Privatizing Disability Insurance*

Arthur Seibold   Sebastian Seitz   Sebastian Siegloch†

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Abstract

Public disability insurance (DI) programs in many countries face pressure to reduce their generosity in order to remain sustainable. In this paper, we investigate the welfare effects of giving a larger role to private insurance markets in the face of public DI cuts. Exploiting a unique reform that abolished one part of the German public DI system for younger cohorts, we find that despite significant crowding-in effects, overall private DI take-up remains modest. Private DI tends to be concentrated among high-income, high-education and low-risk individuals. We do not find any evidence of adverse selection on unpriced risk. Finally, we estimate individual insurance valuations via a revealed preferences approach, a key input for welfare calculations. We find that observed willingness-to-pay of many individuals is low, such that providing coverage partly via a private DI market improves welfare. However, we show that distributional concerns as well as individual risk misperceptions can provide grounds for justifying a full public DI mandate.

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†Seibold (seibold@uni-mannheim.de): University of Mannheim, ZEW, CEPR and CESifo; Seitz (sseitz@mail.uni-mannheim.de): University of Mannheim and ZEW; Siegloch (sebastian.siegloch@zew.de): ZEW, University of Mannheim, CEPR, IZA and CESifo.

1 Introduction

Over the past decades, the number of individuals receiving public disability insurance (DI) benefits has risen rapidly in many countries. This growth in benefit receipt has made DI one of the largest social insurance programs in most OECD countries, which spend an average of 2% of GDP on public DI (OECD, 2019). Due to the increasing fiscal burden of public DI, many governments face pressure to enact reforms reducing the generosity of these programs. While such reforms help improve fiscal sustainability, they come at the cost of providing less insurance to individuals suffering from disability. As a consequence, some economists and policymakers have advocated for a larger role of private DI (e.g. Autor and Duggan (2010) and GAO (2018)). As a matter of fact, sizable private DI markets already exist in some countries.[1] Opponents of this idea point out several potential problems in private DI markets, notably adverse selection, equity concerns and behavioral biases leading to sub-optimal private insurance choices. More generally, such concerns form key part of the rationale for public provision of DI (Liebman, 2015). However, there is remarkably little empirical evidence on these issues and the welfare impact of private DI markets.

In this paper, we directly address and inform this debate. We provide novel empirical evidence on the functioning of DI markets and study the welfare consequences of a larger role of private DI. To do so, we exploit a reform that abolished one part of public DI for younger workers in Germany. Combining administrative micro data on the universe of public DI claims with unique and novel data from a top-10 German private insurer, we document significant crowding-in of private DI. However, overall private DI take-up remains modest at around one quarter. We do not find any evidence that low take-up is driven by adverse selection on unpriced risk. On the contrary, private DI is concentrated among individuals with high income, high education and in low-risk occupations who are charged lower insurance premiums. Using a revealed preferences approach, we estimate individual valuations for DI coverage and show that in the absence of behavioral frictions, partly privatizing DI as done by the reform can be welfare improving. However, a full public DI mandate could be justified by equity concerns or if individuals undervalue DI due to risk misperceptions.

The data and the institutional setting enable us to overcome the two main challenges that have complicated studying the role of private DI markets in the past. First, in order to investigate to what extent private DI could compensate for public DI cuts, suitable variation in public DI coverage is needed. In the German setting, we can exploit a unique reform which sharply reduced the scope of public DI. The reform of 2001 abolished one part of public DI for younger workers, namely *own-occupation* insurance. Receiving own-occupation DI benefits require workers to be unable to work in their previous occupation. In contrast, *general* DI benefits are based on stricter eligibility criteria, requiring an individual to be unable to work in any occupation. Before the reform of 2001, both own-occupation and general DI were part of the social insurance system, but the reform abolished public own-occupation DI for cohorts born in 1961 and later. Importantly, the German private DI market offers contracts including own-occupation DI coverage, such that workers affected by the reform who wish to compensate for the loss of public DI coverage can do so by taking up private insurance.

A second challenge is the difficulty of obtaining comprehensive data on private DI take-up. To address this challenge, we combine a number of different data sources. First, we use microdata on

[1] For instance, in the U.S., 33% of workers have private long-term DI as of 2019 (U.S. Bureau of Labor Statistics, 2019). In Germany, 26% of workers have private DI as of 2015 (TNS Infratest, 2015).

all private DI contracts within a large insurance company, which is one of the top-10 providers in the German private DI market. Second, we obtained aggregate data on the overall private DI market from a leading rating agency, which compiles data from all insurers active in the private DI market. Third, we use administrative data on the universe of public DI claims between 1992 and 2014 provided by the German State Pension Fund. Finally, we use representative household survey data from the Income and Consumption Survey (EVS), which allows us to perform a number of checks to validate results from the insurer microdata. We find similar patterns in the survey and in available market-level data, suggesting that the insurer microdata is representative of the market along key dimensions.

We divide our analysis into two parts. In the first part, we provide empirical evidence on the functioning of the private DI market. We begin by studying *crowding-in* effects of the reform, that is the impact of public DI cuts on private DI take-up. On aggregate, we find substantial growth of the private DI market around the time of the reform. In order to identify a causal effect of the reform on private DI take-up, we use a difference-in-difference strategy exploiting the cohort cutoff of the reform. We find that treated individuals born in the two years after the cutoff increase private insurance purchases by around two thirds compared to control cohorts born prior to the cutoff. We argue that this estimate is likely conservative, since we observe larger increases in take-up among younger workers born further away from the cutoff. Yet, even 15 years after the reform, overall take-up remains modest, as only 26% of workers hold private DI.

We find strong heterogeneity in private DI take-up by observable characteristics. In particular, individuals with high income and high education are much more likely to purchase private DI. For instance, take-up is 65% in the top income quintile, but only 7% to 11% in the bottom three quintiles. Heterogeneity by education is even more pronounced, with 80% take-up in the top education quintile, and only 5% to 8% in the bottom three quintiles. Moreover, there is important heterogeneity in take-up by priced *risk groups*, which insurers assign to workers based on occupations and which determine private DI premiums. Individuals in low risk groups who are charged low premiums are much more likely to take-up insurance than those in high risk groups where premiums are high. This result has two implications. First, individuals with the highest disability risk tend not to be covered by the private DI market. Second, since the relative premiums across risk groups are not far from actuarially fair, the large differences in take-up indicate strong responses of insurance demand to prices.

Next, we investigate risk-based selection into private DI in more detail. We implement a "positive correlation test", regressing post-reform private DI take-up within a three-digit occupation on disability risk among this occupation. Two features of our selection test are worth emphasizing. First, the relevant risk-based selection from an efficiency point of view is selection on *unpriced* risk. Thus, we condition on the priced component of risk by testing for selection within risk groups facing the same insurance prices. Second, an important issue with a correlation test is that it may confound selection and moral hazard. Our solution to this problem is to measure disability risk in an occupation only among workers in cohorts 1960 and older, who are still fully covered by public own-occupation DI. Since these workers are all observed under the same level of DI coverage, differences in observed claims should reflect differences in ex-ante risk rather than ex-post moral hazard responses.

We find no significant correlation between private DI take-up and unpriced risk. The point estimate from the correlation test is negative but close to zero. Importantly, this suggests that the private DI market is not impeded by adverse selection, which is often considered to be the main rationale for a public DI mandate. At first glance, the lack of adverse selection may seem surprising, as insurance should in principle be more valuable to higher-risk individuals. We present suggestive evidence that this could be explained by some individual characteristics driving advantageous selection. In particular, once we condition on education, the correlation of private DI take-up and risk becomes positive. This is consistent with higher-educated workers having stronger preferences for insurance, while they tend to work in lower-risk occupations. In other words, advantageous selection on unpriced characteristics could counterbalance potential adverse selection on unpriced risk, implying no overall adverse selection. Another potential explanation for the lack of adverse selection is that individuals may not correctly perceive their disability risk, which we discuss later in the paper.

In the second part of the paper, we turn to the welfare implications of (partly) privatizing disability insurance. The analysis builds on Einav et al. (2010), who show that insurance demand and cost curves can be used as sufficient statistics to assess welfare in insurance markets. In particular, our post-reform setting with insurance choice provides a unique opportunity to directly estimate individuals' willingness to pay for the DI coverage offered by the private market. Thus, we implement a revealed preferences approach, where observed choices reveal insurance valuations, absent behavioral frictions. To estimate demand elasticities, we exploit the price variation between risk groups. Intuitively, the insurer assigns occupations to a discrete number of risk groups based on underlying disability risk, such that there are occupations with similar risk facing different insurance prices around the risk group boundaries. We find sizeable jumps in insurance take-up in response to these quasi-discontinuities in prices, and the resulting average demand elasticity is -1.16. The second key statistic, namely the cost of providing DI, can be directly estimated based on realized DI claims in each risk group.

Our baseline welfare measure is the *net value* of DI, which expresses the willingness to pay for additional insurance relative to its cost, analogously to the marginal value of public funds (Finkelstein and Hendren, 2020; Hendren and Sprung-Keyser, 2020). Our main counterfactual of interest compares the post-reform status quo where DI is partly provided via the private market to a full public DI mandate including this extra coverage. We find an overall net value of a mandate of 0.76, implying that the revealed insurance valuation among individuals additionally covered by the mandate is only 76% of the cost of insuring them. This result reflects an efficiency advantage of the private insurance market. Since there is no significant adverse selection, the market covers the majority of individuals with sufficiently high willingness to pay, and a mandate would predominantly lead to additional coverage of those with valuations below the cost of insurance.

A first caveat with this baseline result is that distributional concerns are not taken into account. The private DI market tends to leave low-income and high-risk individuals uninsured, which may be undesirable to a social planner with equity concern. To account for this, we extend the analysis and calculate the social net value of DI, applying social welfare weights based on expected lifetime income in each risk group. We find that a full public DI mandate has a social value exceeding its costs even under moderate equity concern given by a Utilitarian social welfare function and low risk aversion. Importantly, we note that the redistributive effects of a mandate hinge on the design of social insurance. A private insurance mandate does not achieve an increase in social net value, since the benefits of insurance to high-risk groups are counteracted by the high risk-based premiums charged to these workers. A public insurance mandate with income-based contributions, on the other hand, effectively redistributes to low-income, high-risk individuals.

A second caveat is that our revealed preferences approach assumes that individuals make optimal insurance purchase decisions, which has been called into question in recent literature (e.g. Chandra et al., 2019). Thus, in a second extension, we account for such behavioral frictions relying on a series of calibration exercises. We proceed in three steps. First, we calibrate risk preferences implied by observed private DI purchases in a simple model of insurance choice under a range of assumptions about the consumption drop upon disability. We find that relative risk aversion would have to be very low for many individuals in order to rationalize low observed private DI take-up. Second, we argue that risk misperceptions could provide an alternative rationale for low revealed insurance valuations. In further calibrations, we find that individuals in higher-risk groups would have to underestimate disability risk by roughly 30% to 60% to explain observed take-up. In the third step, we calculate the wedge between observed willingness to pay and normative valuations implied by calibrated risk misperceptions. The results suggest that willingness to pay of marginal buyers would be about 50% to 150% higher if they correctly perceived their disability risk. Finally, we find that implied normative valuations tend to exceed the cost of insurance, suggesting that risk misperceptions can provide an additional rationale for a mandate.

This paper contributes to a large and growing literature on disability insurance (see Low and Pistaferri, 2020, for a recent review). Much of this literature focuses on the effect of public DI on labor supply and claiming decisions (Bound 1989, Gruber 2000, Autor and Duggan 2003, 2006, 2007, Autor et al. 2011, Staubli 2011, von Wachter et al. 2011, Marie and Castello 2012, Maestas et al. 2013, French and Song 2014, Kostol and Mogstad 2014, Borghans et al. 2014, Koning and Lindeboom 2015, Liebman 2015, Autor et al. 2016, Burkhauser et al. 2016, Deshpande 2016a,b, Mullen and Staubli 2016, Gelber et al. 2017, Autor et al. 2019, Ruh and Staubli 2019). In contrast, there is little existing work on private DI markets. Exceptions include Autor et al. (2014), Stepner (2019) and Seitz (2021), who analyze moral hazard effects of private DI.

We make three main contributions to this literature. First, exploiting the unique German setting where a part the public DI mandate is removed, we provide novel empirical evidence on crowding-out and selection in private DI markets. To our knowledge, our findings constitute the first direct empirical evidence on these issues, which are key in assessing the welfare impact of policies expanding the role of private markets and choice in DI. Second, we further exploit our setting with insurance choice in order to estimate individual valuations for DI in a revealed preferences approach. Our approach is closely related to Cabral and Cullen (2019) who estimate a lower bound on the value of public DI using supplemental private DI purchases within a U.S. employer. Third, we assess the welfare consequences of the private DI market offering some coverage vs. a full public mandate. This complements and extends recent work analyzing welfare and the insurance-incentive trade-off within public DI (Low and Pistaferri 2015, Meyer and Mok 2019, Haller et al. 2020).

The remainder of this paper is organized as follows. Section 2 outlines context and data, Section 3 presents evidence on the crowding-in of private DI, Section 4 shows results on selection into private DI, Section 5 presents the demand and cost curve estimation, Section 6 discusses the welfare effects of private vs. public DI, and finally Section 7 concludes.

2 Context and Data

2.1 Institutional Context

Public Disability Insurance. In Germany, public disability insurance (DI) is administered by the State Pension Fund and shares many of its characteristics with DI programs in other countries. Enrollment in public DI is mandatory for all employed individuals, while most self-employed workers and civil servants are exempt. DI contributions are combined with pension contributions and levied as payroll taxes. Enrolled workers become eligible for DI benefits in the event of a permanent disability. Moreover, eligibility requires having contributed for at least five years in total, and at least three out of the five years before the onset of disability. Upon application, a medical and work capacity assessment is carried out by the Pension Fund. Benefit calculation is based on a worker's contributions so far, assuming that they would have kept contributing according to their average pre-disability earnings until age 63. DI benefits are paid until the individual recovers from disability; otherwise, benefits are paid until the Normal Retirement Age, when they are converted into an old-age pension. Throughout their lifetime, 25.1% of workers claim public DI and the average gross replacement rate is 39% (own calculation based on public pension data).

Crucially for our purposes, the public DI system consists of two branches, *general DI* and *own-occupation DI*. The first branch pays benefits to workers suffering from a general disability (*Erwerbsunfähigkeit*), such that they are unable to work in any occupation for more than three hours per day. Common conditions leading to general disability include degenerative disc disease or severe burn-out/depression. The second branch, on the other hand, requires a so-called own-occupation disability (*Berufsunfähigkeit*) defined as being unable to work in their previous occupation. For instance, a bus driver suffering from severe vision impairment is unable to work in their occupation, but may be able to work in other occupations. Such own-occupation DI cases make up 13.2% of all public DI claims. Besides differences in work capacity assessment, the two DI branches also require separate applications and entail somewhat different benefit rules. Workers on own-occupation DI receive two thirds of general DI benefits, but face a less stringent earnings test.[2]

The Reform of 2001. Before 2001, all workers were covered both by general and own-occupation DI as part of the public DI mandate. However, rising expenditure on DI benefits stoked concerns about the fiscal sustainability of the program in the 1990s. This motivated a major reform in 2001 aimed at reducing public DI spending. Most importantly, the reform featured a sharp, cohort-based change in the scope of public DI: own-occupation DI coverage was abolished for birth cohorts 1961 and younger from 2001 onward. Besides this main element, the reform featured further changes equally affecting all cohorts, including gradually phased-in changes to benefit calculation.[3]

The timing of the reform was noteworthy. Initially, the reform was announced in December 1997

[2] General DI benefits are reduced for monthly earnings above EUR 400, whereas workers on own-occupation DI are allowed to earn at least EUR 700, depending on their prior earnings. Note that these earnings test thresholds are adjusted every few years. The aforementioned figures apply between 2008 and 2017.

[3] More precisely, the reform altered two elements of benefit calculation. First, an adjustment factor was gradually introduced, featuring negative benefit adjustments similar to penalties for claiming old-age pensions early. Second, the hypothetical contribution period used for benefit calculation was gradually extended, somewhat counteracting the new penalties. In addition, the reform introduced the possibility of claiming partial DI benefits for individuals who are able to work between three and six hours per day. Finally, DI benefits are meant to be generally granted on a temporary basis after the reform, but in practice most beneficiaries still receive benefits permanently.

to take effect in January 1999. Importantly, the initial reform proposal intended to abolish own-occupation DI for all workers and not only for younger cohorts. After a change of federal government and in the face of public opposition, the reform was retracted in late 1998. However, in December 2000, the reform was re-announced in its final form featuring the cohort cutoff, and it took effect in January 2001.

Private Disability Insurance. The market for private DI has existed since at least the 1920s in Germany. Around 70 insurance companies currently offer private DI contracts. Crucially, private DI always includes coverage of own-occupation disability risk, closely mirroring the pre-reform public DI system. Thus, workers affected by the reform can choose to purchase private DI to compensate for the loss in public own-occupation DI coverage. Private DI payouts are independent of the public DI system, such that they can also serve as a top-up in case a worker is eligible for public general DI benefits.

An important difference to the public DI system is that private DI premiums are risk-based. In practice, the primary determinant of an individual's private DI premium is their occupation, whereby insurers map occupations into a discrete number of risk groups. The insurer from which our microdata originates uses five risk groups, and other insurers use similar numbers of groups during the period we study. Appendix Table A1 shows examples of frequent occupations in each risk group. Furthermore, insurance premiums can be adjusted for pre-existing medical conditions and risky private activities such as extreme sports, but this is relatively rare.[4] Finally, monthly premiums are actuarially adjusted to the individual's contract start and end date. The level of insured benefits can be specified individually. On average, monthly private DI payouts are EUR 836, a similar magnitude to the average benefits of EUR 711 in the public DI system (Allianz 2018). The majority of 85% of private DI contracts are purchased individually, and the remainder are bought via employers (FAZ 2012). Finally, private DI can be purchased either as a stand-alone product or bundled with other types of insurance, most commonly life insurance.

2.2 Data

An important challenge in studying private DI is that comprehensive, high-quality data on private insurance contracts and take-up is not readily available. We tackle this challenge by combining a number of data sources. First, we use microdata on all DI contracts in a large private insurance company. The insurer is among the top-10 in the private DI market, with a market share between 3% and 6%.[5] We observe private DI contracts existing in any of the years between 2012 and 2017, irrespective of the start date of the contract. The data contains information on contract start and end dates, insured benefits, risk groups as well as some socio-demographics including age and gender. Unfortunately, individual income and education are not included in the microdata. We thus match it with information on average income by occupation, age and gender measured in administrative labor market data[6] Similarly, we add education at the occupation level. Panel A of Table 1 shows summary

[4] In only 4% of private DI contracts, premiums are adjusted beyond risk-group specific prices. Moreover, only 4% of individuals are rejected at the contracting stage in the private DI market (GDV 2016). To our knowledge, this includes a few extremely risky occupations such as circus artists and explosives workers, as well as rejections due to pre-existing conditions or risky activities.

[5] For confidentiality reasons, we are unable to name the insurer or specify its market share more precisely.

[6] See Seitz (2021) for a detailed description of the insurer microdata and the occupation matching procedure.

statistics of the insurer microdata. Our main sample, which excludes contracts held by self-employed and civil servants, contains a high six-digit number of contracts. 61% of contract holders are male, the average purchase age is around 30 and the end age is around 63. Average monthly premiums are EUR 78 and insured monthly benefits are EUR 1383, and 55% of contracts were sold as a stand-alone product.

As a second source of information on private DI, we have obtained aggregate data on the entire private DI market from a leading rating agency. This data, on which we draw mainly for the aggregate patterns shown in Sections 3 and 4.4, contains time-series information on the total number of private DI contracts, the shares of different types of contracts, as well as some information on the shares of contracts held by risk groups and age groups.

Third, we use administrative data on the universe of public DI claims between 1992 and 2014 provided by the German State Pension Fund.[7] This data contains information on the timing and type of DI claims, benefits, as well as information on individual earnings histories necessary to compute benefit eligibility and some socio-demographics including age, marital status and gender. Panel B of Table 1 shows summary statistics of the administrative data. In Column (1), 59% of all DI claimants are male, and the average claiming age is around 52. Monthly DI benefits are on average EUR 1078, and claimants' average earnings were EUR 2305 over all periods, and EUR 1307 in the period before the DI claim. Column (2) shows that compared to all DI claims, own-occupation DI claimants are more likely to be male and married, and their age and income tend to be slightly higher.

Finally, we use data from the Income and Consumption Survey (EVS), a representative household survey conducted by the German Federal Statistical Office. We focus on the 2013 wave of the survey, which contains information on households' private DI take-up. We use this data for complementary analyses, in particular for some of the validation exercises presented in Section 4.4. Appendix Table A2 shows summary statistics of the survey data. 31% of households hold private disability insurance in 2013. Households' average labor earnings are around EUR 2185 per month, the average age of the household head is 44, 59% are male and the average household size is just above two.

Representativeness of the Insurer Microdata. An important question is how representative the insurer providing our microdata is for the private DI market. We argue that the insurer reflects the overall market well in key dimensions. First, the main features of private DI contracts described in Section 2.1, including the definition of disability, benefit levels, and contract durations offered, are similar across providers.[8] Second, the pricing of private DI contracts follows similar rules across insurers, assigning individuals to risk groups primarily based on occupations. As we show in Section 4.4, this results in similar relative prices across risk groups charged by different providers. Third, our insurer offers private DI to individuals across all occupations and industries. Thus, we observe private DI contracts of individuals belonging to 322 out of 334 3-digit occupations in the microdata. Fourth, the insurer has a countrywide presence and does not appear to specialize in particular geographic areas. The insurer has local agencies across all states and in all major cities, as well as in a large

[7] The data on public DI claims is a subset of administrative data on all public pension claims first used by Seibold (2021). We also use the full dataset on all pension claims to calculate some aggregate statistics, such as the distribution of occupations, risk groups, income and education.

[8] According to consumer advice, differences across private DI providers are more fine-grained, such as the precise definition of equivalent occupations, the minimum qualifying period of disability, whether benefits can be paid retroactively and whether coverage can be altered throughout the contract (see e.g. BUVT 2019).

number of rural locations across the country. 93% of the German population has a local agency of the insurer in their county of residence or the neighboring county, and the remainder have access to its products via independent brokers or online. In addition, in Section 4.4, we present a number of validation checks of our main results using independent, representative data sources, which yield similar empirical patterns to the insurer microdata.

3 Crowding-In of Private Disability Insurance

The reform of 2001 abolishes public own-occupation DI for younger birth cohorts, which these individuals could compensate by purchasing private DI covering this risk. In this section, we study the effect of the reform on overall private DI take-up. We refer to the response of private insurance take-up to public DI cuts as a crowding-in effect, analogously to crowding-out effects following social insurance expansions studied in the literature (e.g. Brown and Finkelstein, 2008; Chetty et al., 2014).

3.1 Overall Private DI Take-Up

We begin by showing aggregate patterns in public DI claims and private DI take-up in Figure 1. Panel (a) depicts the total number of public own-occupation DI claims by calendar month. Precisely at the time of the reform, there is a sharp drop in benefit claims, as the younger cohorts affected by the reform lose access to public own-occupation DI. Moreover, the figure indicates a continuing downward trend in claims over the years after the reform, as the share of workers in the older cohorts who are still eligible for own-occupation DI keeps declining. There also appears to be some re-timing of claims in the months just before the reform. Even though the spike just before January 2001 is sharp, the magnitude of these excess claims is small relative to the permanent reduction in claims after the reform.

Panel (b) of Figure 1 shows overall private DI take-up over time. We calculate the take-up rate $Q_t = C_t/N_t$, where C_t is the total number of private DI contracts and N_t is the size of the relevant population. We obtain C_t based on the rating agency data on all contracts in the market in each year, and we take N_t as the total number of individuals contributing to social insurance from social insurance statistics. The figure shows a clear jump in private DI coverage around the time of the reform. By 2015, private DI take-up has increased to 26%, compared to around 10% in the years before the reform was first announced in 1997. This growth of the private DI market provides first suggestive evidence of a crowding-in effect. Yet, overall private DI take-up of around one quarter can be viewed as relatively modest, given that the reform fully removes public own-occupation DI coverage.[9]

3.2 Difference-in-Difference Estimation

The evidence above is suggestive of a crowding-in effect of the reform of 2001, but overall growth in the private DI market could be driven by a number of factors. In order to isolate a causal effect, we exploit the cohort cutoff of the reform to estimate a difference-in-difference specification. We run

[9] Take-up rates are slightly higher when focusing on younger cohorts (29%) or when using only currently employed individuals as the relevant population (38%).

regressions of the following form:

$$Y_{ct} = \beta_0 + \beta_1 treat_c + \beta_2 treat_c \cdot post_t + \delta_t + \epsilon_{ct} \tag{1}$$

where Y_{ct} denotes an outcome of cohort c in calendar month t, $treat_c$ is an indicator for treated cohorts 1961 and younger, $post_t$ is an indicator for post-reform periods January 2001 and later, δ_t is a calendar month fixed effect, and ϵ_{ct} is an error term. The coefficient β_2 yields the difference-in-difference effect of interest. In the baseline specification, we focus on a narrow cohort window of plus/minus two years around the reform cutoff, comparing treated cohorts 1961-1962 to control cohorts 1959-1960.

First, we investigate the effect of the reform on public own-occupation DI claims. Panel (a) of Figure 2 shows the number of claims by cohorts 1961-1962 vs. 1959-1960 over time. Before 2001, claims by both treated and control cohorts follow a similar increasing trend. Precisely in 2001, there is a sharp drop in claims by treated cohorts virtually to zero, while claims by the control group continue increasing similarly to before the reform.[10] Column (1) of Table 2 shows a highly significant difference-in-difference coefficient of -50.6, corresponding roughly to the number of monthly claims by treated cohorts just before the reform. Thus, the estimation confirms that the "first-stage" induced by the reform of 2001 is given by the virtually immediate and complete removal of public own-occupation DI coverage for younger workers. In addition, Column (2) of the table shows that the reform does not lead to spillovers into the other branch of public DI. The estimated effect on *any* type of public DI claims is, if anything, larger in magnitude than the effect on own-occupation DI claims, suggesting no benefit substitution towards general DI claims.

Next, the main outcome of interest is the number of private DI purchases. To analyze these, we turn to the insurer microdata where we can observe individual characteristics. Panel (b) of Figure 2 depicts the number of private DI purchases by cohorts 1961-1962 vs. 1959-1960 over time.[11] Before the first announcement of the reform demarcated by the dashed vertical line, purchases by treated and control cohorts follow a very similar trend. After the first announcement, there is a clear increase in private DI purchases by both groups. This is consistent with the initial reform proposal affecting all cohorts. However, a clear differential increase in purchases by the treated cohorts occurs when the reform is implemented in 2001. Moreover, the differential effect on new contract purchases of the treatment group seems to persist in subsequent years. Column (3) of Table 2 presents the estimated effect on monthly private DI purchases. The coefficient of 15.1 is highly significant and corresponds to a 64% increase over pre-reform average monthly purchases of 23.5. In addition, Column (4) shows that the effect is mostly driven by newly purchased stand-alone DI contracts, where the estimated coefficient is 13.2. This suggests that individuals specifically buy additional DI contracts after the reform, rather than bundling DI with other insurance types. Finally, Column (5) shows the estimated effect on the amount of benefits insured in private DI contracts. We find no significant effect along this "intensive margin" of private DI.[12] This motivates our focus on the extensive margin given by private DI take-up throughout this paper.

Appendix Table A3 shows that these difference-in-difference results are robust to various alternative

[10] Claims by the treated cohorts do not drop precisely to zero in 2001 due to delays in processing claims made before the reform.

[11] The figure shows the annual number of private DI purchases, since the monthly contract data exhibits strong seasonality. Table 2 shows all effects estimated at the monthly level.

[12] See Appendix Figure A1 for graphical results corresponding to Columns (2), (4) and (5) of Table 2.

specifications. First, even though the treated and control cohorts in the baseline estimation are quite close in terms of age, there could be age-specific trends in private DI purchases. Panel A shows results from regressions based on equation (1) including cohort-specific linear trends. The estimated effect remains similar, and if anything the point estimates become slightly larger. Second, as explained in Section 2.1, the reform was first announced to take effect in 1998, but then retracted and re-announced for 2001. In the baseline estimation, the post-reform period is defined as January 2001 and later. This may understate the reform impact, as the initial announcement may already have an effect on private DI purchases. Panel B of Table A3 shows difference-in-difference coefficients under different timing assumptions, including controlling for the period 1998 to 2000 with a separate indicator, omitting the years 1998 to 2000 or defining post-1998 as the post-reform period. Again, the estimated coefficients are slightly larger than the baseline effects, corresponding to increases between 72% and 81% relative to pre-reform purchases.

Our baseline difference-in-difference estimation focuses on a narrow cohort window around the reform cutoff. This has the advantage of comparing relatively similar treated and control cohorts over time. However, this strategy is likely to lead to conservative estimates due to the age composition of the treatment group. Cohorts 1961-1962 are 39 to 40 years old at the time of the reform, while most individuals tend to purchase private DI at younger ages. In the full sample, the average purchase age is below 30 (see Table 1). In order to assess how the reform affects younger workers, we repeat the difference-in-difference estimation for a broader set of cohorts. Figure 3 shows estimated coefficients by cohort, where we replace the treated group in equation (1) by the respective cohorts denoted on the horizontal axis. Two main results emerge from the figure. First, the reform effect appears to be strongly increasing among younger cohorts. For instance, workers aged 29 to 30 at the time of the reform (cohorts 1971 to 1972) exhibit a roughly five times larger increase in the number of private DI purchases than the baseline treatment group. Second, the figure shows very small differences in private DI purchases between different cohorts born before the reform cutoff. Only our baseline control group exhibits a very small increase relative to older cohorts, but there are no differential trends in insurance purchases between cohorts further below the cutoff.

Finally, the difference-in-difference estimates are not directly comparable to overall take-up rates shown in Section 3.1, but a back-of-the-envelope calculation can illustrate such a comparison. For instance, we can calculate the predicted number of contracts held by cohorts 1961-1962 in 2015 based on pre-reform mean purchases, and add the estimated differential increase in purchases in post-reform years. This would imply a 26% increase in the stock of private DI contracts held by the baseline treatment group who were treated at ages 39 to 40. Performing a similar calculation among the full set of treated cohorts from Figure 3 suggests a substantially larger rise in average private DI take-up by 193%. This magnitude is similar to the overall increase in private DI take-up from Figure 1, indicating that much of this growth can be attributed to a reform effect.

4 Selection into Private Disability Insurance

4.1 Calculating Take-Up of Subgroups

In this section, we study which individuals select into private DI. The main challenge in doing so is that comprehensive microdata on the overall private DI market is not available. This challenge is faced by much of the literature investigating private insurance markets, which typically uses data from a specific insurer or employer (e.g. Einav et al., 2010; Autor et al., 2014; Cabral and Cullen, 2019). We follow a similar approach and resort to the insurer microdata. Specifically, our goal is to use this data to calculate private DI take-up rates of subgroups:

$$Q_{g,t} = \frac{C_{g,t}}{N_{g,t}}$$

where $C_{g,t}$ denotes the number of private DI contracts held by subgroup g at time t and $N_{g,t}$ is the size of the respective subgroup. The denominator $N_{g,t}$ is relatively straightforward to obtain. We calculate sub-population sizes by cohort and gender from social insurance statistics. For the distribution of income, education and risk groups, we use the administrative public pension data, where income and education is observed and risk groups can be assigned based on occupations.

The key difficulty in calculating $Q_{g,t}$ lies in the numerator, as market-level data on the total number of contracts held by subgroups is not available. Using the insurer microdata, we calculate the number of contracts held by subgroup g as

$$C_{g,t} = \sum_j \frac{c^j_{g,t}}{marketshare^j_t} \tag{2}$$

where $c^j_{g,t}$ is the number of contracts of type $j \in$ {stand-alone, bundled} within the insurer and $marketshare^j_t$ is the insurer's market share in the respective type of contract in year t. The approach requires the following assumption: Within type of contract and year, the market share of the insurer is constant across subgroups, i.e. $marketshare^j_{g,t} = marketshare^j_t \;\; \forall g$.

This assumption is certainly not innocuous, and its validity hinges on how representative the insurer is for the overall market. In Section 4.4, we present comprehensive validation checks of the resulting take-up rates. We find similar take-up patterns using representative household survey data and other independent data sources, confirming that the selection results we find in this section are present in the overall private DI market.

4.2 Selection on Observable Characteristics

Figure 4 shows private DI take-up rates by observable characteristics, specifically by income, education, gender and risk group. All take-up rates are calculated in 2015, 15 years after the reform. To begin with, Panel (a) shows take-up rates by income quintile. The figure shows a striking positive correlation between private DI take-up and income. In the top income quintile, almost two thirds (65%) of individuals hold private DI. Private DI take-up in the fourth quintile is 30%, in the second and third quintiles take-up is 11% to 12%, and only 7% of individuals in the bottom quintile are covered by private DI.[13] Panel (b) shows an even stronger correlation of private DI take-up and education. 80% of individuals in the highest education quintile hold private DI, while take-up is 26% in the fourth quintile. In the bottom three quintiles, only 5% to 8% take up insurance. Panel (c) shows corresponding results by gender, suggesting that take-up among men (30%) is somewhat higher than among women (20%).

Next, we investigate private DI take-up by priced risk group. Recall that the insurer assigns

[13] Autor et al. (2014) similarly find that high-income individuals are more likely to take up private DI in the U.S.

individuals to one of five risk groups based on occupations, and these risk groups are the primary determinant of private DI premiums. Appendix Table A4 summarizes risk groups. As expected, risk groups differ markedly in terms of lifetime disability risk, which we measure as the fraction of individuals claiming DI in the administrative data. Disability risk of individuals in risk group 1 is less than 5%, while it is 15% in risk group 2, 24% in risk group 3, 31% in risk group 4, and 40% in risk group 5. Moreover, the share of own-occupation DI claims increases with risk groups. For instance, only 8% to 11% of all DI claims in risk groups 1 and 2 are due to own-occupation disability, while the fraction is 32% in risk group 5. Accordingly, individuals are charged strongly varying insurance premiums depending on the risk groups they are assigned to. To insure EUR 1000 of monthly benefits at the age of 25, a worker in risk group 1 has to pay a monthly premium of EUR 32, compared to EUR 42 in risk group 2, EUR 68 in risk group 3, EUR 101 in risk group 4 and EUR 155 in risk group 5. Thus, premiums increase with risk groups roughly in line with disability risk, but there are some differences in pricing relative to risk which we revisit in Section 5.2. It is also worth noting that the population shares of risk groups differ substantially. 10% of the labor force work in an occupation in risk group 1, 17% in risk group 2, 35% in risk group 3, 38% in risk group 4, and only 0.6% in risk group 5. Finally, Panel (d) of Figure 4 shows a striking negative relationship between private DI take-up and risk groups. 68% and 64% of individuals in risk groups 1 and 2 hold private DI, respectively. Among risk group 3, private DI take-up is 23%, and only 9% and 7%, respectively, of individuals in risk groups 4 and 5 are covered by private DI.

These selection results have two key implications. First, they suggest that modest overall private DI take-up is driven by low take-up among individuals with low income, low education and high disability risk. On the other hand, there are groups with high insurance take-up of up to 80%, in particular the top income and education quintiles and the lowest risk group 1. These observations provide a first indication of potential equity issues in the private DI market, as vulnerable groups are much more likely to be without coverage. Second, low observed take-up among high-risk individuals is somewhat puzzling. Premiums are increasing with risk groups in a fashion not far from actuarially fair, and if individuals are well-informed about their risk, willingness to pay for insurance should increase with risk group. One potential explanation for the strong decline of take-up with risk groups is that individuals misperceive their risk, where high-risk individuals may under-estimate risk in particular. We return to this issue in Section 6.3.

As a complementary piece of evidence on heterogeneity in private DI take-up, we repeat the difference-in-difference analysis for each subgroup. Appendix Table A5 shows results from estimating equation (1) separately by income, education, gender and risk group. The table reveals heterogeneity in crowding-in effects similar to simple differences in take-up. The estimated effect of the reform of 2001 on private DI purchases increases strongly with income and education, both in terms of absolute coefficient magnitudes and relative to pre-reform purchases. The effect on purchases by men is slightly larger than by women. Finally, the effects by risk groups have to be interpreted in relation to the size of each group. While raw coefficients are largest for risk groups 2 and 3, the increase in private DI purchases relative to group size are largest among risk groups 1 and 2. Strikingly, the reform seems to have lead only to a negligible number of additional purchases by individuals in the highest risk groups 4 and 5.

4.3 Risk-Based Selection

A crucial question for the efficient functioning of private DI markets is whether individuals select into purchasing insurance based on their risk. The classic theory of adverse selection predicts that high-risk individuals are more likely to purchase insurance, which leads to underprovision of insurance or even complete market unraveling (Akerlof, 1970; Rothschild and Stiglitz, 1976). To investigate this question, we implement a *positive correlation test* (Chiappori and Salanié, 2000; Einav et al., 2010; Landais et al., 2021). The goal is to test whether there is a correlation between private DI take-up and unpriced risk, where a positive correlation would indicate adverse selection. Specifically, we run the following regression at the occupation level:

$$Q_j = \beta_0 + \beta_1 \pi_j + \beta_2 riskgroup_j + \epsilon_j \tag{3}$$

where Q_j denotes private DI take-up of individuals in three-digit occupation j in 2015, π_j is a measure of disability risk in the occupation, and $riskgroup_j$ is the risk group assigned to the occupation by the insurer.[14]

Two features of this specification are worth emphasizing. First, we found a strong negative correlation of private DI take-up and risk groups in the previous section. Risk groups reflect an observed component of risk based on which the insurer prices contracts. However, in assessing whether there is adverse selection, it is key to estimate the correlation of private DI take-up and *unpriced* risk. Thus, the idea behind equation (3) is that β_1 captures selection on unpriced risk, after controlling for priced risk given by risk groups. Second, a potential pitfall of the correlation test is that ex-post measures of risk based on observed insurance claims may confound selection on ex-ante risk and moral hazard responses (see e.g. Landais et al. 2021). A correlation of DI take-up and claiming probabilities may be driven by certain risk types selecting into insurance (selection) or those with more insurance coverage becoming more likely to claim (moral hazard). In order to address this challenge and isolate risk-based selection, we calculate take-up among treated cohorts 1961 and younger, but we measure disability risk π_j as the fraction claiming DI only among control cohorts 1960 and older. This risk measure should not be confounded by differential moral hazard, since all individuals in the control cohorts are still fully covered by public own-occupation DI, i.e. they are observed under the same insurance coverage.

Figure 5 depicts the estimation results in binned scatter plots. First, Panel (a) shows the unconditional correlation of occupation-level private DI take-up and disability risk. This corresponds to estimating equation (3) without controlling for risk groups. There is a highly significant negative relationship between DI take-up and risk, with a slope coefficient of -1.38. This overall correlation is driven by a mixture of the negative relationship of DI take-up and risk groups documented in Figure 4, and any correlation of take-up and unpriced risk. Next, panel (b) of the figure shows the correlation of private DI take-up and unpriced risk, after controlling for priced risk. The relationship is remarkably flat, and the estimated slope coefficient corresponding to β_1 in equation (3) is small and statistically

[14] Note that risk groups are not necessarily the same for all individuals within a three-digit occupation for two reasons. First, the insurer sometimes changes the risk group assigned to an occupation over time. Second, occupation titles considered by the insurer may feature finer-grained distinctions not captured by the occupation classification, such as whether the individual mostly works inside an office. For the results shown here, we assign the average risk group to each occupation. Results remain very similar when considering the modal risk group within occupation.

insignificant. In other words, we do not find any evidence of adverse selection from the point of view of the insurer: within priced risk groups, individuals with higher true disability risk are no more likely to select into purchasing insurance. If anything, the point estimate on risk is slightly negative, which would imply advantageous selection into private DI.

Appendix Table A6 presents regression results based on equation (3). Columns (1) to (3) correspond to the results from Figure 5. In Columns (4) to (7), we add observable characteristics to the regression. This yields two additional insights. First, we can explore how risk-based selection changes conditional on different sets of observables. In Column (4), controlling for income hardly changes the coefficient on risk. However, Column (5) suggests that education may be a driver of advantageous selection. Once we control for education, the coefficient on risk turns sizable and positive, albeit still insignificant due to a sizeable standard error. This indicates that the insurer may face adverse selection if pricing was conditional on education. In practice, not conditioning on education induces some advantageous selection, where individuals with higher education (who are less risky on average) are more likely to buy insurance, such that there is no overall adverse selection. In Column (6), controlling for gender does not alter selection much. Interestingly, adding further observables including economic training, marital status and an indicator for East Germany in Column (7) again turns the effect of risk close to zero and negative, suggesting that these characteristics may drive some adverse selection.

Second, Table A6 is informative of which characteristics themselves predict private DI take-up. In Section 4.2, we show that income, education and risk groups exhibit a strong univariate correlation with take-up, but one may ask which of these remain predictors conditional on risk and other observables. Columns (5) to (7) suggests that income itself is not a significant driver of private DI take-up, once education and risk groups are controlled for. On the contrary, education remains highly positively correlated with take-up in all specifications. Similarly, although the effect of risk group somewhat shrinks when adding socioeconomic controls, it remains a significant negative predictor of take-up. Interestingly, working in an economically trained occupation has a positive impact on take-up beyond the influence of education. Column (7) additionally indicates that private DI take-up is lower among females and married individuals.

4.4 Validation Exercises

Our empirical results on selection into private DI rely on the insurer microdata, as individual-level data on the entire market is not available. As discussed in Section 4.1, the validity of these findings depends on how representative the insurer is for the overall market. In this section, we present a number of validation checks using additional, independent data sources. Overall, we find similar patterns based on these alternative sources, confirming the validity of our main results.

Overall private DI take-up in our data is very similar to estimates from other sources. A survey conducted by TNS Infratest (2015), a private survey company, found that 26% of working adults hold private DI, corresponding precisely to our main take-up rate estimate for the same year from Section 3.1. Using data from the Income and Consumption Survey (EVS), a representative household survey conducted by the German Federal Statistical Office, overall private DI take-up by German households is 31% in 2013. This household-level figure is naturally somewhat larger than our individual-level estimate, since the average household has around two members (see Appendix Table A2) any of whom may have individual private DI contracts.

Next, we turn to private DI take-up by subgroups. Panel (a) of Appendix Figure A2 shows take-up rates clearly increase with income quintile in the household survey, albeit with a somewhat flatter gradient. Panel (b) of the figure shows that we match take-up rates by gender well, taking into account that the survey figures are measured at the household level. In order to validate private DI take-up rates by risk groups, we use the rating agency data, which includes the shares of contracts by "harmonized" risk groups for the entire market. This information is based on insurers reporting the number of contracts in four risk groups defined by the rating agency. These harmonized risk groups correspond largely to the risk groups used by the insurer providing our microdata, but the insurer additionally differentiates the fourth harmonized group into high (risk group 4) and very high risk (group 5). Panel (c) of Figure A2 shows our main estimates for the largest, medium-risk groups 2 and 3, and rates implied by the rating agency are virtually the same. For the low-risk group 1 and the high-risk groups 4 and 5, the rating agency data displays even stronger heterogeneity in take-up than our main results.

Finally, as an additional piece of evidence, Panel (d) of Figure A2 shows a comparison of private DI pricing by different insurers. For this exercise, we web-scraped data on prices charged to the ten most frequent occupations in each risk group for those of the top-10 insurers offering online price calculators. The figure plots the average monthly premium by risk group for the insurer providing our microdata and four large competitors. In general, relative prices charged to different occupations are very similar across insurers. All insurers levy similar relative risk surcharges on higher-risk occupations, suggesting that individuals in certain risk groups should have little reason to select specifically into the insurer providing the microdata, as its insurance pricing is representative of the overall market.

5 Value and Cost of Disability Insurance

5.1 Basic Conceptual Framework

Next, our aim is to quantify the value and cost of DI coverage offered by the private market, which are key inputs to calculate welfare effects. Based on these two components, we can calculate the *net value* of DI, which we define as the value to recipients relative to the cost of insurance (see Section 6.1). Our analysis builds on Einav et al. (2010), who show that in order to evaluate welfare in insurance markets, the key sufficient statistics are given by insurance demand and cost curves. Similar frameworks have recently been used in related social insurance contexts, including DI and unemployment insurance (Cabral and Cullen, 2019; Landais et al., 2021; Hendren et al., 2020).

Following this literature, we consider a population of heterogeneous individuals indexed by θ_i, and $F(\theta_i)$ denotes the distribution of the population. Heterogeneity is unrestricted, and may include variation both in preferences for DI, such as varying risk aversion, and variation in individual disability risks. The first key component for welfare analysis is demand, or willingness to pay, for DI. Denote by $v(\theta_i)$ the utility of consumer i from buying disability insurance, and by p_k the insurance premium charged to individuals in risk group k. In a private market with insurance choice, the individual purchases DI if $v(\theta_i) \geq p_k$. Aggregate demand for private DI in group k can be written as

$$D_k(p_k) = \int \mathbb{1}\left(v(\theta) \geq p_k\right) dF_k(\theta) = \operatorname{Pr}_k\left(v(\theta_i) \geq p_k\right)$$

In words, insurance demand corresponds to the share of individuals whose willingness to pay is above the premium within a given risk group.

The second component we require for welfare analysis is the cost of providing DI. We denote by $c(\theta_i)$ the expected cost associated with the potentially insured risk of individual i. Average cost at price p_k is

$$AC_k(p_k) = \frac{1}{D_k(p_k)} \int c(\theta)\mathbb{1}\left(v(\theta) \geq p_k\right) dF_k(\theta) = \mathbb{E}_k\left(c(\theta_i)|v(\theta_i) \geq p_k\right)$$

Thus, the average cost curve is determined by the cost of providing insurance to those individuals who choose to buy insurance at a given price p_k. In addition, we can write marginal cost as $MC_k(p_k) = \mathbb{E}_k\left(c(\theta_i)|v(\theta_i) = p_k\right)$. The marginal cost curve captures the cost of providing insurance to the marginal individuals who purchase insurance exactly at price p_k.

Before we proceed to the empirical implementation, three aspects are worth noting. First, we assume that individuals make a discrete choice of whether to buy insurance or not (if such choice is permitted), and we abstract from the choice of insured benefit amounts in private DI contracts. This assumption is motivated by our results from Section 3.2, which suggest that individuals mainly respond along this extensive margin of insurance choice, whereas no significant responses occur along the intensive margin of insured benefits. Second, we follow the literature regarding the cost of providing DI and abstract from any other cost incurred by insurers, such as administrative cost. Third, since insurance prices depend on risk groups to which the insurer assigns individuals based on observable characteristics (occupations), we conduct the analysis separately for each risk group. In other words, the insurance demand and cost curves described above apply within risk groups where individuals vary only in unpriced characteristics.

5.2 Estimating Demand and Cost Curves

Demand. The first ingredient for welfare analysis is demand, or willingness to pay for DI. Our post-reform setting with insurance choice provides a unique opportunity to implement a revealed preference approach and to directly estimate individual valuations of the DI coverage offered by the private market. Such an opportunity is rarely available, as public DI is fully mandated in most countries, leaving little choice for workers.[15] In particular, we use two empirical moments to estimate demand for DI. First, the observed post-reform take-up rate at given prices identifies one point on the demand curve of each risk group, anchoring its level. For this purpose, we can directly use the observed take-up rates shown in Panel (c) of Figure 4. Second, to estimate the slope, i.e. the responsiveness of demand to prices, we exploit the discontinuous price variation between risk groups. Assuming a constant elasticity of demand then allows us to construct demand curves of each risk group.

The slope of the demand curve captures the responsiveness of private DI take-up to insurance prices. To estimate such price responses, we run the following regression at the occupation level:

$$Q_j = \beta_0 + \beta_1 \pi_j + \sum_{k=2}^{5} \delta^k \mathbb{1}(riskgroup_j = k) + Z_j' \gamma + \epsilon_j \tag{4}$$

where Q_j denotes private DI take-up by three-digit occupation j, π_j is a measure of disability risk,

[15] Cabral and Cullen (2019) follow a closely related but distinct approach, estimating a lower bound on the willingness to pay for public DI using supplemental private DI purchases of workers at a U.S. employer.

$\mathbb{1}(riskgroup_j = k)$ is an indicator for occupation j being assigned to risk group k by the insurer and Z_j is a vector of control variables. Again, we measure take-up among treated cohorts in 2015 and disability risk only among control cohorts. Equation (4) captures the idea that a discrete number of risk groups are assigned to occupations based on a continuous running variable, namely occupation-level disability risk π_j. Thus, at the boundaries between risk groups, similar occupations with very similar or even the same disability risk are assigned to different risk groups and thus face different prices. The coefficients δ^k capture the jump in private DI take-up between risk groups k and $k-1$ conditional on underlying risk, which we interpret as a response to the local, discrete difference in insurance premiums between the two groups.

This specification is similar to equation (3), but there are two important differences. First, we include indicators for risk groups in order to separately estimate the jump in private DI take-up for each adjacent pair of risk groups. In order to better capture the discrete variation between risk groups, we additionally define risk groups as the modal risk group within each occupation. Second, our preferred specification includes control variables Z_j, such as income, gender and education. We do not include these characteristics in the main correlation test based on equation (3), since they are not priced by the insurer. However, it can be important to add these controls in equation (4) if occupations in different risk groups differ in terms of observable characteristics in a way correlated with private DI take-up.

Based on the estimated regression coefficients, we can then calculate the demand elasticity at the boundary between risk groups k and $k-1$ as

$$\hat{\varepsilon}^k = \frac{(\hat{\delta}^k - \hat{\delta}^{k-1})/\overline{Q_j}^{k,k-1}}{\Delta p^{k,k-1}/\overline{p_j}^{k,k-1}} \tag{5}$$

where $\overline{Q_j}^{k,k-1}$ and $\overline{p_j}^{k,k-1}$ are average private DI take-up and average premiums among occupations belonging to risk group k and $k-1$, respectively, and $\Delta p^{k,k-1}$ is the difference in premiums between groups k and $k-1$.[16]

Figure 6 illustrates the estimation graphically. In Panel (a), we rank occupations by disability risk within risk group in order to depict the variation in prices and DI take-up in a stylized way. The blue line shows the sizeable jumps in premiums between risk groups. The black dashed line shows a linear fit of private DI take-up within risk group, revealing large jumps in take-up at the risk group boundaries. The elasticity calculation in equation (5) relates these jumps in demand to the price variation between the respective groups. Next, Panel (b) shows binned scatter plots of private DI take-up by actual disability risk, corresponding directly to the estimation from equation (4). Similarly to Panel (b) of Figure 5, the relationship between DI take-up and underlying disability risk is slightly downward-sloping within risk group. There appears to be sizable overlap in underlying risk across risk groups. On the one hand, this is perhaps surprising as one may expect the insurer to assign risk groups in a less "fuzzy" way.[17] On the other hand, the large overlap implies that there are many

[16] In contrast to the expected price calculation described in equation (7), we calculate $\Delta p^{k,k-1}$ and $\overline{p_j}^{k,k-1}$ directly based on monthly insurance premiums charged to the respective risk groups. We do this because the relevant jump in prices at the risk group boundaries is the percentage change in premiums conditional on risk, which is directly given by the percentage change in monthly premiums.

[17] One potential reason for the fuzziness in risk group assignment is that the insurer may not have had sufficiently comprehensive data on lifetime DI claiming probabilities by occupation at the time. This argument is consistent with the fact that the insurer carried out a major overhaul of risk groups for new private DI contracts after the end of our

instances of occupations with the same disability risk facing different premiums, providing us with sufficient statistical power to estimate price responses. Indeed, the figure indicates clear, large jumps in private DI take-up conditional on underlying risk across all adjacent risk group pairs, suggesting sizable demand responses of demand to insurance premiums.

Table 3 shows results from the demand elasticity estimation.[18] The average price difference between adjacent risk groups is 40%, and the average unconditional jump in private DI take-up at the risk group boundaries corresponds to a 68% reduction in demand for insurance. Including controls (income, gender, education, economic training, marital status and residence in East Germany) yields a response of 47%. The demand elasticity estimation then relates the demand response to the jump in price for each pair of adjacent risk groups. In on our preferred specifications including controls, we find an average demand elasticity across all risk groups of -1.16. Without controlling for observables, the average elasticity is -1.79. Elasticity estimates among the different risk groups are close to the average, except the estimate between risk groups 2 and 3 where we find a smaller elasticity of -0.32. Overall, there is no clear increasing or decreasing pattern of elasticities with risk groups. This motivates our assumption of a constant elasticity along the demand curve.[19]

Cost. The second ingredient required for welfare analysis is the cost of providing disability insurance. We calculate the expected cost of insuring individual i belonging to risk group k as

$$c_{i,k} = \sum_{t=0}^{T_i} \Pi_{k,t} b_i \delta_t \tag{6}$$

where T_i is the contract end date relative to a contract start date normalized to zero, $\Pi_{k,t}$ is the cumulative disability risk among risk group k in period t, b_i is the level of insured benefits, and $\delta_t = \frac{1}{(1+r)^t}$ is a discount factor. We use a discount rate of $r = 3\%$ and as before, we measure disability risk as the ex-post realized risk of claiming DI benefits in the administrative data. Appendix Figure A3 shows empirical risk paths for each risk group. As expected, lifetime disability risk increases strongly with risk groups (see also Appendix Table A4). Risk paths by age evolves quite similarly across groups, with most disability claims occurring between ages 45 and 60. We calculate $c_{i,k}$ for each individual in the insurer microdata, and then take the average expected cost within risk group. To construct average cost curves, it is crucial that we do not find evidence of adverse or advantageous selection in Section 4.3. Since there is no significant correlation between private DI take-up and disability risk within risk group, average costs are constant with respect to the level of demand, resulting in flat cost curves. Moreover, as average cost is constant, average cost and marginal cost curves coincide. Finally, two important features of cost curves are worth noting. First, the cost estimates can be interpreted as inclusive of a fiscal externality due to moral hazard responses to DI coverage, since our risk measure is based on ex-post observed claims. Second, we assume that the cost of providing insurance is the same across private and public DI systems.[20]

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sample period.

[18] In addition, we show regression results directly corresponding to equation (4) in Appendix Table A7.

[19] Alternatively, the literature often assumes a linear demand curve (e.g. Einav et al., 2010; Landais et al., 2021). In our case, the magnitude of demand responses estimated at different risk group cutoffs suggest a constant elasticity may be a better approximation than a linear curve.

[20] Unfortunately, the insurer microdata does not provide information on claims over a sufficiently long period to directly compare private and public DI claims. However, some aggregate calculations on private DI claiming risk are

Throughout the subsequent analysis, we consider prices in terms of expected insurance premiums paid by individuals and received by the insurer:

$$p_{i,k} = \sum_{t=0}^{T_i} (1 - \Pi_{k,t}) \tilde{p}_k \delta_t \tag{7}$$

where $\tilde{p}_k$ is the per-period premium charged to risk group k. Again, we calculate $p_{i,k}$ for each individual in the insurer microdata and take average expected premiums by risk group $p_k = \mathbb{E}_k(p_{i,k})$. Thus, willingness to pay for insurance and the welfare measures described below are expressed in terms of certainty equivalents.

5.3 Willingness to Pay and Cost Estimates

Figure 7 plots the estimated demand and cost curves by risk group. In each panel, the horizontal axis denotes the fraction of the respective risk group covered by private DI, ranging from zero to one. Demand curves rank individuals from high to low willingness to pay on the horizontal axis and show the fraction of individuals whose willingness to pay is at least equal to a given price. Cost curves show the marginal/average cost associated with insuring the set of individuals willing to purchase insurance at this price. In Panel (a), the expected cost of insuring individuals in risk group 1 is low as this group faces the lowest disability risk. The estimated willingness to pay is above the cost of providing insurance at any level of take-up. Panel (b) shows corresponding results for risk group 2, for whom the cost of insurance is already substantially higher. The demand curve also indicates somewhat higher willingness to pay for DI among risk group 2, but demand and cost curves intersect at an insurance take-up rate of 69%. Thus, willingness to pay is below the cost of insurance for 31% of individuals. In Panel (c), the cost of insuring risk group 3 is higher again, while the demand curve is lower than that of risk group 2. In fact, willingness to pay is above cost for only 30% of individuals in risk group 3. Similarly, in Panels (d) and (e), risk groups 4 and 5 are even costlier to insure, but willingness to pay revealed by observed demand and price responses are low. Thus, the cost of insurance is above willingness to pay for 85% of individuals in the two highest-risk groups.

In addition, Figure 7 is informative of the difference between premiums charged in the private DI market and the expected cost of insuring each risk group. There are notable differences in implied profit markups across risk groups. Premiums are substantially above expected costs for risk group 1, indicating sizable profits from insuring the lowest-risk individuals. For risk group 2, on the other hand, premiums are very close to actuarially fair.[21] Similarly, the markup is modest for risk group 3. For risk group 4 and especially risk group 5, markups appear to be larger again.

Appendix Table A8 quantifies estimated demand and cost. Willingness to pay and cost in the table are calculated for a private DI contract insuring a 30% income replacement rate and scaled relative to lifetime income. Across all groups, median willingness to pay is 0.93% of income and the expected cost of providing this coverage is 1.47% of income. In line with strongly varying disability risk across

provided by the German Actuarial Society (DAV 2018). Panel (f) of Appendix Figure A3 shows private DI claiming risk from this source, calculated for a representative individual. There are some differences in the timing of claims, but overall disability risk is remarkably similar to observed in public DI claims, providing suggestive evidence that our assumption of equal cost is likely a good approximation.

[21] In fact, when the insurer carried out an overhaul of risk groups after the end of our sample period, one major goal was to introduce more fine-grained groups to replace the former risk group 2. This is consistent with the pricing of risk group 2 not being fully optimal from the point of view of the insurer.

groups, we estimate an insurance cost of 0.33% of income in risk group 1, 1.09% in risk group 2, 1.47% in risk group 3, 1.72% in risk group 4, and 2.14% in risk group 5. On the contrary, median valuations do not appear to increase with risk. Our estimates suggest a willingness to pay for private DI of 1.13% of income in risk group 1, 1.42% in risk group 2, 0.96% in risk group 3, 0.63% in risk group 4, and 0.82% in risk group 5.

Decomposing Willingness to Pay. So far, we estimate willingness to pay and cost for the full coverage provided by private DI in the post-2001 setting. This includes coverage of own-occupation DI risk, but private DI can also serve as a top-up insurance if the worker qualifies for public DI in the case of a general disability. In this section, we propose a decomposition of DI valuations into these two components, exploiting differences in insurance take-up over time.

We begin by writing an individual's total disability risk as the sum of two-sub risks: $\pi = \pi_g + \pi_o$, where π_g is the risk of a general disability, and π_o is the risk of disabilities that would prevent individuals from working in their own occupation, but allow them to work in other occupations. In the post-reform setting, observed willingness to pay for private DI captures the sum of valuations for own-occupation DI coverage and top-up insurance for general disability risk:

$$v^{post} = v_g(b_g, \Delta) + v_o(0, \Delta)$$

where $v_j(b_j, \Delta)$ denotes the valuation for an amount Δ of private insurance against risk π_j, $j \in g, o$, given public DI coverage b_j against that risk.[22] In the pre-reform setting, on the other hand, private DI is purely a top-up insurance, such that

$$v^{pre} = v_g(b_g, \Delta) + v_o(b_o, \Delta)$$

Thus, the difference in willingness to pay post-reform vs. pre-reform can be interpreted as a lower bound on the valuation for insurance against own-occupation disability risk:

$$v^{post} - v^{pre} = v_o(0, \Delta) - v_o(b_o, \Delta) \leq v_o(0, \Delta) \tag{8}$$

Furthermore, we can obtain an upper bound on the valuation for own-occupation DI. For this, we assume that the drop in consumption upon own-occupation disability is smaller or equal to the drop in consumption upon general disability. This is likely to hold, since individuals can still work in other occupations in the event of own-occupation disability, while general disability requires being unable to work in any occupation. The assumption implies $v_o(b_o, \Delta) \leq \frac{\pi_o}{\pi} v^{pre}$,[23] and in turn

$$v^{post} - \frac{\pi_g}{\pi} v^{pre} \geq v_o(0, \Delta) \tag{9}$$

Hence, the difference between post-reform willingness to pay and a fraction π_g/π of pre-reform willingness to pay provides an upper bound on valuations for own-occupation DI. Finally, the corresponding share of pre-reform willingness to pay can be interpreted as a lower bound on the valuation for top-up

[22] For simplicity, we drop type θ from the notation here.

[23] To see this, note that $v_o(b_o, \Delta) \approx \frac{\pi_o}{\pi} v^{pre}$ if the drop in consumption upon own-occupation and general disability was the same. If the drop in consumption upon own-occupation disability is smaller, insurance against this risk becomes less valuable, such that $v_o(b_o, \Delta) < \frac{\pi_o}{\pi} v^{pre}$.

insurance against general DI risk:

$$\frac{\pi_g}{\pi} v^{pre} \leq v_g(b_g, \Delta) \tag{10}$$

To empirically implement this decomposition, we construct pre-reform demand for private DI based on observed pre-reform take-up by risk group (see Appendix Figure A4), using the elasticity estimates from Section 5.2. Results from the decomposition are shown in Panel A of Appendix Table A8. We find a median valuation for own-occupation DI between 0.43% and 0.50% of lifetime income, and a lower bound on the valuation for top-up insurance against general DI risk of 0.43%. Thus, roughly half of the post-reform willingness to pay for private DI is attributed to insurance against own-occupation disability risk. Moreover, the estimates suggest that valuations for own-occupation DI decrease with risk groups, whereas general DI valuations tend to increase with risk groups. Panel B of the table additionally shows a decomposition of the cost of private DI into own-occupation DI and the general DI top-up. We calculate these costs analogously to equation (6), using observed shares of claims of the two types of DI. Since own-occupation DI accounts for a modest share of all claims (see Appendix Table A4), the expected cost of providing own-occupation DI is 0.19% of lifetime income, compared to 1.28% for general DI.

6 Welfare Effects of Privatizing Disability Insurance

6.1 Baseline Welfare Calculations

Based on demand and cost curves estimated in the previous section, we can assess welfare in the private DI market. As our main welfare measure, we define the *net value* of DI as its value to the insured relative to the cost to the insurer. In the private market where individuals have the choice whether to purchase DI coverage, the net value is given by

$$NV^{priv} = \frac{\sum_k n_k \left[\int v(\theta) \mathbb{1}(v(\theta) \geq p_k) dF_k(\theta) \right]}{\sum_k n_k \left[\int c(\theta) \mathbb{1}(v(\theta) \geq p_k) dF_k(\theta) \right]} \tag{11}$$

where n_k denotes the size of risk group k. In the market, the net value is thus given by the value of DI to those choosing to take it up, i.e. for whom $v(\theta) \geq p_k$, divided by the cost of providing DI to them. Since we estimate private DI valuations in the presence of baseline public DI coverage, NV^{priv} should be interpreted as the net value of extra coverage provided by the private market.

Our main counterfactual of interest is the introduction of an insurance mandate providing the level of coverage offered by the private DI market to all workers. Starting from the private market equilibrium, the net value of introducing the mandate is

$$\Delta NV^{mand} = \frac{\sum_k n_k \left[\int v(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \right]}{\sum_k n_k \left[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \right]} \tag{12}$$

A mandate ensures all individuals are covered, but it leads to some crowding out of existing private insurance. Individuals whose willingness to pay is above the market price already purchased private DI, and the mandate expands coverage to those individuals whose willingness to pay is below the market price.[24]

[24] In the absence of a private DI market, the net value of the mandate would be given by NV^{mand} =

Our net value measures express the value of providing insurance per Euro of spending, analogously to the marginal value of public funds (Finkelstein and Hendren, 2020; Hendren and Sprung-Keyser, 2020). A reform can be deemed welfare-improving if its net value is greater than one, i.e. it generates value exceeding its costs.[25] For our counterfactual, $\Delta NV^{mand} > 1$ would imply that mandating the coverage offered by private DI (on top of the existing baseline public DI coverage) is welfare-improving, while $\Delta NV^{mand} < 1$ would imply that providing this extra coverage via the private market is preferable.

These welfare effects can be graphically illustrated using the demand and cost curves estimated in Section 5.2. Panel (a) of Figure 8 depicts the net value provided by the private DI market for the case of risk group 3. The total area under the demand curve up to equilibrium take-up corresponds to the numerator in equation (11), and the area under the marginal cost curve corresponds to the denominator. In addition, the figure shows the standard decomposition of willingness to pay into consumer surplus (area A between willingness to pay and the price), producer surplus (area B between the price and marginal cost) and cost (area C below the marginal cost curve). Thus, net value in the private DI market is the sum of areas A, B and C divided by total cost C. Appendix Figure A5 shows analogous graphs for all risk groups. The private DI market generates a surplus, as those individuals with the highest willingness to pay choose to purchase private DI. Consumer surplus is particularly large in risk groups 1 and 2, where individuals exhibit the highest valuations of insurance. Producers receive the largest surplus from risk groups 1, 4 and 5, where markups are highest.

Panel (b) of Figure 8 illustrates the welfare effects of introducing a mandate starting from the private market, again for the case of risk group 3. Insuring all individuals entails additional costs given by the area under the cost curve between equilibrium take-up and complete take-up of 100%. This corresponds to the sum of areas F and G. Expanding insurance to additional consumers yields value $D + G$, but they have to pay premiums equal to areas $D + E + F + G$, implying a net loss in consumer surplus of $-(E + F)$. Insurers, on the other hand, gain surplus equal to area $D + E$. Thus, the overall net value of the mandate is given by $D + G$ relative to $F + G$, which is clearly below one. Appendix Figure A6 shows corresponding graphs for all risk groups. The net value of a mandate is below one for all groups except risk group 1. Mandating private DI coverage would have sizable negative welfare effects for higher risk groups in particular, since the observed willingness to pay is low relative to cost for most individuals in these groups.

Panel A of Table 4 shows results of our baseline net value calculation based on equation (12). We find a net value of introducing a private DI mandate of 0.76. In a way, this result is not too surprising given our empirical findings. First, we do not find adverse selection, which would lead to inefficiently low insurance take-up in the private market, and which is often considered a key rationale for a mandate. Second, insurance premiums are only somewhat above marginal costs for most risk groups. Accordingly, the private DI market seems to cover the majority of individuals whose willingness to pay is above the cost of insuring them. Third, the value of own-occupation DI revealed by insurance choices appears to be low for many individuals, especially in the higher risk groups. This is reflected

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$\frac{\sum_k n_k \left[\int v(\theta) dF_k(\theta) \right]}{\sum_k n_k \left[\int c(\theta) dF_k(\theta) \right]}$.

[25] Instead of dividing the value of insurance by its cost, we could alternatively calculate the difference between the two. In this setting, we prefer to take the net value as the ratio of the two, since the resulting numbers are unit-free and easily interpretable.

both by the low general level of willingness to pay and by the sizable demand elasticities, which imply that the valuation of insurance declines fast among the uninsured.

Overall, our baseline welfare calculations suggest that starting from a full public DI mandate, partly privatizing DI is welfare-improving. Conceptually, these results are closely related to the reform of 2001, which privatized insurance against own-occupation disability. However, it is important to note that the counterfactual should be interpreted as a broader reform, removing own-occupation risk coverage while also cutting benefit levels.[26] In the following sections, we consider two extensions that may justify a full mandate, namely equity concerns and risk misperceptions.

6.2 The Social Value of a DI Mandate

A first potential rationale for mandating additional DI coverage may be equity concerns. Recall that the private DI market disproportionately covers high-income and low-risk individuals. A mandate would extend coverage to more low-income and high-risk individuals, on whom a social planner concerned with equity may place particular weight. In order to account for such distributional issues, we write the social net value of introducing a mandate as

$$\Delta SNV^{mand} = \frac{\sum_k n_k \Big[\lambda_k \overbrace{\int (v(\theta) - p_k)\, \mathbb{1}(v(\theta) < p_k) dF_k(\theta)}^{\text{Consumer surplus}} + \overbrace{\int p_k \mathbb{1}(v(\theta) < p_k) dF_k(\theta)}^{\text{Insurer revenue}}\Big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta)\big]} \tag{13}$$

The first term in the numerator captures the additional net utility individuals in risk group k derive under a mandate, corresponding to their valuation minus the price. The total change in consumer surplus among risk group k is multiplied by λ_k, the social welfare weight on individuals in this group. The second term in the numerator reflects additional revenue to the insurer, corresponding to the sum of producer surplus and cost in Figure 8. Like our baseline measure, the social net value then relates these two components to the change in the cost of providing insurance.[27]

Equation (13) considers a private insurance mandate where individuals are compelled to purchase private DI at market prices. However, in our setting, extra DI coverage was part of the social insurance system before the reform of 2001, where employed individuals are mandated to participate and pay social insurance contributions rather than risk-based premiums. In order to evaluate such a public insurance mandate, we have to take into account that contributions may differ from market prices p_k:

[26] The main reason why we focus on the counterfactual corresponding to a broader reform is that most of our empirical results apply to the DI coverage offered by the private market. This allows us to credibly calculate the welfare effects of different ways of providing this coverage, while analyzing the welfare effects of sub-components would require additional assumptions.

[27] Both insurer revenue and cost carry a weight of one, corresponding to the average social welfare weight in the population.

$\Delta SNV^{pub} =$

$$\frac{\sum_k n_k \left\{ \lambda_k \left[\int (v(\theta) - p_k) \, \mathbb{1}(v(\theta) < p_k) dF_k(\theta) + \overbrace{\int (p_k - p_k^{pub}) dF_k(\theta)}^{\text{Pricing effect}} \right] + \int p_k^{pub} \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \right\}}{\sum_k n_k \left[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \right]} \tag{14}$$

where p_k^{pub} denotes contributions paid by individuals in risk group k. Compared to equation (13), a public insurance mandate thus entails an additional pricing effect, where all individuals experience a change in surplus equal to the difference between private market premiums and social insurance contributions. In particular, we consider two scenarios of public mandates. On the one hand, the government may insure everyone in a public DI system with lump-sum contributions irrespective of risk and income. We calculate the required level of lump-sum contributions as the average cost of providing coverage equivalent to private DI across all risk groups. On the other hand, contributions could be income-based. This reflects the situation in typical real-world social insurance systems, where contributions are levied as a proportion of an individual's gross income. Again, we calculate the required contribution rate such that total contributions equal the cost of providing insurance to all individuals.

In order to obtain welfare weights, we require a social welfare function. As is common in the literature, we assume a Utilitarian social welfare function, such that welfare weights are given by the marginal utility from consumption in each group. Moreover, we assume constant relative risk aversion (CRRA) utility $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ with marginal utility $u'(c) = c^{-\sigma}$, where σ is the coefficient of relative risk aversion. We then calculate social welfare weights for each risk group based on average expected lifetime income in that group, scaled such that the average weight in the population is equal to one. Appendix Table A9 shows average income and resulting social welfare weights by risk group. Expected income decreases monotonically with risk groups. On average, individuals in risk group 1 earn more than double the income of those in risk group 5. We consider a range of values of risk aversion between 1 and 8, where higher σ entails higher relative welfare weights on higher-risk groups. In addition, we show results under a more extreme variant of equity concern given by Rawlsian social preferences, where the planner only places weight on the worst-off individuals in risk group 5.

Panel B of Table 4 shows results from the social net value calculations. Column (1) suggests that a private DI mandate would lower welfare, regardless of the degree of equity concern. In fact, stronger equity concern decreases the social net value of a private DI mandate. This occurs because a private DI mandate is a regressive policy. As can be seen in Appendix Figure A6, forcing all individual to purchase insurance at market prices entails larger reductions in consumer surplus among higher risk groups, since they have to pay higher prices relative to a low revealed willingness to pay. Column (2) shows welfare effects of a public DI mandate with lump-sum contributions. Note that for our baseline net value without social welfare weights, pricing in an insurance mandate leaves welfare unchanged, as it does not affect total of surplus but only its distribution. However, with sufficient equity concern, a public DI mandate with lump-sum contributions can improve welfare relative to the private market. We find that for σ between 2 and 3, the social net value of such a mandate becomes greater than one. Intuitively, lump-sum contributions imply redistribution towards higher-risk individuals on whom the planner places greater weight since they have lower expected lifetime income. In Column (3), this redistributive effect is exacerbated in the scenario with income-based contributions. Since lower-risk groups have higher average income, they now have to pay the highest contributions. Thus, the social insurance system with income-based contributions raises revenue from low-risk, high-income groups, and redistributes towards high-risk, low-income groups by providing them with additional insurance at premiums below risk-based market prices. This redistribution is highly valued by a social planner with equity concern. Even under low risk aversion given by σ=1, the social net value of the DI mandate with income-based contributions is above 1. For σ=3, the social net value is 1.74, and under a Rawlsian social welfare function the social net value is 2.33.

We conclude that equity concern can provide a rationale for including the DI coverage currently offered by the private market in the public DI mandate. For such a reform to improve social welfare, it is crucial to implement non-risk based contributions as is done in real-world social insurance systems. Instead enforcing a private insurance mandate would entail even greater welfare losses in the presence of equity concern than under pure efficiency considerations.

6.3 Risk Misperceptions

A second potential rationale for policy interventions in the DI market could be given by behavioral frictions. So far, our welfare analysis assumes that individuals make optimal insurance purchase decisions, such that we can interpret observed private DI demand as indicative of individuals' true valuations. However, a growing literature documents behavioral frictions in insurance choices (e.g. Ericson and Sydnor, 2017; Chandra et al., 2019). In our setting, two observations point towards a role for such choice frictions. First, private DI take-up is positively correlated with education and economic training, conditional on income, risk and other observables. Thus, low take-up may be concentrated among individuals with low financial literacy who are less likely to make optimal insurance choices. Second, higher-risk groups who are charged higher insurance premiums are less likely to take up private DI. Accordingly, we find in Section 5.2 that willingness to pay for insurance does not increase with risk. Indeed, a number of surveys suggest that most German workers tend to underestimate disability risk (e.g. (Continentale, 2019; SwissLife, 2021)) , implying that they likely undervalue insurance.

The main empirical challenge is to disentangle such behavioral biases from variation in true risk preferences. Workers in higher risk groups may exhibit low willingness to pay for insurance because they misperceive their disability risk, or due to low risk aversion. In this section, we present calibration exercises approaching this challenge in three steps. First, we calibrate risk preferences implied by observed insurance purchase decisions in each risk group, and we argue that risk aversion appears to be implausibly low for many workers. Second, we calibrate a simple model of risk misperceptions which can rationalize low willingness to pay for insurance in higher risk groups. Third, we calculate the wedge between observed willingness to pay (with misperceptions) and normative willingness to pay (without misperceptions), and re-do welfare calculations based on normative valuations.

We begin by asking what level of risk aversion would be implied by observed insurance purchase decisions in each risk group. Individuals buy insurance if the discounted expected utility with insurance V_1 exceeds utility without insurance V_0. We can write an indifference condition for the marginal individual purchasing insurance as

$$\underbrace{\sum_{t=0}^{T}\delta^t\left[(1-\Pi_t)u(c_H^0)+\Pi_t u(c_L^0)\right]}_{V_0\text{ (utility without DI)}}=\underbrace{\sum_{t=0}^{T}\delta^t\left[(1-\Pi_t)u(c_H^1)+\Pi_t u(c_L^1)\right]}_{V_1\text{ (utility with DI)}} \tag{15}$$

where T is the end date of the insurance contract relative to start date normalized to zero, Π_t is cumulative disability risk in period t and δ^t is a discount factor. c_H^0 and c_L^0 denote consumption levels when not disabled (H) and disabled (L), respectively, without insurance, and c_H^1 and c_L^1 denote the corresponding consumption levels with insurance.

For the calibration, we assume again CRRA preferences $u(c)=\frac{c^{1-\sigma}}{1-\sigma}$ and we plug in average income, insured benefits, contract duration, and cumulative risk paths by risk group. Furthermore, differences in consumption levels across disabled and non-disabled states are a crucial input for the calibration. Incomes can be written as $y_H^0=w$, $y_L^0=\underline{y}_0$, $y_H^1=w-p$ and $y_L^1=\underline{y}_1+b$, where w is the individual's wage, $\underline{y}_0$ is an income floor for uninsured individuals, p is the insurance premium, b is the insured benefit, and $\underline{y}_1$ is the income floor for insured individuals (which may differ from $\underline{y}_0$, for instance due to a means test). We consider a range of consumption scenarios. To begin with, we consider hand-to-mouth consumers whose consumption equals income in each state, either with or without a consumption floor given by basic social assistance. In addition, we use estimates of the drop in consumption upon disability based on Meyer and Mok (2019).[28]

Under these assumptions, we can calibrate risk aversion σ of the marginal buyer in each risk group. Results are shown in Appendix Table A10. It is important to note that the marginal buyer whose risk aversion is calibrated at very different percentiles of willingness to pay for DI across risk groups, as shown in Panel A. For instance, 68% of individuals in risk group 1 take up private DI and thus the marginal buyer is at the 32nd percentile of willingness to pay, whereas in risk group 5 take-up is only 7% such that the marginal buyer is at the 93rd percentile. In Panel B, depending on the assumption about consumption levels, we find implied risk aversion coefficients between 0.44 and 3.03 for the marginal individual in risk group 1. In the remaining risk groups, especially in groups 2 to 4, risk aversion implied by observed insurance take-up is considerably lower between 0.03 and 1.34. Interestingly, risk aversion does not appear to decrease monotonically with risk groups. Calibrated risk aversion in group 2 is particularly low, which is due to insurance premiums being close to actuarially fair for this group, such that even under modest risk aversion insurance take-up should be higher than the observed rate. We also note that risk aversion of the marginal buyer in group 5 is higher than in groups 2 to 4. In principle, insurance should be highly valuable to these high-risk individuals, but this is counteracted by two forces. First, insurance premiums for risk group 5 are high, even relative to their high disability risk, and second, basic social assistance provides sizable insurance against inability to work in the absence of formal DI given their low average income. Finally, a direct comparison of the risk aversion estimates across groups is complicated by the fact that the marginal buyer in the high

[28] An important issue with the consumption drop estimates from Meyer and Mok (2019) is that these are reported for individuals covered by disability insurance. We are not aware of any estimates of the consumption drop upon disability in the absence of insurance. Thus, we choose two estimates from Meyer and Mok (2019) that may come closest to consumption drops without insurance. The first is their finding of a 77% drop in earnings before public transfers upon long-term disability. Second, Meyer and Mok (2019)) report a drop in income after public transfers of 28% and a corresponding drop in consumption of 25%, while the income drop before public transfers is 53%. A back-of-the-envelope calculation results in a hypothetical drop in consumption without public transfers of 53%·25%/28%=47%.

risk groups is at very high percentiles of willingness to pay. For instance, the risk aversion estimates of 0.26 to 1.87 in risk group 5 must be interpreted in the sense that 93% of individuals in this group have risk aversion of *at most* 0.26 to 1.87, whereas the risk aversion of 0.44 to 3.03 in risk group 1 applies to an individual closer to the median among this group. Overall, observed insurance choices would imply very low risk aversion for many individuals, especially in risk groups 2 to 4. The implied values for the coefficient of relative risk aversion are considerably lower than most estimates from the literature on insurance choices.[29]

In the second calibration step, our goal is to investigate whether risk misperceptions can rationalize low willingness to pay for DI exhibited by many individuals. We denote individuals' perceived disability risk by $\hat{\Pi}_t \neq \Pi_t$. In particular, we consider risk misperceptions of the form $\hat{\Pi}_t = \alpha \Pi_t$, where α denotes the degree of bias. The indifference condition governing insurance choice of the marginal buyer is

$$\underbrace{\sum_{t=0}^{T} \delta^t \left[(1 - \hat{\Pi}_t) u(c_H^0) + \hat{\Pi}_t u(c_L^0) \right]}_{V_0(\hat{\Pi}_t)} = \underbrace{\sum_{t=0}^{T} \delta^t \left[(1 - \hat{\Pi}_t) u(c_H^1) + \hat{\Pi}_t u(c_L^1) \right]}_{V_1(\hat{\Pi}_t)} \tag{16}$$

Under the assumptions on the utility function and consumption levels described above, we can use equation (16) to calibrate α for the marginal buyer in each risk group. However, we additionally require a benchmark level of risk aversion. To obtain this, we assume that risk group 1 perceives disability risk correctly, and that other groups have the same true risk aversion as group 1 where we found values of σ between 0.44 and 3.03. Panel C of Appendix Table A10 shows resulting estimates of α. Under virtually all specifications, we find that individuals in risk groups 2 to 5 substantially underestimate their disability risk. The proportional underestimation reflected by α is roughly between 30% and 60% in most specifications. Only under hand-to-mouth consumption and basic social assistance, risk groups 4 and 5 is found not to underestimate risk. We conclude that even under modest levels of true risk aversion, risk misperceptions can explain low observed valuations of DI.

In the third step, we calculate the wedge between observed willingness to pay and normative willingness to pay implied by these risk misperceptions. Observed willingness to pay is implied by the indifference condition ((16)), and corresponds to the empirical willingness to pay of the marginal buyer. Normative willingness to pay, on the other hand, is implied by $V_0(\Pi_t) = V_1(\Pi_t)$, that is the hypothetical indifference condition of the marginal buyer without any risk misperception. Panel D of Appendix Table A10 shows estimated ratios between normative and observed willingness to pay. The results suggest that the true value of insurance to marginal buyers is up to 2.6 times higher than the valuation implied by observed choices. In line with the misperception results, we find that undervaluation tends to be most severe among risk groups 2 to 4.

Finally, we return to our welfare calculations. We can interpret the above results as an internality, where individuals do not internalize the full value of DI. In Panel C of Table 4, we show results from net value calculations based on equation (11), where we replace observed demand $v(\theta)$ in each risk group by normative valuations implied by the results from Panel D of Appendix Table A10. We find a net value of mandating private DI coverage between 1.10 and 1.51. In other words, average normative

[29] Studies on insurance choices typically yield larger estimates of risk aversion ranging between 2 and 8 (e.g. French, 2005; Lockwood, 2018; Jacobs, 2020; Landais et al., 2021) and some work implies much larger values (e.g. Cohen and Einav, 2007; Sydnor, 2010). Seitz (2021) estimates a coefficient of around 6 in the German setting, which is identified based on observed asset holdings.

valuations exceed the cost of providing insurance for individuals who choose not to buy private DI in the market. Hence, risk misperceptions can provide an additional rationale for mandating the coverage currently offered by the private DI market.

6.4 Extensions and Robustness

Our main welfare calculations compare the value to the direct cost of providing extra DI. However, there could be various types of indirect costs associated with increasing DI coverage via a mandate. In this section, we present extensions of the welfare analysis taking into account such indirect costs in the spirit of a more complete marginal value of public funds calculation. Overall, we find that allowing for indirect costs does not lead to any substantial changes in our main results.

To begin with, mandating extra DI coverage is likely to impose additional moral hazard costs onto the public baseline insurance, as it includes top-up insurance in case the worker also qualifies for public general DI benefits. To quantify this channel, we use the estimate of Seitz (2021) who finds that taking up private DI increases public DI claims by 4pp. (16%) in the German setting. As shown in Panel A of Appendix Table A11, taking into account this additional moral hazard lowers the net value of a mandate. A second indirect cost may arise when a public DI mandate is financed by income-based payroll taxes, which distort behavior. Thus, a standard fiscal externality from additional payroll taxes may arise. We calibrate this channel based on the Harberger triangle calculation of Feldstein (1999), where we assume an elasticity of taxable income of 0.3. We use the ZEW microsimulation model (ZEW-EviSTA) to calculate marginal and average tax rates faced by individuals in each risk group. In Panel B of the table, the distortion from raising contributions again lowers the net value of a public DI mandate. We note that this fiscal externality likely provides an upper bound, as some studies suggest that social insurance contributions induce much smaller fiscal externalities than income taxes (e.g. Lehmann et al., 2013).

Moreover, providing additional DI could impose a positive fiscal externality on other social programs. In particular, covering all workers with own-occupation DI may reduce their propensity to claim basic social assistance in the case of a disability. We incorporate this externality in Panel C, which shows that the net value of mandating private DI increases. The change in net value is small, however, since social assistance is relatively low in the German setting and for many claims baseline public DI is still available. Finally, Panel D shows the combined effect of all these indirect effects. Qualitatively, results remain very similar to the baseline calculations. Quantitatively, the net value of a full public DI mandate becomes somewhat smaller, such that a higher degree of equity concern (σ around 3) would be needed to justify the mandate.

As a further robustness exercise, we allow for some risk-based selection in the private DI market. We do not find significant selection in Section 4.3 and thus argue that cost curves are flat in the main welfare analysis. However, the estimation results shown in Figure 5 carry some statistical noise, such that we cannot exclude some degree of selection. To quantify the range of potential slopes of cost curves, we invert the specification from equation (3), regressing claiming probabilities on take-up within risk groups. We find a point estimate of -0.3pp., with a 95% confidence interval between -2.8pp. and +2.3pp. These results imply small degrees of selection. The point estimate corresponds to a -1.0% difference in claims between individuals with and without private DI, and the confidence interval includes adverse selection with a 9.3% difference in claims up to advantageous selection with a -11.4% difference. In Panels E and F of Table A11, we replicate the welfare analysis under these statistical bounds on selection. Adverse selection somewhat increases the net value of a mandate and advantageous selection somewhat decreases it, but the results are qualitatively unaffected by the small degrees of selection we cannot exclude.

7 Conclusion

In this paper, we provide novel empirical evidence on the functioning of private DI markets. We show significant crowding-in of private DI when the scope of public DI is reduced, but overall take-up remains relatively modest. In particular, high-risk, low-income and low-education individuals are less likely to take-up private insurance. Yet, we do not find any evidence of adverse selection on unpriced risk. Our welfare analysis highlights the policy implications of these findings. If observed willingness to pay reflects individuals' true valuation of DI, providing extra DI coverage via a private DI market with choice is welfare-improving compared to a full mandate. However, equity concerns provide a potentially important rationale for a public DI mandate, as this would lead to additional coverage predominantly for low-income and high-risk individuals. In addition, we argue that risk misperceptions could explain low observed demand for DI of many workers, which may provide further grounds for policies increasing take-up such as a mandate.

To our knowledge, the German setting is unique in that one branch of the public DI mandate was fully removed. This allows us to provide first-time evidence on partly replacing public DI with a private insurance market. However, a key issue to bear in mind is that our empirical results are specific to to the type of coverage offered by private DI in this setting, combining insurance against own-occupation disability and more general top-up insurance. In principle, one could think of similar reforms privatizing insurance against other sub-risks of disability, such as insurance against short-term disability or against disability due to selected types of medical conditions. But of course our findings cannot simply be extrapolated to privatizing any part of DI coverage. Nevertheless, we believe the issues studied in this paper are likely to be relevant for other DI reforms aimed at an increased role of private insurance. Further research in this area will be highly valuable, as many governments are implementing reforms cutting public DI generosity.

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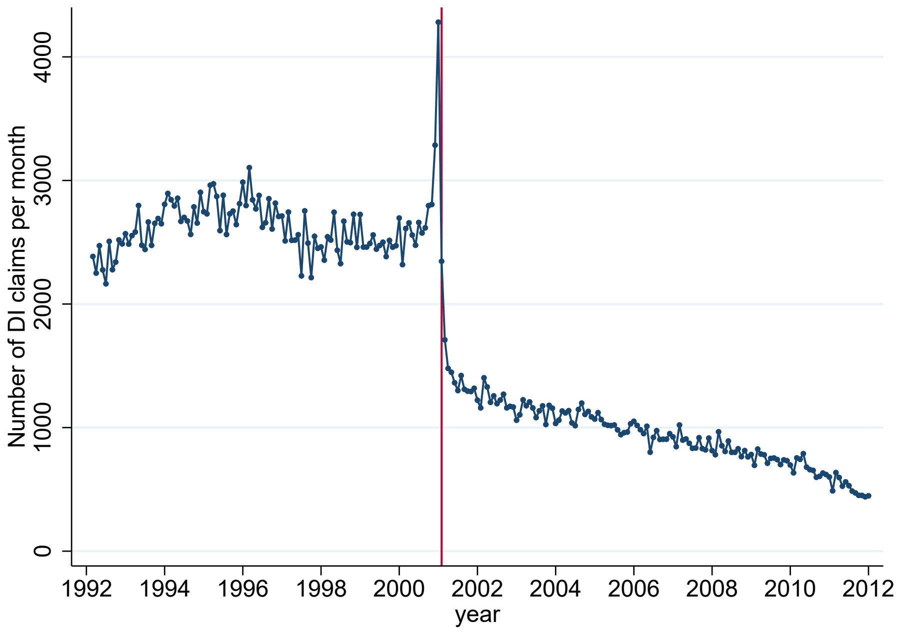
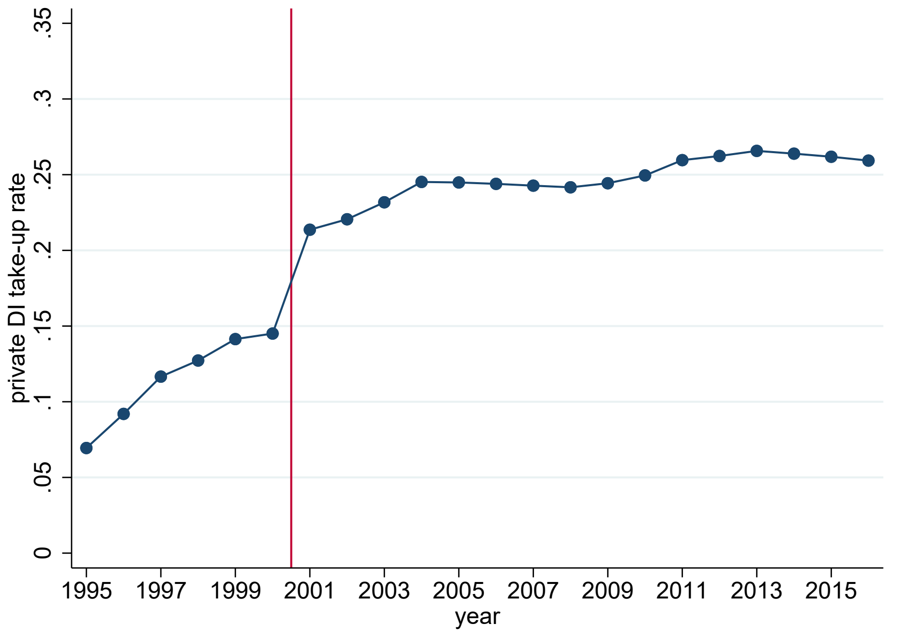
Figure 1: Crowding-In: Descriptive Evidence

(a) Public Own-Occupation DI Claims



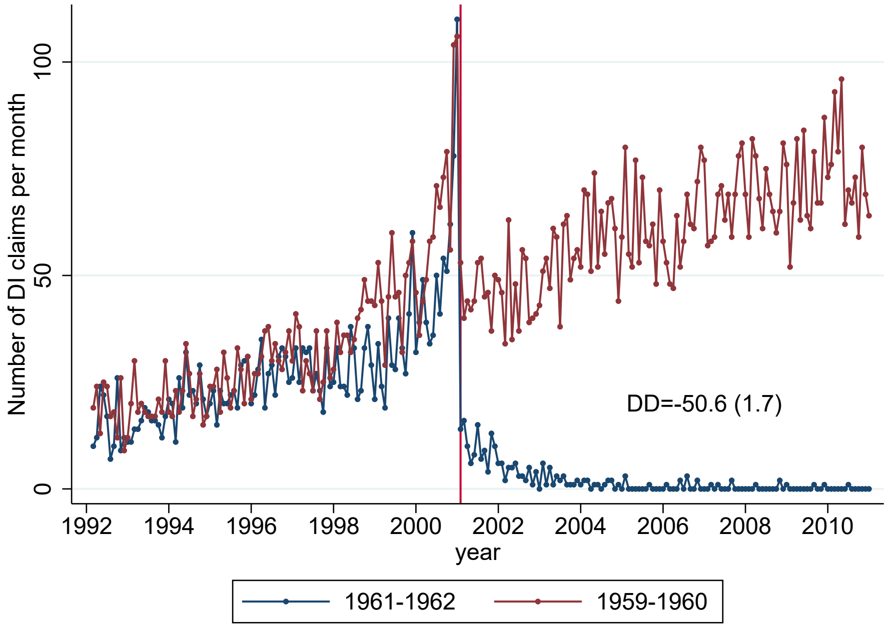
(b) Private DI Take-Up



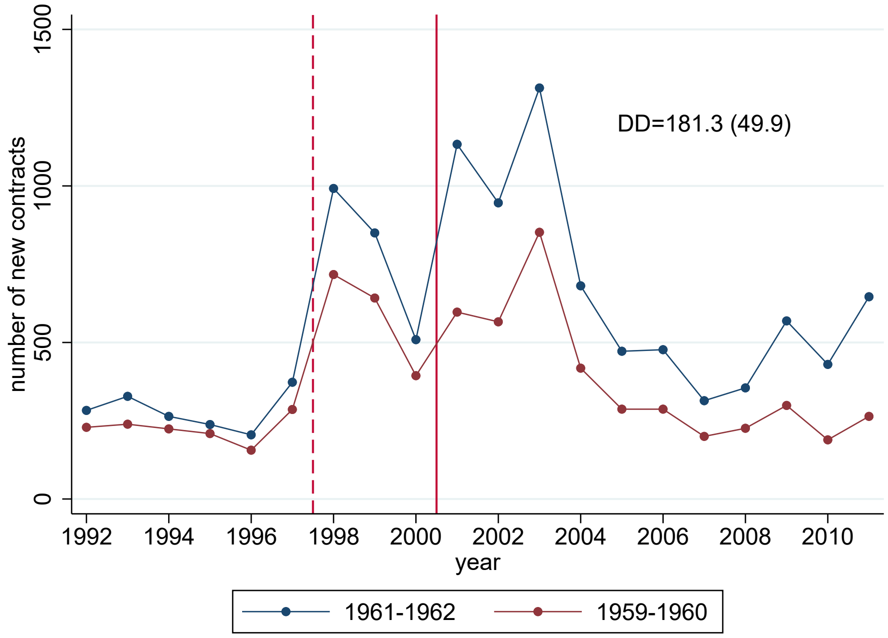
Notes: The figure shows the total number of public own-occupation DI claims (Panel a) and the overall private DI take-up rate (Panel b). In both panels, the vertical line denotes the time the reform of 2001 takes effect (January 2001).

Figure 2: Crowding-In: Difference-in-Differences

(a) Public Own-Occupation DI Claims

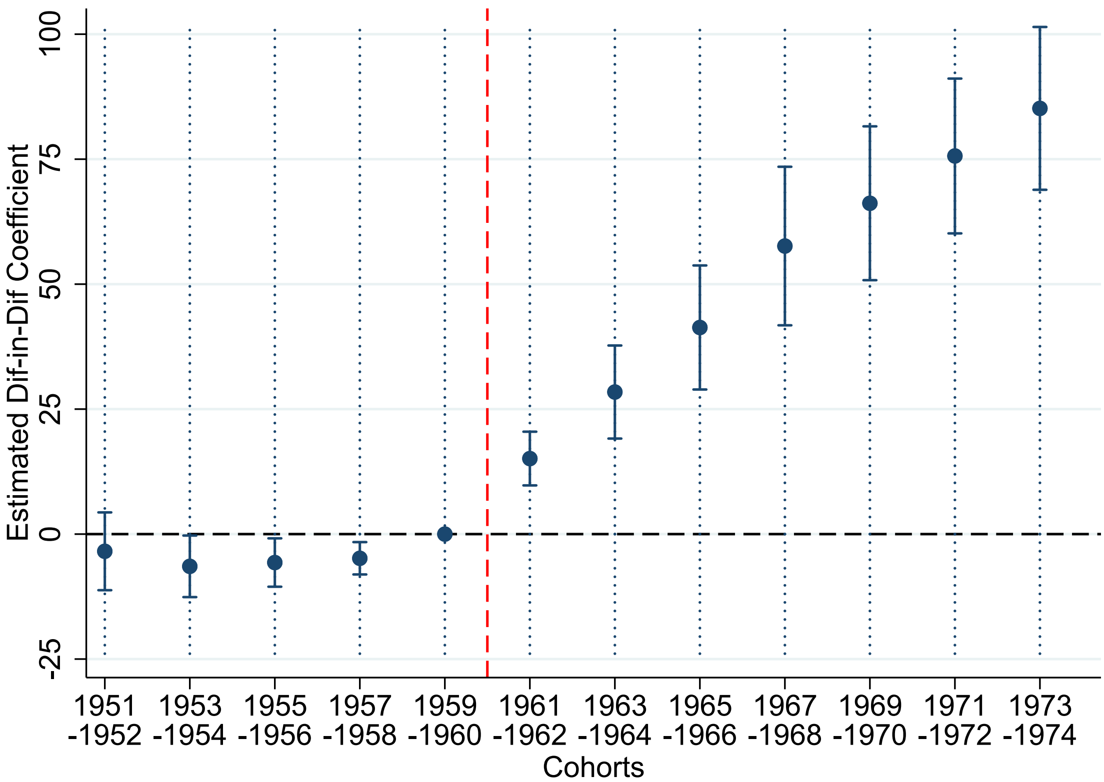


(b) Private DI Purchases



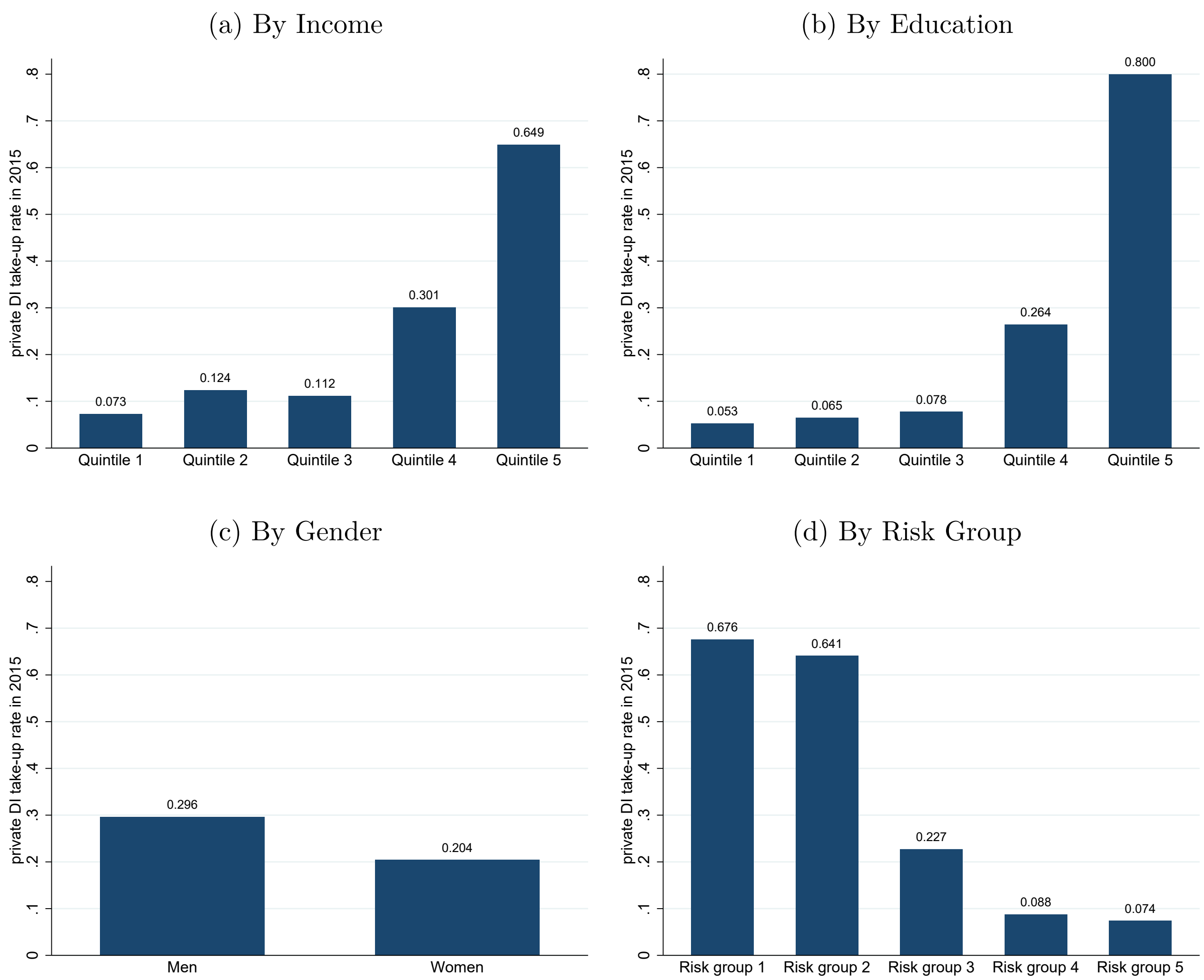
Notes: The figure shows the number of public own-occupation DI claims (Panel a) and private DI purchases (Panel b) of individuals born in 1961-1962 (treated cohorts) vs. 1959-1960 (control cohorts). In both panels, the solid vertical line denotes the time the reform of 2001 takes effect (January 2001). In Panel (b), the dashed vertical line additionally demarcates the time the reform is first announced (December 1997). *DD* denotes the difference-in-difference coefficient estimated for the respective outcome with standard errors in parentheses (see Table 2 for details).

Figure 3: Difference-in-Difference Effects by Cohort



Notes: The figure shows difference-in-difference coefficients for a range of cohorts. The estimates correspond to coefficient β_2 from equation (1), where the treatment group is given by the cohorts reported on the horizontal axis. Point estimates are shown along with 95% confidence intervals. The vertical line denotes the cohort cutoff of the reform of 2001, where all cohorts to the right are affected by the reform.

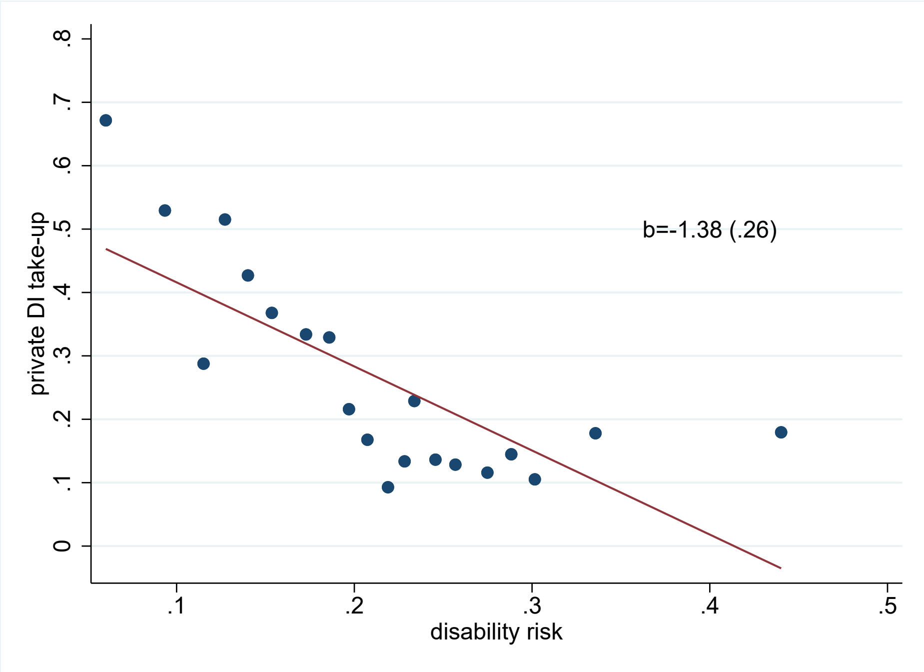
Figure 4: Private DI Take-Up by Observable Characteristics



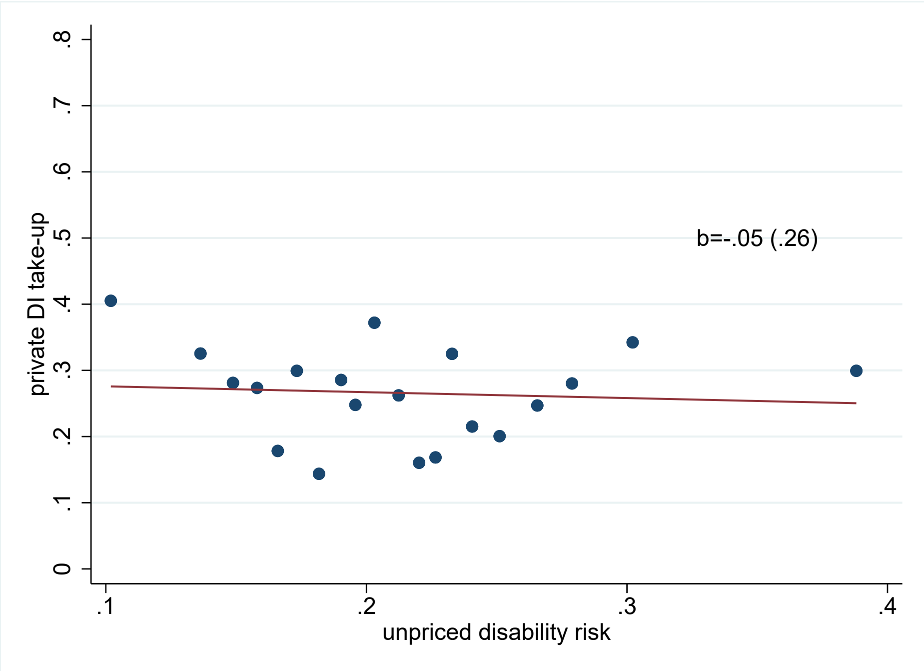
Notes: The figure shows private DI take-up rates in 2015 by income quintile (Panel a), education quintile (Panel b), gender (Panel c) and risk group (Panel d). In Panel (b), education is defined as years of schooling. All take-up rates are calculated as shown in equation (2).

Figure 5: Risk-Based Selection

(a) Unconditional Correlation of Take-Up and Risk



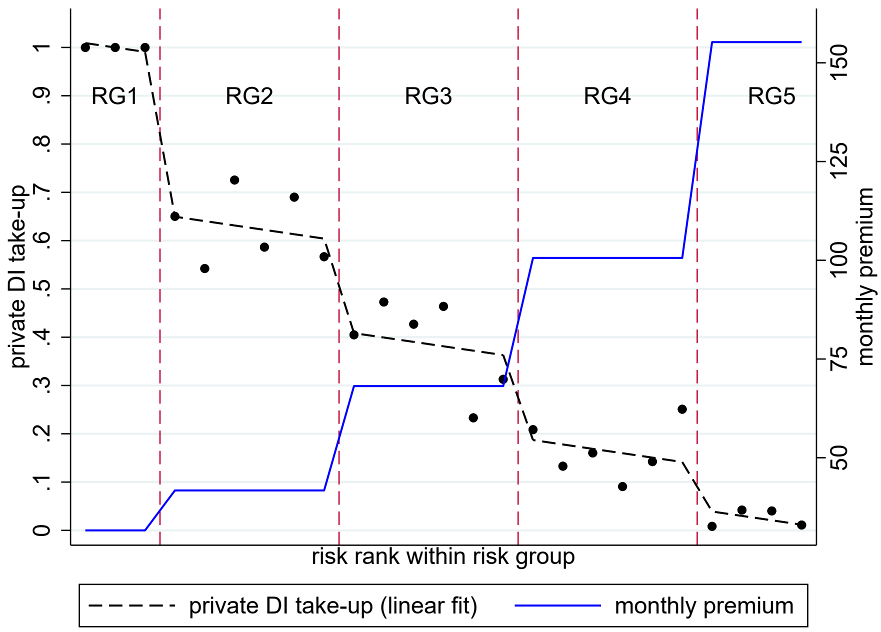
(b) Selection on Unpriced Risk



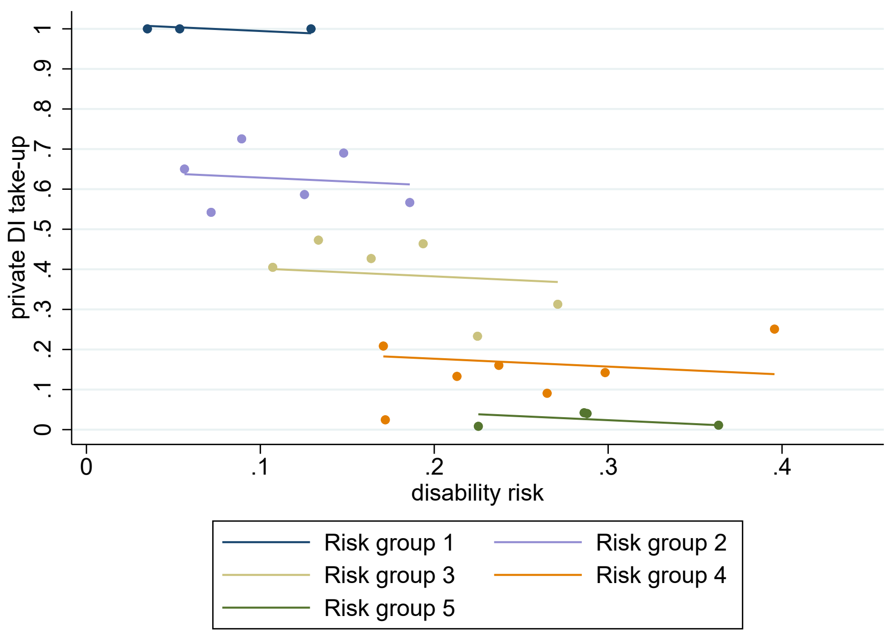
Notes: The figure shows binned scatterplots of the correlation between private DI take-up in 2015 and disability risk at the three-digit occupation level. Panel (a) shows the unconditional correlation between take-up and risk, corresponding to estimating equation (3) without controlling for risk groups. Panel (b) shows the correlation between take-up and unpriced risk, controlling for risk groups.

Figure 6: Demand Responses to Insurance Prices

(a) Take-Up vs. Price by Risk Ranks

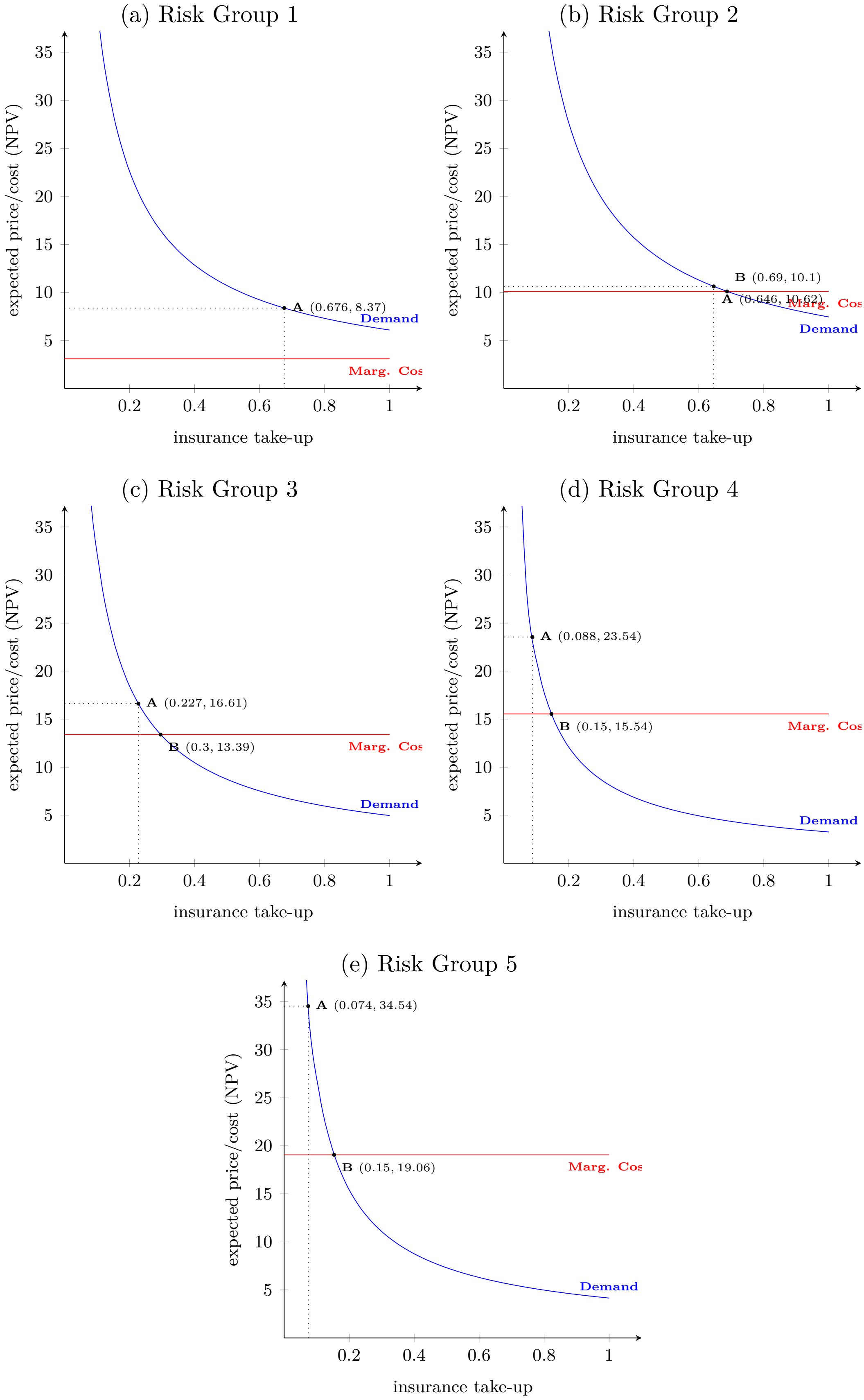


(b) Take-Up by Actual Risk



Notes: The figure presents evidence of demand responses to insurance premiums. In Panel (a), we rank three-digit occupations by disability risk within risk for a stylized depiction of jumps in premiums and take-up rates between risk groups. The blue line shows monthly private DI premiums, which increase discontinuously at the risk group boundaries. The black dots denote average private DI take-up in risk bins, and the dashed black line shows a linear fit within risk group. Panel (b) shows binned scatter plots of private DI take-up by disability risk at the three-digit occupation level, corresponding to the regression shown in equation (4).

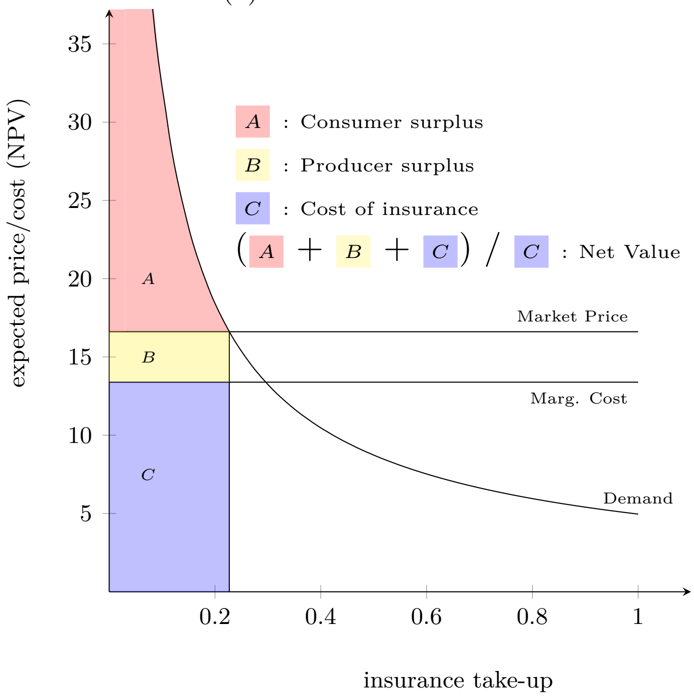
Figure 7: Demand and Cost Curves



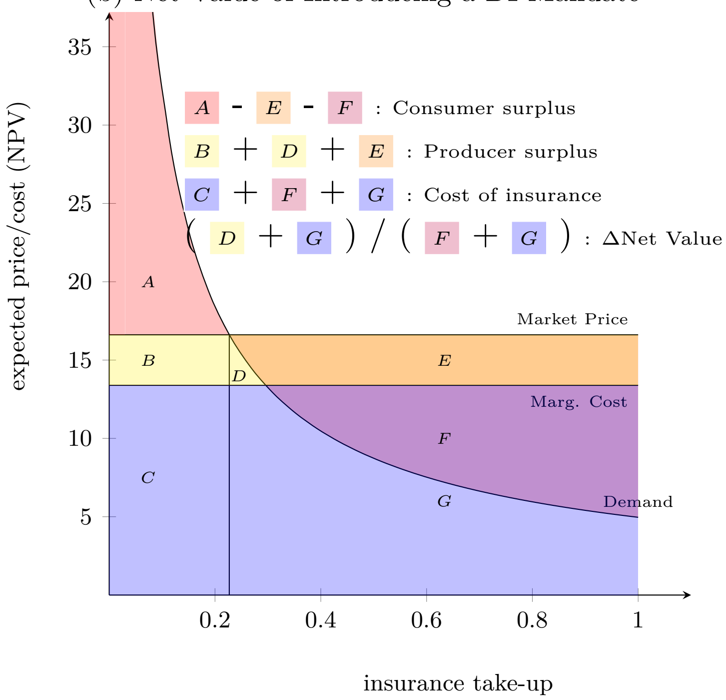
Notes: The figure presents own-occupation DI demand and cost curves estimated as described in Section 5.2. The horizontal axes display private DI take-up rates between zero and one, and the vertical axes show expected prices and cost as defined in equations (6) and (7). Each panel shows the demand curve (blue line) and the marginal/average cost curve (red line) for the risk group indicated in the panel title. Points A denotes the private market equilibrium in each risk group, with associated insurance take-up and price in parentheses. Points B denote the points of intersection of demand and marginal cost curves, associated take-up and price in parentheses.

Figure 8: Welfare Calculations

(a) Private DI Market



(b) Net Value of Introducing a DI Mandate



Notes: The figure illustrates our welfare calculations for the case of risk group 3. Panel (a) depicts welfare in the private DI market equilibrium, where the net value is given by the total area under the demand curve $(A+B+C)$ divided by the area under the cost curve (C). Panel (b) illustrates the net value of introducing a DI mandate. The mandate increases DI take-up from the market equilibrium to 1. The net value of the reform is given by the additional area under the demand curve $(D+G)$ divided by the additional cost $(F+G)$. In both panels, net value can be further decomposed as explained in the respective legend. See Appendix Figures A5 and A6 for graphs for all risk groups.

Table 1: Summary Statistics

Panel A: Insurer Microdata on Private DI Contracts

	(1) Full Sample	(2) Cohorts 1959-1962
Male	0.61	0.71
	(0.49)	(0.45)
Income (monthly)	4132.05	4422.10
	(1385.57)	(1364.61)
Education (years)	12.42	12.22
	(1.97)	(2.03)
Risk Group	1.96	2.55
	(1.13)	(0.92)
Age at Purchase	29.79	40.79
	(7.81)	(4.95)
Age at Contract End	62.53	60.18
	(3.75)	(2.77)
Insured Benefits (monthly)	1377.72	1553.75
	(913.28)	(1242.95)
Insurance premium (monthly)	77.82	106.67
	(51.86)	(77.50)
Stand-Alone DI contract	0.55	0.57
	(0.50)	(0.50)
Observations	*confidential*	18,659

Panel B: Public DI Administrative Data

	(1) All DI Claims	(2) Own-Occupation DI Claims	(3) Cohorts 1959-1962
Male	0.59	0.82	0.53
	(0.49)	(0.39)	(0.50)
Married	0.66	0.77	0.51
	(0.47)	(0.42)	(0.50)
Benefit claiming age	51.80	53.84	43.34
	(7.66)	(6.32)	(5.52)
Monthly benefit (Euros)	1,077.85	867.57	856.94
	(606.83)	(500.49)	(433.90)
Average monthly earnings before claim	2,304.71	2,737.17	2,164.25
	(1,109.40)	(1,010.85)	(1,230.59)
Monthly earnings in year before claim	1,306.87	1,536.96	1,217.28
	(1,026.46)	(1,101.52)	(1,005.15)
Education (years)	10.39	10.35	10.64
	(1.19)	(1.11)	(1.48)
Observations	4,138,105	411,141	304,095

Notes: The table presents summary statistics of the insurer microdata (Panel A) and the administrative data on public DI claims (Panel B). In Panel A, "risk group" denotes risk groups assigned by the insurer to individuals based on their occupation. "Stand-Alone DI contract" denotes whether a contract was purchases on its own or in a bundle with other insurance products. Number of observations refers to number of private DI contracts, which we cannot show for the full sample due to confidentiality reasons. In Panel B, number of observations refers to number of DI claims.

Table 2: Crowding-In: Difference-in-Differences

	(1)	(2)	(3)	(4)	(5)
	Public DI Claims		Private DI Contracts		
	Own-Occupation DI Claims	All Public DI Claims	Number of Purchases: All Contracts	Number of Purchases: Stand-Alone	Insured Benefits (All Contracts)
Treated×post	-50.57***	-110.2***	15.11***	13.22***	-462.2
	(1.710)	(6.355)	(2.739)	(1.676)	(384.1)
Observations	480	480	480	480	480
R-squared	0.935	0.990	0.939	0.939	0.926
Mean (pre-reform)	26.70	410.4	23.49	6.640	10,236
Calendar month FE	yes	yes	yes	yes	yes

Notes: The table shows results from the difference-in-difference regressions as described by equation (1). Regressions are run at the level of cohort × calendar month cells. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3: Demand Elasticity Estimation

	(1) Average	(2) Groups 1-2	(3) Groups 2-3	(4) Groups 3-4	(5) Groups 4-5
dp/p	0.398	0.246	0.439	0.370	0.536
dQ/Q					
Without controls	-0.675	-0.563	-0.495	-0.814	-0.829
	(0.051)	(0.133)	(0.152)	(0.153)	(0.088)
With controls	-0.468	-0.274	-0.141	-0.571	-0.885
	(0.111)	(0.210)	(0.170)	(0.152)	(0.321)
Elasticity					
Without controls	-1.791	-2.285	-1.129	-2.201	-1.548
	(0.146)	(0.541)	(0.347)	(0.415)	(0.165)
With controls	-1.155	-1.110	-0.322	-1.542	-1.646
	(0.293)	(0.852)	(0.388)	(0.412)	(0.597)

Notes: The table shows results from the demand elasticity estimation. The first row shows the percentage change in price between adjacent risk group pairs. The next two rows show estimates of the corresponding percentage change in private DI take-up. The estimates are based on regression results shown in Appendix Table A7. "Without controls" indicates that the respective figure is obtained from a regression without controls. "With controls" indicates that income, education, gender, marital status, economic training and residence in East Germany are included as controls. The bottom two rows show elasticity estimates, relating the respective percentage change in take-up to the percentage change in price as shown in equation (5). For each outcome, Column (1) shows the weighted average of the estimates among the different risk group pairs from Columns (2) to (5). Bootstrapped standard errors are shown in parentheses.

Table 4: **Welfare Effects of Insurance Mandate**

	(1) Private DI Mandate	(2) Public DI Mandate: Lump-Sum Contributions	(3) Public DI Mandate: Income-Based Contributions
Panel A: Baseline Calculation			
Net Value	0.762	0.762	0.762
Panel B: Social Net Value			
Utilitarian, σ=1	0.704	0.941	1.218
Utilitarian, σ=3	0.612	1.142	1.743
Utilitarian, σ=5	0.549	1.221	1.960
Utilitarian, σ=8	0.488	1.255	2.064
Rawlsian	0.131	1.455	2.328
Panel C: Net Value under Risk Misperceptions			
Hand-to-mouth (σ=0.44)	1.506	1.506	1.506
Hand-to-mouth + SA floor (σ=0.84)	1.100	1.100	1.100
High ΔC + SA floor (σ=1.16)	1.469	1.469	1.469
Low ΔC + SA floor (σ=3.03)	1.418	1.418	1.418

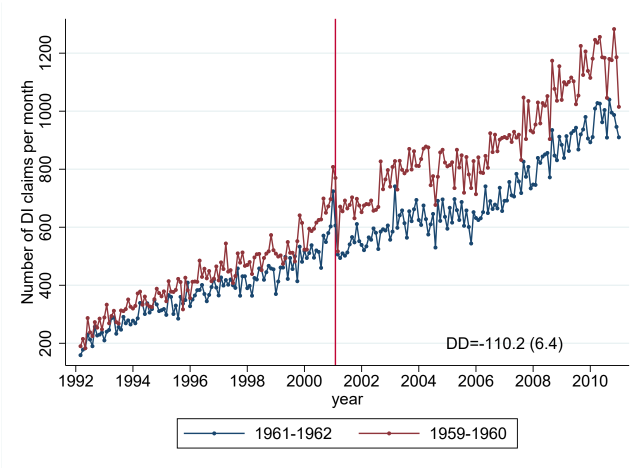
Notes: The table shows the net value of mandating the DI coverage offered by the private insurance market. Panel A shows the baseline net value calculated as shown in equation (12). Panel B shows the social net value calculated as in equations (13) and (14), under different social welfare functions indicated in the row titles. Panel C shows the net value under risk misperceptions, based on calibrated normative insurance valuations from Appendix Table A10.

Online Appendix

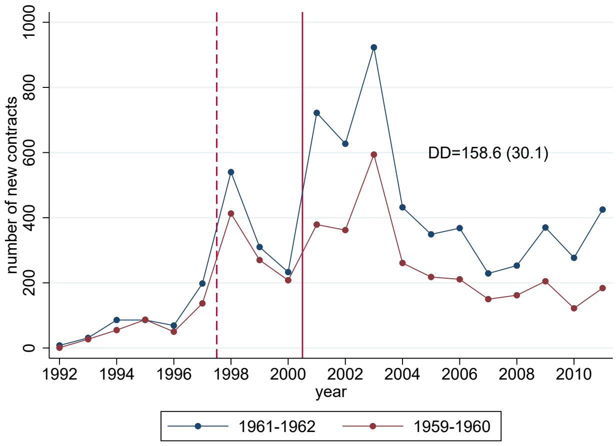
A Appendix Figures and Tables

Figure A1: Additional Difference-in-Difference Results

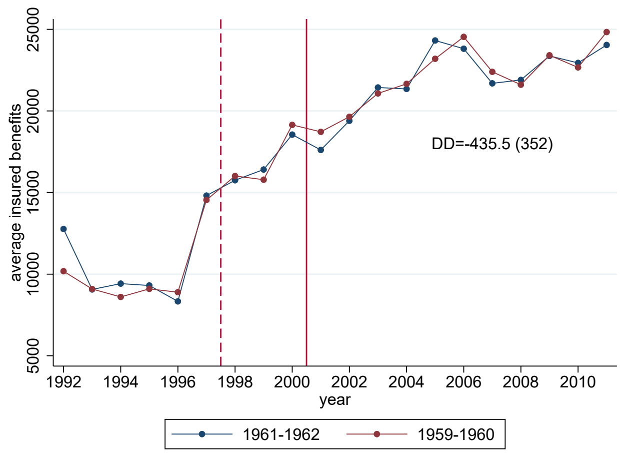
(a) All Public DI Claims



(b) Private Stand-Alone DI Purchases

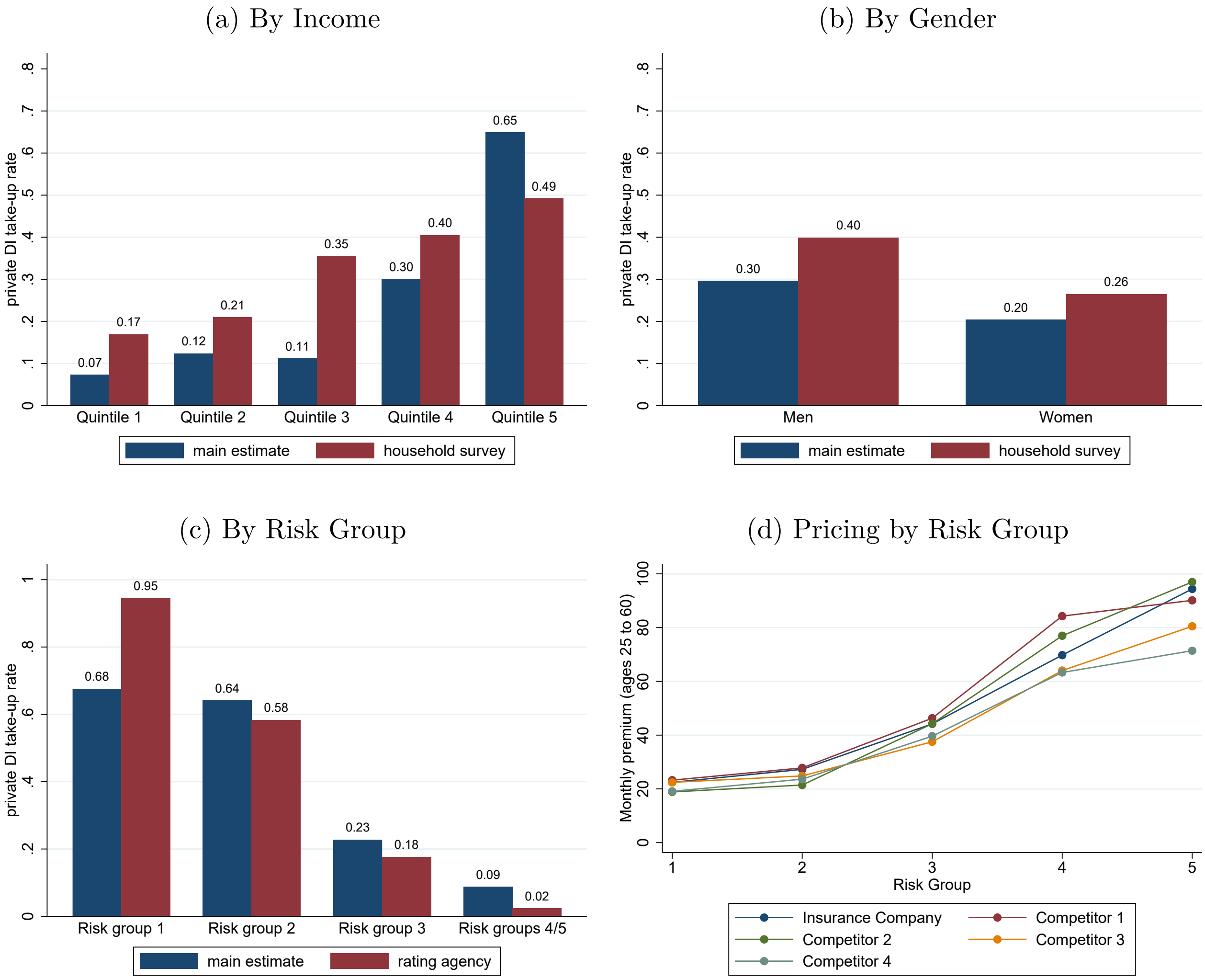


(c) Private DI Benefits



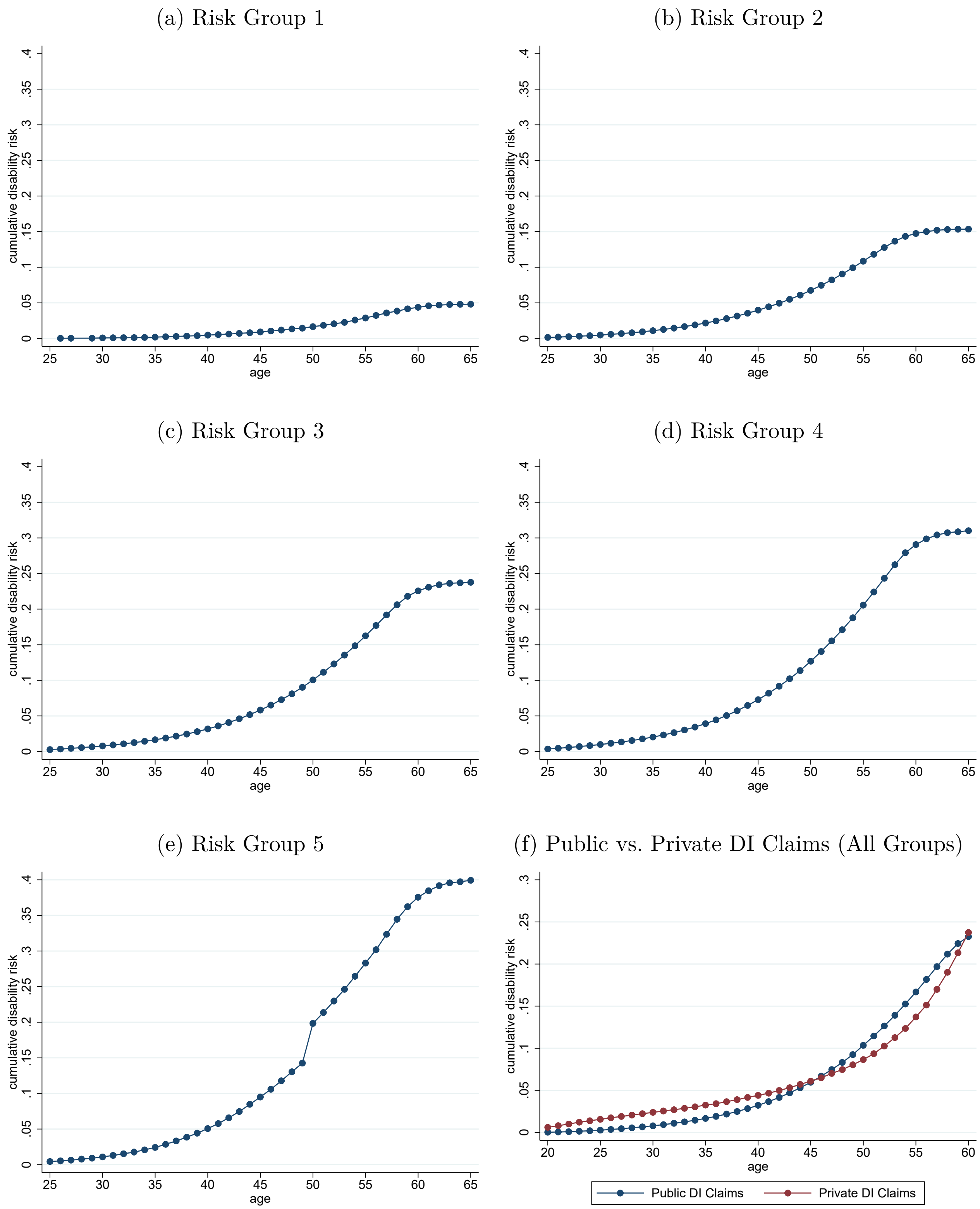
Notes: The figure shows the number of public DI claims (Panel a), stand-alone private DI purchases (Panel b) and insured benefits in private DI contracts of individuals born in 1961-1962 (treated cohorts) vs. 1959-1960 (control cohorts). In all panels, the solid vertical line denotes the time the reform of 2001 takes effect (January 2001). In Panels (b) and (c), the dashed vertical line additionally demarcates the time the reform is first announced (December 1997). *DD* denotes the difference-in-difference coefficient estimated for the respective outcome with standard errors in parentheses (see Table 2 for details).

Figure A2: Validating Take-Up Rates



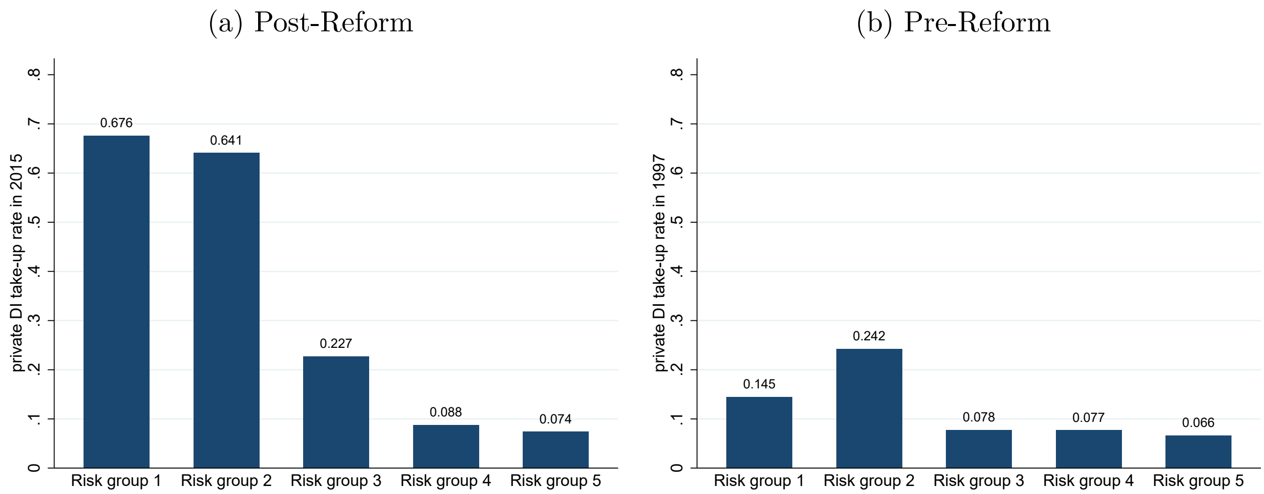
Notes: The figure collects various pieces of evidence supporting the validity of our main empirical results. Panels (a) and (b) show a comparison of the take-up rates we find based on the insurer microdata (blue bars) to take-up rates based on representative household survey data (red bars), by income quintile (Panel a) and gender (Panel b). Panel (c) compares take-up rates by risk group based on the insurer microdata (blue bars) to take-up rates based on the rating agency data (red bars). The rating agency data uses four harmonized risk groups, and we assign risk groups 4 and 5 from the insurer microdata to the fourth harmonized risk group. Panel (d) shows average monthly insurance premiums charged to the ten most frequent occupations in each risk group by the insurer providing our microdata and four large competitors.

Figure A3: Disability Risk Paths



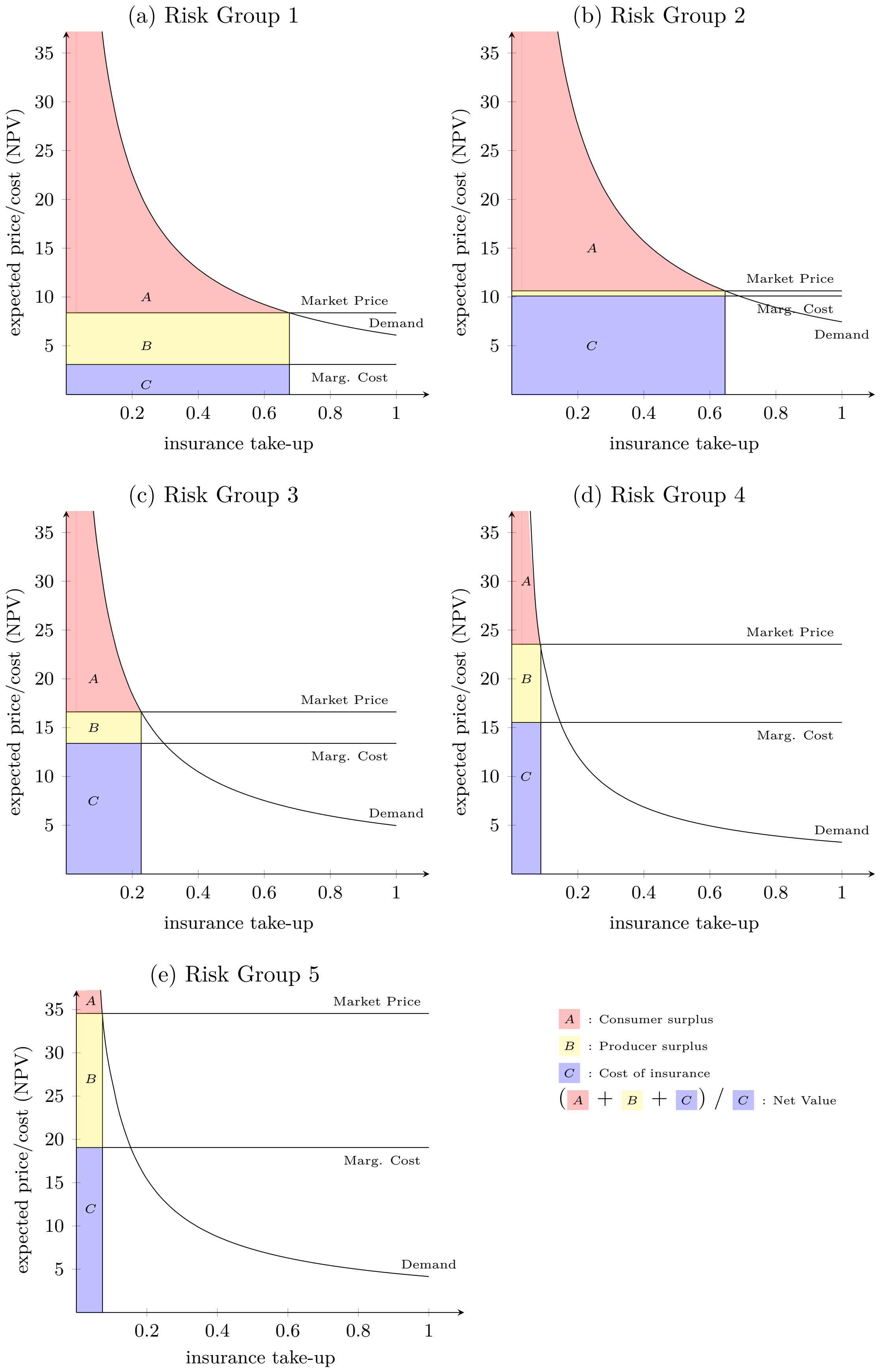
Notes: The figure shows the cumulative fraction of individuals claiming DI benefits. Panels (a) to (e) show the fraction claiming public DI benefits by age in each risk group. Panel (f) shows a comparison of public DI claims among all risk groups to private DI claiming risk calculated by the German Actuarial Association for a representative individual.

Figure A4: Private DI Take-Up Pre- vs. Post-Reform



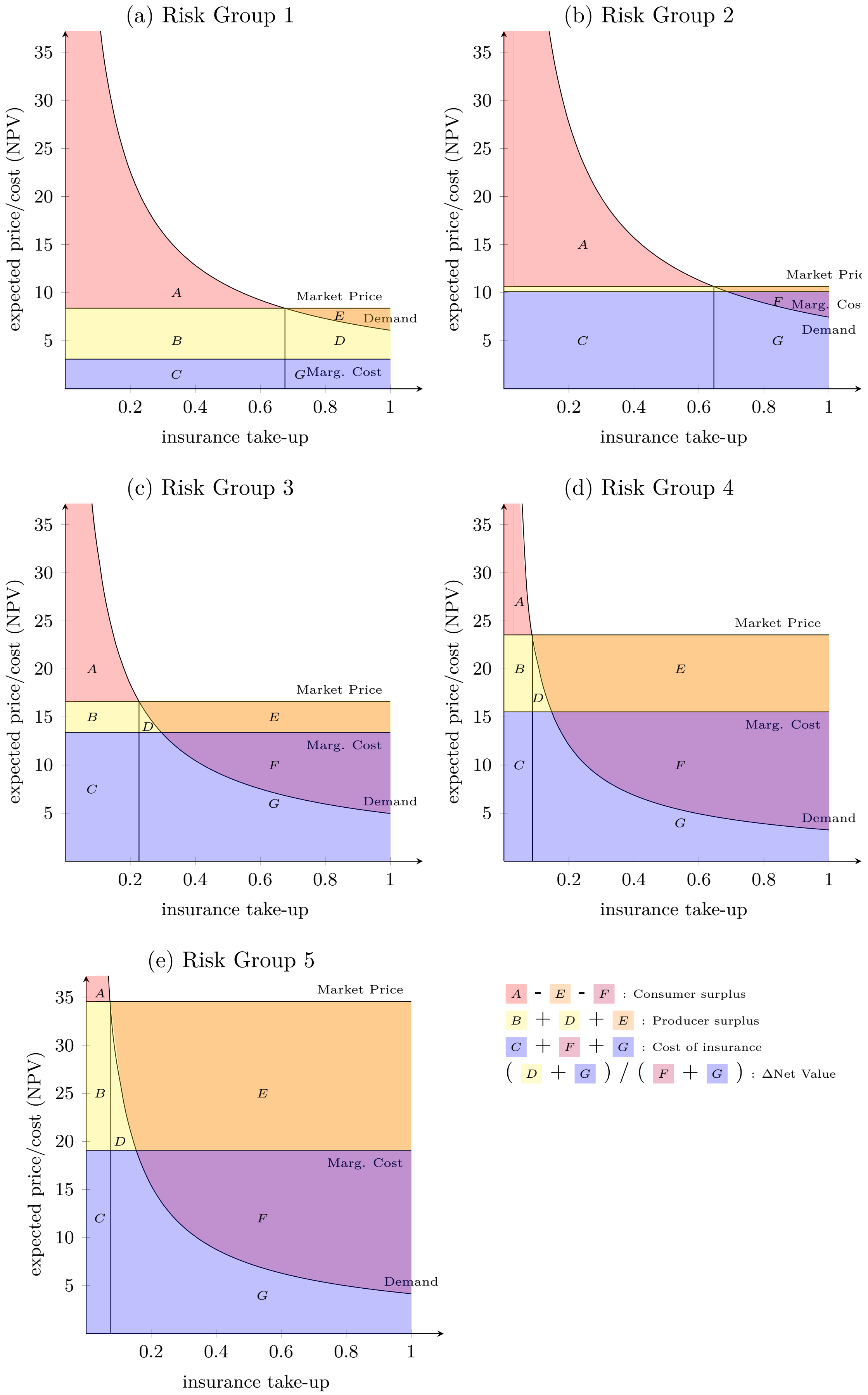
Notes: The figure shows private DI take-up rates in 2015 by risk group in 2015 (Panel a) and in 1997, the year before the reform of 2001 was announced (Panel b). All take-up rates are calculated as shown in equation (2).

Figure A5: Net Value in Private DI Market



Notes: The figure depicts welfare in the private DI market equilibrium by risk group. In each panel, the net value is given by the total area under the demand curve ($A+B+C$) divided by the area under the cost curve (C). Net value can be further decomposed as explained in the figure legend.

Figure A6: Net Value of Introducing a DI Mandate



Notes: The figure shows the net value of introducing a DI mandate by risk group. The mandate increases DI take-up from the market equilibrium to 1. The net value of the reform is given by the additional area under the demand curve $(D + G)$ divided by the additional cost $(F + G)$. Net value can be further decomposed as explained in the figure legend.

Table A1: Occupations and Risk Groups

Risk group	Frequent occupation titles
RG 1	Medical doctor (no surgeon), civil engineer*, business economist*, managing director*, business consultant*, tax consultant, pharmacist, computer scientist*, economist*, accountant*
RG 2	Commercial clerk, surgeon, dentist, managing director, executive assistant, business consultant, construction engineer, IT technician, lawyer, bank clerk
RG 3	Physiotherapist, high school teacher, sales clerk, educator, secretary, social worker, electrical engineer, hotel clerk, administrative clerk, beautician
RG 4	Carpenter, nurse, metalworker, plumber, mason, hairdresser, painter, driver, roofer, car mechanic, electrician, toolmaker, tiler, gardener, waiter
RG 5	Baker, dairy worker, firefighter, miner, road builder, pipe cleaner, steelworker, concrete worker, warehouse worker, excavation worker

Notes: The table shows examples among the most frequent occupation titles in each risk groups, based on the insurer microdata. * denotes occupations included in risk group 1 under the condition that the individual works mostly inside an office.

Table A2: Summary Statistics: Household Survey Data

	(1) All households	(2) Employed households
Private DI owner	0.31	0.35
	(0.46)	(0.48)
Gross labor income (annual)	26,218.6	35,103.9
	(23,384.1)	(20,629.2)
Age	44.09	43.39
	(11.83)	(11.17)
Male	0.59	0.61
	(0.49)	(0.49)
Household size	2.01	2.09
	(1.14)	(1.15)
Observations	31,452	21,037

Notes: The table shows summary statistics of the 2013 wave of the Income and Consumption Survey (EVS).

Table A3: Difference-in-Differences: Robustness

Panel A: Controlling for Cohort-Specific Trends

	(1)	(2)	(3)	(4)
	Number of Private DI Purchases			
	All Contracts		Stand-Alone	
Treated × post-2001	15.11***	17.38**	13.22***	17.33***
	(2.739)	(7.107)	(1.676)	(4.297)
Observations	480	480	480	480
R-squared	0.939	0.939	0.939	0.940
Calendar month FE	yes	yes	yes	yes
Group-specific trend	no	yes	no	yes
Mean (pre-reform)	23.49	23.49	6.640	6.640

Panel B: Robustness to Timing of Reform

	(1)	(2)	(3)	(4)
	Number of Private DI Purchases (All Contracts)			
	baseline (post-2001)	control for 1998-2000	omit 1998-2000	post-1998
Treated × post	15.11***	19.04***	16.96***	17.48***
	(2.739)	(2.539)	(2.456)	(2.202)
Observations	480	480	384	480
R-squared	0.939	0.940	0.944	0.940
Calendar month FE	yes	yes	yes	yes
Mean (pre-reform)	23.49	23.49	23.49	23.49

Notes: Panel A shows results from difference-in-difference regressions as described by equation (1). Columns (1) and (3) replicate the baseline estimation and Columns (2) and (4) additionally control for a linear time trend interacted with an indicator for treated cohorts. Panel B shows difference-in-difference regressions with varying timing assumptions. Column (1) replicates the baseline estimation, Column (2) additionally controls for an indicator for the period 1998 to 2000 and its interaction with the indicator for treated cohorts, Column (3) omits the period 1998 to 2000 from the estimation, and Column (4) defines the post-reform indicator as post-1998 instead of post-2001. All regressions are run at the level of cohort × calendar month cells. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A4: Risk Groups and Disability Risk

Risk group	(1) Share of labor force	(2) Lifetime disability risk	(3) Share of own-occupation DI claims	(4) Monthly insurance premium for contract start at... age 25	(5) age 35	(6) age 45
All	100%	25.07%	13.20%	72.83	83.53	98.15
RG 1	9.72%	4.81%	10.85%	31.61	35.95	43.22
RG 2	16.96%	15.35%	8.06%	41.73	49.08	57.50
RG 3	35.14%	23.77%	12.57%	68.15	79.91	93.73
RG 4	37.55%	31.02%	15.74%	100.60	113.31	133.03
RG 5	0.62%	39.94%	31.95%	155.24	175.78	210.68

Notes: The table shows information on risk groups assigned by the insurer to individuals based on their occupations. Column (1) shows the share of each risk group out of the labor force based on occupations observed in the administrative public pension data. Column (2) shows the fraction of individuals in each risk group claiming public DI benefits at any age. Columns (3) shows the share of own-occupation DI claims out of all DI claims. Columns (4) to (6) show the monthly premium (in EUR) charged to an individual insuring EUR 1000 of private DI benefits by risk group and contract start age, for a fixed contract end age of 65.

Table A5: Difference-in-Difference Results by Subgroup

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	A: Private DI Contracts by Income					**B: by gender**	
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Men	Women
Treated × post	0.316	1.573***	1.240***	4.377***	7.602***	8.460***	6.652***
	(0.454)	(0.512)	(0.458)	(0.820)	(1.330)	(1.870)	(1.108)
Observations	480	480	480	480	480	480	480
R-squared	0.838	0.889	0.818	0.886	0.944	0.944	0.897
Mean (pre-reform)	3.180	2.720	2.710	6.350	7.940	17.24	6.250
Calendar month FE	yes	yes	yes	yes	yes	yes	yes

	(1)	(2)	(3)	(4)	(5)
	C: Private DI Contracts by Risk Group				
	Risk group 1	Risk group 2	Risk group 3	Risk group 4	Risk group 5
Treated × post	1.756***	6.833***	6.699***	0.0749	0.0909*
	(0.571)	(1.063)	(1.221)	(0.674)	(0.0470)
Observations	480	480	480	480	480
R-squared	0.899	0.933	0.913	0.898	0.516
Mean (pre-reform)	2.720	7.640	6.190	6.030	0.0700
Calendar month FE	yes	yes	yes	yes	yes

	(1)	(2)	(3)	(4)	(5)
	D: Private DI Contracts by Education				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Treated × post	0.0867	0.355	0.920**	3.861***	9.889***
	(0.388)	(0.414)	(0.419)	(0.807)	(1.546)
Observations	480	480	480	480	480
R-squared	0.786	0.866	0.856	0.887	0.947
Mean (pre-reform)	2.100	3.180	3.250	4.780	10.18
Calendar month FE	yes	yes	yes	yes	yes

Notes: The table shows results from difference-in-difference regressions as described by equation (1) for subgroups specified in the column titles. Regressions are run at the level of cohort × calendar month cells. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Risk-Based Selection

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variable: Private DI Take-Up						
Actual Disability Risk	-1.383***		-0.0513	-0.0341	0.374	0.327	-0.0343
	(0.260)		(0.263)	(0.263)	(0.288)	(0.289)	(0.243)
Risk Group		-0.257***	-0.252***	-0.245***	-0.147***	-0.149***	-0.137***
		(0.0238)	(0.0323)	(0.0324)	(0.0386)	(0.0384)	(0.0385)
Log income				0.0391**	0.0204	0.0184	0.0209
				(0.0160)	(0.0139)	(0.0141)	(0.0161)
Education (years)					0.114***	0.113***	0.104***
					(0.0201)	(0.0203)	(0.0203)
Female						-0.0631	-0.279***
						(0.0590)	(0.0771)
Economic training							0.161*
							(0.0946)
Married							-1.363***
							(0.431)
East Germany							0.254*
							(0.150)
Observations	293	293	293	293	293	293	293
R-squared	0.126	0.270	0.270	0.277	0.359	0.361	0.398

Notes: The table shows regression results on the correlation between private DI take-up in 2015 and disability risk at the three-digit occupation level. Column (1) corresponds to estimating equation (3) without controlling for risk groups (cf. Figure 5, Panel (a)). Column (2) shows a specification where actual disability risk is omitted. We find a strong negative correlation between private DI take-up and risk groups, as expected from Figure 4. Column (3) corresponds to the specification shown in equation (3) (cf. Figure 5, Panel (b)). Columns (4) to (7) add varying set of control variables to the regression. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A7: Demand Elasticity Estimation Regressions

	(1)	(2)	(3)	(4)
	Dependent Variable: Private DI Take-Up			
Actual disability risk	-0.0513	-0.0343	-0.226	-0.0579
	(0.263)	(0.243)	(0.248)	(0.240)
Risk group	-0.252***	-0.137***		
	(0.0323)	(0.0385)		
Risk group 2			-0.345***	-0.183
			(0.0574)	(0.128)
Risk group 3			-0.581***	-0.249*
			(0.0486)	(0.139)
Risk group 4			-0.784***	-0.399***
			(0.0494)	(0.147)
Risk group 5			-0.926***	-0.549***
			(0.0501)	(0.155)
Log income		0.0209		0.0201
		(0.0161)		(0.0162)
Female		-0.279***		-0.301***
		(0.0771)		(0.0787)
Education (years)		0.104***		0.112***
		(0.0203)		(0.0204)
Economic training		0.161*		0.178*
		(0.0946)		(0.0968)
Married		-1.363***		-1.312***
		(0.431)		(0.440)
East Germany		0.254*		0.211
		(0.150)		(0.148)
Observations	293	293	293	293
R-squared	0.270	0.398	0.266	0.403

Notes: The table shows results from the demand elasticity estimation regressions described by equation (4). Columns (1) and (2) estimate the average jump in private DI take-up between risk groups, and Columns (3) and (4) estimate the jump in take-up separately at each risk group boundary. Table 3 converts the estimates into implied demand elasticities.

Table A8: Value and Cost of Insurance

	(1)	(2)	(3)	(4)	(5)	(6)
	All	RG 1	RG 2	RG 3	RG 4	RG 5
Panel A: Median Willingness to Pay (in % of Income)						
Full private DI coverage	0.930	1.134	1.418	0.958	0.633	0.818
Own-occupation DI (lower bound)	0.434	0.812	0.780	0.559	0.065	0.070
Own-occupation DI (upper bound)	0.499	0.847	0.832	0.609	0.154	0.309
General DI top-up (lower bound)	0.431	0.288	0.586	0.349	0.479	0.509
Panel B: Median Cost of Insurance (in % of Income)						
Full private DI coverage	1.469	0.327	1.094	1.469	1.720	2.140
Own-occupation DI	0.185	0.035	0.088	0.185	0.271	0.684
General DI top-up	1.284	0.291	1.006	1.284	1.450	1.457

Notes: The table shows estimated willingness to pay and cost of disability insurance. Column (1) shows median valuations and cost among all workers, and Columns (2) to (6) show median valuations and cost by risk group. Besides willingness to and cost for the full private DI coverage, the table also displays a decomposition into own-occupation and general DI as described by equations (8), (9) and (10).

Table A9: Social Welfare Weights

	(1) RG 1	(2) RG 2	(3) RG 3	(4) RG 4	(5) RG 5
Income (annual)	64,605	54,998	40,648	35,202	31,546
Income (NPV)	1,524,574	1,269,566	926,151	794,701	702,268
Social welfare weights					
Utilitarian, σ=1	0.629	0.752	1.021	1.183	1.332
Utilitarian, σ=3	0.225	0.385	0.962	1.496	2.135
Utilitarian, σ=5	0.074	0.180	0.831	1.734	3.137
Utilitarian, σ=8	0.013	0.053	0.610	1.980	5.116
Rawlsian	0.000	0.000	0.000	0.000	161.290

Notes: The table shows average income and social welfare weights by risk group. "Income (NPV)" denotes the net present value of expected lifetime income calculated at age 25. Social welfare weights are calculated for the social welfare function specified in the row titles, and serve as an input into the social net value calculations shown in Panel B of Table 4.

Table A10: Risk Misperception: Calibration Results

	(1) RG 1	(2) RG 2	(3) RG 3	(4) RG 4	(5) RG 5
Panel A: Location of marginal buyer					
Percentile of willingness to pay in group	0.324	0.359	0.773	0.912	0.926
Panel B: Risk aversion of marginal buyer					
Hand-to-mouth	0.437	0.034	0.115	0.194	0.264
Hand-to-mouth + SA floor	0.841	0.304	0.581	0.902	1.216
High ΔC + SA floor	1.158	0.085	0.287	0.492	0.769
Low ΔC + SA floor	3.030	0.241	0.811	1.339	1.866
Panel C: Risk underestimation of marginal buyer					
Hand-to-mouth (σ=0.44)	1.000	0.394	0.469	0.543	0.642
Hand-to-mouth + SA floor (σ=0.84)	1.000	0.448	0.705	1.086	1.586
High ΔC + SA floor (σ=1.16)	1.000	0.397	0.475	0.554	0.720
Low ΔC + SA floor (σ=3.03)	1.000	0.400	0.484	0.557	0.674
Panel D: Implied normative WTP/observed WTP					
Hand-to-mouth (σ=0.44)	1.000	2.596	2.187	1.880	1.594
Hand-to-mouth + SA floor (σ=0.84)	1.000	2.255	1.440	0.901	0.600
High ΔC + SA floor (σ=1.16)	1.000	2.532	2.133	1.817	1.400
Low ΔC + SA floor (σ=3.03)	1.000	2.447	2.027	1.743	1.455

Notes: The table shows results from the calibrations described in Section 6.3. Panel A shows the willingness-to-pay percentile of the marginal buyer among the risk group indicated by the column title. Panel B shows the calibrated coefficient of relative risk aversion σ of the marginal buyer under the assumption about consumption levels indicated in the respective row title. Panel C shows calibrated risk underestimation α, i.e. the ratio of perceived to actual disability risk, of the marginal buyer. Panel D shows the implied ratio of normative willingness to pay to observed willingness to pay.

Table A11: Welfare Calculations: Extensions and Robustness

	(1)	(2)	(3)
	Private DI Mandate	Public DI Mandate	
		Lump-Sum Contributions	Income-Based Contributions
Panel A: Moral Hazard Effect on Baseline Insurance			
Net Value	0.668	0.668	0.668
Social Net Value, σ=1	0.616	0.824	1.067
Social Net Value, σ=3	0.535	1.000	1.526
Social Net Value, σ=5	0.480	1.069	1.715
Panel B: Fiscal Externality from Social Insurance Contributions			
Net Value	0.762	0.762	0.625
Social Net Value, σ=1	0.704	0.941	0.971
Social Net Value, σ=3	0.612	1.142	1.369
Social Net Value, σ=5	0.549	1.221	1.534
Panel C: Reduction in Social Assistance Claims			
Net Value	0.776	0.776	0.776
Social Net Value, σ=1	0.713	0.954	1.232
Social Net Value, σ=3	0.614	1.154	1.757
Social Net Value, σ=5	0.546	1.231	1.974
Panel D: Combining A to C			
Net Value	0.680	0.680	0.558
Social Net Value, σ=1	0.625	0.835	0.861
Social Net Value, σ=3	0.537	1.010	1.209
Social Net Value, σ=5	0.477	1.078	1.353
Panel E: Some Adverse Selection			
Net Value	0.777	0.777	0.777
Social Net Value, σ=1	0.719	0.962	1.248
Social Net Value, σ=3	0.628	1.171	1.791
Social Net Value, σ=5	0.565	1.253	2.014
Panel F: Some Advantageous Selection			
Net Value	0.745	0.745	0.745
Social Net Value, σ=1	0.686	0.916	1.184
Social Net Value, σ=3	0.594	1.109	1.689
Social Net Value, σ=5	0.531	1.185	1.898

Notes: The table shows the net value of mandating the DI coverage offered by the private insurance market under the various extensions of our welfare calculations described in Section 6.4.