Online Appendix

A1 Joining the PKV System and Enrolling in GLTHI

As mentioned in Section 2, the decision to join the PKV is essentially a lifetime decision. The basic social insurance principle is: "Once private, always private[ly insured]."

There are several reasons why people leave the GKV permanently to join the PKV system: First, PKV premiums are actuarially fair instead of income-dependent contribution rates. On the other hand, GKV offers free family coverage for non-working relatives. This implies that childless and healthy high income earners tend to be better off financially in the PKV.[57]

Second, in the PKV system, people can choose between thousands of plans which they can customize according to individual preferences and needs. Applicants can choose their benefit level and cost-sharing amounts, within some lax regulatory limits.[58] Most insurers operate nationwide, are open to all applicants, and policies are sold and portable across state lines.

Third, the PKV relies on private contracts with one-sided commitment over the lifecycle. GKV pricing and benefits depend inherently on the political situation and funding. One could argue that the public system carries more uncertainty about future benefits and contribution rates. Below we discuss the GLTHI lifecycle premium calculation in theory and practice.

Fourth, the regulation makes the GLTHI particularly attractive for civil servants. The large majority of them enrolls in it. The reason is that, since the 1920s, German law stipulates that the state has the obligation to care for their civil servants (*Fürsorgeplicht*), which is why the government self-insures (at least) 50 percent of their civil servants' health care costs directly (*Beihilfe*).[59] However, in general, the government does not pay half the GKV contribution rates as private employers do (Schmidt, 2020). This implies that civil servants would have to pay the full GKV contribution rate, but only insure 50 percent of their health care costs on the PKV market which makes the latter much more attractive.[60]

[57] Obviously, the advantage of having income-independent premiums can backfire when income drops later in life. For financial hardship cases, the regulator introduced the Basic Plan, see footnote 63.

[58] For example, effective 2009, the government mandated that deductible cannot exceed €5,000 for new policies (see *GKV-Wettbewerbsstärkungsgesetz*).

[59] In practice, this means that civil servants, first have to pay providers out-of-pocket and then submit their claims to a state agency *and* the private insurer, both of which then reimburse half the costs. This principle that the insured must first pay providers and then submit claims (*Kostenerstattungsprinzip*) is a general GLTHI principle and downside for policyholders. Compared to GKV, where providers directly submit claims to sickness funds and cost-sharing is low, it implies more paperwork, uncertainty about claim denials, and requires more cash liquidity.

[60] The exact share of *Beihilfe* depends on the state, see Schmidt (2020) for details. Several private insurers have specialized in providing customized coverage for the remaining uninsured share. One out of 16 states, Bremen, also generally offers civil servants the option to get half of their GKV contribution rate covered, which essentially implies giving them

Finally, while both systems cover all medically necessary benefits and the medical treatment quality is very similar, waiting times in the outpatient sector are shorter for the privately insured as outpatient reimbursement rates are structurally higher (Werbeck et al., 2021). Thus, the privately insured are more profitable for providers because sometimes PKV benefit packages are more generous than the GKV benefit package. As a consequence, they enjoy higher service quality (but potentially also overtreatment) by physicians.

The fact that some population subgroups have the right to choose between GKV and PKV has not only been criticized on the ground of fairness, but it implies selection into the PKV system. Specifically, as initial premiums are risk-rated, those who have pre-existing conditions and are unhealthy, likely decide to stay in the public system. Further, as just discussed, income and family status (and spouse's labor supply decisions) also determine the decision to sign a GLTHI contract. Further, preferences and risk tolerance may determine the decision to opt out of GKV.

A1.1 Switching from PKV to GKV

There exist very limited institutional exemptions for PKV insured to return to the public GKV system. Below we provide empirical evidence on the switching rates.

First, for PKV insured above the age of 55, switching back to GKV is essentially impossible, even when their income decreases substantially or when they become unemployed. For those above 55, one of the few options would be to exit the labor force and enroll under the GKV family plan of the spouse, if available. Rules for switching back to the GKV have been very strict for older employees. This is to avoid that individuals join the private system when young and healthy, and switch back to the public system when old and sick with little income (and thus low income-dependent contribution rates).

Second, PKV insured employees below the age of 55 can only return to the public GKV system if they become unemployed or if their gross wage from dependent employment permanently drops below the income threshold below which one is mandatorily insured with the GKV ("pflichtversichert").[61] However, permanently switching to the GKV implies loosing the entire old-age provisions.

Third, PKV insured who are self-employed and below the age of 55 can only switch to GKV if they give up their business and become an employee with a gross salary below the income threshold

the choice between GKV and PKV. The other states only approve such requests in exceptional cases.

[61] Assuming an average annual premium of €3,900 (as observed in our data), for an equally high GKV premium (15.5% of the gross wage), annual labor income would need to be as low as €25,000. Hence, artifically reducing income just to be able to join the GKV does not make sense for the overwhelming majority of cases.

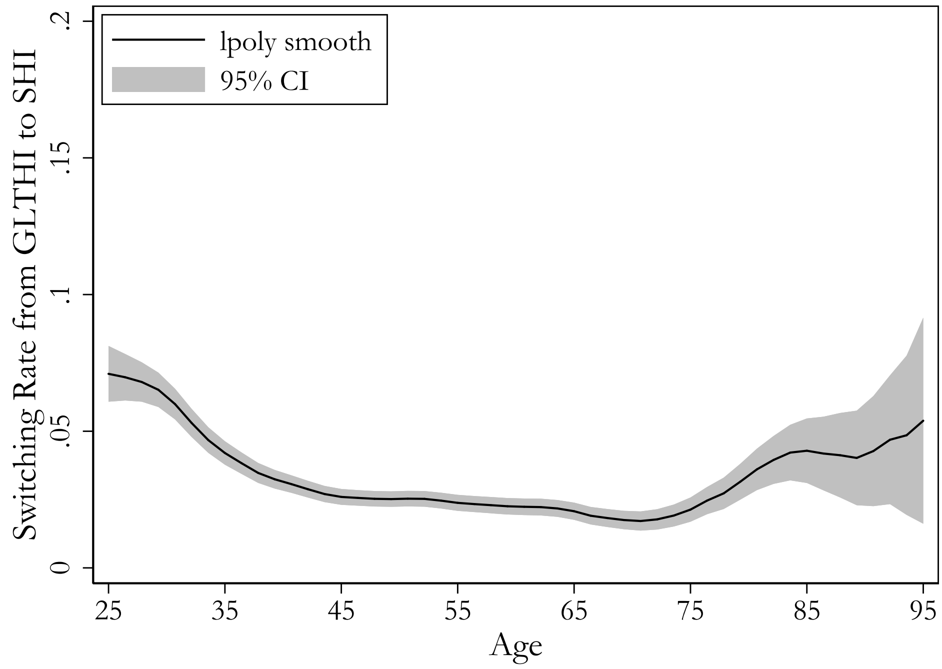


Figure A1: Likelihood to Return to GKV by Age

Source: SOEP (2018), the long version from 1984 to 2016. Epanechnikov kernel, degree 0, bandwidth 2.6.

(see Social Code Book V, Para. 6 for details of the law, Büser, 2012; Cecu, 2018).

Data from the Association of German Private Healthcare Insurers (*Verband der Privaten Krankenversicherung*) show that 124,900 individuals, or 1.4 percent of all PKV insured, switched from PKV to GKV and 145,000 switched from GKV to PKV (Association of German Private Healthcare Insurers, 2022a). Since 1997, the number of switchers to the GKV system has been very stable between 124,900 and 154.800 per year (Bundesministerium für Gesundheit, 2022). [62] Figure A1 uses representative SOEP data to plot switching rates by age. As seen, the likelihood to return to GKV decreases substantially between the age of 25 and 35. We conjecture that this is mostly because those who were privately insured as students enter the labor market and have to enroll in GKV if their gross wages are below the mandatory income threshold. Switching rates remain stable at a low level between age 40 and age 75, and then slightly increase again. Using a fixed effects regression for the probability of switching to GKV among the universe of Germans who were at least once GLTHI policyholder, we find few significant predictors of switching back to GKV. In particular, health care utilization (number of hospital nights and doctor visits) are not significant predictors. The results of this analysis are

[62] As the total number of PKV insured has increased from in 1991 to 8.976.400 in 2011 and, since then, decreased slightly to 8.723.900 in 2020 (Bundesministerium für Gesundheit, 2022; Association of German Private Healthcare Insurers, 2022a). Several reforms in the last decades have at least partly determined switching rates over time: The *Gesundheitsreformgesetz* of December 20, 1988 substantially tightened the possibility of joining the PKV for pensioners; the *Gesundheitsstrukturgesetz*, passed on December 21, 1992, introduced the free choice of GKV sickness funds, along with other provisions about the regulation of private insurers. Due to these and other reforms (e.g. the *GKV-Wettbewerbsstärkungsgesetz* of 2007), the GKV-PKV switching rate as a share of all GLTHI policyholders has declined over time.

Figure A2: Age Distribution of Initial Plan Inception

Source: German Claims Panel Data.

available upon request.

A2 Premium Calculation in GLTHI, Further Details

This section first summarizes the institutional details of the PKV lifecycle premium calculation, also see Hofmann and Browne (2013) and Atal et al. (2019) for English references on the topic.

Ihe initial GLTHI premium is individually underwritten, but all subsequent premium changes over the lifecycle must be community rated.[63] Premiums consist of several components. The *Kalkulationsverordnung (KalV)* regulates the actuarial calculations. These calculations have to be approved by a federal financial regulatory agency (the *Bundesanstalt für Finanzdienstleistungsaufsicht, BaFin*). The *KalV* specifies that premiums have to be a function of the expected per capita health care claims (*Kopfschäden*, which depend on the plan chosen, age, gender, and health risks),[64] the assumed guaranteed interest rate (*Rechnungszins*), the probability to lapse (*Stornowahrscheinlichkeit*), and the life expectancy (*Sterbewahrscheinlichkeit*).

One important and distinct characteristic of the GLTHI market is the legal obligation of insurers to build up *old-age provisions*, typically until age 60 of the policyholder, see Atal et al. (2019) for further details. The old-age provisions accumulated early in the policyholder's lifecycle serve as the capital stock to cover higher health expenditures later in the lifecycle.

Premiums are then calculated under the basic principle of a constant lifecycle premium, sufficient to cover lifecycle health care expenses of the policyholder. Section 3.1 formally expresses this principle. Thus, in young ages, premiums exceed expected claims while in old ages, premiums fall short of expected claims—a phenomenon known as "front-loading" in long-term insurance contracts (Hendel and Lizzeri, 2003; Nell and Rosenbrock, 2007, 2009; Fang and Kung, 2020).[65]

While, theoretically, premiums are stable over individuals' lifecycles, in reality, nominal (and also real) premiums do increase. The main factors that trigger such "premium adjustments" (*Beitragsanpassungen*) are structural and unexpected changes in (i) life expectancy, (ii) health care consumption, (iii) health care prices, for example, due to new medical technology,[66] (iv) economic fundamentals.

[63] The only exception is the Basic Plan (*'Basistarif*). All insurers have to offer a Basic Plan. It follows the standardized GKV plan with the same essential benefits and actuarial values. For the Basic Plan, guaranteed issue exists for people above 55 and those who joined the GLTHI after 2009. The maximum premium is capped at the maximum GKV contribution (2021: €769,16 per month). The legislature mandated the Basic Plan to provide an "affordable" private option for GLTHI enrollees who cannot switch back to GKV, are uninsured, would have to pay excessive premiums, or would be denied coverage. However, the demand for the Basic Plan has been negligible; thus henceforth, we will abstain from it. In 2019, in the entire GLTHI, only 32,400 people, or 0.4 percent, were enrolled in the Basic Plan (Association of German Private Healthcare Insurers, 2020). In our data, only 1,006 enrollees chose the basic plan in 2010.

[64] Gender rating was allowed until December 21, 2012. After this date, for new contracts, all insurers in the European Union (EU) have to provide unisex premiums as the EU Court of Justice banned gender rating as discriminatory (Schmeiser et al., 2014)

[65] Such front-loading creates a "lock-in" effect, in addition to the lock-in induced by guaranteed renewability (Atal, 2019). To strengthen consumer power and reduce this lock-in, the German legislature made a standardized portion of these old-age provisions portable across insurers for contracts signed after Jan 1, 2009; see Atal et al. (2019) for an evaluation of this reform. For existing contracts, Atal et al. (2019) do not find a significant impact on the liklihood to switch insurers.

[66] The Health Care Reform 2000 (*GKV-Gesundheitsreformgesetz 2000*) introduced a mandatory 10 percent premium

An example of (iv) is the shift of central banks to a super-low interest rate environment over the past decade; this shift implies a significant decrease in the returns to risk-free capital investment. Because GLTHI insurers (like life insurers) are heavily invested in the bond market, premium adjustments are a consequence of super-low interest rates.[67]

In some cases, premium adjustments are not only allowed, but *required* by the financial regulatory oversight agency *BaFin*. This is to ensure financial stability within the regulatory framework of the *Versicherungsvertragsgesetz (VVG)*, the *Versicherungsaufsichtsgesetz (VAG)*, and the *KalV*.[68] Most insurers have to follow the *Solvency II* reporting requirements. Each year, insurers have to check whether their underlying assumptions to calculate premiums and old age provision are still accurate. If they deviate by a certain amount, they have to adjust the premiums, which can result in two-digit premium increases, bad press, and lawsuits (Krankenkassen-Zentrale (KKZ), 2020).[69] However, average nominal premium increases have been moderate in an international comparison. According to data by the Association of German Private Healthcare Insurers (*Verband der Privaten Krankenversicherung*) total revenues from premiums increased annually between 0 and 4.5 percent from 2011 to 2020 (Bundesministerium für Gesundheit, 2022); the industry reports average annual premium increases of 2.6% from 2012-2022 (Bahnsen and Wild, 2021). Most important for our analysis is that, after the initial risk rating, premium adjustments do not depend on policyholders' evolving health status.

A3 Proof for Lemma 1

We prove the lemma through induction. With $b_T = 0$, we first show that Equation (2) holds for period $T-1$, i.e. $b_{T-1}(\zeta_T|\Xi_{T-1})$. Then, we show that Equation (2) holds for period t, given it holds for $t+1$. First, note that for the securities to replicate the premium path of the GLTHI contract, the following equations must hold

surcharge up to age 60 to dampen structural increases in health care spending due to medical progress. This surcharge only applies to GLTHI contracts signed after January 1, 2000 (see article 14 of GKV-Gesundheitsreformgesetz (2000)).

[67] The *KalV* has traditionally capped the assumed return on equity—the "guaranteed interest rate" (*Rechnungszins*)—at 3.5 percent for the premium calculation. This was the case for five decades. However, in 2016 for the first time, the average net return on investment has dropped below 3.5 percent, which is why the *German Actuary Association* has issued a new guideline to calculate the new insurer-specific "maximum allowed interest rate" (*Höchstrechnungszins*), see Deutsche Aktuarvereinigung (DAV) (2019).

[68] Effective January 1, 2016 the *KalV* has been replaced by the *Krankenversicherungsaufsichtsverordnung (KVAV)*.

[69] All premium adjustments have to be legally checked and approved by 16 independent actuaries who are appointed by the *BaFin*. However, some plaintiffs in lawsuits argue that some of these actuaries would not be sufficiently independent. Other reasons of courts to declare a premium increase as "not justified" were insufficient explanations by the insurers or a deliberate initial underpricing of premiums in the first year to attract enrollees (Krankenkassen-Zentrale (KKZ), 2020).

$$-\tilde{P}_t(\Xi_t) = -E(m|\xi_t) - \sum_{\xi_{t+1}\in\mathcal{Z}} \delta\pi(\xi_{t+1} \mid \xi_t) b_t(\xi_{t+1}|\Xi_t) + b_{t-1}(\xi_t|\Xi_{t-1}) \quad \text{for } t \in \{1, 2, ..., T\} \tag{12}$$

with $b_0 = 0$ and $b_T = 0$. The previous expressions ensure that the addition of the premium of the short-term contract and the net proceeds from the Arrow securities equate the premium paid in the GLTHI contract after history Ξ_t.

Terminal Period. In the terminal period, the price of a GLTHI contract in the spot market is equal to the price of a short term contract: $P(\xi_T) = E(m_T \mid \xi_T)$. The price paid under the GLTHI contract is therefore $\tilde{P}_T(\Xi_T) = \min\left\{P_T(\xi_T), \tilde{P}_{T-1}(\Xi_{T-1})\right\}$. There are two relevant cases:

1. $P_T(\xi_T) \leq \widetilde{P}_{T-1}(\Xi_{T-1})$ (*lapsation in* T). From equation (12), we get:

$$b_{T-1}(\xi_T \mid \Xi_{T-1}) = E(m_T \mid \xi_T) - \tilde{P}_T(\Xi_T) = P_T(\xi_T) - P_T(\xi_T) = 0$$

2. $P_T(\xi_T) > \widetilde{P}_{T-1}(\Xi_{T-1})$ (*no lapsation in* T). From equation (12), we get:

$$b_{T-1}(\xi_T \mid \Xi_{T-1}) = E(m_T \mid \xi_T) - \tilde{P}_T(\Xi_T) = E(m_T \mid \xi_T) - \tilde{P}_{T-1}(\Xi_{T-1})$$

Therefore equation (2) holds for $T - 1$.

Period $t < T-1$. We now consider a period $t < T-1$. First, note that $\mathbb{1}\left(P_{t+2}(\xi_{t+2}) > \tilde{P}_{t+1}(\Xi_{t+1})\right) = 1 \iff b_{t+1}(\xi_{t+2}|\Xi_{t+1}) > 0$, and therefore,

$$\pi\left(\xi_{t+2} \mid \xi_{t+1}\right) b_{t+1}\left(\xi_{t+2} \mid \Xi_{t+1}\right) = \pi\left(\xi_{t+2} \mid \xi_{t+1}\right) b_{t+1}\left(\xi_{t+2} \mid \Xi_{t+1}\right) \mathbb{1}\left(P_{t+2}(\xi_{t+2}) > \tilde{P}_{t+1}(\Xi_{t+1})\right)$$

Given that equation (2) holds for period $t+1$,

$$\pi\left(\xi_{t+2} \mid \xi_{t+1}\right) b_{t+1}\left(\xi_{t+2} \mid \Xi_{t+1}\right) = \left(E\left(m_{t+2} \mid \xi_{t+2}\right) - \tilde{P}_{t+1}(\Xi_{t+1})\right) \pi\left(\xi_{t+2} \mid \xi_{t+1}\right) \mathbb{1}\left(P_{t+2}(\xi_{t+2}) > \tilde{P}_{t+1}(\Xi_{t+1})\right)$$
$$+ \left(\sum_{\tau > t+2}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+2)} \left(E\left(m_\tau \mid \xi_\tau\right) - \tilde{P}_{t+1}(\Xi_{t+1})\right) \times q_\tau\left(z \mid \xi_{t+2}, \mathbf{P}_{t+3}^{\tau}, \tilde{P}_{t+1}\left(\Xi_{t+1}\right)\right)\right) \pi\left(\xi_{t+2} \mid \xi_{t+1}\right) \mathbb{1}\left(P_{t+2}(\xi_{t+2}) > \tilde{P}_{t+1}(\Xi_{t+1})\right)$$

By definition, $q_\tau\left(\xi_\tau \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, \tilde{P}_t(\Xi_t)\right) = \prod_{j=t+2}^{\tau}\left[\mathbb{1}(P_j(\xi_j) > \tilde{P}_t(\Xi_t))\pi(\xi_{j+1}|\xi_j)\right]$. Therefore, we can re-write the expression above as:

$$\pi\left(\xi_{t+2} \mid \Xi_{t+1}\right) b_{t+1}\left(\xi_{t+2} \mid \Xi_{t+1}\right) = \left(E\left(m_{t+2} \mid \xi_{t+2}\right) - \tilde{P}_{t+1}(\Xi_{t+1})\right) \times q_{t+2}\left(\xi_{t+2} \mid \xi_{t+1}, \mathbf{P}_{t+2}^{t+2}, \tilde{P}_{t+1}\left(\Xi_{t+1}\right)\right)$$
$$+ \sum_{\tau > t+2}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+2)} \left(E\left(m_\tau \mid \xi_\tau\right) - \tilde{P}_{t+1}(\Xi_{t+1})\right) \times q_\tau\left(z \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, \tilde{P}_{t+1}\left(\Xi_{t+1}\right)\right)$$

Summing across ξ_{t+2} and multiplying by δ, we get:

$$\delta \sum_{\xi_{t+2}} \pi\left(\xi_{t+2} \mid \Xi_{t+1}\right) b\left(\xi_{t+2} \mid \Xi_{t+1}\right) = \sum_{\tau > t+1}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+1)} \left[E\left(m_\tau \mid \xi_\tau\right) - \tilde{P}_{t+1}(\Xi_{t+1})\right] \times q_\tau\left(z \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, \tilde{P}_{t+1}\left(\Xi_{t+1}\right)\right)$$

We now consider the two relevant cases.

1. $P_{t+1}\left(\xi_{t+1}\right) \leq \widetilde{P}_t\left(\Xi_t\right)$ (*lapsation in* $t+1$). We have $\tilde{P}_{t+1}(\Xi_{t+1}) = P_{t+1}(\xi_{t+1})$. From equation (12) we get:

$$\begin{aligned}
b_t\left(\xi_{t+1} \mid \Xi_t\right) &= E\left(m_{t+1} \mid \xi_{t+1}\right) - \tilde{P}_{t+1}\left(\Xi_{t+1}\right) + \delta \sum_{\xi_{t+2}} \pi\left(\xi_{t+2} \mid \Xi_{t+1}\right) b_{t+1}\left(\xi_{t+2} \mid \Xi_{t+1}\right) \\
&= E\left(m_{t+1} \mid \xi_{t+1}\right) - \tilde{P}_{t+1}\left(\Xi_{t+1}\right) + \sum_{\tau > t+1}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+1)} \left[E\left(m_\tau \mid \xi_\tau\right) - \tilde{P}_{t+1}(\Xi_{t+1})\right] \times q_\tau\left(z \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, \tilde{P}_{t+1}\left(\Xi_{t+1}\right)\right) \\
&= E\left(m_{t+1} \mid \xi_{t+1}\right) - P_{t+1}\left(\xi_{t+1}\right) + \sum_{\tau > t+1}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+1)} \left[E\left(m_\tau \mid \xi_\tau\right) - P_{t+1}(\xi_{t+1})\right] \times q_\tau\left(z \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, P_{t+1}\left(\xi_{t+1}\right)\right) \\
&= 0
\end{aligned}$$

where the last step follows from the insurer's zero-profit condition.

2. $P_{t+1}(\xi_{t+1}) > \widetilde{P}_t(\Xi_t)$ (*no lapsation in* $t+1$). We have $\tilde{P}_{t+1}(\Xi_{t+1}) = \widetilde{P}_t(\Xi_t)$ .From equation (12) we get:

$$b_t(\xi_{t+1} \mid \Xi_t) = E(m_{t+1} \mid \xi_{t+1}) - \tilde{P}_{t+1}(\Xi_{t+1}) +$$
$$\sum_{\tau > t+1}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+1)} [E(m_\tau \mid \xi_\tau) - \tilde{P}_{t+1}(\Xi_{t+1})] \times q_\tau\left(z \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, \tilde{P}_{t+1}(\Xi_{t+1})\right)$$
$$= E(m_{t+1} \mid \xi_{t+1}) - \tilde{P}_t(\Xi_t) + \sum_{\tau > t+1}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+1)} [E(m_\tau \mid \xi_\tau) - \tilde{P}_t(\Xi_t)] \times q_\tau\left(z \mid \xi_{t+1}, \mathbf{P}_{t+2}^{\tau}, \tilde{P}_t(\Xi_t)\right)$$

Therefore, equation (2) also holds for period t.

Then the equation holds for all $t \in \{1, 2, ..., T\}$.

A4 Lifecycle Premiums in the Optimal Dynamic Health Insurance Contract (GHHW)

Ghili et al. (2019) study the optimal dynamic health insurance contract. It maximizes consumer welfare, subject to break-even, no lapsation, and no borrowing constraints—in an environment where individuals have *time-separable* and *risk averse* preferences subject to stochastic health expenditure shocks.

Ghili et al. (2019) show that the optimal dynamic insurance contract provides a *consumption guarantee* $\bar{c}_t(\xi_t, \mathbf{y}_t^T)$ that is a function of enrollees' current health risk and the vector of current and future income $\mathbf{y}_t^T \equiv \{y_t, y_{t+1}, ...y_T\}$. The individual will start consuming $\bar{c}_1(\xi_1, \mathbf{y}_1^T)$ and, over time, the individual's consumption guarantee $\bar{c}$ is bumped up in every period t such that a competing firm can offer a higher guarantee $\bar{c}_t(\xi_t, \mathbf{y}_t^T) > \bar{c}$ and still break-even in expectation.

Analogous to the GLTHI lifecycle premium calculation, $\bar{c}_t(\xi_t, \mathbf{y}_t^T)$ is solved by backwards induction. Specifically, the consumption guarantee in period T is given by $\bar{c}_t(\xi_t, y_T) = y_T - \mathbb{E}(m_T|\xi_T)$. For any $t < T$ and $\tau > t$, denote the set of future equilibrium consumption guarantees $\bar{\mathbf{c}}_{t+1}^\tau \equiv \{\bar{c}_{t+1}(.), ..., \bar{c}_\tau(.)\}$. Then an algebraic reformulation of the consumption guarantee in Ghili et al. (2019) shows that the equilibrium break-even consumption guarantee under the optimal dynamic contract for an individual purchasing a long-term optimal contract at time t under health status ξ_t is recursively determined by:

$$\bar{c}_t(\xi_t, \mathbf{y}_t^T) = \frac{y_t - \mathbb{E}(m_t|\xi_t) + \sum_{\tau>t}^{T} \sum_{z\in\Xi} \delta^{\tau-t}(y_\tau - \mathbb{E}(m_\tau|z)) \times q_\tau(z|\xi_t, \bar{\mathbf{c}}_{t+1}^\tau, \bar{c}_t(\xi_t, \mathbf{y}_t^T))}{1 + \sum_{\tau>t}^{T} \sum_{z\in\Xi} \delta^{\tau-t} \times q_\tau(z|\xi_t, \bar{\mathbf{c}}_{t+1}^\tau, \bar{c}_t(\xi_t, \mathbf{y}_t^T))}, \tag{13}$$

where $q_\tau(z|\xi_t, \bar{\mathbf{c}}_{t+1}^\tau, \bar{c}_t(\xi_t, \mathbf{y}_t^T))$ is, with some slight abuse of notation, the probability that (i) $\xi_\tau = z$, and (ii) the individual does not lapse (or die) between periods t and τ, given the set of future equilibrium consumption guarantees $\bar{\mathbf{c}}_{t+1}^\tau$.

As with the GLTHI lifecycle premium, Equation (13) implicitly determines the equilibrium consumption guarantee in period t under health status ξ_t. As noted in Ghili et al. (2019), these consumption guarantees can be re-interpreted as a series of contracts with guaranteed premium *paths* $P_\tau(\xi_\tau, y_\tau) = y_\tau - \bar{c}_t(\xi_t, \mathbf{y}_t^T)$ for $\tau \geq t$; and the consumer would lapse at a time $\tau > t$ under health status ξ_τ whenever $\bar{c}_\tau(\xi_\tau, \mathbf{y}_\tau^T) > \bar{c}_t(\xi_t, \mathbf{y}_t^T)$. That is, a consumer who chose an optimal long-term contract at time t under health status ξ_t will lapse at a future time τ under health status ξ_τ if the market provides a new long-term contract with higher consumption guarantees.

Remark 4 *The consumption guarantee under GHHW's optimal long-term contract, recursively characterized* *by Equation (13), do not depend on the utility function. However it is important that consumers' preferences are time separable and exhibit risk aversion.*

Remark 5 *The consumption guarantee under GHHW's optimal long-term contract, recursively characterized by Equation (13), does depend on income. This implies that the corresponding guaranteed premium path $P_\tau(\xi_\tau, y_\tau) = y_\tau - \bar{c}_t(\xi_t, \boldsymbol{y}_t^T)$ also depends on income. As income profiles differ by education, the GHHW premiums differ by education. The GLTHI premiums differ and neither depend on income nor education (see Remark 2).*

A4.1 Characterizing Optimal Contracts with Arrow Securities

This section shows how to implement the optimal dynamic long-term contracts as in Ghili et al. (2019) with one-sided commitment by trading state-contingent one-period Arrow securities.

First, we define the individual's consumption when only short-term contracts are available $c_t(\xi_t)$:

$$c_t(\xi_t) = y_t - E(m_t \mid \xi_t).$$

Equation (13) provides the individual's long-term guaranteed consumption offered by a competitive insurer. We define the guaranteed consumption from the previous period, $\tilde{c}_t$:

$$\tilde{c}_t(\Xi_t) = \max\{\tilde{c}_{t-1}(\Xi_{t-1}), \quad \bar{c}_t(\xi_t)\}$$

We aim to find the quantities of Arrow securities that would replicate the consumption path under the optimal contract when combined with short-term contracts. In particular, it must be true that

$$\tilde{c}_t(\Xi_t) = y_t - E(m|\xi_t) - \sum_{\xi_{t+1} \in \mathcal{Z}} \delta\pi(\xi_{t+1} \mid \xi_t) b_t(\xi_{t+1}|\Xi_t) + b_{t-1}(\xi_t|\Xi_{t-1}) \quad \text{for } t \in \{1, 2, ..., T\}$$

with $b_0 = 0$ and $b_T = 0$

Lemma 2 *The consumption path under the optimal dynamic contract can be replicated by purchasing short-term insurance contracts supplemented by Arrow securities. The quantity of Arrow securities bought after history Ξ_t that pay one dollar in state ξ_{t+1} are equal to*

$$
b_t\left(\xi_{t+1} \mid \Xi_t\right) = \begin{cases} 0 \quad \textit{if } \bar{c}_{t+1}\left(\xi_{t+1}\right) > \tilde{c}_t\left(\Xi_t\right) \\ (\tilde{c}_t(\Xi_t) - c_{t+1}(\xi_{t+1})) + \\ \quad \sum_{\tau>t+1}^{T} \sum_{z \in \mathcal{Z}} \delta^{\tau-(t+1)} [\tilde{c}_t(\Xi_t) - c_\tau(\xi_\tau)] q_\tau\left(z \mid \xi_{t+1}, \mathbf{C}_{t+2}^{\tau}, \tilde{c}_t(\Xi_t)\right) \quad \textit{otherwise} \end{cases} \tag{14}
$$

where $q_\tau\left(z \mid \xi_{t+1}, \mathbf{C}_{t+2}^{\tau}, \tilde{c}_t(\Xi_t)\right)$ *is the probability that (i)* $\xi_\tau = z$*, and (ii) the enrollee does not lapse (or die) between periods* $t+1$ *and* τ*, given the subsequent equilibrium consumption* $\mathbf{C}_{t+2}^{\tau}$ *and the guaranteed-renewable consumption* $\tilde{c}_t(\Xi_t)$*.*

A5 Descriptive Statistics for GLTHI Dataset and SOEP Dataset

Table A1: Summary Statistics: German Claims Panel Data

	Mean	SD	Min	Max	N
Socio-Demographics					
Age (in years)	45.5	11.4	25.0	99.0	1,867,465
Female	0.276	0.447	0.0	1.0	1,867,465
Policyholder since (years)	6.5	5.0	1.0	40.0	1,867,465
Client since (years)	12.8	11.0	1.0	86.0	1,867,465
Employee	0.336	0.473	0.0	1.0	1,867,465
Self-Employed	0.486	0.500	0.0	1.0	1,867,465
Civil Servant	0.132	0.338	0.0	1.0	1,867,465
Health Risk Penalty	0.358	0.480	0.0	1.0	1,867,465
Pre-Existing Condition Exempt	0.016	0.126	0.0	1.0	1,867,465
Health Plan Parameters					
TOP Plan	0.377	0.485	0.0	1.0	1,867,465
PLUS Plan	0.338	0.473	0.0	1.0	1,867,465
ECO Plan	0.285	0.451	0.0	1.0	1,867,465
Annual premium (USD)	4,749	2,157	0	33,037	1,867,318
Annual risk penalty (USD)	157	453	0	21,752	1,867,465
Deductible(USD)	675	659	0	3,224	1,867,465
Total Claims (USD)	3,289	8,577	0	2,345,126	1,867,465

Source: German Claims Panel Data. *Policyholder since* is the number of years since the client has enrolled in the current plan; *Client since* is the number of years since the client joined the company. *Employee* and *Self-Employed* are dummies for the policyholders' current occupation. *Health Risk Penalty* is a dummy that is one if the initial underwriting led to a health-related risk penalty on top of the factors age, gender, and type of plan; *Pre-Existing Conditions Exempt* is a dummy that is one if the initial underwriting led to exclusions of pre-existing conditions. The mutually exclusive dummies *TOP Plan*, *PLUS Plan* and *ECO Plan* capture the generosity of the plan. *Annual premium* is the annual premium, and *Annual Risk Penalty* is the amount of the health risk penalty charged. *Deductible* is the deductible and *Total Claims* the sum all claims in a calendar year. See Section 4.1 for further details.

Table A2: Summary Statistics: German Socio-Economic Panel Study

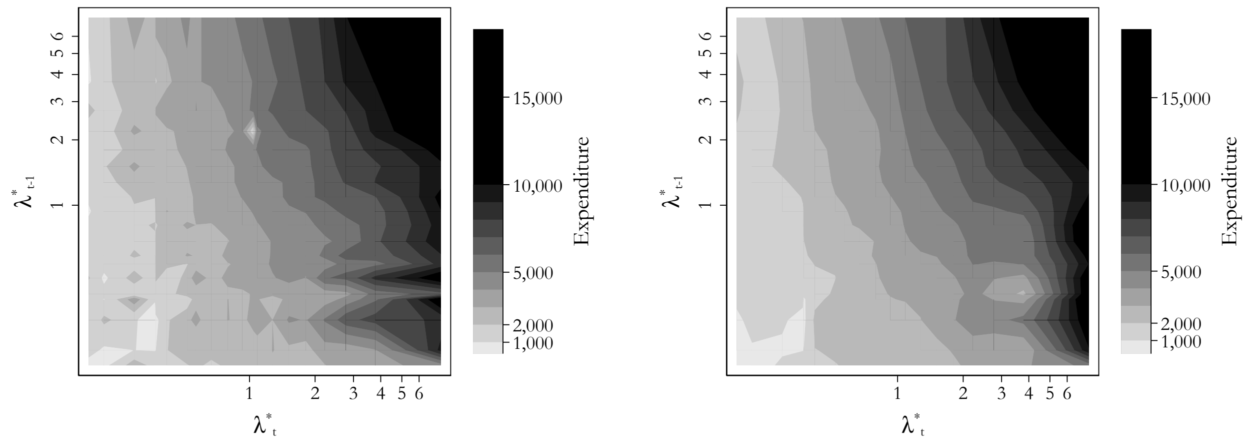
	Mean	SD	Min	Max	N
Socio-Demographics					
Female	0.5217	0.4995	0	1	530,228
Age	46.9119	17.4922	17	105	530,228
No degree yet	0.058	0.2338	0	1	530,228
Dropout of high school	0.0378	0.1908	0	1	530,228
Degree after 8/9 years of schooling (Ed 8)	0.3619	0.4805	0	1	530,228
Degree after 10 years of schooling (Ed 10)	0.2737	0.4459	0	1	530,228
Degree after 13 years of schooling (Ed 13)	0.1746	0.3796	0	1	530,228
Employment					
Civil servant	0.0393	0.1943	0	1	530,228
Self-employed	0.0624	0.2419	0	1	530,228
White collar	0.2736	0.4458	0	1	530,228
Full-time employed	0.4152	0.4928	0	1	530,228
Part-time employed	0.1402	0.3471	0	1	530,228
Income Measures in 2016 USD					
Monthly gross wage	2,940	2,506	0	215,093	310,460
Monthly net wage	1,921	1,527	0	134511.5	310,460
Individual annual total income	20,361	24,434	0	2,580,000	530,228
Equivalized post-tax post-transfer annual income	26,433	18,731	0	2,155,394	530,228
Insurance and Utilization					
Hospital nights in past calendar year	1.6652	8.3794	0	365	530,228
Doctor visits in past 3 months	2.4941	4.1436	0	99	461,971
Privately insured	1	0	1	1	57,558

Source: SOEP (2018), the long version from 1984 to 2016. Whenever the number of person-year observations is less than 530,228 the question was not asked in all years from 1984 to 2016. For example, *Doctor visits in past 3 months* has only been routinely asked since 1995. *Privately insured* indicates that 57,558/530,228=10.8% of all observations are by people who are insured on the GLTHI market. All income measures have been consistently generated and cleaned by the SOEP team; e.g., *Monthly gross wage* is labeled *labgro* and *Monthly net wage* is labeled *labnet* in SOEP (2018). See Section 4.2 for a detailed discussion of the variables.

A6 Risk Classification: Further Details and Robustness Checks

A6.1 Further Details

Smoothing. To get accurate predictions for expected claims along the entire distribution of risk, including the tails, we use cubic regression splines in the estimation of $\mathbb{E}\left(m_t \mid \Lambda_t^*(n)\right)$. Figure A3 provides a comparison of mean expenditure by $\Lambda_t^*(n)$ before and after smoothing for $n = 2$.



(a) Raw Averages **(b)** Smoothed Expenditure

Figure A3: Mean Expenditure by Λ_t^*.

Note: The left figure is based on average expenditure within each of 400 cells (ventiles in λ_t^* and λ_{t-1}^*). The right figure uses predicted values from a cubic spline regression. Source: German Claims Panel Data.

Stochastic Dominance. In their characterization of the optimal contract, Ghili et al. (2019) invoke an assumption of stochastic dominance. It requires that transition rates between risk categories—which are represented by the cumulative distribution function $F(\lambda_{t+1} \mid \lambda_t)$—satisfy first-order stochastic dominance in the following sense: if $\lambda'_t > \lambda_t$, then $F(\lambda_{t+1} \mid \lambda'_t) \succ_{FSD} F(\lambda_{t+1} \mid \lambda_t)$. Figure A4 shows that this property holds for all pairwise combinations of (λ_t, λ'_t) such that $\lambda'_t > \lambda_t$.

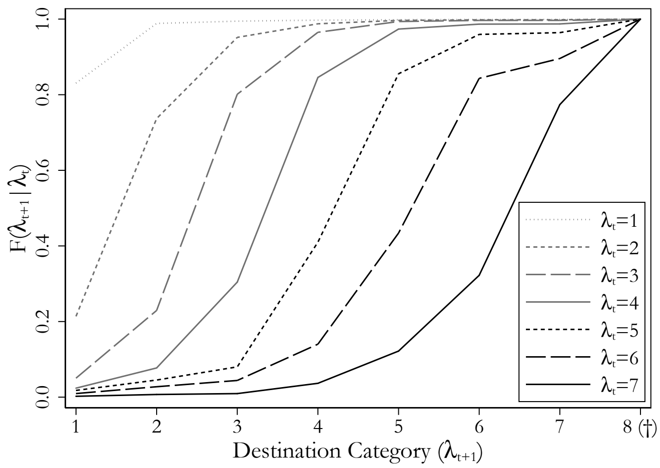


Figure A4: Stochastic Dominance.

Predicted Expenditures. Figure A5 shows the estimated mean expenditure by age for each risk category.

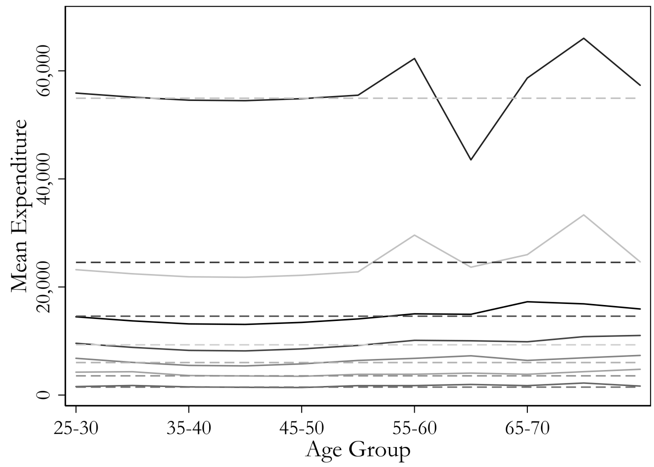


Figure A5: Predicted Health Expenditure

Note: Solid curves represent mean expenditure by age for each risk category λ_t, estimated according to Equation (7) in Section 5.2. The dashed lines represent the corresponding predictions assuming expenditure does not depend on age.

Transition Matrices. Table A3 and A4 show risk category transition matrices for those aged 25-54 and 55+, respectively.

Table A3: λ Risk Category Transitions by Age Group—Ages 25–54

		λ_{t+1}							
Age	λ_t	1	2	3	4	5	6	7	8 (†)
25-29	1	0.8907	0.1024	0.0047	0.0011	0.0004	0.0003	0.0001	0.0004
	2	0.3197	0.4257	0.2020	0.0432	0.0077	0.0011	0.0003	0.0003
	3	0.1242	0.2829	0.4104	0.1404	0.0378	0.0043	0.0000	0.0000
	4	0.0892	0.1688	0.2484	0.3917	0.0860	0.0159	0.0000	0.0000
	5	0.0938	0.1250	0.0625	0.3750	0.2917	0.0521	0.0000	0.0000
	6	0.0909	0.0000	0.0455	0.2273	0.3182	0.3182	0.0000	0.0000
	7	0.0000	0.0000	0.0002	0.0045	0.0240	0.1447	0.7619	0.0647
30-34	1	0.8767	0.1145	0.0055	0.0018	0.0009	0.0002	0.0001	0.0003
	2	0.3212	0.4347	0.1909	0.0438	0.0080	0.0006	0.0001	0.0007
	3	0.1241	0.3015	0.4080	0.1409	0.0229	0.0016	0.0000	0.0011
	4	0.1039	0.1640	0.2407	0.3739	0.1032	0.0115	0.0007	0.0021
	5	0.0734	0.0911	0.0506	0.2911	0.3747	0.1089	0.0025	0.0076
	6	0.0422	0.0438	0.0529	0.1678	0.3628	0.2450	0.0525	0.0329
	7	0.0128	0.0115	0.0083	0.0574	0.1545	0.1663	0.4524	0.1368
35-39	1	0.8427	0.1480	0.0055	0.0022	0.0009	0.0002	0.0001	0.0004
	2	0.2798	0.4635	0.2113	0.0360	0.0076	0.0013	0.0000	0.0005
	3	0.1177	0.2379	0.4850	0.1288	0.0275	0.0028	0.0001	0.0002
	4	0.0719	0.0967	0.3055	0.4085	0.0999	0.0158	0.0003	0.0014
	5	0.0743	0.0493	0.0691	0.3402	0.3629	0.0958	0.0039	0.0045
	6	0.0415	0.0331	0.0340	0.1180	0.2958	0.4009	0.0455	0.0312
	7	0.0127	0.0088	0.0054	0.0409	0.1276	0.2757	0.3975	0.1313
40-44	1	0.8514	0.1392	0.0050	0.0024	0.0010	0.0003	0.0001	0.0006
	2	0.2862	0.4666	0.2050	0.0329	0.0075	0.0014	0.0001	0.0003
	3	0.1137	0.2229	0.5134	0.1225	0.0241	0.0022	0.0001	0.0011
	4	0.0790	0.0769	0.2936	0.4213	0.1113	0.0157	0.0003	0.0018
	5	0.0640	0.0392	0.0759	0.3281	0.3763	0.1055	0.0038	0.0072
	6	0.0295	0.0382	0.0342	0.1605	0.2773	0.3613	0.0539	0.0450
	7	0.0081	0.0091	0.0049	0.0502	0.1079	0.2240	0.4247	0.1710
45-49	1	0.8148	0.1736	0.0059	0.0028	0.0012	0.0006	0.0002	0.0009
	2	0.2267	0.5059	0.2229	0.0329	0.0093	0.0013	0.0001	0.0010
	3	0.0653	0.2027	0.5708	0.1309	0.0258	0.0031	0.0001	0.0012
	4	0.0427	0.0712	0.2877	0.4655	0.1153	0.0140	0.0005	0.0029
	5	0.0303	0.0438	0.0475	0.3570	0.3964	0.1101	0.0058	0.0090
	6	0.0153	0.0266	0.0211	0.1118	0.2919	0.4163	0.0607	0.0563
	7	0.0038	0.0057	0.0027	0.0314	0.1021	0.2321	0.4298	0.1923
50-54	1	0.8117	0.1740	0.0056	0.0035	0.0020	0.0008	0.0004	0.0020
	2	0.2283	0.4979	0.2228	0.0377	0.0101	0.0016	0.0002	0.0015
	3	0.0602	0.1799	0.5727	0.1509	0.0317	0.0027	0.0001	0.0018
	4	0.0398	0.0648	0.2660	0.4930	0.1160	0.0155	0.0007	0.0041
	5	0.0274	0.0387	0.0426	0.3666	0.3866	0.1182	0.0075	0.0124
	6	0.0130	0.0222	0.0179	0.1084	0.2688	0.4220	0.0746	0.0732
	7	0.0028	0.0042	0.0020	0.0265	0.0819	0.2049	0.4600	0.2176

Source: German Claims Panel Data. Sample includes all years, 25-30 year old enrollees, and uses the ACG© score as λ.

Table A4: λ Risk Category Transitions by Age Group—Ages 55+

		λ_{t+1}							
Age	λ_t	1	2	3	4	5	6	7	8 (†)
55-59	1	0.7261	0.2537	0.0101	0.0037	0.0020	0.0013	0.0004	0.0027
	2	0.0932	0.6432	0.2123	0.0357	0.0110	0.0018	0.0004	0.0025
	3	0.0002	0.1739	0.6167	0.1690	0.0335	0.0044	0.0001	0.0024
	4	0.0001	0.0637	0.2426	0.5404	0.1287	0.0180	0.0007	0.0058
	5	0.0001	0.0356	0.0363	0.3758	0.4009	0.1282	0.0069	0.0163
	6	0.0000	0.0195	0.0145	0.1061	0.2662	0.4370	0.0650	0.0917
	7	0.0000	0.0037	0.0016	0.0260	0.0813	0.2126	0.4016	0.2732
60-64	1	0.7558	0.2147	0.0145	0.0044	0.0042	0.0019	0.0011	0.0033
	2	0.1023	0.6414	0.1981	0.0387	0.0120	0.0031	0.0004	0.0040
	3	0.0002	0.1612	0.6076	0.1836	0.0394	0.0053	0.0001	0.0028
	4	0.0001	0.0555	0.2243	0.5507	0.1419	0.0204	0.0008	0.0063
	5	0.0001	0.0292	0.0317	0.3610	0.4168	0.1370	0.0075	0.0168
	6	0.0000	0.0153	0.0122	0.0980	0.2660	0.4489	0.0686	0.0910
	7	0.0000	0.0028	0.0013	0.0235	0.0794	0.2136	0.4143	0.2651
65-69	1	0.3707	0.5949	0.0172	0.0076	0.0030	0.0015	0.0009	0.0042
	2	0.0624	0.6492	0.2407	0.0352	0.0065	0.0012	0.0004	0.0045
	3	0.0008	0.1058	0.6561	0.2082	0.0223	0.0013	0.0000	0.0056
	4	0.0002	0.0335	0.2013	0.6242	0.1261	0.0052	0.0005	0.0090
	5	0.0000	0.0128	0.0159	0.3546	0.4985	0.0763	0.0019	0.0400
	6	0.0000	0.0000	0.0107	0.0551	0.4067	0.3517	0.0195	0.1563
	7	0.0006	0.0066	0.0029	0.0264	0.0553	0.1690	0.5289	0.2103
70-74	1	0.3848	0.5793	0.0225	0.0060	0.0011	0.0003	0.0014	0.0048
	2	0.0070	0.6771	0.2554	0.0406	0.0105	0.0012	0.0000	0.0082
	3	0.0001	0.0810	0.6277	0.2599	0.0230	0.0014	0.0001	0.0068
	4	0.0002	0.0115	0.1625	0.6579	0.1404	0.0080	0.0002	0.0195
	5	0.0000	0.0015	0.0184	0.2829	0.5654	0.0736	0.0010	0.0572
	6	0.0000	0.0000	0.0000	0.0327	0.3039	0.4052	0.0065	0.2516
	7	0.0005	0.0056	0.0033	0.0184	0.0172	0.0263	0.7192	0.2094
75+	1	0.1770	0.5900	0.0442	0.0995	0.0598	0.0063	0.0083	0.0150
	2	0.0006	0.6237	0.2903	0.0471	0.0094	0.0012	0.0000	0.0277
	3	0.0000	0.0525	0.5876	0.2988	0.0254	0.0012	0.0000	0.0344
	4	0.0000	0.0029	0.1012	0.6668	0.1623	0.0055	0.0008	0.0605
	5	0.0000	0.0000	0.0060	0.2262	0.5581	0.0837	0.0028	0.1232
	6	0.0000	0.0000	0.0019	0.0206	0.3127	0.4064	0.0225	0.2360
	7	0.0000	0.0000	0.0000	0.0000	0.1111	0.1481	0.4630	0.2778

Source: German Claims Panel Data. Sample includes all years, 25-30 year old enrollees, and uses the ACG© score as λ.

A6.2 Robustness Checks

Winsorizing. First, we analyse the extent to which results are driven by outliers in m_{it}. It is of course desirable that outliers are considered in the classification, given their disproportionate contributions to means and variances; however, if the performance of the classification were widely different when they are not considered, it would cast doubt on how well the scheme performs with regard to less extreme risks. Therefore, we compared the performance of different classification schemes after the top percentile of expenditure had been been winsorized. Results are provided in Figure A6. As

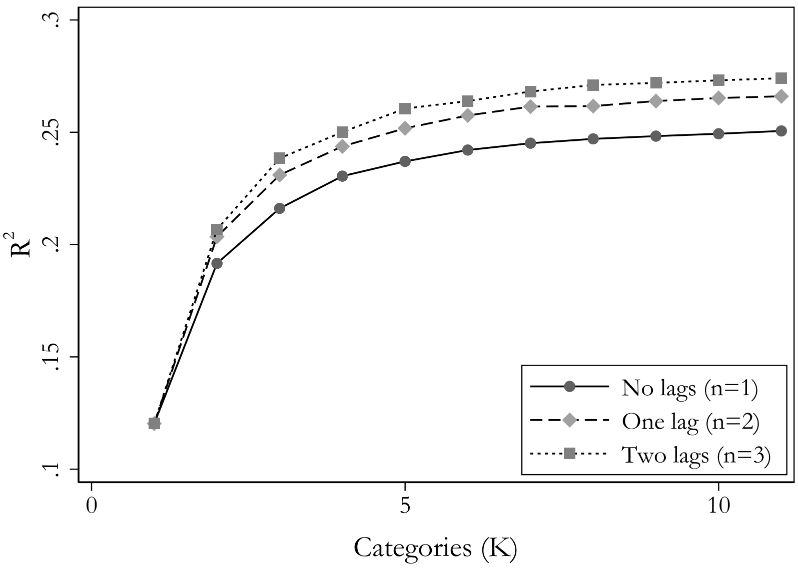


Figure A6: Performance of Alternative Risk Classifications: Winsorized Expenditure.

Note: Each specification includes 21 age times gender fixed effects, 5 year fixed effects and 79 plan fixed effects. Source: German Claims Panel Data.

expected, the topcoding of outliers improves the predictive power of all schemes; however, their relative performance is unaffected by this change.

Lags of classes. Second, we compare two different ways of including a longer history of claims. Instead of expanding on the information set Λ_t before discretizing, we consider an alternative based on $\Lambda_t^* = \lambda_t^*$ but where we consider the predictive power of the classification scheme interacted with its lags (i.e. a classification based on K^2 classes). Results are provided in Figure A7. It compares the two alternatives $q = 0$ and $q = 1$ from above, and in addition an interacted version, where the classification is based on $q = 0$ but this classification scheme is interacted with its lags in the regressions (leading effectively to K^2 classes). Clearly, this alternative has similar, actually even better, predictive power than $q = 1$. However, the variant with $q = 1$ thus achieves similar performance with a much smaller number of classes.

Sample selection. The results in Figure 3 are based on a sample of individuals who are observed over 4 years, since three lags are needed in Λ_{it}^*. In figure A8 we check how robust the finding is to varying the observation window required for sample selection. Sample 1 requires only that m_i and λ_t^* are observed, sample 2, also that λ_{t-1}^* is observed, and sample 3 in addition that λ_{t-2}^* is observed. The results provided in Figure A8 show that the predictive performance is sensitive to the sample used; however, the relative performance between schemes is the same regardless of the sample considered.

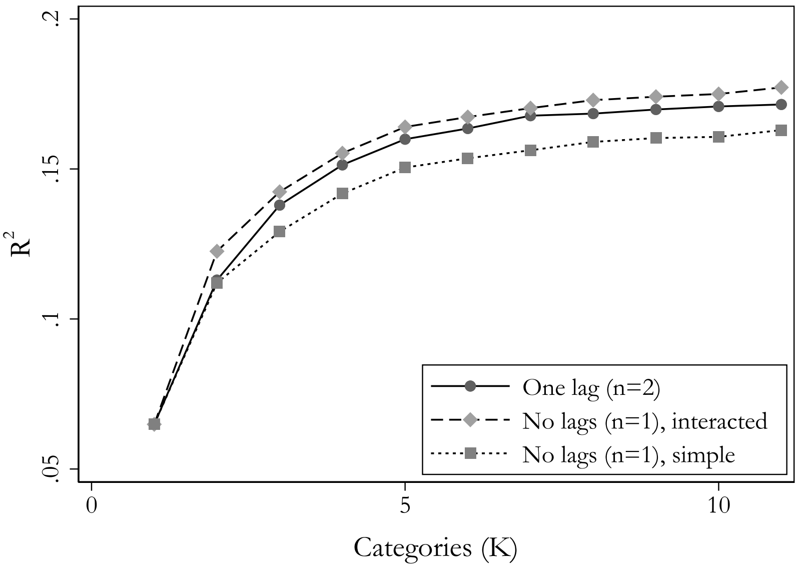


Figure A7: Performance of Alternative Risk Classifications: lags of classification.

Note: Each specification includes 21 age times gender fixed effects, year fixed effects and 79 plan fixed effects. Source: German Claims Panel Data.

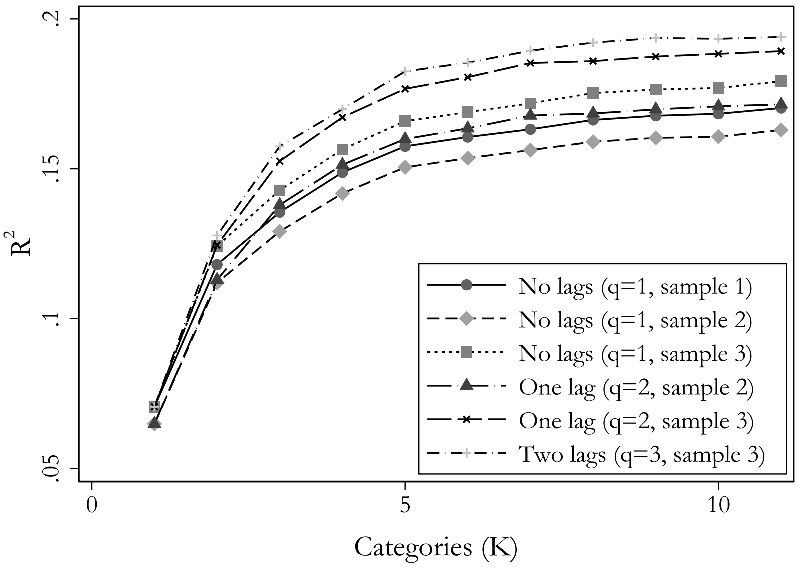


Figure A8: Performance of Alternative Risk Classifications: Different Samples.

Note: Each specification includes 21 age times gender fixed effects, year fixed effects and 79 plan fixed effects. Source: German Claims Panel Data.

Sample with low deductible. This robustness section focuses on plans with low deductibles. We consider a stricter sample selection rule, where we only include plans with deductibles below \$400.[70] These plans have approximately full coverage and thus more reliable information on the universe of health care expenditures. Summary statistics for this subsample are provided in Table A5. A comparison with the numbers in Table A1 makes clear that the two samples are very similar in terms of age, gender and history with the company. On the other hand, the restricted sample has a greater share of employees and civil servants, but a smaller share of self-employed. The plan characteristics are also similar to a great extent—with the obvious exceptions of deductible size and average claims.

Table A5: Summary Statistics: Low-Deductible Plans

	Mean	SD	Min	Max	N
Socio-Demographics					
Age (in years)	44.8	11.8	25.0	99.0	879,468
Female	0.256	0.437	0.0	1.0	879,468
Policyholder since (years)	7.7	5.3	1.0	40.0	879,468
Client since (years)	13.9	11.7	1.0	84.0	879,468
Employee	0.414	0.493	0.0	1.0	879,468
Self-Employed	0.281	0.449	0.0	1.0	879,468
Civil Servant	0.280	0.449	0.0	1.0	879,468
Health Risk Penalty	0.338	0.473	0.0	1.0	879,468
Pre-Existing Condition Exempt	0.015	0.121	0.0	1.0	879,468
Health Plan Parameters					
TOP Plan	0.342	0.475	0.0	1.0	879,468
PLUS Plan	0.397	0.489	0.0	1.0	879,468
ECO Plan	0.261	0.439	0.0	1.0	879,468
Annual premium (USD)	5,208	2,005	0	33,037	879,374
Annual risk penalty (USD)	133	347	0	21,214	879,468
Deductible(USD)	154	164	0	395	879,468
Total Claims (USD)	3,868	9,064	0	2,345,126	879,468

Source: German Claims Panel Data. *Policyholder since* is the number of years since the client has enrolled in the current plan; *Client since* is the number of years since the client joined the company. *Employee* and *Self-Employed* are dummies for the policyholders' current occupation. *Health Risk Penalty* is a dummy that is one if the initial underwriting led to a health-related risk add-on premium on top of the factors age, gender, and plan; *Pre-Existing Conditions Exempt* is a dummy which equals one if the initial underwriting led to a coverage exclusion of services for some conditions. The mutually exclusive dummies *TOP Plan*, *PLUS Plan* and *ECO Plan* capture the generosity of the plan. *Annual premium* is the annual premium, and *Annual Risk Penalty* is the amount of the health risk penalty charged. *Deductible* is the deductible and *Total Claims* the sum all claims in a calendar year. See Section 4.1 for further details.

Figure A9 compares the distributions of λ^* in the two samples. As expected, the zero-deductible

[70] This is the lowest cutoff for the deductible which gives us a sufficient number of observations to analyze health risk transitions within each age group.

plans have higher ACG© scores in general.

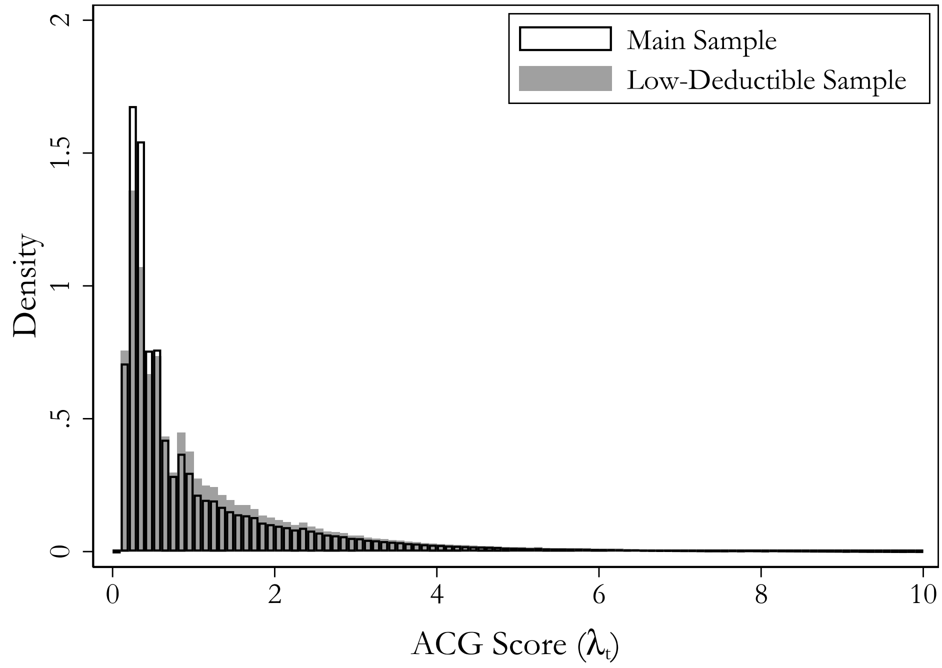


Figure A9: Distribution of λ^* for Main Sample vs. Low-Deductible Plans.

Table A6 shows how clients distribute over different risk categories by age in the low-deductible sample. A comparison with Table 2 confirms that the individuals in the low-deductible sample are in slightly worse health.

Table A6: Health Risk Categories λ by Age Group: Low-Deductible Sample

Age	1 (Healthiest)	2	3	4	5	6	7 (Sickest)
25-30	0.739	0.190	0.049	0.016	0.006	0.001	0.000
30-35	0.672	0.225	0.069	0.025	0.007	0.002	0.000
35-40	0.559	0.282	0.112	0.034	0.011	0.003	0.000
40-45	0.507	0.291	0.141	0.043	0.015	0.003	0.000
45-50	0.406	0.317	0.190	0.060	0.021	0.005	0.001
50-55	0.316	0.311	0.244	0.090	0.030	0.008	0.001
55-60	0.172	0.309	0.320	0.139	0.045	0.013	0.002
60-65	0.093	0.263	0.361	0.190	0.069	0.022	0.003
65-70	0.038	0.200	0.423	0.252	0.072	0.014	0.002
70-75	0.011	0.131	0.403	0.333	0.107	0.015	0.001
75+	0.000	0.055	0.286	0.453	0.179	0.024	0.003

Source: German Claims Panel Data. Sample includes all age groups and uses the ACG© score for the classification.

Table A7 shows the transition probabilities between different health states in the low-deductible sample. The probabilities are very similar to those reported in Table 1.

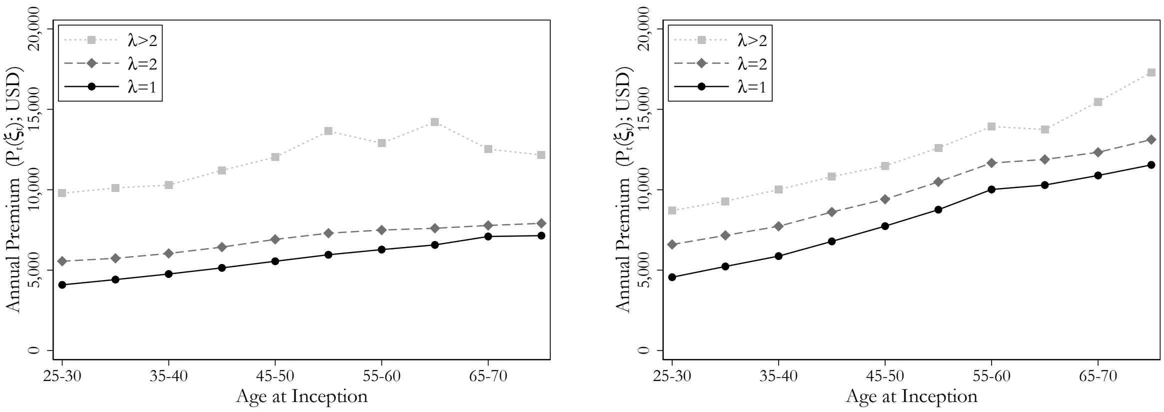
Table A7: Health Risk Category Transitions: Low-Deductible Sample

	λ_{t+1}							
λ_t	1	2	3	4	5	6	7	8 (†)
1	0.802	0.187	0.006	0.002	0.001	0.000	0.000	0.001
2	0.192	0.533	0.232	0.032	0.008	0.001	0.000	0.001
3	0.040	0.168	0.600	0.159	0.026	0.003	0.000	0.003
4	0.017	0.041	0.237	0.553	0.126	0.012	0.000	0.013
5	0.015	0.019	0.034	0.339	0.452	0.102	0.004	0.035
6	0.008	0.013	0.017	0.102	0.313	0.402	0.051	0.094
7	0.000	0.000	0.003	0.027	0.115	0.231	0.426	0.198

Source: German Claims Panel Data. Sample includes all years, all age groups, and uses the ACG© score for the classification.

A7 Observed vs. Calibrated GLTHI Premium Profiles

Figure A10 compares the (a) calibrated and (b) observed premium profiles for individuals entering their plan at different ages. In both figures, the highest category ($\lambda_t > 2$) is a weighted average calculated according to the actual distribution of λ_t in the different age groups.



(a) Calibrated

(b) Observed

Figure A10: Calibrated vs. Actual Starting Premiums $P_t(\xi_t)$ by Age at Inception

Source: German Claims Panel Data. In Figure A10 (b), the sample includes all years and all health plans, and clients who have been in their contract for 2 to 5 years. We adjusted premiums for the three benefit categories *TOP, PLUS, ECO* and deductible size.

A8 Quantifying Arrow Securities for the Optimal Contract

As discussed in Section 3.2 optimal dynamic long term contracts with one sided commitment can also be implemented by letting the individuals trade state-contingent one-period Arrow securities. Here we provide numerical examples for the optimal contract, equivalent to the the numerical examples provided in Section 6.3 for the GLTHI contract.

Using the results in A4.1, the vector $b_1^{GHHW}(1)$ shows the quantities of securities purchased for the period-2 contingencies given the individual starts in period 1 that replicate the optimal contract.

$$b_1^{GHHW}(1) = 1000 \times \begin{bmatrix} 0.00 & 3.36 & 8.88 & 15.68 & 25.55 & 44.70 & 181.93 \end{bmatrix}$$

The vector $b_2^{GHHW}([1,1])$ shows the quantities of securities that an individual who starts in period 1 in health state $\xi_1 = 1$, and transitions to state $\xi_2 = 1$ buys for the contingency of transitioning to state $\xi_3 = k$ in period 3.

$$b_2^{GHHW}([1,1]) = 1000 \times \begin{bmatrix} 0.00 & 3.36 & 8.92 & 15.79 & 25.76 & 45.13 & 172.15 \end{bmatrix}$$

A9 Welfare Concepts

We use the concept of lifetime utility U to quantify welfare following, e.g., Ghili et al. (2019):

$$U = \mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0} u(c_t)\right)$$

where S_t is an indicator of survival until period t, and c_t is the consumption in period t that is specified by the contract. It may depend on the history of health and income realizations up to t. Expectation is taken over the individual's lifetime health history $(\xi_1, \xi_2, ..., \xi_t)$ and survival.

Certainty Income Equivalent. With a parametric assumption for flow utility $u(.)$, and knowing income y_t, we can summarize welfare with the "*certainty income equivalent*", denoted CE, such that:

$$u(CE) = \frac{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0} u\left(c_t\right)\right)}{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0}\right)} \tag{15}$$

This simple expression captures the main trade-offs in health insurance design for lifetime welfare. Lifetime utility is higher when consumption is smoothed across health states and across periods.

First-Best. In particular, the *first-best* consumption level equals the annualized present discounted value of "net income" $y_t - \mathbb{E}(m_t)$, taking into account mortality risk.[71] This constant optimal consumption level C^* is given by:

$$C^* = \frac{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0} (y_t - \mathbb{E}(m_t))\right)}{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0}\right)} \tag{16}$$

Short-Term Contracts. Under a series of actuarially fair *short-term* contracts, the premium in period t with health status ξ_t will simply be $\mathbb{E}(m_t)$. Thus consumption will be $c_t = y_t - \mathbb{E}(m_t|\xi_t)$, and the certainty equivalent CE becomes:

$$u(CE_{ST}) = \frac{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0} u(y_t - \mathbb{E}(m_t|\xi_t))\right)}{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0}\right)} \tag{17}$$

[71] We assume that there is no annuity market, so mortality risk is still considered.

A10 Allowing for Savings

Individuals solve the following maximization problem:

$$\begin{aligned}
\max_{c_t} \quad & \mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^t u(c_t)\right) \\
\text{s.t.} \quad & a_{t_0} = 0 \\
& a_t \geq 0 \;\; \forall t \\
& a_{t+1} = (1+r)a_t + y_t - c_t - \tilde{P}_t(\Xi_t)
\end{aligned}$$

where $\tilde{P}_t(\Xi_t)$ is the premium in period t as a function of an individual's medical history $\boldsymbol{\Xi_t} \equiv (\xi_1, \xi_2, ..., \xi_t)$, and a_t is the level of assets.

Different contracts result in different mappings between an individual's medical history up to period t and an individual's premium in t. Under a series of short-term contracts, only an individual's current health status matters since $\tilde{P}_t(\Xi_t) = \mathbb{E}(m_t|\Xi_t) = \mathbb{E}(m_t|\xi_t)$. In contrast, for a GLTHI contract, the entire medical history matters. Due to guaranteed-renewability, $\tilde{P}_t(\Xi_t)$ is defined recursively: In the first period, $\boldsymbol{\Xi_1} = \xi_1$ and $\tilde{P}_1(\boldsymbol{\Xi_1}) = P_1(\xi_1)$, where Equation (1) defines $P_t(\xi_t)$. In any period $t > 1$, $\tilde{P}_t(\boldsymbol{\Xi_t}) = \min\{\tilde{P}_t(\boldsymbol{\Xi_{t-1}}), P_t(\xi_t)\}$.[72] (Note that, in this optimal consumption problem with savings, there is uncertainty regarding net income $y_t - \tilde{P}_t(\Xi_t)$ and mortality risk.[73]) For a given lifecycle income profile, the dynamic program provides an optimal consumption policy $C_t^*(\xi_t, a_t)$ where a_t is the level of assets carried into period t. The certainty equivalent (CE) of the dynamic problem is equal to:

$$u(C_{SAV}) = \frac{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0} u(C_t^*(\xi_t, a_t))\right)}{\mathbb{E}\left(\sum_{t=t_0}^{T} S_t \delta^{t-t_0}\right)} \tag{18}$$

[72] The state variable in the dynamic program under GLTHI is the guaranteed-renewable premium; its law of motion is given by the probability of qualifying for a lower premium.

[73] Mortality risk implies that individuals may die with positive assets. Therefore, the expected net present value of consumption with optimal savings will be lower than the net present value of resources. Our calculations implicitly assume that individuals do not derive value from bequests.

A11 Certainty Equivalent with CARA-EZ preferences

We provide the derivation for the formula of the certainty consumption equivalent for Epstein-Zin preferences, provided in Equation (10). Preferences are defined recursively as

$$V_t = F(c_t, R_t(V_{t+1})),$$

with $R_t(V_{t+1}) = G^{-1}(\mathbb{E}_t G(V_{t+1}))$. As mentioned in the main text, we use the CES aggregator for $F(c,z) = \left((1-\delta)c^{1-1/\psi} + \delta z^{1-1/\psi}\right)^{\frac{1}{1-1/\psi}}$, and incorporate the CARA utility function as $G(c) = u(c) = \frac{1}{\gamma}e^{-\gamma c}$.

Throughout we have assumed that utility is zero if the individual is dead. We can re-interpret V_t as the value of being alive in period t. Under that interpretation, one can write preferences recursively as:

$$V_t = \left((1-\delta)\, c_t^{1-1/\psi} + s_t \delta R_t\left(V_{t+1}\right)^{1-1/\psi}\right)^{\frac{1}{1-1/\psi}} \tag{19}$$

where s_t is the probability of survival between t and $t+1$.

We now derive an expression for the certainty equivalent consumption c for any given value V_t under recursive preferences. Consider the situation in which consumption (while alive) is constant and equal to c. This means that $R_t\left(V_{t+1}\right) = V_{t+1}$, and therefore we can re-write

$$V_t = \left((1-\delta)\, c^{1-1/\psi} + s_t \delta \left(V_{t+1}\right)^{1-1/\psi}\right)^{\frac{1}{1-1/\psi}} \tag{20}$$

Replacing the V_{t+1} in Equation (20) as a function of V_{t+2} yields

$$\begin{aligned} V_t &= \left((1-\delta)\, c^{1-1/\psi} + s_t \delta \left((1-\delta)\, c^{1-1/\psi} + \delta s_{t+1} \left(V_{t+2}\right)^{1-1/\psi}\right)\right)^{\frac{1}{1-1/\psi}} \\ &= \left((1-\delta)\, c^{1-1/\psi} + s_t \delta (1-\delta)\, c^{1-1/\psi} + s_t s_{t+1} \delta^2 V_{t+1}^{1-1/\psi}\right)^{\frac{1}{1-1/\psi}} \end{aligned}$$

Iterating forward we can show that

$$\frac{V_t^{1-1/\psi}}{1-\delta} = \sum_{j=t}^{T} c^{1-1/\psi} \delta^{j-t} S_t^j$$

where $S_t^j \equiv \Pi_{k=t}^j s_k$ is the survival probability from t to j. Solving for c, we get an expression defining the certainty equivalent:

$$c = \left(\frac{\frac{V_t^{1-1/\psi}}{1-\delta}}{\sum_{j=t}^{T} \delta^{j-t} S_t^j} \right)^{\frac{1}{1-1/\psi}} \tag{21}$$

Equation (21) provides the certainty equivalent consumption to a program that provides value V_t.

We are interested in the certainty equivalent taking into account the uncertainty regarding the "birth state" ξ_{t_0}. Denote the value of this lottery V_b. It can be expressed as a function of V_{t_0} (the value at age 25):

$$V_b = G^{-1}(\mathbb{E}_0(G(V_{t_0}(\xi_{t_0})))) \tag{22}$$

where $\mathbb{E}_0()$ takes expectations with respect to the uncertain "birth" state, ξ_{t_0}.

For each contract, we can compute the value $V_{t_0}(\xi_{t_0})$, for each state ξ_{t_0}, *via* backwards induction. Plugging Equation (22) into Equation (21), applied to the initial period t_0 we get the expression in the text.

A12 Including the GKV Population

As mentioned in Appendix A, there is selection into GLTHI contracts for a number of reasons, some imposed by law and some resulting from private incentives of clients and insurance providers. For this reason, it is of great interest to understand if and how our welfare results change when we consider the GKV population. We start by characterizing and contrasting the two populations, where we draw on two distinct datasets: the representative SOEP panel and a GKV claims dataset. The latter includes a random 5% sample from 2010-11 from one of the largest GKV insurers, 5.6 million enrollees.

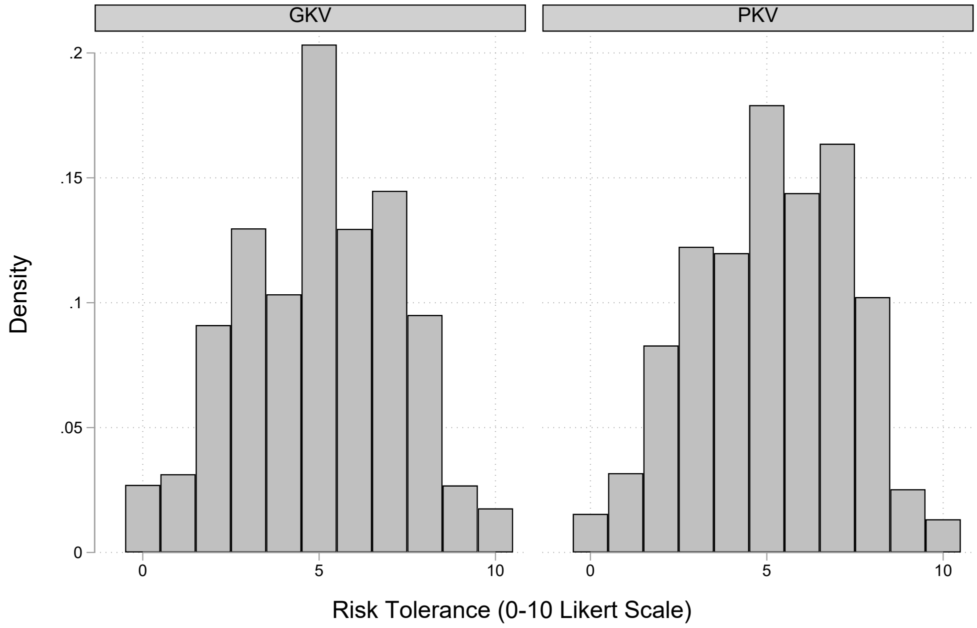
Table A8 provides descriptive statistics from the SOEP, focusing on the 25-35 year-olds. It confirms that the PKV population is positively selected in terms of health and various socioeconomic outcomes. Figure A11 plots the distribution of risk tolerance in the two groups. Even if the risk tolerance is higher among the privately insured on average (5.4 versus 5.0) there is a great deal of overlap of the two distributions, for younger individual as well as for the entire population.

Table A9 compares summary statistics from our PKV claims data to GKV claims data. The GKV sample is seven years older than the PKV sample. The ACG score is also larger on average. When we consider the subsample of 25-35-year-olds in the two rightmost columns, the difference in ACG scores shrinks, but remains larger for the GKV sample. Figure A12 shows the distribution of 2011 ACG scores in the GKV and PKV samples; the left panel plots the raw data for both; the right panel re-weights the GKV observations in order to achieve the same distribution of age by gender as in the PKV dataset.

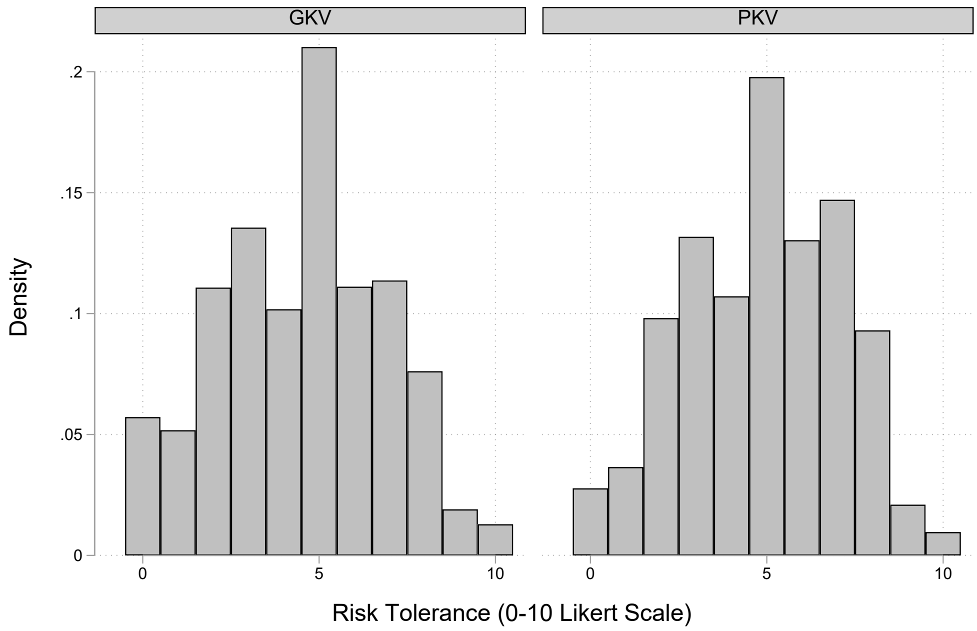
Table A8: Socio-Demographics of GKV versus PKV Population

	GKV	**PKV**		**PKV**		
			civil servants	white collar	self-employed	non-working
Age	30.110	30.802	30.464	31.540	31.608	29.615
Female	0.467	0.414	0.570	0.195	0.216	0.600
Full-time	0.625	0.817	0.908	0.891	0.931	0.000
Part-time	0.166	0.087	0.092	0.109	0.069	0.000
Dropout	0.017	0.011	0.019	0.000	0.010	0.000
High school	0.315	0.643	0.705	0.723	0.410	0.709
Monthly gross wage	2,611	3,773	3,104	5,285	3,884	2,820
Monthly net wage	1,671	2,581	2,396	3,196	2,466	2,595
Annual household income	24,575	34,858	30,620	46,927	35,540	28,729
Risk tolerance (0-10)	5.040	5.355	4.808	5.885	6.301	4.620
Smoker	0.395	0.292	0.300	0.222	0.385	0.162
BMI	25.032	23.995	23.581	24.536	24.453	23.350
Physical issues, accomplishes less 0.064	0.036	0.036	0.019	0.016	0.090	
Physical limitations	0.053	0.031	0.021	0.012	0.025	0.117
Emotional issues, accomplishes less	0.053	0.030	0.022	0.017	0.012	0.153
Emotional limitations	0.033	0.015	0.012	0.001	0.004	0.085
Hospital stay last year	0.097	0.078	0.073	0.050	0.050	0.235
Hospital nights last year	0.804	0.445	0.374	0.302	0.178	1.613
Doctor visits last quarter	1.780	1.775	2.036	1.247	1.399	2.588
N	23,250	2282	997	465	503	262

Source: SOEP (2018), V33. Just 25 to 35 year olds from 2004 to 2016 (except 2005 and 2007). SOEP-provided Weights are applied. The number of observations is small for the health behavior, health, and health care utilization measures as they were not surveyed in all years. All income measures have been consistently generated and cleaned by the SOEP team; e.g., *Monthly gross wage* is labeled *labgro* and *Monthly net wage* is labeled *labnet* in SOEP (2018). All income measures in $2016. When applying t-tests, all means for GKV and PKV are statistically different from one another at conventional levels. See Section 4.2 for a detailed discussion of the dataset.



(a) *25-35 Year Olds*



(b) *All adults*

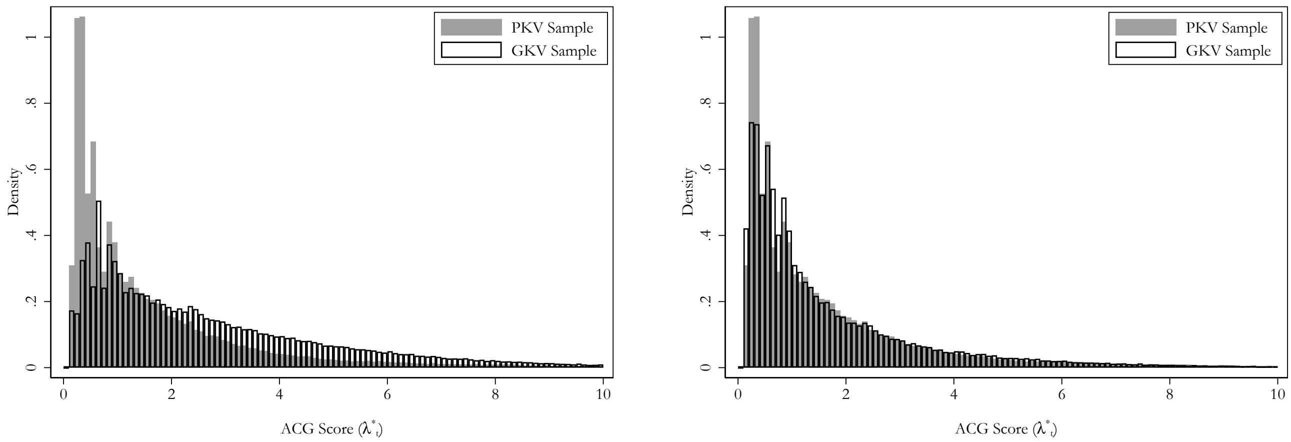
Figure A11: Risk Tolerance: GKV versus PKV population

Source: SOEP (2018), V33.

Table A9: Summary Statistics: PKV versus GKV Claims Data, 2011

	ALL AGED 25+		AGE 25 − 35	
	GKV	**PKV**	**GKV**	**PKV**
Age (in years)	56.3	48.9	29.9	32.2
Female	0.648	0.290	0.558	0.246
ACG Score	2.886	1.745	1.233	0.928
N	226,054	96,511	28,795	9,857

Source: German Claims Panel Data. GKV statistics are based on a 5% random sample of a population of 5.6 million enrollees.



(a) *Unweighted* (b) *Weighted*

Figure A12: Distribution of 2011 ACG Scores: GKV versus PKV population

Note: The figures show histograms of 2011 ACG scores for the GKV and the PKV sample. Panel (a) plots the raw data and panel (b) re-weights the GKV data to get identical distributions of age and gender. Both samples are truncated at an ACG score of 10.

Table A10: Health Risk Categories λ by Age Group: GKV Sample, 2011

Age	1 (Healthiest)	2	3	4	5	6	7 (Sickest)
25-30	0.474	0.316	0.143	0.052	0.012	0.002	0.001
30-35	0.423	0.325	0.161	0.069	0.018	0.004	0.001
35-40	0.296	0.364	0.216	0.088	0.028	0.007	0.001
40-45	0.262	0.366	0.230	0.099	0.033	0.009	0.002
45-50	0.153	0.366	0.290	0.130	0.046	0.013	0.002
50-55	0.127	0.311	0.309	0.165	0.067	0.018	0.003
55-60	0.038	0.254	0.350	0.228	0.097	0.029	0.005
60-65	0.024	0.204	0.333	0.265	0.127	0.042	0.006
65-70	0.025	0.115	0.357	0.330	0.147	0.022	0.003
70-75	0.005	0.069	0.306	0.377	0.205	0.035	0.003
75+	0.000	0.025	0.172	0.407	0.322	0.068	0.005

Source: GKV Claims Panel Data. Sample includes all age groups and uses the ACG scores to construct risk categories λ as explained in Section 5.1. The corresponding data for the PKV sample is provided in Table 2.

Table A11 compares our baseline welfare results (Panel (h)) to those of a GKV-only population based on their distribution over starting states (Panel (i)) and to a population approximating the real-world mix of 90% GKV and 10% PKV enrollees (Panel(j)).

Table A11: Benchmarking Welfare under GLTHI; GKV and GVK + PKV population

	C^* (1)	C_{ST} (2)	C_{GLTHI} (3)	C_{GHHW} (4)	$\frac{C_{GLTHI}-C_{ST}}{C^*-C_{ST}}$ (5)	$\frac{C_{GHHW}-C_{GLTHI}}{C_{GHHW}}$ (6)
	Panel (h): $\Delta_0 = \frac{1}{100}[89.10, 10.25, 0.47, 0.11, 0.04, 0.03, 0]$					
Ed 10	22,980	-10,119	21,168	21,945	0.945	0.035
Ed 13	34,159	-2,223	25,088	26,093	0.751	0.039
	Panel (i): $\Delta_0 = \frac{1}{100}[47.47, 31.58, 14.33, 5.16, 1.21, 0.24, 0]$					
Ed 10	22,669	-10,522	18,904	19,160	0.886	0.013
Ed 13	33,877	-3,066	21,357	21,538	0.661	0.008
	Panel (j): $\Delta_0 = \frac{1}{100}[51.63, 29.45, 12.95, 4.65, 1.10, 0.22, 0]$					
Ed 10	22,729	-10,494	19,133	19,417	0.892	0.015
Ed 13	33,907	-3,127	21,656	21,861	0.669	0.009

Source: German Claims Panel Data, SOEP data. Table shows welfare measured by the consumption certainty equivalents in 2016 USD dollars, per capita, per year, separately for two income profiles (see Figure 4). Panel (h) reiterates the results for the PKV population from Table 4, Panel (i) uses the estimated initial probabilities at 25 for the GKV population, and Panel (j) uses a mixture including 90% of individuals in GKV and 10% of individuals in PKV. Columns (1) to (4) show welfare according to the (1) first-best (C^*), (2) a series of short-term contracts (C_{ST}), (3) the GLTHI, and (4) the optimal contract (C_{GHHW}). Column (5) shows how much of the welfare gap between (2) and (1) is closed by GLTHI. Column (6) shows the percentage of welfare loss under GLTHI relative to the optimal contract.

A13 Welfare Results for Different Distribution of Starting States

In this section, we asses the robustness of results in Table 4 to varying assumptions regarding the distribution of starting states. We also provide an assessment of how welfare gains associated with GLTHI change when we benchmark them against short-term contracts, instead of the benchmark against a certainty equivalent of 0 that we use in the main analysis.

Simulation. For this test, we sampled 20 million probability simplices $\tilde{\Delta}_r \in \Delta^7$ from a Dirichlet distribution with concentration parameters equal to the baseline probabilities coming out of the risk classification procedure (including the most severe state 7). The resulting distribution contains probability simplices with average health and expected costs quite different from the one that we consider in out baseline scenario in Table 4.

For each draw $\tilde{\Delta}_r$ (with $r \in [1, \ldots, 20M]$), we calculate certainty equivalents for the various contracts. The CE of each such lottery may be calculated in the following steps:

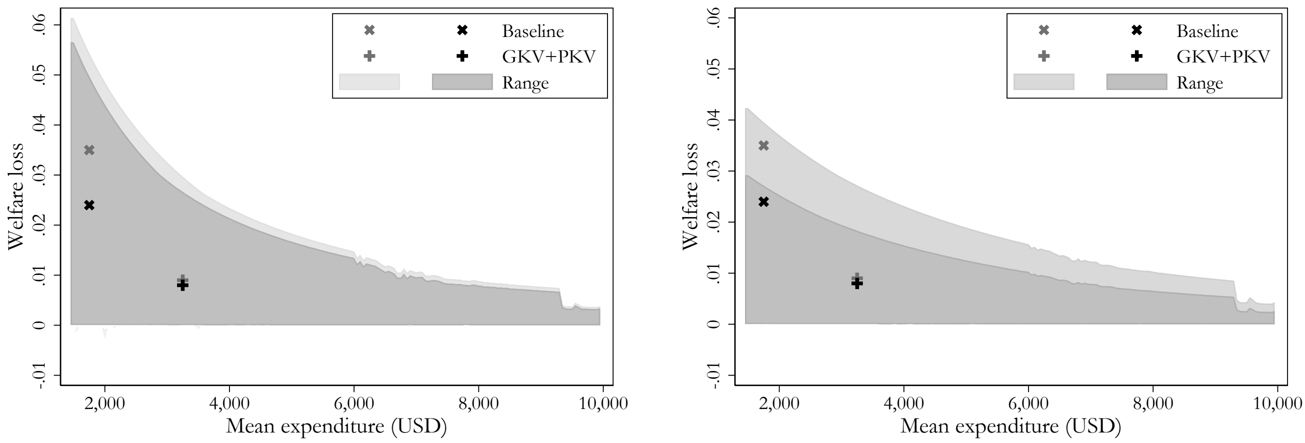
1. Construct $CE(\Delta_1), \ldots, CE(\Delta_7)$ for the 7 degenerate simplices Δ_k with a 1 in k and 0 otherwise (i.e. corresponding to being born for sure in state k).
2. Compute $V_k = U(CE(\Delta_k))$ representing the utility of being born in each state k. Stacking all states k gives a vector of V's that we call $\mathbf{V}$.
3. We compute $EU_r = \tilde{\Delta}_r \times \mathbf{V}$ as the expected utility associated with lottery $\tilde{\Delta}_r$.
4. Finally, $CE\left(\tilde{\Delta}_r\right) = U^{-1}(EU_r)$ is the certainty equivalent of the lottery.

Alternative Welfare Measure. Besides, we calculate two different welfare measures associated with each draw:

(a) **Benchmark at 0**: $\frac{C_{GHHW} - C_{GLTHI}}{C_{GHHW}}$ – i.e. the criterion used in Table 4 and elsewhere.

(b) **ST as benchmark**: $\frac{C_{GHHW} - C_{GLTHI}}{C_{GHHW} - C_{ST}}$ – this alternative measure represents how much of the welfare gap between GHHW and ST that is closed by GLTHI.

Results. In Figure A13, we plot the resulting welfare results in relation to the average expenditure associated with each draw. The point "Baseline" corresponds to our baseline estimate in Table 4 and the point "GKV+PKV" corresponds to results for a mixture including 90% of individuals in GKV and 10% of individuals in PKV (cf. Table A11). In addition, the figure shows, for each level of expected expenditure, the entire range of welfare losses according to our simulation exercise. Results according to our main welfare criterion ($\frac{C_{GHHW}-C_{GLTHI}}{C_{GHHW}}$) are displayed with lighter markers and lighter-gray areas; whereas results according to the alternative welfare criterion ($\frac{C_{GHHW}-C_{GLTHI}}{C_{GHHW}-C_{ST}}$) are displayed with darker markers and areas.



(a) *Ed 13* (b) *Ed 10*

Figure A13: Sensitivity Analysis: Distribution of Starting States.

Note: The figures show maxima and minima of GLHTI welfare losses within increments of \$50 of expected expenditure. The underlying distribution is based on 20 million draws from a Dirichlet distribution. For Ed 13, 13 draws were discarded due to GHHW having a CE in a neighborhood of zero; for Ed 10, 15 draws were discarded for the same reason. Results according to our main welfare criterion ($\frac{C_{GHHW}-C_{GLTHI}}{C_{GHHW}}$) are displayed with lighter markers and lighter-gray areas; whereas results according to the alternative welfare criterion ($\frac{C_{GHHW}-C_{GLTHI}}{C_{GHHW}-C_{ST}}$) are displayed with darker markers and areas.

According to Figure A13, the welfare loss is bounded above at about 6% (4% for the less-educated group). The maximum welfare loss is decreasing in expected expenditure, and the relatively healthy population we consider is in fact quite close to the maximum. Moreover, Figure A13 shows that our main welfare criterion tends to *exaggerate* the welfare loss associated with GLTHI; when we use the welfare from ST as an alternative benchmark for welfare, we find that the welfare loss associated with GLTHI is smaller, in particular for the less-educated group.

A14 US lifecycle income profiles

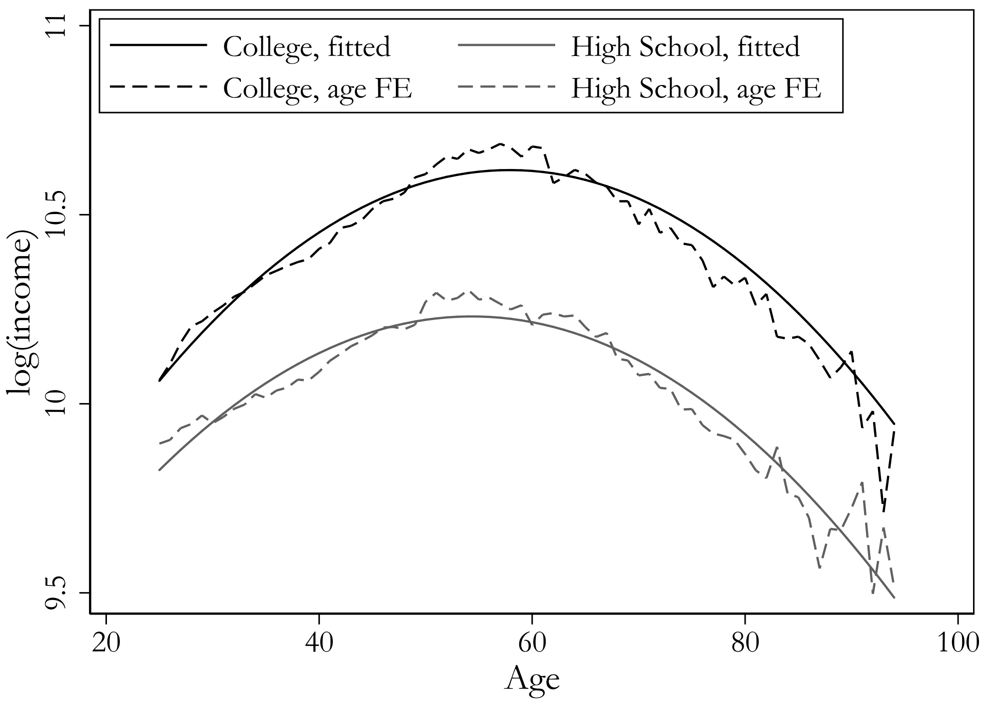


Figure A14: Lifecycle Income Paths for the United States, Nonparametric and Fitted.

Source: Panel Study of Income Dynamics (2018); Frick et al. (2007), years 1984 to 2015. All values in 2016 USD.

A15 Trading Off the Medicare Payroll Tax and Medicare Premiums

In this section, we evaluate the welfare consequence of changing the timing of payments into Medicare. Our baseline scenario assumes that Medicare coverage is completely free without any premium. However, the actual Medicare program in the US entails a premium (Part B) and cost-sharing provisions (Part A and B). In the context of our lifecycle model, premiums and cost-sharing provisions back-load Medicare expenses by reducing the Medicare tax rate required to fund Medicare.

As a first approach, we maintain the assumption of no cost-sharing, but vary the level of premiums charged during retirement. Specifically, we assume a Medicare premium p has to be paid, starting at age 65. The associated Medicare tax rate $\tau(p)$ is such that the revenue neutrality condition holds

$$\tau(p)\,\mathbb{E}\left(\sum_{25}^{64} S_t \delta^{t-24} y_t\right) = \mathbb{E}\left(\sum_{65}^{94} S_t \delta^{t-24}(m_t - p)\right)$$

It is clear from this equation that a higher premium at old age is compensated by a lower tax rate at younger ages. Figure A15 shows this trade-off, where the y-axis depicts the tax rate that is needed for each premium level depicted on the x-axis.

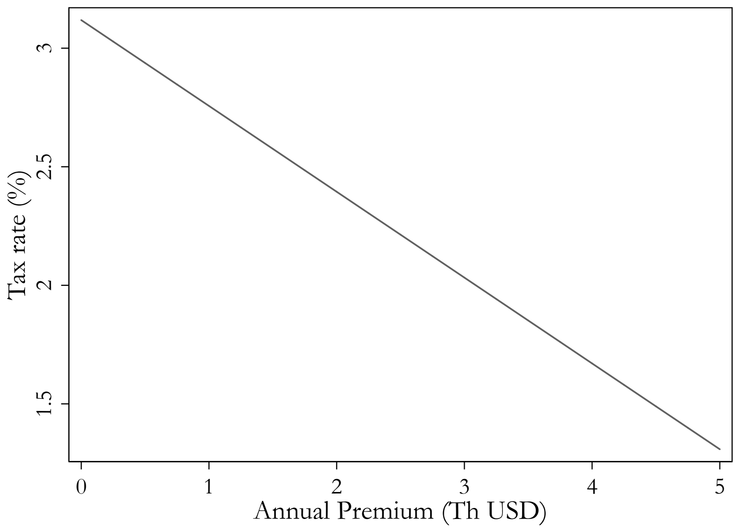


Figure A15: Tax Rate and Medicare Premium

Figure A16 shows welfare for the combined GLTHI + Medicare case, and when charging a Medicare premium in addition to the Medicare tax. The x-axis shows different premium levels, and the y axis shows the welfare consequences.

Three findings emerge from Figure A16: (1) a higher Medicare premium (and thus lower tax rate) is desirable from a welfare perspective, and (2) at any premium level, GHHW does better than

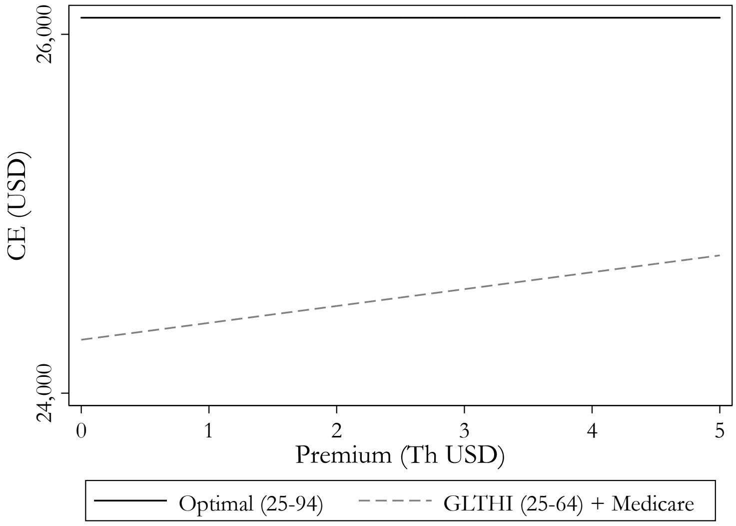


Figure A16: Welfare of GHHW and Medicare with different Premiums

GLTHI.

To understand the intuition behind the welfare result in Figure A16, Figure A17 shows the expected lifecycle consumption profiles under (a) GHHW over the entire lifecycle, (b) GLTHI + Medicare with a zero premium and the corresponding tax rate in Figure A15, (c) GLTHI + Medicare with a premium of $5K and the corresponding tax rate in Figure A15.

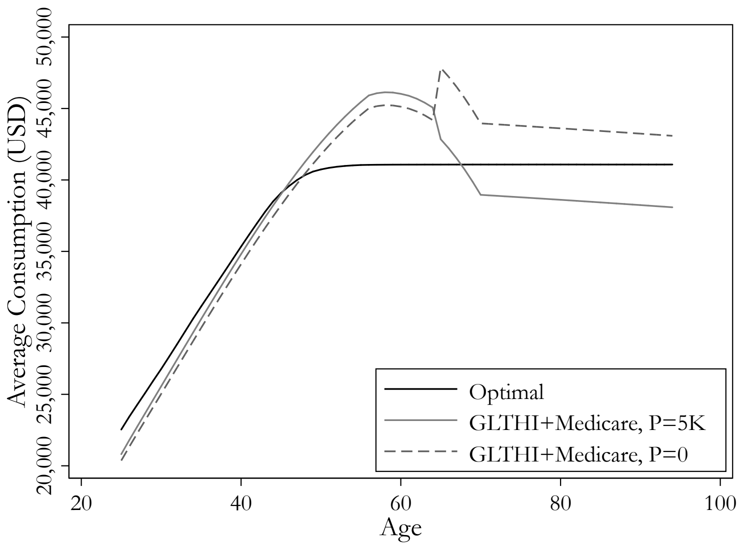


Figure A17: Expected Consumption Profile; Hybrid System

Figure A17 illustrates that a higher Medicare premium increases consumption in early ages (because it decreases the tax rate). Under the GLTHI + free Medicare scenario, one observes a sharp increase in consumption at retirement, because individuals stop paying GLTHI premiums and stop paying Medicare taxes. Under the GLTHI + Medicare with a \$5K premium scenario, one observes a reduction in consumption at retirement because the Medicare premiums exceeds the GLTHI premium. Figure A17 also illustrates than even a very large Medicare premium (and almost zero Medicare tax) does not outperform GHHW because it fails to achieve the same level of consumption at early ages. Compared with the optimal contract, it still has too much frontloading.