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Privatizing Disability Insurance*

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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 workers, we find that despite significant crowding-in effects, overall private DI take-up remains modest. We do not find any evidence of adverse selection on unpriced risk. On the contrary, private DI tends to be concentrated among high-income, high-education and low-risk individuals. Using a revealed preferences approach, we estimate individual DI valuations, a key input for welfare calculations. We find that observed willingness-to-pay of many individuals is low, such that providing DI partly via a private insurance market with choice improves welfare. However, we show that distributional concerns as well as individual risk misperceptions can provide grounds for justifying a full public DI mandate.

JEL codes: H55, G22, G52
Keywords: disability insurance, social insurance, mandate, privatization, risk-based selection, welfare

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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, governments face pressure to enact reforms reducing the generosity of public DI programs. While such reforms help improve fiscal sustainability, they come at the cost of providing less insurance to individuals at risk of disability.

As a consequence, some economists and policymakers have proposed a larger role of private DI (e.g. Autor and Duggan, 2010; GAO, 2018). As a matter of fact, sizable private DI markets already exist in some countries, including the U.S. and Germany.[1] Opponents of this idea point out several potential problems in private DI markets, notably inefficiencies due to 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 provision.

In this paper, we aim at filling this gap and provide novel evidence directly informing this debate. We empirically investigate 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 unique and novel microdata from a top-10 private insurer and administrative data on the universe of public DI claims, we document significant crowding-in of private DI. Yet, 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 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 insurance valuations and find that in the absence of behavioral frictions, partly privatizing DI as done by the reform can be welfare improving. However, we show that a full public DI mandate can be justified by equity concerns or by individuals undervaluing DI due to risk misperceptions.

Our institutional setting and data 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 that partly privatized DI. The reform of 2001 removed one part of public DI for younger workers, namely *own-occupation* insurance. Receiving own-occupation DI benefits requires workers to be unable to work in their previous occupation. In contrast, general DI benefits are based on stricter eligibility criteria, namely being unable to work in any occupation. Before the reform, both own-occupation and general DI were part of the social insurance system, but the reform completely removed 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 can choose to purchase private DI if they wish to compensate for the loss of public DI coverage.

A second challenge is the difficulty of obtaining comprehensive data on private DI. To address this challenge, we combine a number of different data sources. First, we obtained a unique dataset on all

[1] 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).

private DI contracts issued by a large insurance company, which is one of the top-10 providers in the German private DI market. As a second source of information, we obtained aggregate data on the entire private DI market from a leading rating agency, which compiles data from all private insurers. 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 in order to validate results from the insurer microdata. We generally find similar patterns in the survey and in available market-level data, suggesting that the insurer microdata is representative of the market in 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 after the reform. In order to identify a causal effect 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 have private DI.

We find strong heterogeneity in private DI take-up by observable characteristics. To begin with, 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 12% 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. Thus, modest overall private DI take-up is driven by low take-up among individuals with low income, low education and high disability risk.

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, to assess whether there is adverse selection, we have to estimate the correlation between take-up and *unpriced* risk. Thus, we condition on the priced component of risk and test for selection within risk groups facing the same insurance prices. Second, an important issue with the positive correlation test is that it may confound risk-based selection and moral hazard. Our solution to this problem is to measure disability risk only among older cohorts who are still fully covered by public own-occupation DI. For this group, differences in observed claims across occupations should reflect differences in ex-ante risk rather than ex-post moral hazard responses to differential insurance coverage.

The main result from our positive correlation test is that we do not find any evidence of adverse selection. The point estimate of the correlation between take-up and risk is negative and insignificant, if anything suggesting slight advantageous selection. This is important, as adverse selection is typically considered the canonical rationale for a public DI mandate. At first glance, the lack of adverse selection may be surprising, as insurance should in principle be more valuable to higher-risk individuals. We discuss two main potential explanations for this result. First, there could be heterogeneity in preferences for DI that is negatively correlated with risk, as has been document in other insurance markets (e.g. Finkelstein and McGarry, 2006; Cutler et al., 2008). We present suggestive evidence along these lines: In particular, high-income and highly educated groups being more likely to purchase private DI seems to drive some advantageous selection. A second explanation for the lack of adverse selection, to which we return later in the paper, is that individuals may not correctly perceive their disability risk.

In the second part of the paper, we turn to the welfare consequences of (partly) privatizing DI. 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 can implement a revealed preferences approach using observed choices to uncover insurance valuations. To estimate demand for private DI, we exploit the discrete price variation between risk groups. Intuitively, the insurer assigns occupations to 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 estimate sizable jumps in private DI 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 insurance, can be directly calculated 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 DI relative to its cost, analogously to the marginal value of public funds (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 such a mandate of 0.74, implying that the revealed insurance valuation among individuals receiving additional coverage is only 74% of the cost of insuring them. This result is mainly driven by two of our findings, (i) the absence of significant adverse selection, and (ii) heterogeneity in DI valuations. Given these circumstances, the majority of individuals with sufficiently high willingness to pay are covered by the private market, 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* DI 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. In contrast, a *public* DI mandate financed by income-based social insurance contributions 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 (e.g. Chandra et al., 2019). Thus, in a second extension, we account for such behavioral frictions. 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 40% 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 up to 2.4 times higher if they correctly perceived their disability risk. Finally, we find that implied normative valuations exceed the cost of insurance, suggesting that risk misperceptions can provide an alternative 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.[2] Second, we further exploit our setting with insurance choice in order to estimate willingness to pay for DI in a revealed preferences approach. With the exception of Cabral and Cullen (2019) who estimate a lower bound on the value of public DI using supplemental DI purchases within a U.S. employer, little is known about individual DI valuations so far. Third, we assess the welfare consequences of private DI provision 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., 2022).

More broadly, this paper contributes to a recent literature investigating the welfare effects of universal mandates vs. voluntary markets in social insurance settings. Existing studies on these issues include work on health insurance (e.g. Einav et al., 2010; Finkelstein et al., 2019), unemployment insurance (Landais et al., 2021; Hendren et al., 2021) and workers' compensation (Cabral et al., 2022). Our main contribution to this broader literature is that we provide the first welfare analysis of a private market with choice vs. a full public mandate in the context of DI, one of the most important social insurance programs.

The remainder of this paper is organized as follows. Section 2 outlines context and data, Section 3

[2] Hendren (2013) provides indirect evidence on potential risk-based selection in DI by documenting that individuals have some private information about their disability risk.

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 analysis, 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 is mandatory for all employed individuals, while most self-employed workers and civil servants are exempt. DI contributions are levied as payroll taxes together with pension contributions. 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. According to our administrative data, 25.1% of German workers become disabled and claim public DI throughout their lifetime, and the average gross replacement rate is 39%.

Crucially for our purposes, the public DI system consists of two separate tiers, *general DI* and *own-occupation DI*. The first tier 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 tier, on the other hand, requires a so-called own-occupation disability (*Berufsunfähigkeit*) defined as being unable to work in one's 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.[3]

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 completely removed for birth cohorts 1961 and younger from 2001 onward. Besides this main element, the reform featured further changes equally

[3] 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.

affecting all cohorts, including gradually phased-in changes to benefit calculation.[4]

The timing of the reform was noteworthy. Initially, the reform was announced in December 1997 to take effect in January 1999. 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 the changes took effect in January 2001.

Private Disability Insurance. The private DI market 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 in order to compensate for the removal of public own-occupation DI. 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 awarded 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 private DI premiums are individuals' occupations, whereby insurers map occupations into a discrete number of risk groups. Following standard practice in the industry, the insurer from which our microdata originates uses five risk 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 occurs infrequently.[5] 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). German private DI is largely a nongroup market: the majority of 85% of contracts are purchased individually, and the remainder are obtained via employers (FAZ, 2012). According to official statistics, only a small minority of contract applications are rejected by insurers.[6] Finally, private DI can be bought 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 take-up and contract characteristics is not readily available. We tackle this challenge by combining a number of data sources. First, we obtained a unique dataset on all private DI contracts issued by a large insurance company. The insurer is among the top-10 in the private DI market, with a

[4] 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.

[5] Premiums are adjusted beyond risk-group specific prices in only 4% of private DI contracts (GDV, 2016).

[6] Across the entire private DI market, only 4% of individuals are rejected at the contracting stage (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. This appears to be an important difference to U.S. nongroup insurance markets, where rejections are more common and can affect broader sets of occupations and income groups (Hendren, 2013).

market share between 3% and 6%.[7] We observe contracts existing in any of the years between 2012 and 2017, irrespective of their start date. The data contains information on key contract characteristics as well as some limited socio-demographics information. 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[8] Similarly, we add education at the occupation level. Table 1A shows summary 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. With an average purchase age of 31 and an end age of 61, private DI contracts tend to cover the bulk of individuals' working lives. 60% of contract holders are male, average monthly premiums are EUR 86 and insured monthly benefits are EUR 1494, and 54% of contracts were sold as a stand-alone product.

As a second source of information on private DI, we obtained aggregate data on the entire private DI market from a leading rating agency. The agency provides ratings of insurance companies and collects data from all private insurers for this purpose. 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 as well as the shares of contract types, risk 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.[9] 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. Table 1B 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 EUR 1075 on average, and claimants' monthly earnings were EUR 2295 over all periods, and EUR 1306 in the year before claiming. 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 income is around EUR 2185 per month and the average age of the main earner is 44. 59% of main earners are male and the average household size is just above two.

Representativeness of the Insurer Microdata. An important question for the validity of our results is how representative the insurer providing our microdata is for the overall private DI market. We show that the insurer reflects the market well in a number of 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. Second, the pricing of private DI contracts follows common industry practice, assigning individuals to risk groups primarily based

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

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

[9] 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.

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 in 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. In web-scraped data, we find that the insurer has local agencies across all states and in all major cities, as well as in a large 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, we present quantitative validation checks of our main results using independent, representative data sources in Section 4.4, which yield similar empirical patterns to the insurer microdata.

3 Crowding-In of Private Disability Insurance

The reform of 2001 removes 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 month. Precisely at the time of the reform, there is a sharp drop in claims, reflecting that younger cohorts affected by the reform immediately 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 the number of 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 official statistics. The figure shows a clear jump in private DI take-up around the time of the reform. By 2015, 26% of workers have private DI, compared to around 10% in the years before the reform was first announced in 1997. This substantial 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 15 years after the reform is modest, given that all workers were covered by public own-occupation DI before the reform.[10]

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

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 follow a difference-in-difference strategy exploiting the cohort cutoff of the reform. We run 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 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 month-by-year 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 differential drop in claims by treated cohorts virtually to zero, while claims by the control group continue increasing similarly to before the reform.[11] 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 tier 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.[12] 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 an 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. This differential effect on new contract purchases of the treatment group persists 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

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

[12] 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.

private DI.[13] 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 specifications. First, even though the treated and control cohorts in the baseline estimation are quite close in terms of age, there could be some 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 around 31 (see Table 1A). 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 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 194%. 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 an effect of the reform.

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

4 Selection into Private Disability Insurance

4.1 Calculating Take-Up of Subgroups

In this section, we study which types of 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. Finkelstein and Poterba, 2004, 2014; 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 $j \in \{\text{stand-alone}, \text{bundled}\}$ in the insurer data 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 contract type and year, the market share of the insurer is constant across subgroups, that is $marketshare^j_{g,t} = marketshare^j_t \ \forall g$.

This assumption is certainly not innocuous and its validity hinges on how representative the insurer is for the overall market. In Section 2.2, we argued that the insurer reflects the market well in terms of contract design, pricing, occupational coverage and geographic coverage. Moreover, we present comprehensive validation checks of the resulting take-up rates in Section 4.4. 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 have 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.[14] Panel (b) shows an even stronger correlation of private DI take-up and education. 80% of individuals in the highest education quintile have purchased private DI, while take-up is 26% in the fourth quintile. In the bottom three quintiles, private DI take-up is only 5% to 8%. Panel (c) shows corresponding results by gender, suggesting that take-up among men (30%) is somewhat higher than among women (20%).

Next, we investigate take-up patterns by priced risk group. Recall that the insurer assigns 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 provides summary information about risk groups. As one may expect, risk groups capture large differences in 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, the insurer charges strongly varying private DI premiums depending on the risk group an individual is 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 vary across 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. Finally, we note that risk groups differ substantially in size. 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.

In Panel (d) of Figure 4, we find strong heterogeneity in private DI take-up by risk group. In particular, lower-risk groups facing lower insurance premiums are much more likely to purchase private DI. In the lowest-risk groups 1 and 2, 58% and 56% of individuals have private DI, respectively. Among risk group 3, private DI take-up is 20%, and only 7% to 8% of individuals in risk groups 4 and 5 are covered by private DI.

These heterogeneity results have some notable 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. High-income, high-education and low-risk groups, on the other hand, display high take-up rates of up to 80%. The fact that vulnerable groups are more likely to be uninsured provides a first indication of potential equity issues in the private DI market, which will be an important factor in our welfare analysis later on. Second, low observed take-up among high-risk individuals is somewhat puzzling. Premium increases with risk groups are not far from actuarially fair, and in principle willingness to pay for insurance should increase with risk. In the following section, we investigate risk-based selection in more detail and discuss potential explanations for this finding.

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 2001 reform 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

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

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 led 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 disability risk. Standard models of adverse selection predict that high-risk individuals are more likely to purchase insurance, which can lead to underprovision of insurance or even complete market unraveling (Akerlof, 1970; Rothschild and Stiglitz, 1976). To investigate such risk-based selection, we implement a so-called positive correlation test (Chiappori and Salanié, 2000). The goal is to test for a correlation between private DI take-up and disability risk, where a positive correlation would indicate adverse selection. Specifically, we run the following regression at the occupation level:

$$Q_j = \beta_0 + \beta_1 \pi_j + \sum_{k=2}^{5} \gamma^k \mathbb{1}(riskgroup_j = k) + \epsilon_j \tag{3}$$

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, and $\mathbb{1}(riskgroup_j = k)$ is an indicator for occupation j being assigned to risk group k by the insurer.[15]

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 insurance contracts are priced. However, in assessing whether there is adverse selection, it is key to estimate the correlation of private DI take-up and risk within groups of individuals facing the same insurance prices. In equation (3), we control flexibly for prices by including a set of risk group dummies, such that we can interpret β_1 as capturing selection on *unpriced risk*. Second, a well-known difficulty with the positive 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 ex-post 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 the treated cohorts 1961 and younger, but we measure disability risk π_j as the fraction claiming DI only among the control cohorts 1960 and older. This risk measure should not be confounded by moral hazard responses to differential take-up among treated cohorts, since all individuals in the control cohorts are observed under full public own-occupation DI coverage.

Figure 5 depicts the estimation results in binned scatter plots. 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

[15] More precisely, we measure $riskgroup_j$ as the modal risk group in an occupation. Risk groups are not necessarily the same for all individuals within a three-digit occupation in the data because the insurer changed risk group assignment over time in some cases.

between DI take-up and risk, with a slope coefficient of -1.39. 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 risk groups. The relationship becomes quite flat, and the estimated slope coefficient corresponding to β_1 in equation (3) is small and statistically insignificant. In other words, we do not find any 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 negative, which would imply slight advantageous selection into private DI.[16]

At first glance, the lack of adverse selection may seem surprising, as insurance should in principle be more valuable to higher-risk individuals. However, there are several potential explanations for this empirical finding. First, evidence from other insurance markets points at an important role for heterogeneity in non-risk related preferences for insurance. If such preferences are negatively correlated with underlying risk, they can un-do potential adverse selection (e.g. Finkelstein and McGarry 2006; Cutler et al. 2008). Our finding that high-income and highly educated individuals, who have lower disability risk on average, are more likely to purchase private DI could reflect this type of negatively correlated preference heterogeneity. Appendix Table A6 presents further suggestive evidence along these lines. In Columns (1) to (2), we first replicate the results from Figure 5. Columns (3) to (6) then explore how risk-based selection changes conditional on different sets of observables by subsequently adding characteristics to the regression. The table confirms that education, and to a lesser extent income, may be drivers of advantageous selection countering potential adverse selection on risk itself. In particular, once we control for education in Column (4), the coefficient on risk turns positive, albeit still insignificant due to a sizeable standard error. This suggests that the insurer may face adverse selection if pricing was conditional on education. In practice, not conditioning prices on education induces some advantageous selection, such that there is no overall adverse selection within risk groups. Interestingly, adding further observables including gender and marital status in Columns (5) and (6) again turns the effect of risk negative, suggesting that these characteristics may drive some adverse selection.[17]

Second, in standard models a key part of the mechanism leading to adverse selection is that individuals have private information about their risk. However, a number of surveys suggests that German workers may not be well-informed about their disability risk (e.g. Continentale 2019; SwissLife 2021). In Section 6.3, we provide suggestive evidence of such risk misperceptions, where high-risk groups under-estimate their risk in particular. This type of behavioral friction could explain both the low take-up among high risk groups and the lack of adverse selection within risk groups (Spinnewijn, 2017). Third, related to the discussion above, an important factor is given by the pricing scheme devised by insurers. Even though somewhat coarse, assigning a relatively small number of discrete risk groups based on occupations seems to be effective in preventing adverse selection.[18] In fact, the

[16] Taking the point estimate from our correlation test at face value would imply that insured individuals have 5.0% lower disability risk than the uninsured (see Section 6.4). This small amount of advantageous selection does not change any of our welfare conclusions.

[17] These results are consistent with "passive" selection on socioeconomic characteristics being a key determinant of overall risk-based selection into insurance (Finkelstein and Poterba, 2014).

[18] Closely related, Bundorf et al. (2012) argue that risk-rated premiums can improve efficiency by limiting risk-based selection into health insurance.

results from Table A6 suggest that it may be optimal for insurers not to use additional observable characteristics such as education to price contracts, as this may risk inducing some adverse selection.

Finally, we note that Table A6 is also informative of which characteristics themselves predict private DI take-up. In Section 4.2, we show that income, education and risk groups exhibit strong univariate correlations with take-up, but one may ask which of these remain strong predictors conditional on risk and other observables. Interestingly, the table indicates that income becomes a less 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, take-up remains significantly lower among high-risk groups in all columns. Additionally, private DI take-up is lower among females and married individuals, and economic training has a positive effect on take-up beyond the influence of education.

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.

To begin with, 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, finds that 26% of working adults have private DI in 2015, 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 that 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. Harmonized risk groups correspond roughly 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 that our main estimates for the largest risk groups 2 and 3 are virtually the same as the take-up rates implied the rating agency data. For the lowest and highest-risk groups, 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 particular risk groups should have little reason to select specifically into the insurer providing our microdata, as its pricing is quite 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 for our welfare analysis. 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 are recently used in related social insurance contexts, including DI and unemployment insurance (Cabral and Cullen, 2019; Landais et al., 2021; Hendren et al., 2021).

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 risk. The first key component for our welfare analysis is demand, or willingness to pay for DI. Denote by $v(\theta_i)$ the utility of consumer i from buying DI, 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

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

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 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 this extensive margin is the empirically relevant dimension 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 our welfare analysis is demand 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 no insurance choice to workers.[19] In particular, we use two empirical moments to estimate demand. First, the observed post-reform private DI take-up rate identifies one point on the demand curve of each risk group, anchoring its level. Second, to estimate the slope, i.e. the responsiveness of demand to prices, we exploit the discrete price variation between risk groups. Assuming a constant elasticity of demand then allows us to construct risk-group specific demand curves.

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:

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

where Q_j denotes private DI take-up by three-digit occupation j, π_j is a measure of disability risk, $\mathbb{1}(riskgroup_j = k)$ is an indicator for occupation j being assigned to risk group k by the insurer and Z_j is a vector of control variables. This regression 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 γ^k capture the jump in private DI take-up between risk groups conditional on underlying risk, which we interpret as a response to the local, discontinuous price variation in insurance premiums between the two groups.

While the goal behind estimating equation (4) is different, the regression specification itself is similar to the positive correlation test from Section 4.3. Econometrically, the main difference to equation (3) is that we now include control variables Z_j, such as income, gender and education. In the correlation test, we do not control for these characteristics because they are not used by the insurer to price contracts. However, it is important to add these controls in equation (4) since they potentially affect demand for private DI and they may differ systematically across risk groups.

Based on the estimated coefficients γ^k, we can then calculate the demand elasticity at the boundary

[19] Presumably for this reason, there is very little direct evidence on individual valuations of DI. To our knowledge, the only exception is given by Cabral and Cullen (2019) who estimate a lower bound on the willingness to pay for public DI using supplemental private DI purchases of workers at a U.S. employer. More generally, the literature often resorts to indirect methods to quantify the value of social insurance, such as consumption-based methods which require stronger assumptions (Landais and Spinnewijn, 2021).

between risk groups k and $k-1$ as

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

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 $k-1$.[20]

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, discrete 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 a binned scatter plot 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 substantial overlap in underlying risk across risk groups. This implies that there are many instances of occupations with the same disability risk facing different premiums, providing us with statistical power to estimate price responses.[21] 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 to insurance premiums as in Panel (a).

Table 3 shows results from the demand elasticity estimation.[22] 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 income, education, gender, marital status, economic training and residence in East Germany as controls somewhat reduces the estimated response to 47%. The demand elasticity estimation then relates the demand response to the jump in price for each pair of adjacent risk groups. In our preferred specifications including the full set of 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 for the different risk groups are close to the average, except the smaller estimate we find between risk groups 2 and 3. 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.[23]

Cost. The second ingredient required for our welfare analysis is the cost of DI. We calculate the expected cost of providing the DI coverage offered by the private market to individual i in risk group k

[20] 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 we can infer directly from the difference in monthly premiums.

[21] According to industry experts, one potential reason for the fuzziness in risk group assignment is that insurers 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 sample period.

[22] Regression results directly corresponding to equation (4) are shown in Column (6) of Appendix Table A6.

[23] 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 that a constant elasticity is a better approximation than a linear curve.

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 any significant risk-based 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 costs are constant, average cost and marginal cost curves coincide. Finally, two additional features of our cost curves are worth noting. First, the cost estimates can be interpreted as inclusive of a fiscal externality due to moral hazard responses to insurance 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.[24]

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 each panel, point A denotes empirically observed private DI take-up and point B

[24] 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 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, suggesting that our assumption of equal cost is a good approximation.

denotes the intersection of estimated demand and cost curves.[25] 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 68%. Thus, willingness to pay is below the cost of insurance for 32% of individuals. In Panel (c), the cost of insuring risk group 3 is yet higher, while the demand curve is lower than that of risk group 2. In fact, willingness to pay is above cost for only 29% of individuals in risk group 3. Similarly, in Panels (d) and (e), risk groups 4 and 5 are even costlier to insure, but estimated willingness to pay for insurance is low. Thus, the cost is above willingness to pay for around 85% of individuals in the two highest-risk groups.

In addition, we note that Figure 7 hints at some differences in insurer profits 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.[26] Similarly, the markup is modest for risk group 3. For risk group 4 and especially risk group 5, markups appear to be larger again.

Finally, we further quantify estimated demand and cost in Appendix Table A7. We calculate willingness to pay and cost for a private DI contract insuring a 30% gross income replacement rate and scale magnitudes as a percentage of lifetime income. Across all groups, median willingness to pay for the coverage offered by the private DI market is 0.90% of income and the expected cost of providing this coverage is 1.47% of income. In line with strongly varying disability risk across risk groups, we estimate group-specific insurance costs between 0.33% of income in risk group 1 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 1.15% of income in risk group 1 and 1.42% in risk group 2, but only between 0.58% and 0.92% for risk groups 3 to 5. These quantitative results directly echo the large differences in empirically observed private DI take-up across risk groups.

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

$$NV^{priv} = \frac{\sum_k n_k \big[\int v(\theta) \mathbb{1}(v(\theta) \geq p_k) dF_k(\theta) \big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) \geq p_k) dF_k(\theta) \big]} \tag{8}$$

[25] Note that we use observed take-up only among treated cohorts to anchor the level of demand curves. Thus, empirical take-up denoted by points A is slightly higher than the rates shown in Figure 4.

[26] 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.

where n_k denotes the size of risk group k. In the private 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 the additional coverage offered by the private market.

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

$$\Delta NV^{mand} = \frac{\sum_k n_k \big[\int v(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]} \tag{9}$$

Individuals whose willingness to pay is above the market price already purchased private DI when they had the choice. Thus, a mandate expands coverage to those individuals whose willingness to pay is below the market price.[27]

Our net value measures express the value of providing insurance per Euro of spending, analogously to the marginal value of public funds (MVPF) (Finkelstein and Hendren, 2020; Hendren and Sprung-Keyser, 2020).[28] A reform can be deemed welfare-improving if its net value is greater than one, i.e. it generates value exceeding its costs. 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 leaving the provision of this extra coverage to the private market is preferable.

These welfare effects can be graphically illustrated using our estimated demand and cost curves. 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 (8), 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 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 A4 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 insurance valuations. Producers receive the largest surplus from risk groups 1, 4 and 5, where markups are highest.

Panel (b) of Figure 8 illustrates the welfare effect 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 mandated take-up of 100%. This corresponds to the sum of areas F and G. Expanding insurance to additional consumers yields value

[27] In the absence of a pre-existing private DI market, the net value of the mandate would be given by $NV^{mand} = \frac{\sum_k n_k \big[\int v(\theta) dF_k(\theta) \big]}{\sum_k n_k \big[\int c(\theta) dF_k(\theta) \big]}$.

[28] Relative to typical MVPF calculations, two features of our net value measure are worth noting. First, since our counterfactual corresponds to a large reform moving insurance take-up to 100%, we use the entire estimated demand and cost curves in equations (8) and (9). Second, our baseline analysis follows Einav et al. (2010) and considers only the direct costs of providing additional DI. In Section 6.4, we show that incorporating various types of indirect costs associated with extra DI does not substantially change the main results.

$D+G$, 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. Again, Appendix Figure A5 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 in particular for higher risk groups, 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 (9). We find a net value of introducing a private DI mandate of 0.74.[29] This implies that partly privatizing DI, similarly to the reform of 2001, is welfare-improving compared to a full public DI mandate. This finding is perhaps not too surprising, given our main empirical results. First, we do not find adverse selection, which would lead to inefficiently low insurance take-up in the private market, and which would be the canonical 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 insurance. Third, the value of extra DI coverage revealed by insurance choices appears to be low for many individuals, especially in the higher risk groups. This is reflected both by the low general level of willingness to pay and by the sizable demand elasticities, which imply that insurance valuations decline fast among the uninsured.

As our main counterfactual, we analyze a reform mandating the full coverage provided by the private DI market here. As explained in Section 2.1, this includes insurance against own-occupation disability and top-up insurance against general disability in case an individual is also eligible for public DI benefits. While one could in principle think of alternative policies, e.g. mandating certain parts of private DI coverage, we focus on this counterfactual for two reasons. First, the "fairest" comparison is arguably one between two policies providing the same insurance coverage, so it seems natural to consider a mandate of actual private DI coverage. Second, our empirical estimates are directly related to this counterfactual, since we quantify selection, insurance demand and cost for the coverage provided by the private DI market. Thus, we consider a counterfactual based on actual private DI coverage to be most empirically credible.[30]

6.2 The Social Value of a DI Mandate

As a first extension of the welfare analysis, we introduce 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

[29] As an interesting point of comparison, Hendren and Sprung-Keyser (2020) find a similar MVPF of providing additional DI benefits between 0.74 and 0.96.

[30] In principle, it may be possible to decompose private DI valuations into different components relating to own-occupation insurance and top-up insurance. However, a particular issue with counterfactuals related to these components is that we cannot necessarily infer the nature of selection into these types of insurance from observed selection in the private DI market.

value of introducing a mandate as

$$\Delta SNV^{mand} = \frac{\sum_k n_k \Big[\lambda_k \overbrace{\int (v(\theta) - p_k)\, \mathbb{1}(v(\theta) < p_k) dF_k(\theta)}^{\text{Consumer surplus}} + \overbrace{\int p_k \mathbb{1}(v(\theta) < p_k) dF_k(\theta)}^{\text{Insurer revenue}} \Big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]} \tag{10}$$

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 of extra DI. 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.[31]

Equation (10) considers a private insurance mandate where individuals are compelled to purchase private DI at market prices. However, in our setting, extra DI coverage was provided via 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 DI mandate, we have to take into account that contributions can differ from market prices p_k. Formally, the social net value of a public DI mandate is given by

$$\Delta SNV^{pub} =$$

$$\frac{\sum_k n_k \Big\{ \lambda_k \Big[\int (v(\theta) - p_k)\, \mathbb{1}(v(\theta) < p_k) dF_k(\theta) + \overbrace{\int (p_k - p_k^{pub}) dF_k(\theta)}^{\text{Pricing effect}} \Big] + \int p_k^{pub} \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \Big\}}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]} \tag{11}$$

where p_k^{pub} denotes contributions paid by individuals in risk group k. Compared to equation (10), a public DI 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 a public DI mandate financed by income-based contributions. This reflects the situation in typical real-world social insurance systems, where contributions are levied as a proportion of an individual's gross income. We calculate the required contribution rate such that total contributions equal the cost of providing the extra coverage to all individuals.

In order to obtain welfare weights, we require a social welfare function. As is common in the literature, we assume Utilitarian social welfare, 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 A8 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

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

higher σ entails larger 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, indicating that a private DI mandate would be a regressive policy. As can be seen in Appendix Figure A5, 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 income-based 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 surplus but only its distribution. However, with equity concern, a public DI mandate can improve welfare relative to the private market. Intuitively, 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 is already 1.25. As expected, the social net value rises with the degree of equity concern, for instance it becomes 1.98 for σ=3 and 2.30 under a Rawlsian social welfare function.

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 reflecting 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, several 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, as discussed in Section 4.3, the low observed willingness to pay for insurance among high-risk groups is puzzling, and behavioral frictions affecting these individuals could provide an explanation. Moreover, a number of independent surveys suggest that most German workers tend to underestimate disability risk (e.g. Continentale 2019; SwissLife 2021), such that they may undervalue insurance.

Empirically disentangling such behavioral biases from other factors influencing individual insurance choices is challenging. Perhaps most importantly, different risk groups may vary in their true risk preferences: Workers in higher risk groups may exhibit low willingness to pay for DI because they misperceive their disability risk, or due to low risk aversion. Another factor we may have to take into account is the availability of non-contributory benefits to individuals who are unable to work. In particular, basic social assistance could be an attractive alternative to private DI for low-income individuals. 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. This last part of our approach is closely related to Spinnewijn (2017) who theoretically analyzes how behavioral frictions distort observed insurance demand and shows that they can magnify the welfare gains of a mandate.

6.3.1 Risk Aversion Implied by Observed Insurance Choices

We begin by asking what level of risk aversion would be implied by observed private DI 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 private DI as

$$\underbrace{\sum_{t=0}^{T} \delta^t \left[(1-\Pi_t)u(c_H^0) + \Pi_t(\eta_t u(c_L^{0,0}) + (1-\eta_t)u(c_L^{0,1}))\right]}_{V_0 \text{ (utility without private DI)}} = \underbrace{\sum_{t=0}^{T} \delta^t \left[(1-\Pi_t)u(c_H^1) + \Pi_t(\eta_t u(c_L^{1,0}) + (1-\eta_t)u(c_L^{1,1}))\right]}_{V_1 \text{ (utility with private DI)}} \tag{12}$$

where T is the end date of the insurance contract relative to a start date normalized to zero, Π_t is cumulative disability risk in period t, η_t is the probability of not qualifying for public DI in case of disability, and δ^t is a discount factor. Consumption depends on whether the individual is disabled, whether they qualify for public DI benefits, and whether they have purchased private DI. c_H^j denotes consumption when not disabled, $c_L^{j,0}$ is consumption when disabled and qualifying for public DI, and $c_L^{j,1}$ is consumption when disabled and not qualifying for public DI, where $j \in \{0,1\}$ is an indicator for having private DI.

For the calibrations, we assume again CRRA preferences $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ and we use the information on average income, insured benefits, premiums, contract duration, and cumulative risk paths by risk group contained in our data. Furthermore, differences in consumption levels across disabled and non-disabled states are a crucial input for the calibrations. Incomes can be written as $y_H^0 = w$, $y_H^1 = w - p$, $y_L^{0,0} = \underline{y}$, $y_L^{1,0} = b$, $y_L^{0,1} = \max(b^{pub}, \underline{y})$ and $y_L^{1,1} = b + b^{pub}$ where w is the individual's wage, p is the private DI premium, b is the insured private DI benefit, b^{pub} is the public DI benefit the individual may be eligible for, and $\underline{y}$ is an income floor given by basic social assistance. We consider a range of consumption scenarios. At one extreme, we consider hand-to-mouth consumers whose consumption equals income in each state. In addition, we use estimates of the drop in consumption upon disability based on Meyer and Mok (2019). Our baseline "high consumption drop" scenario assumes a change in consumption of 41% upon disability, and an alternative "low consumption drop" scenario assumes a drop of 25%.[32]

[32] Based on U.S. survey data, Meyer and Mok (2019) report a drop in earnings of 77%, a drop in income before public transfers of 53%, a drop in income after public transfers of 28% and a drop in consumption of 25%. Given the higher

Moreover, we consider a range of assumptions about η_t, the probability of not qualifying for public DI upon disability. As a lower bound, we set η_t equal to the fraction of own-occupation DI claims by risk group, which are not covered by public DI after the reform. In addition, we consider rejection rates for public DI applications between zero and 44%, where the latter is the actual public DI rejection rate. Throughout, we use a discount rate of 3%.

Under these assumptions, we can calibrate risk aversion σ of the marginal buyer in each risk group. Results are shown in Appendix Table A9. First, it is important to note that the marginal buyer is located at very different percentiles of willingness to pay for DI across risk groups, as shown in Panel A. For instance, 68% of individuals among treated cohorts 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 drops and public DI rejections, we find implied coefficients of relative risk aversion between 1.12 and 4.96 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. Most estimates are below 2 and some as low as 0.20, except under the "low consumption drop" scenario where the highest estimate is 2.87. Interestingly, calibrated risk aversion does not appear to decrease monotonically with risk groups. In particular, risk aversion of the marginal buyer in group 5 tends to be higher than in groups 2 to 4. Intuitively, this occurs due to a combination of basic social assistance providing sizable insurance against inability to work given low average income of group 5, and high private DI premiums charged to this group.

As noted above, a direct comparison of risk aversion estimates across risk groups is complicated by the fact that the respective marginal buyers represent very different percentiles of willingness to pay. Thus, to further illustrate the implied distribution of risk aversion, we repeat the calibration for the median individual in each group. To do this, we can again use equation (12), but replace the market price, at which the condition holds for the marginal buyer, by the median willingness to pay from our estimated risk-group specific demand curves. Panel C of Table A9 shows resulting median risk aversion estimates. In risk groups 1 and 2, estimates are slightly higher than those from Panel B, since the marginal buyer is located below the median in these groups. For instance, we find risk aversion between 1.34 and 6.00 for the median individual in risk group 1. Strikingly, we find that median risk aversion would have to be negative in risk groups 3 to 5 under all calibration scenarios. Taken at face value, this would imply that at least half of the individuals in these higher-risk groups do not value insurance.

Overall, we conclude that observed insurance choices would imply very low risk aversion for many individuals in higher-risk groups. The risk aversion coefficients we find for marginal buyers in these groups are considerably lower than most estimates from the literature on insurance choices.[33] Our

public DI replacement rate in the U.S. than in Germany, we consider the estimate of 25% for our "low consumption drop" scenario. An important issue is that we also need to assume a value for the consumption drop in the absence of public DI, but we are not aware of any such estimate from the literature. Thus, we choose two estimates from Meyer and Mok (2019) that may come closest to consumption drops without public DI. First, for the "high consumption drop" scenario, we use their finding of a 77% drop in earnings. Second, combining the remaining estimates, a back-of-the-envelope calculation results in a hypothetical "low consumption drop" in the absence of public DI of 53%·25%/28%=47%. Finally, we complete the "high consumption drop" scenario by supposing a 77%·25%/28%=41% drop with public DI in this case.

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

finding of negative median risk aversion in risk groups 3 to 5 reinforces the conclusion that low but plausible risk preferences cannot rationalize observed insurance choices of many individuals.

6.3.2 Risk Misperceptions and Welfare Implications

In the second step, our goal is to investigate whether risk misperceptions can rationalize the 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 $\hat{\Pi}_t = \alpha \Pi_t$. In the case of risk under-estimation ($0 \leq \alpha < 1$), a smaller α would indicate more severe bias. The indifference condition governing insurance choice of the marginal buyer can be written as $V_0(\hat{\Pi}_t) = V_1(\hat{\Pi}_t)$, replacing Π_t by $\hat{\Pi}_t$ in equation (12). Under the assumptions on the utility function and consumption levels described above, we can use this condition 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 1.12 and 4.96. Panel D of Appendix Table A9 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 risk under-estimation reflected by α is roughly between 40% and 60% in most specifications. Only under hand-to-mouth consumption, risk group 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 of higher-risk groups.

In the third step, we calculate the wedge between observed willingness to pay and normative willingness to pay implied by these risk misperceptions. Observed valuations are implied by the indifference condition $V_0(\hat{\Pi}_t) = V_1(\hat{\Pi}_t)$, and corresponds to the empirical willingness to pay of the marginal buyer. Normative valuations, on the other hand, are 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 E of Appendix Table A9 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 2.4 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 (8), where we replace observed demand $v(\theta)$ in each risk group by normative valuations implied by the results from Panel D of Appendix Table A9. We find a net value of mandating extra DI coverage between 1.13 and 1.34. In other words, average true valuations of individuals who choose not to buy private DI in the private market exceed the average cost of providing insurance to them. Hence, risk misperceptions can provide an additional rationale for mandating the coverage offered by the private DI market.

6.4 Extensions and Robustness

Indirect Costs. 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 providing additional DI coverage. We address this by conducting extensions of the welfare analysis in the spirit of a more complete MVPF calculation. Overall, we find that allowing for indirect costs does not lead to any substantial changes in our main results.

To begin with, mandating private 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 A10, taking into account this additional moral hazard lowers the net value of a mandate to around 0.65. A second indirect effect may be given by additional DI imposing 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 B, which shows that the net value of mandating private DI increases slightly to 0.75. The change in net value is small because social assistance is relatively low and for many claims baseline public DI is still available.

A third 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. Standard MVPF calculations do not necessarily consider this type of fiscal externality in order to remain agnostic about how policies are financed. However, in our setting it seems reasonable to assume that public DI expansions are financed by raising social insurance contributions, and switching to income-based contributions is a key factor in our social net value calculations. Hence, 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 German tax and transfer microsimulation model ZEW-EviSTA (Buhlmann et al., 2022) to calculate marginal and average tax rates faced by individuals in each risk group. In Panel C of the table, the distortion from raising contributions lowers the net value of a public DI mandate to around 0.61. We note that this fiscal externality likely provides an upper bound, as some studies suggest that social insurance contributions induce much smaller distortions than income taxes (e.g. Lehmann et al., 2013).

Finally, Panel D shows the combined effect of all these indirect effects. Overall, results remain similar to our baseline calculations, but the net value of a mandate becomes somewhat smaller. We find a baseline net value of 0.66 for a private DI mandate and 0.54 for a public DI mandate, and a somewhat higher degree of equity concern (σ around 3) would be needed to justify the public mandate. As is typical for MVPF calculations, which of these indirect costs should ultimately be included remains to some extent a judgment call. This makes it particularly reassuring that our welfare results do not qualitatively change when considering various types of indirect effects.

Bounds on Risk-Based Selection. 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 are subject to some statistical uncertainty, such that we cannot exclude small degrees of risk-based selection. To quantify the potential range of slopes of cost curves, we invert the specification from equation (3), regressing claiming probabilities on take-up conditional on risk groups. We find a point estimate of -1.3 pp., with a 95% confidence interval between -3.9 pp. and +1.4 pp. These results imply small degrees of selection. The point estimate corresponds to a -5.0% difference in claims between individuals with and without private DI, and the confidence interval ranges from adverse selection with a 5.5% difference in claims to advantageous selection with a -15.6% difference. In Panels E and F of Table A10, we replicate the welfare analysis under these statistical bounds on risk-based 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 document significant crowding-in of private DI when the scope of public DI is reduced, but find that overall private DI take-up remains relatively modest. In particular, high-risk, low-income and low-educated 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 insurance valuations, providing extra DI coverage via a private DI market with choice is welfare-improving compared to a mandate. However, equity concerns provide an important potential rationale for a full 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 can explain low observed willingness to pay for private DI of many workers, which can provide further grounds for interventions aimed at increasing take-up, such as a mandate.

To our knowledge, the German setting is unique in that one tier of the public DI mandate was completely removed. This allows us to provide first-time evidence on the key issues determining the welfare effects of partly privatizing DI. In interpreting our results, it is important to bear in mind that a specific type of coverage is offered by the private DI market in our setting, combining insurance against own-occupation disability risk and more general top-up insurance. One could think of similar reforms privatizing insurance against other sub-risks, for instance insurance against short-term disability (Autor and Duggan, 2010) or insurance against disability due to a subset of medical conditions. While our results cannot be directly extrapolated to privatizing any type of DI coverage, we believe that the issues studied in this paper are the relevant ones for other DI reforms aimed at increasing the role of private insurance. Exploring which sub-risks or sub-parts of DI can and should be optimally privatized could be a promising avenue for future research.

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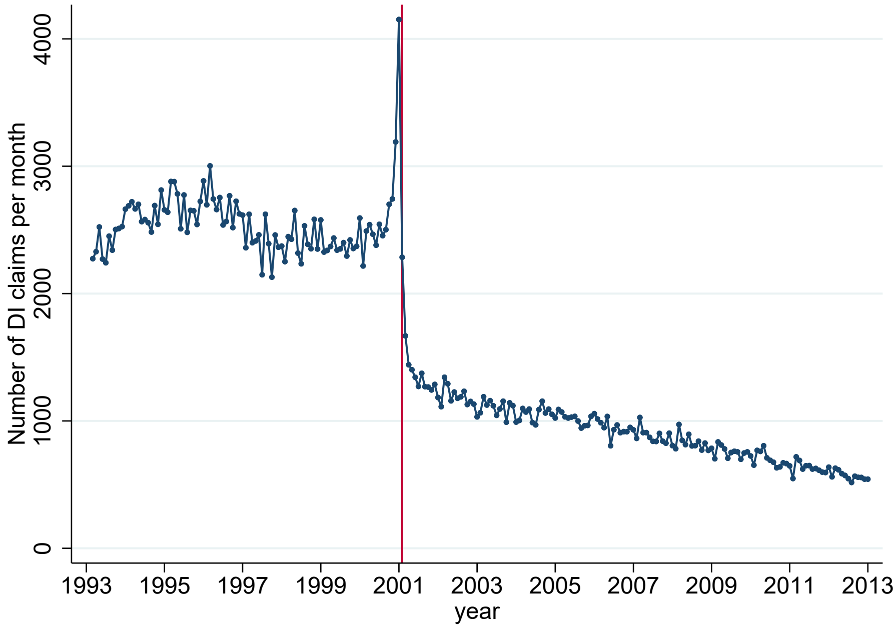
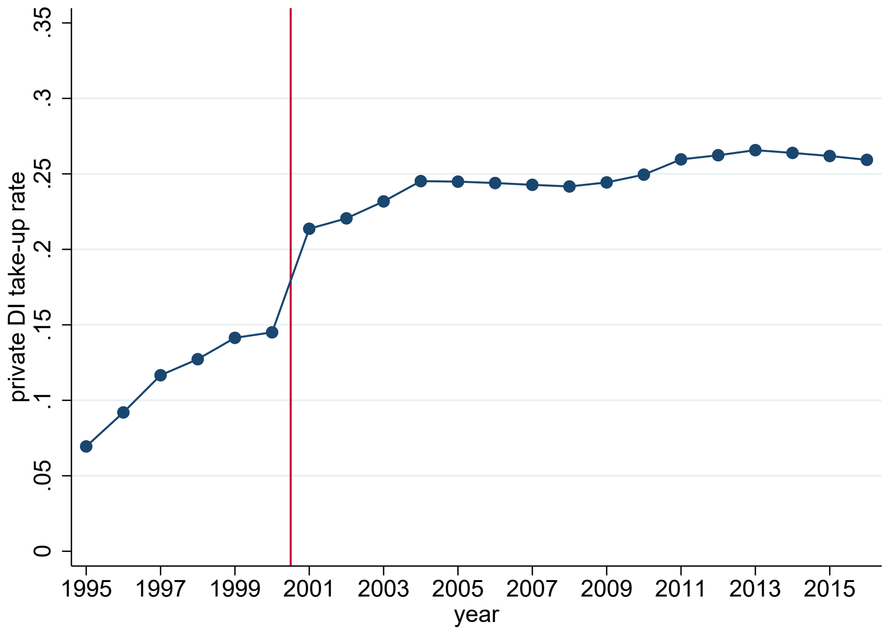
Figure 1: Crowding-In: Descriptive Evidence

(a) Public Own-Occupation DI Claims



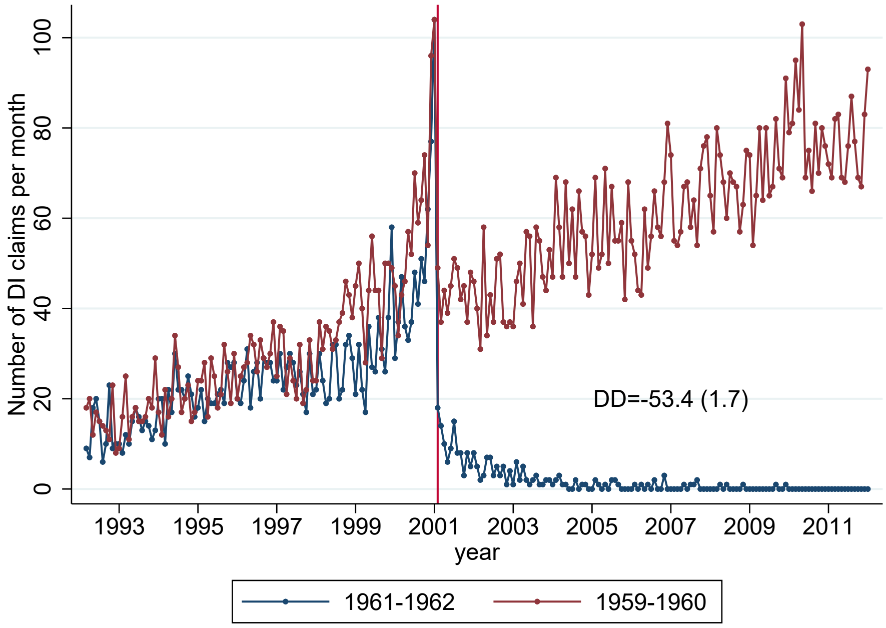
(b) Private DI Take-Up



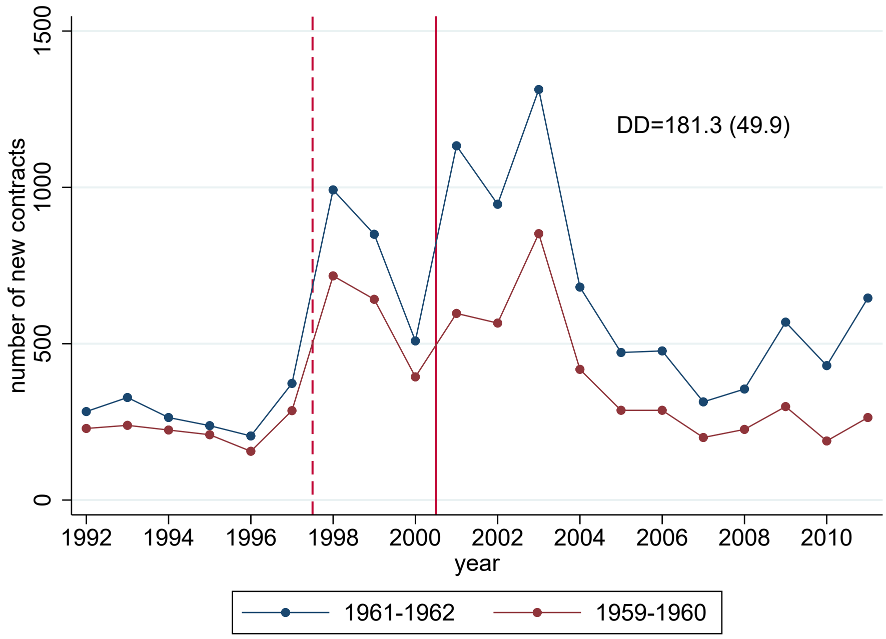
Notes: Panel (a) of the figure shows the number of monthly public own-occupation DI claims. Panel (b) shows the overall private DI take-up rate, i.e. the fraction of workers covered by private DI, by year. In both panels, the vertical line demarcates the reform of 2001.

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

(a) Public Own-Occupation DI Claims

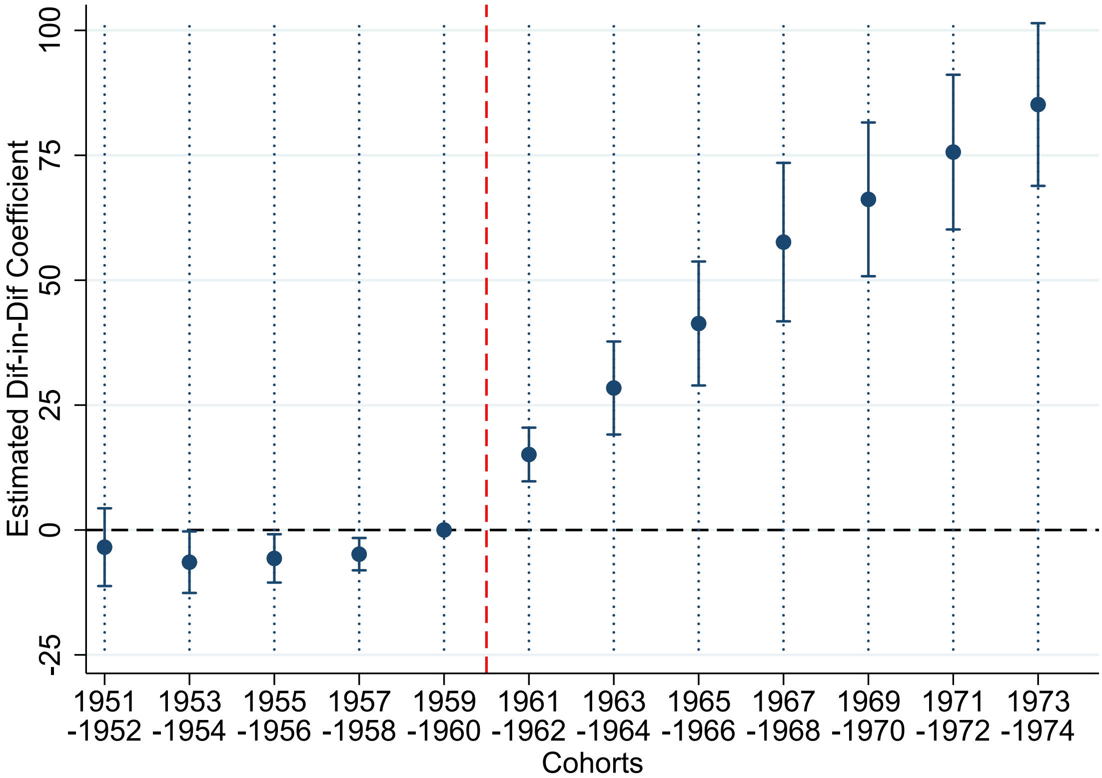


(b) Private DI Purchases



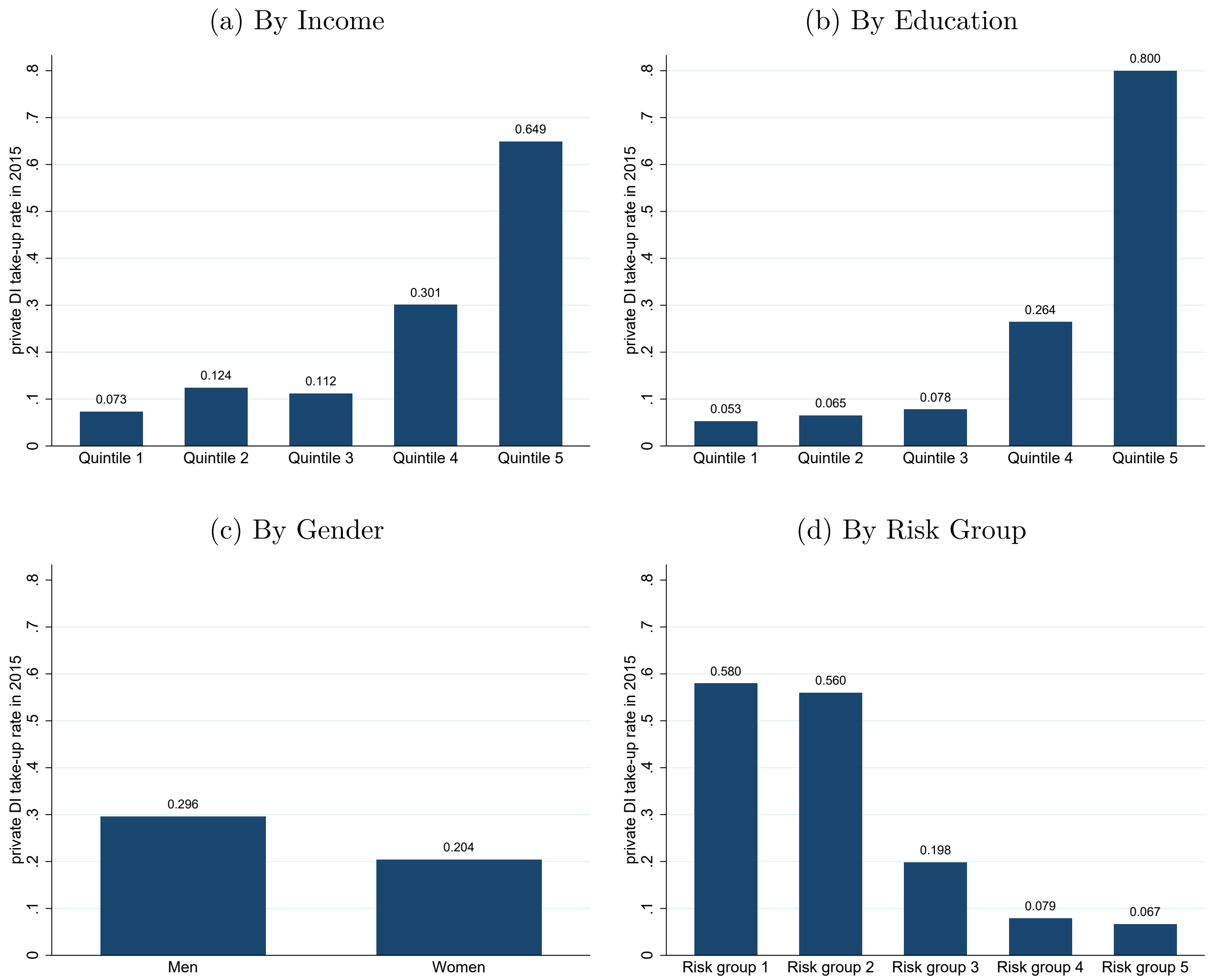
Notes: The figure shows the number of public own-occupation DI claims (Panel a) and private DI purchases (Panel b) of individuals born in 1961-1962 (treated cohorts) vs. 1959-1960 (control cohorts). In both panels, the solid vertical line demarcates the time when the reform of 2001 takes effect (January 2001). In Panel (b), the dashed vertical line additionally demarcates the time when 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 estimates of the effect of the 2001 reform on private DI purchases for a range of cohorts. The estimates correspond to coefficient β_2 from equation (1), where the respective 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, such that the cohorts to the right of the line are affected by the reform.

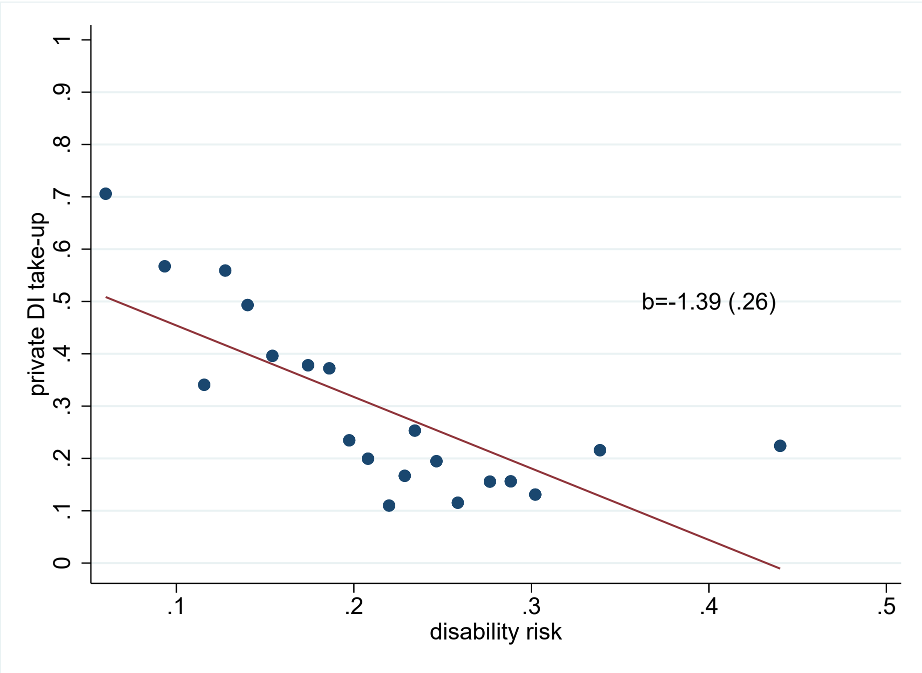
Figure 4: Private DI Take-Up by Observable Characteristics



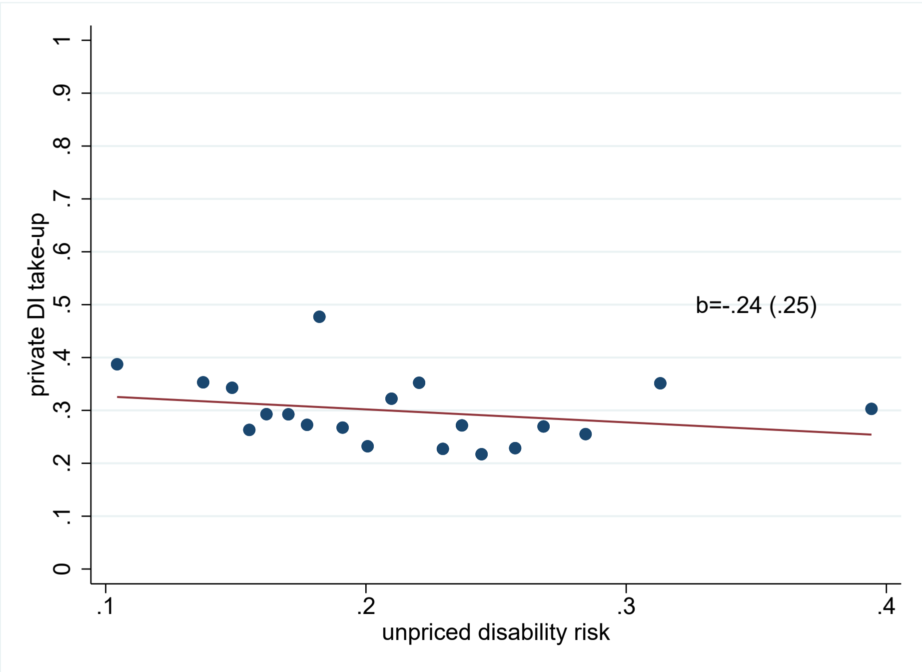
Notes: The figure shows private DI take-up rates in 2015 by income quintile (Panel a), education quintile (Panel b), gender (Panel c) and risk group (Panel d). In Panel (b), education is defined as years of schooling. Take-up rates are calculated among all cohorts as shown in equation (2).

Figure 5: Risk-Based Selection

(a) Unconditional Correlation of Take-Up and Risk



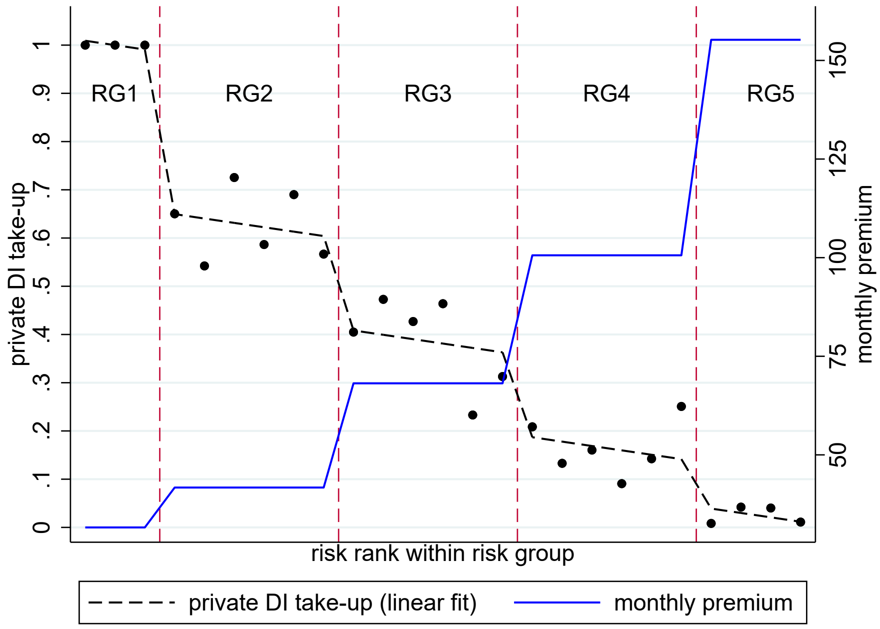
(b) Selection on Unpriced Risk



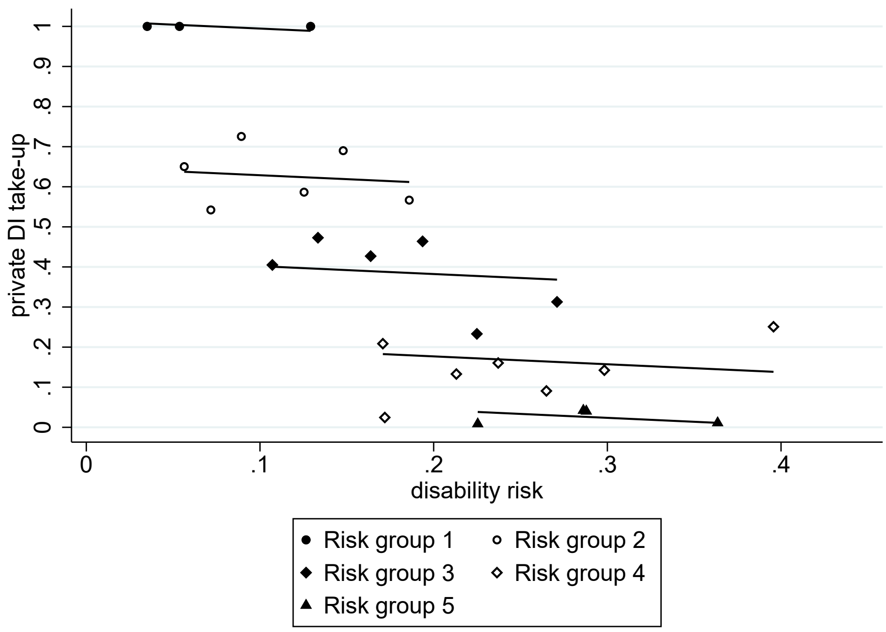
Notes: The figure shows binned scatterplots depicting the correlation between private DI take-up and disability risk at the three-digit occupation level. Panel (a) shows the unconditional correlation between take-up and risk, corresponding to estimating equation (3) without controlling for risk groups. Panel (b) shows the correlation between take-up and unpriced risk, controlling for risk groups. As explained in Section 4.3, take-up rates are calculated among treated cohorts in 2015, while disability risk is measured only among control cohorts. Each panel also includes the estimated slope coefficient b with its standard error in parantheses.

Figure 6: Demand Responses to Insurance Prices

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

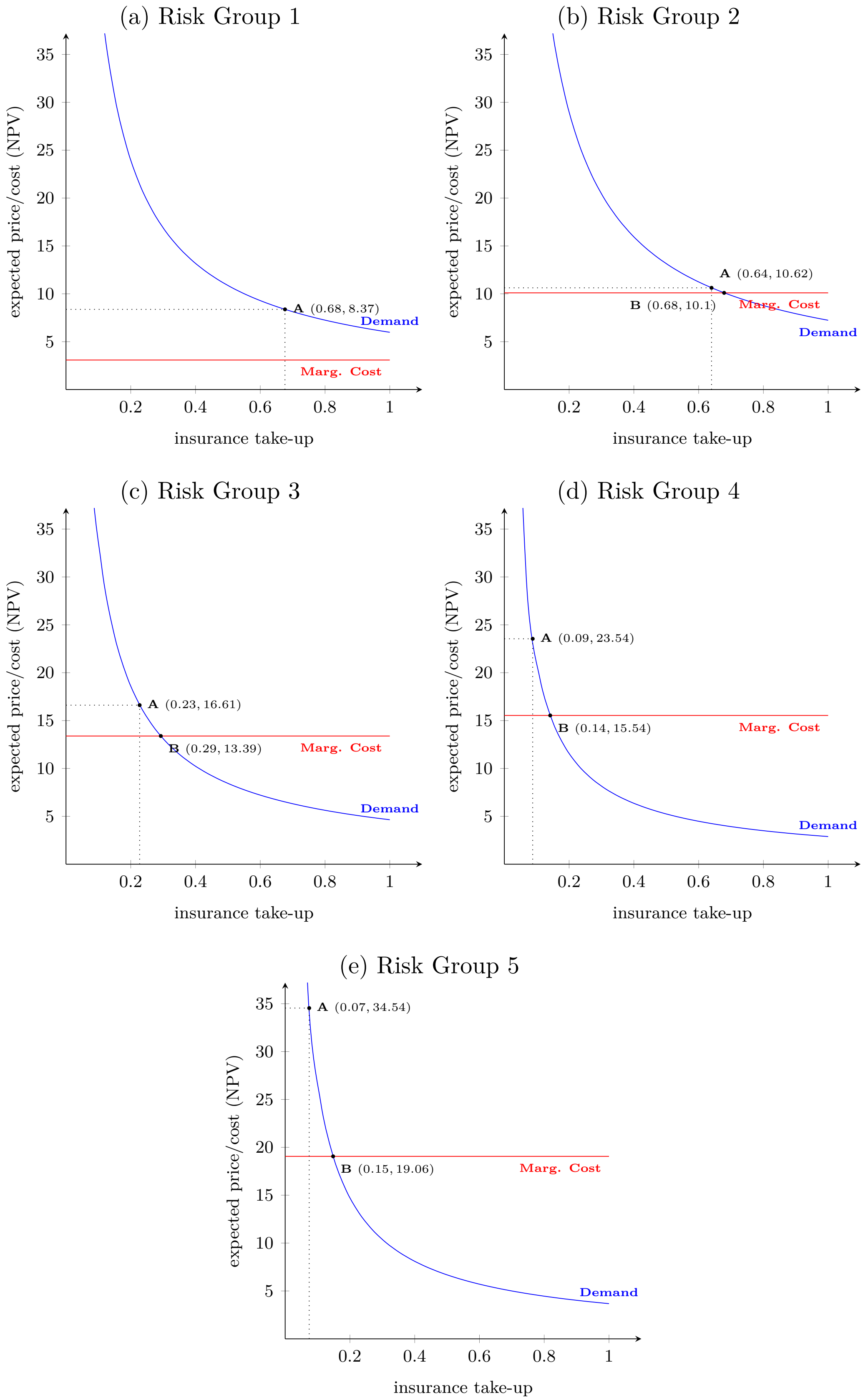


(b) Take-Up by Actual Risk



Notes: The figure presents evidence of demand responses to private DI premiums. Panel (a) shows a stylized depiction of jumps in premiums and take-up rates between risk groups, ranking three-digit occupations by disability risk within risk group. 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 directly to the regression shown in equation (4).

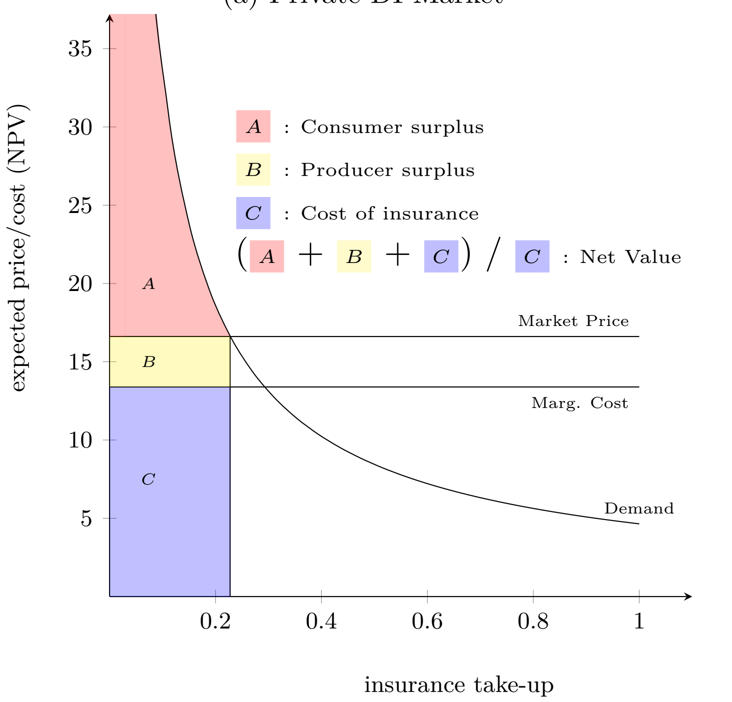
Figure 7: Demand and Cost Curves



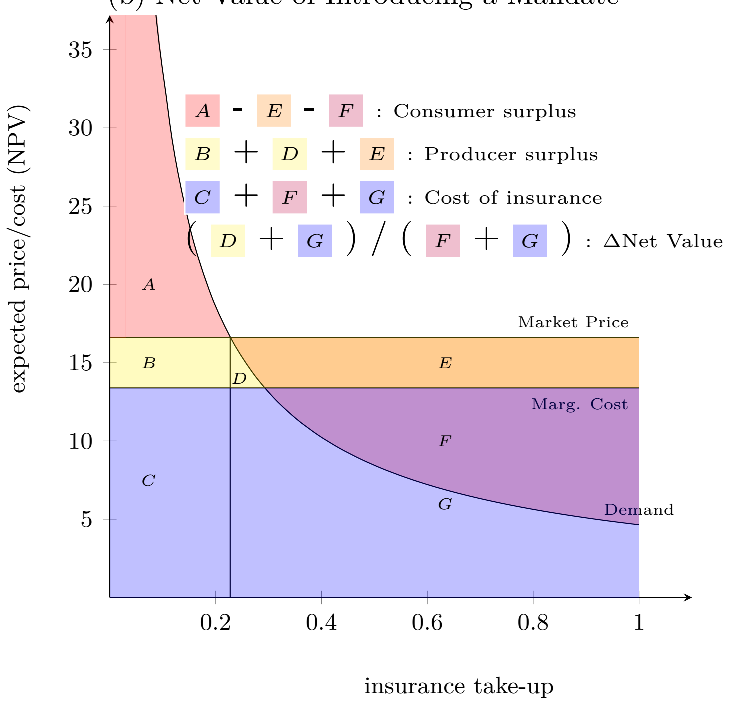
Notes: The figure presents private DI demand and cost curves estimated in Section 5.2. The horizontal axes display private DI take-up rates between zero and one, and the vertical axes show expected prices and cost as defined in equations (6) and (7). Each panel shows the demand curve (blue line) and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

Figure 8: Welfare Calculations

(a) Private DI Market



(b) Net Value of Introducing a 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 a reform mandating private DI coverage. 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. Appendix Figures A4 and A5 show corresponding graphs for all risk groups.

Table 1A: Summary Statistics of the Private Insurer Microdata

	(1) Full Sample	(2) Cohorts 1959-1962
Male	0.60	0.71
	(0.49)	(0.45)
Income (monthly)	4232.53	4422.10
	(1382.31)	(1364.61)
Education (years)	12.42	12.22
	(1.97)	(2.03)
Risk Group	2.42	2.55
	(0.86)	(0.92)
Age at Purchase	31.54	40.79
	(7.44)	(4.95)
Age at Contract End	61.33	60.18
	(3.55)	(2.77)
Insured Benefits (monthly)	1494.34	1553.75
	(1009.46)	(1242.95)
Insurance premium (monthly)	85.98	106.67
	(58.93)	(77.50)
Stand-Alone DI contract	0.54	0.57
	(0.50)	(0.50)
Observations	*confidential*	18,659

Notes: The table presents summary statistics of the insurer microdata on private DI contracts. Column (1) summarizes the full sample and Column (2) focuses on the cohorts included in the difference-in-difference estimation from Section 3.2. “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. “Observations” refers to number of private DI contracts, which we cannot show for the full sample for confidentiality reasons.

Table 1B: Summary Statistics of the 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)	(0.38)	(0.50)
Married	0.66	0.77	0.51
	(0.47)	(0.42)	(0.50)
Benefit claiming age	51.91	53.90	43.34
	(7.72)	(6.35)	(5.52)
Monthly benefit (Euros)	1,075.43	868.42	856.89
	(605.43)	(498.52)	(433.90)
Average monthly earnings before claim	2,294.88	2,723.25	2,163.97
	(1,114.82)	(1,020.91)	(1,1230.72)
Monthly earnings in year before claim	1,306.23	1,534.41	1,217.20
	(1,029.26)	(1,100.02)	(1,005.19)
Education (years)	10.39	10.35	10.64
	(1.18)	(1.10)	(1.48)
Observations	4,174,584	415,948	304,162

Notes: The table presents summary statistics of the administrative data on all public DI claims between 1992 and 2014. Column (1) summarizes all claims including general DI and own-occupation DI, Column (2) focuses on own-occupation DI claims, and Column (3) provides summary statistics of claims among the cohorts included in the difference-in-difference estimation from Section 3.2. "Observations" refers to the number of 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	-53.37***	-116.3***	15.11***	13.22***	-462.2
	(1.677)	(5.734)	(2.739)	(1.676)	(384.1)
Observations	480	480	480	480	480
R-squared	0.929	0.993	0.939	0.939	0.926
Mean (pre-reform)	46.80	501.0	23.49	6.640	10,236
Calendar month FE	yes	yes	yes	yes	yes

Notes: The table shows results from the difference-in-difference estimation described by equation (1). Outcomes are indicated by the respective column titles. Regressions are run at the level of cohort × month cells. Pre-reform means are calculated in the year 2000 for Columns (1) and (2), and in years 1992 to 1997 for Columns (3) to (5). 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
	(0.053)	(0.140)	(0.164)	(0.157)	(0.094)
With controls	-0.470	-0.273	-0.140	-0.575	-0.889
	(0.104)	(0.206)	(0.180)	(0.151)	(0.308)
Elasticity					
Without controls	-1.791	-2.285	-1.129	-2.201	-1.548
	(0.149)	(0.567)	(0.373)	(0.424)	(0.176)
With controls	-1.160	-1.109	-0.321	-1.556	-1.655
	(0.277)	(0.834)	(0.410)	(0.409)	(0.573)

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. "Without controls" indicates that the respective estimate 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. Raw regression results are shown in Columns (2) and (6), respectively, of Appendix Table A6. The bottom two rows show elasticity estimates, relating the estimated 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 Mandates

	(1) Private DI Mandate	(2) Public DI Mandate (Income-Based Contributions)
Panel A: Baseline Calculation		
Net Value	0.739	0.739
Panel B: Social Net Value		
Utilitarian, σ=1	0.670	1.251
Utilitarian, σ=3	0.566	1.788
Utilitarian, σ=5	0.498	1.976
Utilitarian, σ=8	0.436	2.050
Rawlsian	0.101	2.295
Panel C: Net Value under Risk Misperceptions		
Baseline (σ=1.85)	1.331	1.331
Hand-to-mouth (σ=1.12)	1.132	1.132
Low consumption drop (σ=4.96)	1.264	1.264
No public DI rejections (σ=2.53)	1.340	1.340
High public DI rejections (σ=1.53)	1.264	1.264

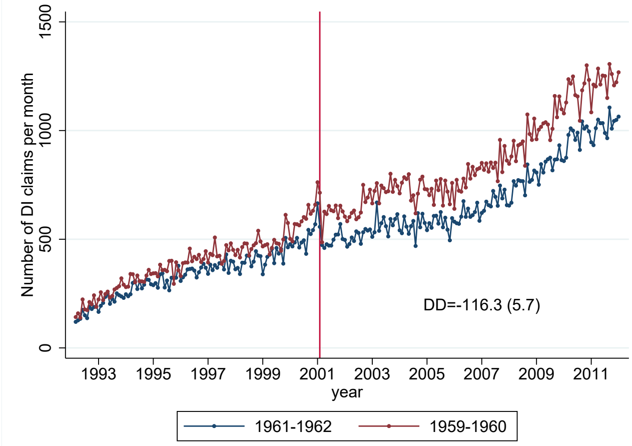
Notes: The table shows the net value of mandating the DI coverage offered by the private insurance market. Column (1) presents net value estimates for a private DI mandate and Column (2) presents estimates for a full public DI mandate financed by income-based social insurance contributions. Panel A shows the baseline net value calculated as shown in equation (9). Panel B shows the social net value calculated as in equations (10) and (11), under different social welfare functions (SWF) indicated in the row titles. σ denotes the coefficient of relative risk aversion we assume in the case of a Utilitarian SWF. Panel C shows the net value under risk misperceptions, based on calibrated normative insurance valuations from Appendix Table A9. Row titles indicate different assumptions about consumption patterns and public DI rejections, with true risk aversion σ calibrated under each scenario parantheses.

Online Appendix

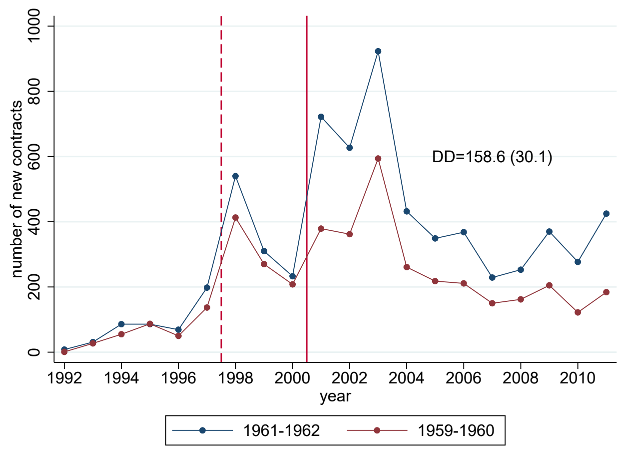
A Appendix Figures and Tables

Figure A1: Additional Difference-in-Difference Results

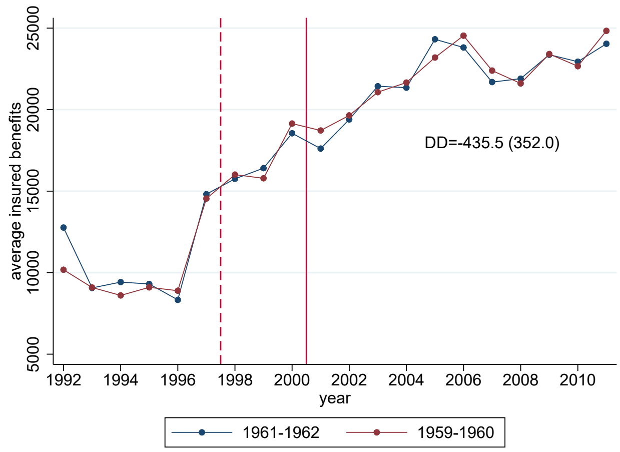
(a) All Public DI Claims



(b) Private Stand-Alone DI Purchases

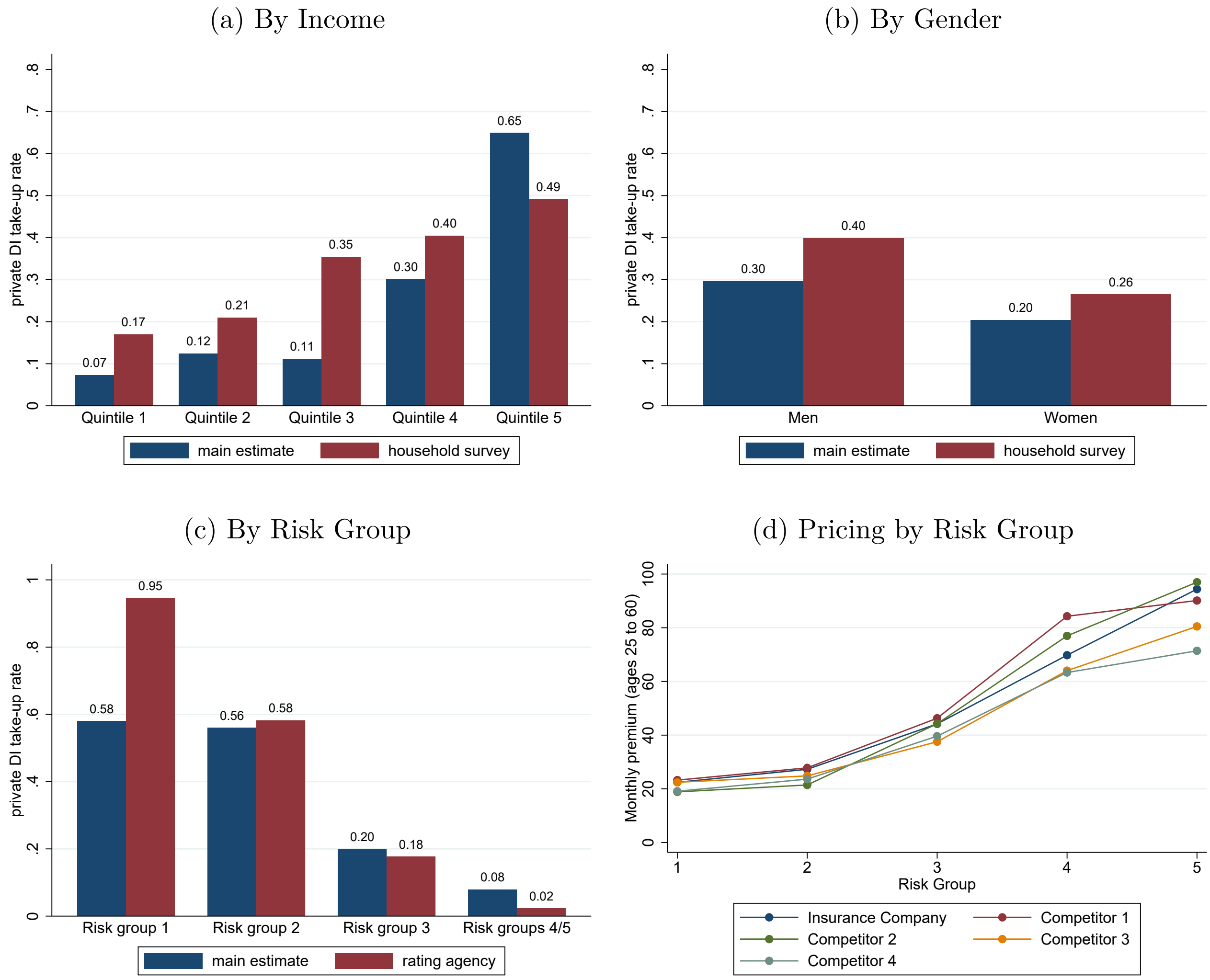


(c) Private DI Benefits



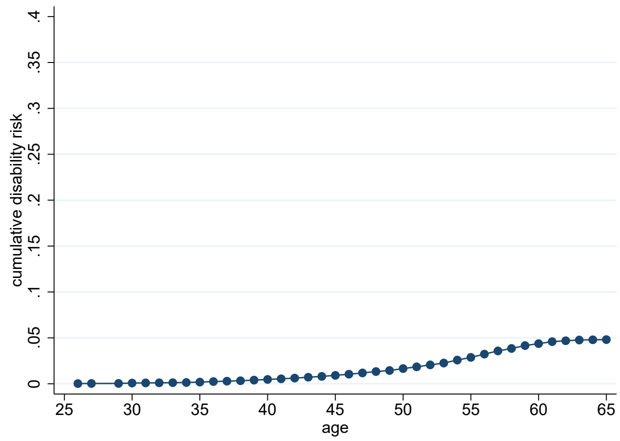
Notes: The figure shows the number of public DI claims (Panel a), stand-alone private DI purchases (Panel b) and insured benefits in private DI contracts of individuals born in 1961-1962 (treated cohorts) vs. 1959-1960 (control cohorts). In all panels, the solid vertical line demarcates the time when the reform of 2001 takes effect (January 2001). In Panels (b) and (c), the dashed vertical line additionally demarcates the time when 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

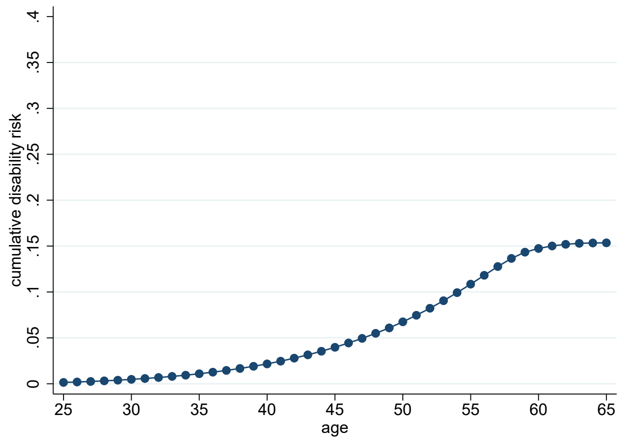


Notes: The figure collects various pieces of evidence validating our main empirical results. Panels (a) and (b) show a comparison of the private DI take-up rates we find based on the insurer microdata (blue bars) to take-up rates based on representative household survey data (red bars), by income quintile (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.

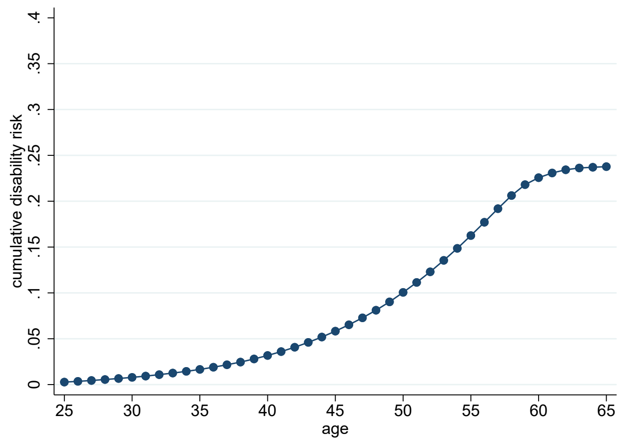
Figure A3: Disability Risk Paths



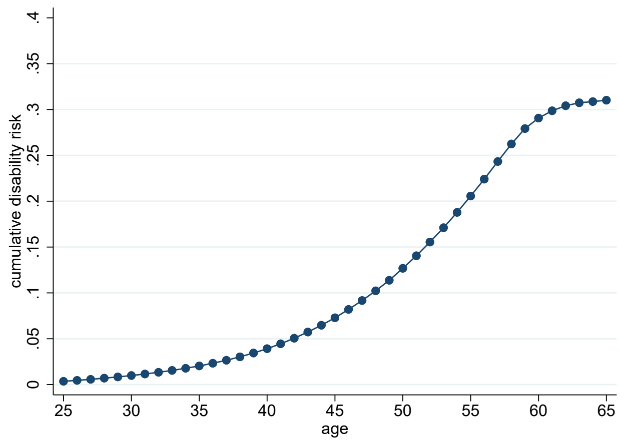
(a) Risk Group 1



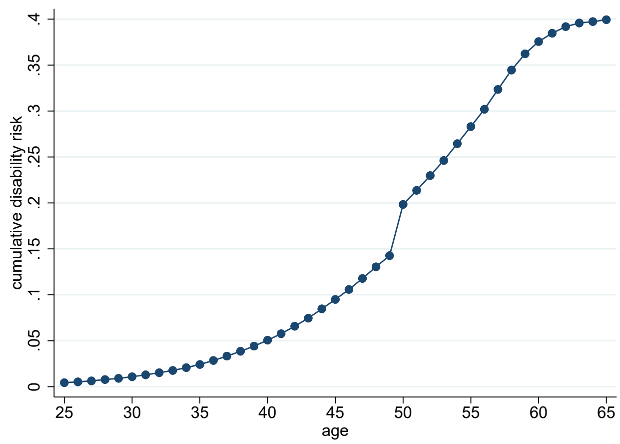
(b) Risk Group 2



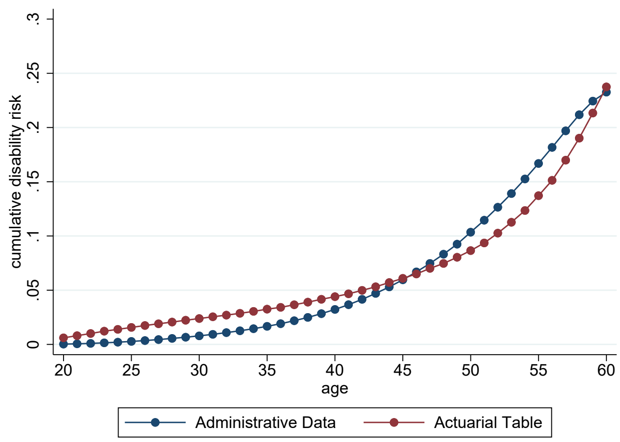
(c) Risk Group 3



(d) Risk Group 4



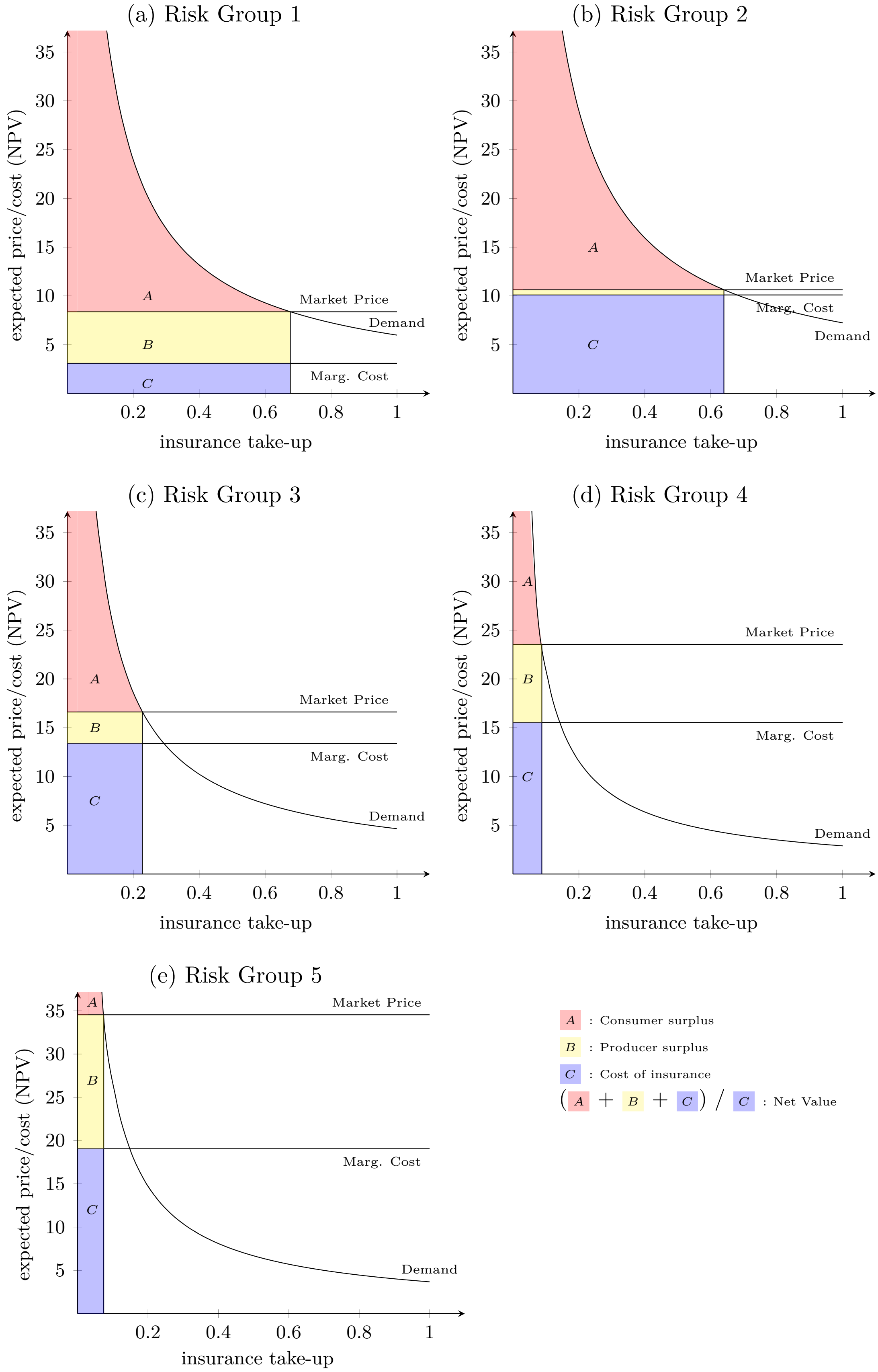
(e) Risk Group 5



(f) Public vs. Private DI Data (All Groups)

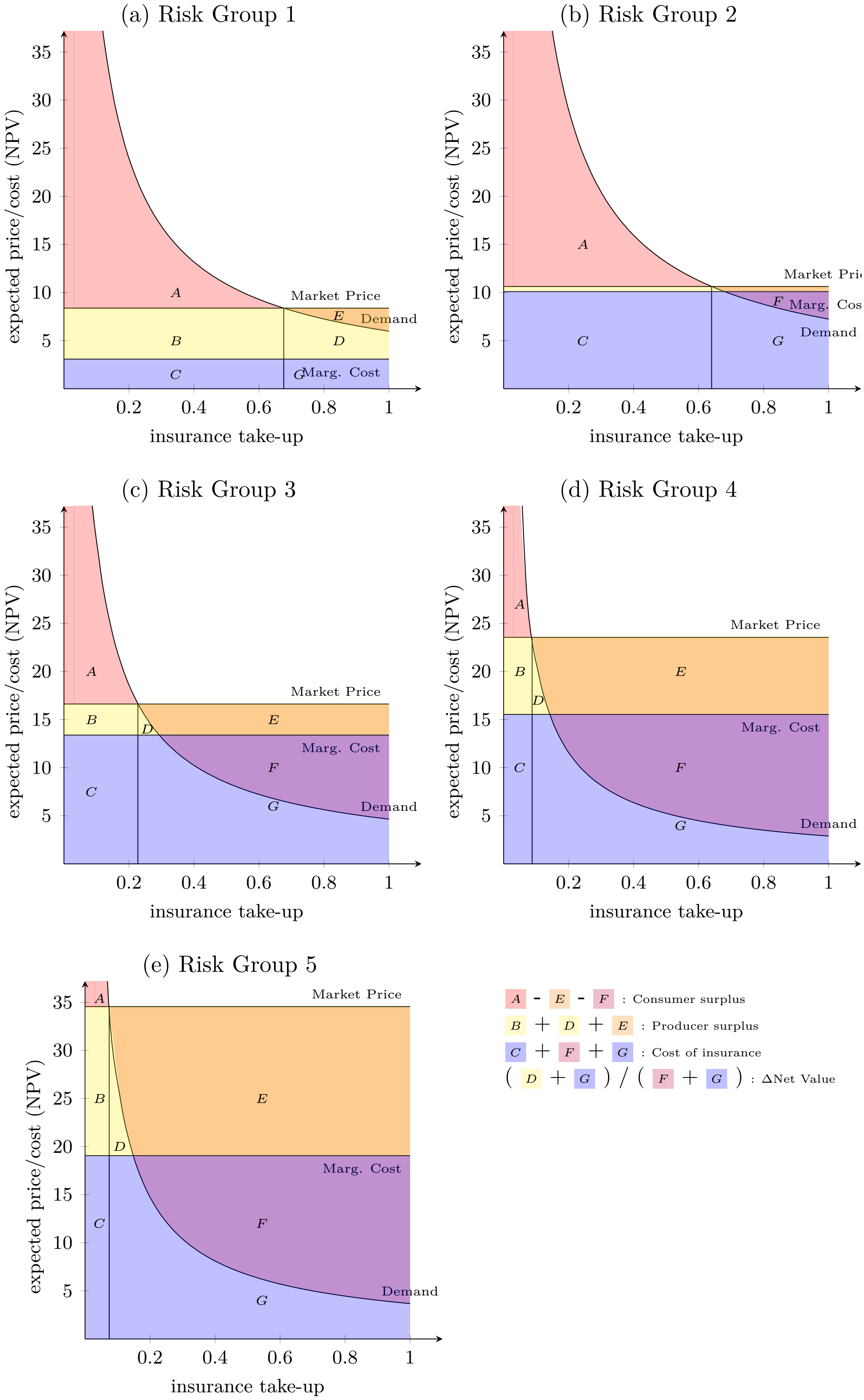
Notes: The figure shows the cumulative fraction of individuals claiming DI benefits. Panels (a) to (e) show the fraction claiming public DI benefits by age for the risk group indicated by the panel title. Panel (f) shows a comparison of claims among all risk groups in the administrative data to DI claiming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

Figure A4: Net Value in the Private DI Market



Notes: The figure depicts welfare in the private DI market equilibrium for each risk group indicated by the panel titles. 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 A5: Net Value of Introducing a Mandate



Notes: The figure shows the net value of a reform mandating private DI coverage. 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 group, 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
Household has private DI	0.31	0.35
	(0.46)	(0.48)
Main earner's monthly labor income	2184.88	2925.33
	(1948.68)	(1719.10)
Main earner's age	44.09	43.39
	(11.83)	(11.17)
Main earner 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 Household Income and Consumption Survey (EVS). Column (1) summarizes the full data and Column (2) focuses on employed households which we use as the main sample for the validation exercises discussed in Section 4.4.

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: The table presents robustness checks for our difference-in-difference estimation. Panel A shows results from regressions as described by equation (1), where 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 results from 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. In terms of outcomes, both panels focus on private DI purchases as indicated by the column titles. All regressions are run at the level of cohort × 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	100.00%	25.06%	13.20%	72.84	83.54	98.15
RG 1	9.72%	4.81%	10.85%	31.61	35.95	43.22
RG 2	16.99%	15.35%	8.06%	41.72	49.08	57.49
RG 3	35.12%	23.77%	12.56%	68.14	79.90	93.73
RG 4	37.56%	31.01%	15.74%	100.60	113.31	133.03
RG 5	0.62%	39.92%	31.94%	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 ever claiming public DI benefits. 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

	A: Private DI Contracts by Income					B: by gender	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	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

	C: Private DI Contracts by Risk Group				
	(1)	(2)	(3)	(4)	(5)
	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

	D: Private DI Contracts by Education				
	(1)	(2)	(3)	(4)	(5)
	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. The outcome in all panels and columns is the number of private DI purchases. Regressions are run at the level of cohort × month cells. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Private DI Take-Up, Disability Risk and Risk Groups

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Private DI Take-Up					
Actual Disability Risk	-1.395***	-0.235	-0.208	0.341	-0.0378	-0.0680
	(0.259)	(0.247)	(0.246)	(0.279)	(0.237)	(0.237)
Risk Group 2		-0.345***	-0.334***	-0.158	-0.226	-0.183
		(0.0574)	(0.0587)	(0.146)	(0.152)	(0.128)
Risk Group 3		-0.580***	-0.560***	-0.240	-0.319**	-0.249*
		(0.0486)	(0.0501)	(0.151)	(0.156)	(0.139)
Risk Group 4		-0.784***	-0.758***	-0.398**	-0.475***	-0.398***
		(0.0493)	(0.0515)	(0.158)	(0.163)	(0.147)
Risk Group 5		-0.924***	-0.915***	-0.545***	-0.636***	-0.548***
		(0.0499)	(0.0507)	(0.157)	(0.169)	(0.155)
Log income			0.0434***	0.0245*	0.0208	0.0228
			(0.0154)	(0.0135)	(0.0160)	(0.0166)
Education (years)				0.120***	0.114***	0.112***
				(0.0201)	(0.0202)	(0.0204)
Female					-0.307***	-0.302***
					(0.0788)	(0.0784)
Married					-1.405***	-1.323***
					(0.429)	(0.438)
Economic training						0.177*
						(0.0967)
East Germany						0.216
						(0.147)
Observations	295	295	295	295	295	295
R-squared	0.129	0.269	0.277	0.366	0.396	0.406

Notes: The table shows regression results on the correlation between private DI take-up, disability risk and risk groups 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) corresponds directly to the specification shown in equation (3), which controls for risk groups (cf. Figure 5, Panel (b)). Columns (3) to (6) subsequently add control variables to the regression as shown in equation (4). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A7: Estimated Value and Cost of Private DI

	(1) All	(2) RG 1	(3) RG 2	(4) RG 3	(5) RG 4	(6) RG 5
Median Willingness to Pay (in % of Income)	0.901	1.151	1.423	0.924	0.581	0.749
Median Cost (in % of Income)	1.469	0.327	1.094	1.469	1.720	2.140

Notes: The table shows estimated willingness to pay for private DI and the cost of providing this insurance. Willingness to pay and cost are calculated for a private DI contract insuring a 30% gross replacement rate and scaled in percent of lifetime income. Column (1) shows median valuations and cost among all workers, and Columns (2) to (6) show median valuations and cost by risk group.

Table A8: 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)	1,524,573	1,269,563	926,151	794,701	702,268
Social welfare weights					
Utilitarian, σ=1	0.585	0.710	1.015	1.217	1.408
Utilitarian, σ=3	0.176	0.314	0.915	1.579	2.444
Utilitarian, σ=5	0.047	0.124	0.741	1.838	3.806
Utilitarian, σ=8	0.006	0.028	0.487	2.083	6.675
Rawlsian	0.000	0.000	0.000	0.000	161.549

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 functions specified in the row titles, and serve as an input into the social net value calculations shown in Panel B of Table 4.

Table A9: Risk Misperception: Calibration Results

	(1)	(2)	(3)	(4)	(5)
	RG 1	RG 2	RG 3	RG 4	RG 5
Panel A: Location of marginal buyer					
Percentile of willingness to pay in group	0.324	0.360	0.773	0.912	0.926
Panel B: Risk aversion of marginal buyer					
Baseline	1.853	0.299	0.605	0.822	1.030
Hand-to-mouth	1.124	0.214	0.504	0.820	1.152
Low consumption drop	4.956	1.981	2.480	2.802	2.866
No public DI rejections	2.531	0.507	0.907	1.131	1.267
High public DI rejections	1.529	0.197	0.451	0.660	0.881
Panel C: Risk aversion of median individual					
Baseline	2.195	0.737	¡0	¡0	¡0
Hand-to-mouth	1.340	0.465	¡0	¡0	¡0
Low consumption drop	5.696	2.818	¡0	¡0	¡0
No public DI rejections	2.934	1.141	¡0	¡0	¡0
High public DI rejections	1.842	0.548	¡0	¡0	¡0
Panel D: Risk underestimation of marginal buyer					
Baseline (σ=1.85)	1.000	0.416	0.468	0.510	0.559
Hand-to-mouth (σ=1.12)	1.000	0.439	0.588	0.773	1.029
Low consumption drop (σ=4.96)	1.000	0.422	0.476	0.512	0.503
No public DI rejections (σ=2.53)	1.000	0.440	0.456	0.468	0.440
High public DI rejections (σ=1.53)	1.000	0.409	0.469	0.523	0.605
Panel E: Implied normative WTP/observed WTP					
Baseline (σ=1.85)	1.000	2.383	2.133	1.936	1.764
Hand-to-mouth (σ=1.12)	1.000	2.298	1.733	1.303	0.970
Low consumption drop (σ=4.96)	1.000	2.255	1.987	1.826	1.794
No public DI rejections (σ=2.53)	1.000	2.255	2.160	2.073	2.152
High public DI rejections (σ=1.53)	1.000	2.447	2.133	1.908	1.655

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. Similarly, Panel C shows calibrated risk aversion for the median individual in each risk group. Panel D shows calibrated risk underestimation α, i.e. the ratio of perceived to actual disability risk, of the marginal buyer. Panel E shows the ratio of normative willingness to pay to observed willingness to pay based on the calibrated risk misperception of the marginal buyer.

Table A10: Welfare Calculations: Extensions and Robustness

	(1) Private DI Mandate	(2) Public DI Mandate (Income-Based Contributions)
Panel A: Moral Hazard Effect on Baseline Insurance		
Net Value	0.648	0.648
Social Net Value, σ=1	0.587	1.096
Social Net Value, σ=3	0.494	1.565
Social Net Value, σ=5	0.434	1.729
Panel B: Reduction in Social Assistance Claims		
Net Value	0.753	0.753
Social Net Value, σ=1	0.678	1.264
Social Net Value, σ=3	0.565	1.801
Social Net Value, σ=5	0.491	1.988
Panel C: Fiscal Externality from Social Insurance Contributions		
Net Value	0.739	0.606
Social Net Value, σ=1	0.670	0.994
Social Net Value, σ=3	0.566	1.401
Social Net Value, σ=5	0.498	1.543
Panel D: Combining A to C		
Net Value	0.660	0.541
Social Net Value, σ=1	0.594	0.880
Social Net Value, σ=3	0.494	1.236
Social Net Value, σ=5	0.428	1.360
Panel E: Some Adverse Selection		
Net Value	0.757	0.757
Social Net Value, σ=1	0.688	1.289
Social Net Value, σ=3	0.584	1.846
Social Net Value, σ=5	0.517	2.041
Panel F: Some Advantageous Selection		
Net Value	0.696	0.696
Social Net Value, σ=1	0.625	1.158
Social Net Value, σ=3	0.519	1.642
Social Net Value, σ=5	0.451	1.812

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 indicated by the panel titles and described in Section 6.4. Column (1) presents net values estimates for a private DI mandate and Column (2) presents estimates for a full public DI mandate financed by income-based social insurance contributions.