- The *self insurance (SI)* model, where households insured in SHI and PHI have to bear a co-insurance burden of 10 percent (i.e. $\vartheta = 0.1$) of their health costs ($hc_j(u)$).[13]
- The *citizen insurance (CI) model*, where the PHI scheme is phased out for current members and the SHI scheme becomes universal for all households in the long run.
- The *social premium (SP) model*, where the current SHI/PHI membership structure is retained, but SHI contributions are turned into premiums q_t^{sp}, which are independent of labor income and balance

$$q_t^{sp} \int_{\mathcal{Z}_1} \mathrm{d}X_t(z_1) = SHC_t.$$

- The *citizen premium (CP) model*, where the PHI scheme is phased out for current members and premiums q_t^{cp} with universal coverage are introduced successively. The long-run budget balance is therefore

$$q_t^{cp} \int_{\mathcal{Z}} \mathrm{d}X_t(z) = SHC_t + PHC_t.$$

- The *private premium (PP) model*, where the SHI scheme is phased out for current members and the health care system is completely privatized (i.e. funded premiums plus better treatment efficiency) in the long run. In this case, we distinguish two cost scenarios: a) in the PP(h.c.) simulation we assume that all members of the future private system incur the high costs of the current PHI system; b) in the PP(l.c.) scenario we assume that all members of the future private system incur the low costs of the previous SHI scheme.

[11] Transfer payments in the model are mainly introduced for technical reasons so that nobody runs out of resources.
[12] For a discussion of the different reform proposals see Kifmann and Nell (2014).
[13] Such a co-insurance level for the German health system was proposed – among others – by Drabinski (2018).

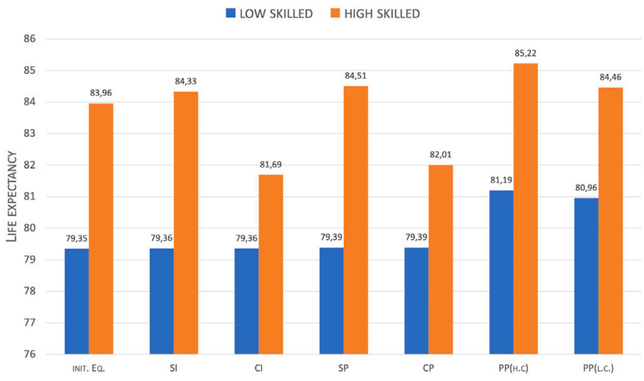


Fig. 6. Health care system and life expectancy.

Consequently, all reforms retain the existing PHI insurance for high-skilled already alive in the reform period. Those households are only indirectly affected by changes in tax rates and factor prices, which of course may also affect their premiums.[14]

In the following, the macroeconomic consequences of the different simulations are discussed first. Then the respective welfare effects for specific cohorts and households as well as in the aggregate are compared. In all these simulations we start from the benchmark equilibrium described in Table 2 above. The third subsection presents sensitivity analysis with respect to preference parameters and institutional arrangements. These simulations are performed in a small open economy setting where factor prices are exogenously set so that the initial equilibrium differs only slightly from the benchmark equilibrium.

5.1. Macroeconomic effects

Before going into the details, it is useful to highlight a general adjustment mechanism of the considered reform scenarios. They all reduce the marginal tax burden on labor for SHI-insured employees, either by reducing their contribution level or by introducing premiums. The resulting increase in labor supply and employment typically induces more savings and higher capital stock, leading further to higher wages, consumption, and output. Higher income tax revenues then allow for a reduction in consumption taxation. Despite these similarities in the adjustment to the new long-run equilibrium, Table 3 displays significant differences in the magnitudes and pace of the macroeconomic changes on the transition path.

When the co-insurance rate is increased to 10 percent of health costs in the SI simulation, the SHI contribution rate falls by 1.7 percentage points. The PHI premium for new entrants is reduced from 268 to 243 € per month (not reported). Existing PHI members experience a stronger reduction which even rises with age since they have accumulated assets from the past. Overall, labor supply and employment rise on impact by roughly 0.6 percent, which reduces the wage rate in the reform year. Since households now increase their precautionary savings, the long-run capital stock rises by about 3 percent much stronger than long-run output, which only increases by about 1.5 percent. Non-medical consumption is also rising by about 1.5 percent. However, private health investment increases stronger with almost 3.8 percent in the long run, which indicates the moral hazard costs of the insurance system. Closer inspection reveals that PHI policyholders want to counteract the high costs of sickness. Their medical investment rises by roughly 7 percent, while those insured under the SHI scheme react less.[15] As shown in Fig. 6 below, this adjustment slightly increases the gap in life expectancy. Finally, the higher long-run capital stock increases wages, so that the average income and pensions also rise. As a consequence, the consumption tax rate falls and the pension contribution rate has to increase by about 0.3 percentage points in the long run.

The CI model forces high-skilled households into the SHI system. Due to their higher incomes, the CI contribution rate falls during the transition until finally all high-skilled are members of the new system. Consequently, labor supply distortions fall slightly for former SHI members, but they rise strongly for former PHI members who now join the CI system. This explains the rising decline in employment on the transition path. Lower incomes reduce medical and non-medical consumption and private savings. Lower savings and the elimination of PHI assets reduce the capital stock during the transition. Output therefore declines by 1.5 percent in the long run, while wages decline much less. The consumption tax rate steadily increases during the transition. Overall the CI system provides better protection against health shocks but this comes at the expense of higher moral hazard costs and a loss in life expectancy for those previously privately insured, see Fig. 6.

When the SP model is introduced in the third column of Table 3, SHI contributions of low-skilled are immediately substituted by premiums. The latter are only slightly lower than those in the private system since the lower health costs of SHI members are partially neutralized by their higher sickness risk. Premiums reduce labor supply distortions immediately so that employment,

[14] This modeling assumption requires a long phase-out period of the existing system, but it is the most intuitive approach to deal with the existing PHI capital stock.

[15] If we allow for different health shocks and more uncertainty regarding the cost, precautionary behavior would further rise.

Table 3
Macroeconomic and welfare effects of the reform models[a].

		SI	CI	SP	CP	PP (h.c.)	PP (l.c.)
Employment							
	2020–24	0.59	−0.11	4.08	4.02	−0.04	−0.13
	2030–34	0.59	−0.02	3.77	3.74	1.54	0.94
	2040–44	0.64	−0.15	3.83	3.57	2.78	1.78
	∞	0.75	−1.42	4.11	2.29	6.65	4.31
Capital stock							
	2025–29	0.72	−0.21	2.61	2.50	−0.39	−0.44
	030–34	1.27	−0.37	4.49	4.28	−0.35	−0.57
	2040–44	2.02	−0.58	6.90	6.58	0.70	−0.05
	∞	2.86	−1.67	8.72	7.12	16.69	13.75
Output							
	2020–24	0.39	−0.07	2.68	2.64	−0.03	−0.09
	2030–34	0.81	−0.15	4.05	3.92	0.53	0.18
	2040–44	1.09	−0.24	4.83	4.58	1.64	0.87
	∞	1.47	−1.50	5.65	3.91	9.96	7.43
Consumption							
	2020–24	−0.49	0.25	0.72	0.84	0.62	0.60
	2030–34	0.26	0.20	3.41	3.47	0.27	0.41
	2040–44	0.77	0.23	4.93	4.98	0.54	0.75
	∞	1.49	−0.86	6.86	5.57	6.71	7.71
Health investment							
	2020–24	−0.67	−1.10	−2.43	−2.60	0.66	0.38
	2030–34	0.25	−1.29	4.64	4.26	−0.65	−0.56
	2040–44	1.32	−2.54	8.27	2.80	1.41	0.13
	∞	3.77	−0.77	13.24	9.46	−0.81	−3.00
Wage rate							
	2020–24	−0.20	0.04	−1.35	−1.33	0.01	0.05
	2030–34	0.23	−0.12	0.22	0.18	−0.45	−0.39
	2040–44	0.47	−0.18	1.01	0.98	−0.48	−0.47
	∞	0.71	−0.09	1.48	1.58	3.11	2.99
Contribution rate/Premiums							
	2020–24	−1.73	−0.38	264/275	272	271/268	212/210
	2030–34	−1.76	−1.04	263/272	265	273/270	214/212
	2040–44	−1.77	−1.56	262/270	260	276/273	216/214
	∞	−1.80	−2.28	273/267	259	285/279	223/220
Consumption tax rate							
	2020–24	−0.22	−0.03	−0.52	−0.56	0.08	0.04
	2030–34	−0.61	0.06	−1.85	−1.89	0.50	0.36
	2040–44	−0.86	0.12	−2.53	−2.54	0.39	0.25
	∞	−1.12	0.57	−3.07	−2.60	−3.42	−3.63
Pension contribution rate							
	2020–24	−0.07	0.01	−0.42	−0.41	0.01	0.01
	2030–34	0.00	0.02	−0.16	−0.13	−0.13	−0.09
	2040–44	0.08	0.03	0.13	0.14	−0.25	−0.20
	∞	0.29	−0.64	1.04	0.31	2.94	2.23
CEV		−0.31	0.65	1.63	2.28	−1.11	0.88

All other changes are reported in percent of baseline path.

[a] Changes in tax rates are in percentage points, premiums are in €.

output, and savings now increase strongly on impact. Consequently, wages and consumption increase steadily during the transition. Low-skilled households slightly invest more in health, since the premiums provide less insurance. High-skilled benefit from higher wages and lower consumer prices, which increases their health investment strongly. The consequence is a greater gap in high- and low-skilled health investment causing greater inequality as measured via life expectancy, see Fig. 6.

The fourth simulation introduces the CP model, where the whole population is finally insured in the unfunded (and uniform) premium system. Consequently, impact effects are very similar to the previous SP model, but now the funded system is eliminated during the transition and the formerly privately insured do not receive better health treatment anymore. The latter induces a decline in life expectancy for high-skilled as shown in Fig. 6, although they increase their health investment. They also build up more precautionary savings which compensates the phased-out savings from the private fund. Compared to the previous simulation, capital accumulation is dampened, so that long-run employment, output, and consumption are reduced.

In the next simulation with the PP(h.c.) model, it is assumed that all agents in the new insurance system face higher health costs and better treatment of the private system.[16] Low-skilled households, who enter the labor market are now forced to pay into a health fund which finances their health costs later in life. Note that premiums for low-skilled are now slightly higher than those

[16] Implicitly it is assumed here that the higher demand for better treatment induces a higher supply of medical providers.

of high-skilled due to higher health investment and the resulting better health of the latter. Low-skilled cohorts in the PHI are also forced to pay contributions to finance those who remain in the SHI system. These contributions decline to zero during the transition. While their labor supply distortions hardly fall initially, they reduce savings to finance their additional bills and smooth consumption. As a consequence, initial employment, capital stock, and output fall, while ordinary consumption rises. Therefore, wages decline and consumption tax rates increase initially. Note that the premiums are significantly higher than in the CP model, which reflects the higher health care costs in the private system. However, labor distortions are reduced during the transition, and employment, capital stock, output, wages, and consumption rise in the long run. The higher capital stock is mainly due to the accumulated assets of the private insurance. Since PHI offers better treatment than SHI, the life expectancy of low-skilled increases by almost two years in the long run, although their health investment slightly decreases (not shown). High-skilled, however, significantly increase their health investment in this scenario, due to higher incomes. As shown in Fig. 6, long-run life expectancy is now 81.2 and 85.2 years for low- and high-skilled, respectively.

The last simulation combines the funded premium insurance with higher treatment efficiency and the lower health costs of the former public system. Now the premiums are significantly lower than in the previous simulation so that households can afford to consume more and work less than before in the long run. This, however, does not apply to private health investment, which now decreases compared to the previous simulation. Lower health investments and lower health costs explain why life expectancy in Fig. 6 declines for both skill types compared to the previous simulation.

5.2. Welfare effects

Fig. 7 compares the welfare effects of the different reforms discussed above for specific cohorts and skill types measured in CEV. On the one side, the reported welfare changes are due to intra- and intergenerational income redistribution induced by changes in financing burdens and factor prices. On the other side, all reform models change the incentives for labor supply and other precautionary behavior against health shocks as well as the implied insurance provision. While the premium models reduce labor supply distortions and the insurance provision against productivity shocks, the opposite applies to the CI model.

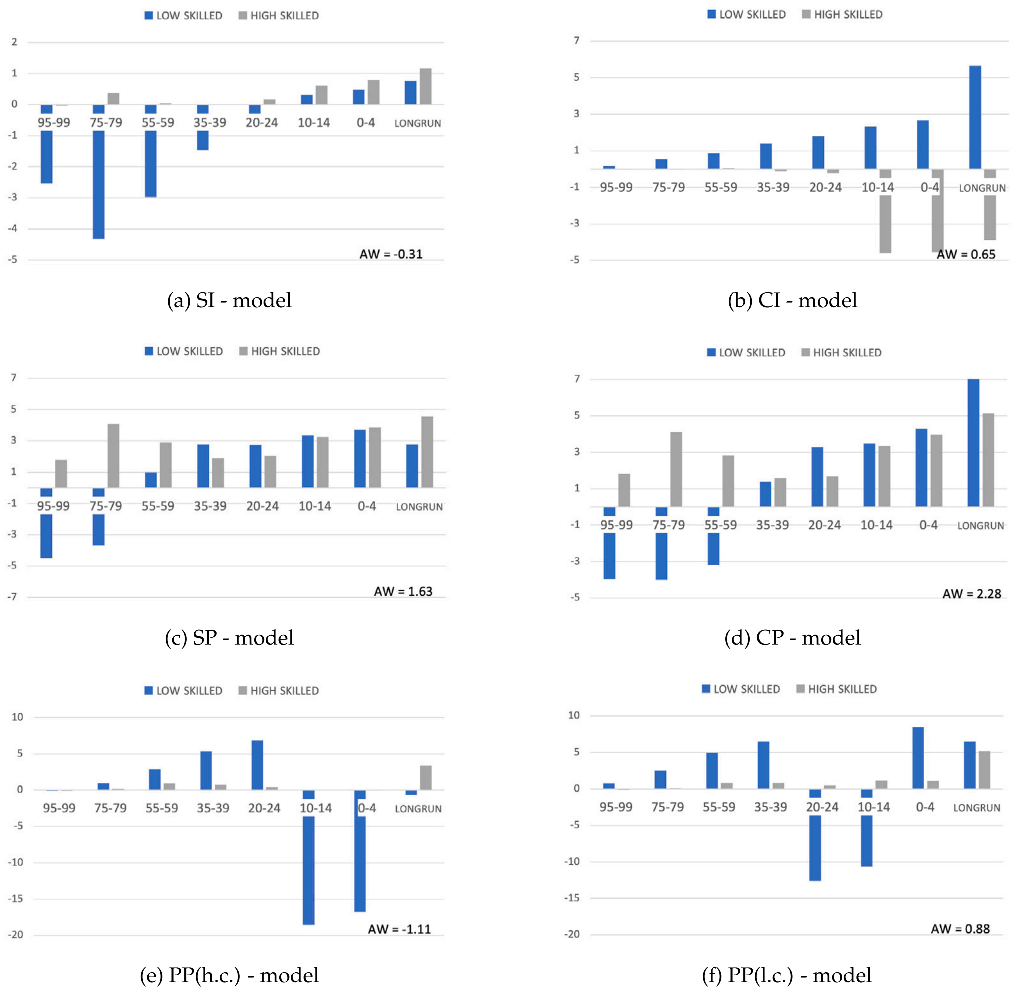
The increase in the share of co-payments in health care costs primarily harms the older pensioner cohorts in the SHI system. They have high costs and at the same time often low savings so that they are extremely exposed to health shocks. The retired cohorts in the PHI system are less affected because on the one hand, their premiums are reduced much stronger due to the accumulated PHI assets and on the other hand, they have typically higher additional savings. During the transition, younger and future cohorts can self-insure their health risk and benefit from higher wages, lower contributions, and consumption taxes. Hence, younger and future cohorts realize a significant welfare increase. Overall, the future welfare gains cannot fully compensate for the welfare losses of the initial elderly, so the aggregate welfare measure reported in the last line of Table 3 indicates a loss of 0.3 percent of initial consumption. Consequently, despite the reduced moral hazard, a health care system with deductibles reduces efficiency in our model.

The welfare effects of the CI model in Fig. 7(b) are quite different. On the one side, all low-skilled benefit, since their health insurance contributions are sequentially reduced throughout the transition. In the long run their welfare increase corresponds to an almost six percent rise in initial consumption. The remaining PHI-insured high-skilled realize hardly any welfare changes since they are only slightly affected by changes in consumption taxes and factor prices. On the other side, high-skilled labor market entrants who are now forced into the public system are much worse off than before. Their labor supply distortions rise significantly and the health treatment they receive when sick has deteriorated. They benefit from the lower cost of the public system, but they have to co-finance the higher health costs of low-skilled. The latter generate higher costs due to their lower health investment shown in Fig. 4. Overall, contribution financing of health care improves the insurance provision even for high-skilled. This seems to dominate the increased labor supply distortions of high-skilled, so that this reform increases aggregate welfare by 0.65 percent of initial consumption, see the last line in Table 3.

The social premium model in Fig. 7(c) clearly hurts the low-skilled pensioners of the initial reform periods. They now have to bear on average much higher insurance costs than before. The retired high-skilled, however, benefit from lower consumption taxes and higher interest rates. Elderly low-skilled employees of the reform period experience a significant welfare increase because their financing burden decreases. Younger and future cohorts benefit from higher wages and lower consumption taxes. The overall welfare change in Table 3 is now significantly positive, amounting to 1.63 percent of aggregate consumption.

As shown in Fig. 7(d), when the high-skilled are forced into the unfunded public premium system, low-skilled are better off in the long run than in the previous simulation due to the improved cost sharing. High-skilled benefit from the lower health costs, but are hurt due to redistribution and the lower treatment quality. These latter effects are clearly dominated by the former. The overall welfare increase is now even 2.3 percent of initial aggregate consumption. All in all, financial health costs are lower and more equally distributed within the society which implicitly improves the insurance provision and explains the resulting aggregate welfare increase. When comparing the CP and the CI model, one can see that young and future high-skilled are worse off compared to respective low-skilled due to the higher health care contributions.

The welfare effects in the two PP models in Figs. 7(e) and 7(f) are quite different compared to the SP and CP models. The oldest cohorts are hardly affected by these reforms because factor prices and consumption taxes remain initially fairly stable. The middle-aged low-skilled, who remain in the SHI system, benefit significantly since their contributions decline when the system is phased out. At the same time, younger low-skilled cohorts who enter the labor market are dramatically hurt because they have to co-finance the health bills of the elderly in the SHI system and are forced to build up PHI assets at the same time. During the



(a) SI - model (b) CI - model

(c) SP - model (d) CP - model

(e) PP(h.c.) - model (f) PP(l.c.) - model

Fig. 7. Welfare consequences of the considered reform models.

transition, this double burden falls and turns eventually positive in the long run.[17] Note that the welfare losses for some cohorts amount to roughly 20 percent of initial consumption. As a consequence, the society realizes an overall welfare loss amounting to 1.11 percent of initial consumption. This welfare loss, despite many positive aspects and higher life expectancy, can be attributed to the fact that the costs of private insurance are much higher than those of public health care.

Fig. 7(f) shows, that younger and future cohorts would benefit if the introduction of the privately funded insurance system is accompanied by a reduction in health costs. The dramatic welfare losses from the last simulation are then significantly reduced and the future welfare increases are much higher than before. Overall welfare is now even increasing at 0.88 percent of aggregate initial consumption. Compared to the CP model, the aggregate welfare gain of the PP(l.c.) model is lower, despite the improved treatment quality and lower premiums. This reflects the higher labor supply distortions during transitional years when the savings of the funded system have to be built up and two systems have to be financed.

5.3. Sensitivity analysis

Welfare effects reported in the previous subsection are strongly dependent on the assumptions made about preferences and the institutional setting of the public system. With respect to household choice modeling, we would like to quantify the impact of health investment options as well as the elasticity of labor supply and risk aversion level. The problem is that every parameter change also alters the initial equilibrium, which makes it difficult to compare the numerical results. We, therefore, compare all

[17] Of course, this specific burden-sharing mechanism for the health costs of transitional cohorts in the SHI insurance is very arbitrary. One could easily image different ones which imply a more equal burden sharing.

Table 4
Sensitivity analysis: Aggregate welfare effects in a small open economy[a].

	SI model	CI model	CP model	PP(h.c.) model
Benchmark	−0.30	0.64	2.23	−0.98
No health investment $\lambda_3 = 0$	−0.33	0.31	2.00	−0.77
Fixed labor supply $l = \max[0.37; 1 - s(h)]$	−1.36	0.80	−1.21	−2.16
Higher risk aversion $\varrho = 6.0$	−0.64	−0.04	−0.20	−2.70

[a] CEV measured in percent of initial consumption.

sensitivity calculations in a small open economy, where we exogenously specify the interest rate of Table 2. With this specification, the initial equilibrium is close to the one reported in Table 2. Table 4 shows the impact of alternative assumption on the aggregate welfare effects when we simulate the SI model and three reform models in a small open economy.

In the "benchmark" simulations we always start from the initial equilibrium of Table 2, but keep the factor prices constant throughout the transition. As a consequence, international capital and trade flows balance the capital and the goods market. Table 3 shows that (except for the SI reform) wages typically decrease initially (so that the interest rate falls), but increase significantly in the long run. Without the initial fall in wages, the consumption tax can be reduced stronger initially than in the closed economy. Thus initially elderly cohorts benefit from higher interest rates and lower consumption taxes. During the transition, younger and future cohorts are worse off than in the closed economy, since the wages remain constant. The missing wage increase hurts low-skilled less than high-skilled, since tax burdens are now shifted back towards the latter. However, the described redistribution of resources across and within cohorts hardly changes incentives and insurance provisions. Therefore, the aggregate welfare effects in the first row of Table 4 hardly change compared to those in the respective closed economy case reported in Fig. 7. In all following simulations, we change preference or institutional parameters so that the initial equilibrium will be (slightly) different from the one shown in Table 2.

In the second line, a model is shown in which private investment in health has no impact on health. Accordingly, differences in life expectancy arise exclusively from different treatments and costs by different health insurers. Now (high-skilled) households can only react with their labor supply and savings to self-insure. As a consequence insurance provision is lower, which in turn reduces the aggregate welfare effects of the considered policies. The constant wage rate also dampens the redistribution towards the high-skilled at least in the CP and the PP(h.c.) models. The latter will improve aggregate welfare. The lower aggregate welfare loss in the PP(h.c.) model might be because the wage effect dominates the insurance effect.

When the policy reform is simulated with a fixed labor supply, households cannot self-insure by working more. To be able to insure oneself against health shocks, people in all four considered scenarios invest more in health, which leads to higher life expectancy. As they do not benefit from reduced distortions of labor supply, aggregate welfare losses are much higher in the SI model and the PP(h.c.) model, and formerly welfare gains turn into significant losses in the CP model. In all these reforms households only suffer from the reduced insurance value of premiums. Since labor supply distortions even increase for formerly PHI insured in the CI model (which is now absent), aggregated welfare even slightly increases compared to the benchmark simulation, reflecting better risk allocation compared to the other models.

Since more risk-averse households build higher precautionary savings, the reduction in insurance protection in the SI and the two premium models reduces aggregate welfare compared to the respective benchmark situation.[18] The premium models especially reduce insurance protection of low-skilled households, so that higher risk aversion intensifies this effect. This mainly explains the significant fall in aggregate welfare reported in Table 4 above. Aggregate welfare also is reduced in the CI model, but much less than in the two premium models. This reflects the fact that the CI model provides more insurance than the two premium models. Now the CI model performs best relative to all other models.

6. Conclusion

This paper develops a stochastic overlapping generations model that accounts for endogenous health and survival, differences in individual health ability as well as cost and quality differences between private and public health insurance. The model is simulated to quantify the impact of alternative financing and coverage schemes for the German health insurance system. Our simulations highlight three major results. First, while premiums entail lower labor supply distortions, contribution-financed health care has better insurance properties. If the latter dominates the former, then contribution-financed health care is preferred from a welfare point of view. In our benchmark calibration, however, the citizen premium model dominates all other reform models in terms of welfare. Second, despite significant moral hazard costs in the existing system, compulsory deductibles would reduce aggregate welfare in Germany. Third, the transition towards the private system is more expensive than the immediate introduction of a public premium system. In addition, although private insurance provides a better treatment quality which leads to higher life expectancies,

[18] Since we are unsure about the exact value of ϱ, we assume same value as Palumbo (1999), so that $\varrho = 6$. Asset pricing studies such as Heathcote et al. (2008) simulate with $\varrho \in [1; 10]$.

the higher cost induces a welfare loss. This poses the question, of whether we should consider not only life expectancy but also healthy life expectancy as an indicator in future work.

The sensitivity analysis reveals that the economic benefits of the premium system are fairly robust. Contribution-financed health care is only preferred with very low labor supply elasticities and/or very risk-averse households. We also show that private health investment may significantly affect the welfare of individuals. While complete insurance only finances the direct monetary costs of health problems, households still bear indirect costs of sick time and lower life span which can be reduced by individual behavior. Finally, we highlight different causes for the observed (and growing) gap in intra-generational life expectancy. Not only individual monetary investment but also individual ability and better behaviors and genetics play a role as well as differences in treatment quality of the health care system. All these channels are present in our model and have a significant impact.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euroecorev.2024.104755.

References

Attanasio, O., Kitao, S., Violante, G.L., 2010. Financing medicare: A general equilibrium analysis. In: Shoven, J.B. (Ed.), Demography and the Economy. University of Chicago Press, Chicago.
Capatina, E., 2015. Life-cycle effects of health risks. J. Monetary Econ. 74, 67–88.
Conesa, J.C., Costa, D., Kamali, P., Kehoe, T.J., Nygaard, V.M., Raveendranathan, G., Saxena, A., 2018. Macroeconomic effects of medicare. J. Econom. Ageing 11, 27–40.
De Nardi, M., French, E., Jones, J.B., 2010. Why do the elderly save? The role of medical expenses. J. Polit. Econ. 118, 39–75.
De Nardi, M., Pashchenko, S., Porapakkarm, P., 2023. The Lifetime Costs of Bad Health. NBER Working Paper No. 23963.
Drabinski, T., 2018. Reformierte dualität zur auflösung von ineffizienzen in GKV und PKV. Ifo Schnelldienst 71 (5), 3–6.
European Central Bank (ECB), 2020. The household finance and consumption survey. In: Wafe 2017. Frankfurt.
Elstner, S., Feld, L.P., Schmidt, C.M., 2018. The German Productivity Paradox - Facts and Explanations. Ruhr Economic Papers 767, Bochum.
Epstein, L.G., Zin, S.E., 1991. Substitution, risk aversion, and the temporal behavior of consumption and asset returns: An empirical analysis. J. Polit. Econ. 99, 263–286.
Fehr, H., Kalweit, M., Kindermann, F., 2013. Should pensions be progressive? Eur. Econ. Rev. 63, 94–116.
Fehr, H., Kindermann, F., 2018. Introduction to Computational Economics. Oxford University Press, Oxford.
Feng, Z., Zhao, K., 2018. Employment-based health insurance and aggregate labor supply. J. Econ. Behav. Organ. 154, 156–174.
Frankovic, I., Kuhn, M., 2019. Access to health care, medical progress and the emergence of the longevity gap: A general equilibrium analysis. J. Econom. Ageing 14, 100188.
Grossman, M., 1972. On the concept of health capital and the demand for health. J. Polit. Econ. 80 (2), 223–255.
Hall, R.E., Jones, C.I., 2007. The value of life and the rise in health expenditures. Q. J. Econ. 122 (1), 39–72.
Halliday, T.J., He, H., Ning, L., Zhang, H., 2019. Health investment over the life cycle. Macroecon. Dyn. 23, 178–215.
Hansen, G.D., Hsu, M., Lee, J., 2014. Health insurance reform: The impact of a medicare buy-in. J. Econom. Dynam. Control 45, 315–329.
He, H., Huang, K.X.D., Ning, L., 2021. Why do Americans spend so much more on health care than Europeans? Internat. Econom. Rev. 62 (4), 1363–1399.
Heathcote, J., Storeletten, K., Violante, G.L., 2008. Insurance and opportunities: A welfare analysis of labor market risk. J. Monetary Econ. 55, 501–525.
Hsu, M., Lee, J., 2013. The provision of public universal health insurance: Impacts on private insurance, asset holdings, and welfare. Macroecon. Dyn. 17, 1252–1280.
Jeske, K., Kitao, S., 2009. U.S. tax policy and health insurance demand: Can regressive policy improve welfare? J. Monetary Econ. 56, 210–221.
Jung, J., Tran, C., 2016. Market inefficiency, insurance mandate and welfare: U.S. health care reform 2010. Rev. Econ. Dyn. 20, 132–159.
Jung, J., Tran, C., Chambers, M., 2017. Aging and health financing in the U.S.: A general equilibrium analysis. Eur. Econ. Rev. 100, 428–462.
Karlsson, M., Klein, T.J., Ziebarth, N.R., 2016. Skewed, persistent and high before death: Medical spending in Germany. Fiscal Stud. 37 (3–4), 527–559.
Kifmann, M., Nell, M., 2014. Fairer wettbewerb zwischen gesetzlicher und privater krankenversicherung. Pers. Wirtsch. 15 (1), 75–87.
Kriwy, P., Mielck, A., 2006. Versicherte der gesetzlichen krankenversicherung (GKV) und der privaten krankenversicherung (PKV): Unterschiede in morbiditaät und gesundheitsverhalten. Das Gesundheitswes. 68, 281–288.
Palumbo, M.G., 1999. Uncertain medical expenses and precautionary saving near the end of the life cycle. Rev. Econ. Stud. 66, 395–421.
Pashchenko, S., Porapakkarm, P., 2013. Quantitative analysis of health insurance reform: Separating regulation from redistribution. Rev. Econ. Dyn. 16, 383–404.
Picone, G., Uribe, M., Wilson, R.M., 1998. The effect of uncertainty on the demand for medical care, health capital and wealth. J. Health Econom. 17, 171–185.
Rosen, S., 1988. The value of changes in life expectancy. J. Risk Uncertain. 1, 285–304.
Schneider, B.S., Schneider, U., 2012. Wartezeiten auf facharztbesuche - eine analyse versicherungsbedingter diskriminierung und gesundheitlicher nachteile. In: Kuchinke, B.A., Sundmacher, T., Zerth, J. (Eds.), MÄrkte Und Versorgung, Band 6 67. Jhg.. Univerlag Illmenau, pp. 68–81.
Schneider, M.T., Winkler, R., 2021. Growth and welfare under endogenous lifetimes. Scand. J. Econ. 123 (4), 1339–1384.
Stauder, J., Kossow, T., 2017. Selektion oder bessere leistungen - warum sínd privatversicherte gesünder als gesetzlich versicherte? Gesundheitswesen 79, 181–187.
Storesletten, K., Telmer, C.I., Yaron, A., 2004. Consumption and risk sharing over the life cycle. J. Monetary Econ. 51, 609–633.
Wasem, J., Buchner, F., Lux, G., Schillo, S., 2018. Health plan payment in Germany. In: McGuire, T.G., van Kleef, R.C. (Eds.), Risk Adjustment, Risk Sharing and Premium Regulation in Health Insurance Markets. Academic Press, pp. 295–329.
Zhao, K., 2014. Social security and the rise in health spending. J. Monetary Econ. 64, 21–37.
Zhao, K., 2017. Social insurance, private health insurance and individual welfare. J. Econom. Dynam. Control 78, 102–117.