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Abstract

Public disability insurance (DI) programs in many countries are under pressure to reduce spending to maintain fiscal sustainability. In this paper, we investigate the welfare effects of expanding the role of private insurance markets in the face of public DI cuts. We exploit a reform that abolished one part of German public DI and use unique data from a larger insurer. We document modest crowding-out effects of the reform, such that private DI take-up remains incomplete. We find no adverse selection in the private DI market. Instead, private DI tends to attract individuals with high income, high education, and low disability risk. Using a revealed preference approach, we estimate individual insurance valuations. Our welfare analysis finds that partial DI provision via the voluntary private market can improve welfare. However, distributional concerns may justify 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

Across the developed world, the number of individuals receiving public disability insurance (DI) benefits has risen rapidly over the past decades. This has made DI one of the largest social insurance programs in OECD countries (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 naturally 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. GAO, 2018). Sizable private DI markets already exist in many countries, including the U.S. and Germany. However, private DI provision faces several potential problems, including market failures due to adverse selection and equity concerns (Liebman, 2015). Despite the significance of this policy debate, there is remarkably little empirical evidence on the functioning of private DI markets.[1]

In this paper, we break new empirical ground on these issues. We investigate key features of private DI markets and study the welfare consequences of expanding the role of private DI. We exploit a unique reform that abolished one part of public DI for German workers. Our analysis is based on novel microdata from a top 10 private insurer and administrative data on the universe of public DI claims. This setting and data allow us to obtain three pieces of empirical evidence that govern the welfare impact of private DI provision. First, we estimate crowding-out effects between public and private DI. Second, we document substantial heterogeneity in private DI take-up, which raises distributional concerns. Third, we carefully test for risk-based selection, which provides crucial information about the efficiency of the private DI market. We adopt a revealed preference approach to estimate individual insurance valuations based on these empirical facts. Our welfare analysis shows that partly privatizing DI can improve welfare. However, a full public DI mandate could be justified by equity concerns.

Assessing the potential of private DI to complement public DI is challenging for two reasons. First, suitable variation in public DI coverage is needed. Second, comprehensive and reliable data on private insurance is necessary to quantify the interaction between public and private DI. This paper is the first to overcome both of these challenges.

We exploit exogenous variation induced by a reform that removed one part of German public DI and replaced it with a voluntary private DI market. Specifically, the reform of 2001 privatized

[1] For instance, in their report to Congress, the U.S. Government Accountability Office (GAO, 2018) concludes that the implications of various proposals to expand private DI cannot be fully assessed due to "an array of complex factors that could influence private DI expansions and SSDI cost savings – factors for which data, methods, and assumptions [...] are either unreliable, unsupported, or unavailable."

own-occupation DI for younger workers. 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: being unable to work in any occupation. Before the reform, both own-occupation and general DI were part of the social insurance system. The reform completely removed public own-occupation DI for birth cohorts 1961 and younger. Importantly, the German private DI market offers contracts including own-occupation DI coverage, for which workers can opt if they wish to compensate for the loss of public DI coverage.

To address the second challenge, we obtained a novel dataset on all private DI contracts issued by a top 10 insurer in the German private DI market. This data contains high-quality information on private DI coverage, prices, and individual characteristics, which are critical inputs into our empirical analysis. We demonstrate that the insurer microdata is representative of the overall private DI market in key dimensions using aggregate data on the entire private DI market from a leading rating agency and representative household survey data. Complementing the data on private DI, we use administrative data on the universe of public DI claims.

We provide three pieces of empirical evidence on the private DI market. First, we study crowding-out effects of the reform, that is, the impact of public DI cuts on private DI take-up. On aggregate, we find substantial growth in the private DI market after the reform. To identify a causal effect, we use a difference-in-difference strategy exploiting the cohort cutoff of the reform. We find that treated individuals born above the cutoff significantly increase private DI purchases compared to control cohorts below the cutoff. Yet, even 15 years after the reform, overall take-up remains modest, as only 26% of workers have private DI. Thus, crowding-out is far from complete.

Second, we document substantial heterogeneity in private DI take-up. Modest overall private DI take-up is mainly driven by low take-up among individuals with low income and low education. For instance, take-up is 65% in the top income quintile but only 7% to 12% 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. Individuals in high-risk groups facing higher premiums are much less likely to take up insurance. These patterns indicate potential equity issues in the private DI market.

Third, we carefully investigate risk-based selection into private DI using two complementary empirical strategies. The first strategy is a "positive correlation test" (Chiappori and Salanié, 2000), regressing private DI take-up on disability risk at the level of fine-grained occupations. As a second strategy, we conduct a "cost curve test" (Einav et al., 2010), which exploits variation in private DI premiums over time to test for differences in risk across individuals. We do not find any evidence of adverse selection. In both empirical designs, risk-based selection is of a small and insignificant degree. 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 several potential explanations for this result. For instance, there could be heterogeneity in preferences for insurance that is negatively correlated with risk. In particular, the fact that individuals with high education and high income are more likely to purchase private DI seems to counter adverse selection. We also explore the possibility of heterogeneous earnings losses upon disability that could make private DI more valuable for workers in high-skill occupations.

We then turn to the welfare consequences of privatizing DI provision. The analysis builds on Einav et al. (2010), who show that insurance demand and cost curves are sufficient statistics to assess welfare in insurance markets. Our setting with insurance choice provides a unique opportunity to implement a revealed preference approach and directly estimate individuals' willingness to pay for the DI coverage offered by the private market. To trace out the slope of the private DI demand curve, we implement an event study design around occupation reclassifications, which entail large changes in private DI premiums. This estimation yields a demand elasticity of -1.06.

Our counterfactual analysis 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 consider two welfare measures: (i) the net value of DI, which expresses the value of DI relative to its direct cost, and (ii) the marginal value of public funds (Hendren and Sprung-Keyser, 2020). For the latter, we calibrate additional indirect fiscal effects based on our data and estimates from the literature. Our main net value estimate implies that revealed insurance valuations among individuals receiving extra coverage amount to only 70.5% of the direct cost of insurance. Similarly, the marginal value of public funds of a mandate is 0.617.

This initial welfare analysis ignores distributional concerns. In an extension, we incorporate welfare weights based on a Utilitarian social welfare function. We find that a full public DI mandate has a social value exceeding its costs, even under small degrees of equity concern. Importantly, redistributive effects hinge on the design of social insurance. A *private* DI mandate does not increase social welfare since insurance benefits to high-risk groups are counteracted by risk-rated premiums. In contrast, a *public* DI mandate financed by income-based social insurance contributions effectively redistributes to low-income, high-risk individuals.

Overall, this paper shows that several market failures discussed in prior literature cannot justify mandating extra DI coverage in this context. Most importantly, we do not find any evidence of adverse selection in the private DI market, which is often considered the canonical rationale for a public DI mandate. We also account for market power and administrative costs, which contribute to low take-up in other private insurance markets (Braun et al., 2019), and we calibrate several potential externalities. We find that none of these factors can warrant a mandate in our setting. Hence, the private market covers the majority of individuals with a sufficiently high willingness to pay, and a mandate would predominantly enroll those with valuations below marginal cost. It is important to note that our welfare analysis follows existing literature and maintains the assumptions of the revealed preference approach, which abstracts from behavioral biases. Studying such biases is beyond the scope of this paper.

We argue that our findings are relevant beyond the German context for two main reasons. First, we conduct a systematic review of DI systems across countries. We find that both the German public DI system and the German private DI market share many key characteristics with other countries, making our setting a broadly representative case study of privatizing DI. We also provide evidence that our results are not driven by specific institutional features, such as means-tested social assistance. Second, own-occupation disability risk – the sub-risk our setting centers on – is strongly positively correlated with overall disability risk in the data. Hence, the types of individuals who would benefit from private DI tend to be those who would benefit from DI more generally. One may therefore expect similar patterns to emerge in other settings, including those where the details of DI coverage differ. Indeed, the limited existing evidence on private DI take-up from other countries points in this direction.[2]

This paper contributes to a large and growing literature on DI (see Low and Pistaferri, 2020, for a review). Much of this literature focuses on public DI and its effect on labor supply and claiming decisions (Bound, 1989; Gruber, 2000; Autor and Duggan, 2003, 2006, 2007; Chen and van der Klaauw, 2008; Autor et al., 2011; Staubli, 2011; von Wachter et al., 2011; Marie and Vall 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 much less prior work on private DI markets. Exceptions include Autor et al. (2014), Stepner (2021), and Seitz (2021), who analyze moral hazard effects of private DI. A recent working paper by Fischer et al. (2024) also investigates the German reform of 2001. Their approach is complementary to ours, combining survey data with a general equilibrium model of the private DI market. Similar to our results, they find modest private DI take-up after the reform, particularly among low-income

[2] For instance, Autor et al. (2014) and GAO (2018) report that private DI take-up increases with income in U.S. data, similar to our findings.

groups. While our welfare analysis focuses on the trade-off between private and public DI provision, they emphasize the role of supply-side factors for take-up and welfare within the private DI market.

We make three main contributions to this literature. First, exploiting our unique data and setting, we provide novel empirical evidence on crowding-out and selection in private DI markets. Our findings constitute the first direct empirical evidence on these issues, which are key in assessing the welfare impact of policies expanding the role of private markets and choice in DI. Second, we further exploit our setting with insurance choice to estimate willingness to pay for DI in a revealed preference approach. So far, little is known about how individuals value DI. One exception is Cabral and Cullen (2019), who estimate willingness to pay for supplemental DI coverage within a U.S. firm and derive a lower bound on public DI valuations.[3] Our third contribution is to assess the welfare consequences of partial private DI provision vs. a full public mandate. This complements and extends existing work analyzing welfare and the insurance-incentive trade-off within public DI (Diamond and Sheshinski, 1995; Low and Pistaferri, 2015; Meyer and Mok, 2019; Haller et al., 2024).

More broadly, our work builds on a rich literature testing for risk-based selection in social insurance settings. In Appendix C, we provide a more detailed review of this literature and conduct a meta-analysis of studies on risk-based selection published in leading economics journals since 2000. A large majority of existing studies focus on health insurance. Several papers have also studied long-term care insurance (LTCI), pension annuities, and unemployment insurance. Evidence on risk-based selection in DI is particularly scarce. The only exception is Hendren (2013), who provides indirect evidence on potential risk-based selection in DI by documenting that individuals have private information about their disability risk.

While prior work on health insurance, pension annuities, and unemployment insurance tends to find evidence of adverse selection, our analysis of DI shows some interesting parallels to recent work on LTCI. DI and LTCI share several features, including risks predominantly occurring later in life, strong risk-rating in the private market, and the co-existence of public and private schemes. Like us, Finkelstein and McGarry (2006) and Boyer et al. (2020) find no adverse selection in private LTCI, with point estimates indicating advantageous selection. Braun et al. (2019) investigate the interplay of asymmetric information, market power on the supply side, and other transfer programs in explaining low observed LTCI take-up.

Finally, this paper contributes to a nascent literature investigating the welfare effects of universal mandates vs. voluntary markets in social insurance settings. Existing studies on these issues include

[3] In addition, a few studies use indirect consumption-based methods to quantify the insurance value of public DI (e.g. Meyer and Mok, 2019; Deshpande and Lockwood, 2022).

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 wider 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 presents evidence on crowding-out effects, Section 4 discusses heterogeneity in private DI take-up, Section 5 tests for risk-based selection, Section 6 presents the demand and cost estimation, Section 7 shows the welfare analysis, and finally Section 8 concludes.

2 Institutional Background and Data

2.1 Disability Insurance in Germany

Public Disability Insurance. In Germany, public disability insurance (DI) is administered by the State Pension Fund. 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 old-age pension contributions. Enrolled workers become eligible for DI benefits in the event of a long-term disability limiting their work capacity. 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. Benefits are a function of workers' contributions, assuming they would have kept contributing according to their average pre-disability earnings until age 63. Public DI benefits are thus roughly proportional to individuals' pre-disability earnings, with an average gross replacement rate of 39%. Benefits can be paid until a worker reaches 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.

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 an 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 jobs. The two DI tiers require separate applications. Workers on own-occupation DI receive two-thirds of general DI benefits but face a less stringent earnings test.[4] Own-occupation DI cases make up 13.2% of all public DI claims.

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 affecting all cohorts, including gradually phased-in changes to benefit calculation.[5]

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, 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. According to our rating agency data, at least 73 insurance companies offer private DI contracts. In 2015, the top 3 providers had a combined market share of 34.2%, and the top 10 providers had a market share of 62.7%. 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 DI benefits. Before 2001, private DI purely served as such top-up insurance.

An important difference to the public DI system is that private DI premiums are risk-based. The primary determinant of private DI premiums are individuals' occupations, whereby insurers map occupations into a discrete number of risk groups (see below). Furthermore, insurance premiums can be

[4] 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.

[5] 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 early old-age pension claims. 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 with a general disability who can work between three and six hours per day. Finally, work capacity reassessments were introduced, but in practice, most beneficiaries still receive benefits permanently.

adjusted for pre-existing medical conditions and risky leisure activities, but this occurs infrequently.[6] Finally, monthly premiums are actuarially adjusted to the individual's contract start and end date. This pricing practice has remained largely unchanged throughout our sample period and applies to all buyers. Private DI contracts typically specify a fixed amount of insured benefits, which can be set individually. In practice, monthly private DI payouts are of a similar magnitude to public DI benefits (see Section 2.3). 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). Except a few niche providers, insurers generally offer contracts to all occupations. According to official statistics, only 3% of contract applications are denied by insurers (GDV, 2023).[7] In terms of primary features, including the definition of disability, benefit levels, and contract duration, private DI contracts are quite homogenous across providers.[8] Private DI can be bought either as a stand-alone product or bundled with other types of insurance, most commonly life insurance.

Table 1 provides summary information about private DI premiums and risk groups. The average monthly premium to insure EUR 1000 of monthly benefits is around EUR 73 for a contract start age of 25 and EUR 98 for a start age of 45. Following standard practice in the industry, the insurer from which our microdata originates uses five risk groups to price DI contracts. Appendix Table A1 shows frequent occupations in each risk group. Examples of occupations classified as low-risk include medical doctors, computer scientists, and accountants. Medium-risk occupations include high-school teachers, secretaries, and electrical engineers; high-risk occupations include bakers, firefighters, and warehouse workers. Private DI premiums differ strongly across risk groups: for instance, an individual in the lowest-risk group 1 is charged EUR 32 at age 25, while premiums rise up to EUR 155 for the highest-risk group 5. This variation in premiums is roughly in line with differences in disability risk across occupations. According to our administrative data, the lifetime disability risk of individuals in risk group 1 is less than 5%, while it is 24% in risk group 3, and 40% in risk group 5.[9] Own-occupation disability risk is strongly positively correlated with overall disability risk and increases even faster

[6] Premiums are adjusted beyond risk-group specific prices in only 4% of private DI contracts (GDV, 2023).

[7] 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 leisure activities. Besides coverage denials, another 12% of private DI contracts feature exclusion clauses for pre-existing conditions. The relatively low denial and exclusion rates are an important difference to U.S. nongroup insurance markets, where these are more frequent and can affect broader sets of occupations and income groups (Hendren, 2013; Braun et al., 2019).

[8] The well-known consumer advice organization Stiftung Warentest (2024) finds in their latest report that contracts offered by 67 private DI providers are essentially homogenous in these primary characteristics. Even on secondary characteristics such as waiting periods, retroactive benefit adjustments, and rules on occupation switches, contracts are quite similar: the average provider satisfies 86% of secondary criteria set by the report. Ultimately, 85% of providers receive the highest ("very good") or second-highest ("good") rating.

[9] Note that we calculate disability risk among cohorts 1960 and older, who are observed under full public DI coverage, including own-occupation DI. Thus, our risk measure is not confounded by endogenous claiming responses to the 2001 reform (see also Section 5).

across risk groups. For instance, 8% to 11% of all disability cases in risk groups 1 and 2 are due to own-occupation disability, but the share increases to 32% for risk group 5. Finally, we note that risk groups differ in size, where risk group 1 and especially risk group 5 make up a smaller share of the labor force than the middle groups.

Table 1: Risk Groups, Disability Risk, and Private DI Premiums

	(1)	(2)	(3)	(4)	(5)	(6)
Risk group	Share of labor force	Lifetime disability risk	Share of own-occupation DI claims	Monthly insurance premium for contract start at...		
				age 25	age 35	age 45
All	100.00%	25.06%	13.20%	72.84	83.54	98.15
Risk Group 1	9.72%	4.81%	10.85%	31.61	35.95	43.22
Risk Group 2	16.99%	15.35%	8.06%	41.72	49.08	57.49
Risk Group 3	35.12%	23.77%	12.56%	68.14	79.90	93.73
Risk Group 4	37.56%	31.01%	15.74%	100.60	113.31	133.03
Risk Group 5	0.62%	39.92%	31.94%	155.24	175.78	210.68

Notes: The table shows information on disability risk and private DI premiums by risk group. Risk groups are assigned by the insurer to individuals based on their occupations. See Appendix Table A1 for frequent occupations in each risk group. Column (1) shows the share of each risk group out of the labor force based on administrative data. Column (2) shows the fraction of individuals ever claiming public DI benefits in each group. Column (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 contract start age for a fixed contract end age of 65. The information in columns (1) to (3) is from our administrative data, and premiums are based on the insurer microdata.

Other Safety Net Programs. In the German context, a number of other safety net programs are potentially available to individuals who are unable to work. Most importantly, means-tested social assistance (*Arbeitslosengeld II*) pays a flat benefit to individuals at risk of poverty, which could provide an alternative to DI benefits for some workers. Other transfer programs, including unemployment, sickness, and accident insurance, have a maximum benefit duration of up to two years and thus cannot substitute DI for permanently disabled workers. Since a large welfare reform in 2005, social assistance benefits have been relatively low; for instance, the average beneficiary received EUR 469 per month in 2015. Social assistance is also subject to a strict means test at the household level: households owning any assets worth more than EUR 10k are ineligible, and transfers are withdrawn at a rate of 80% for household income exceeding EUR 100 per month. Moreover, benefit receipt requires actively searching for a job. Thus, social assistance is unlikely to be a meaningful substitute for DI for most workers, except perhaps for those in very low-income, low-asset households. We return to this discussion in Sections 3.2 and 4.2, where we show that the availability of social assistance cannot explain much of our results.

2.2 Comparison to Other Countries

To assess the external validity of our analysis, it is useful to understand to what extent the German setting resembles DI provision in other countries. In Appendix D, we present a detailed survey of public DI systems and private DI markets in selected OECD countries, including Austria, Canada, Denmark, France, Norway, the Netherlands, Spain, the U.K., and the U.S. We briefly summarize key results in this section.

Overall, DI in Germany shares many key characteristics with DI in other settings. Across all countries included in our survey, public DI is a mandatory social security program for private-sector employees, and benefits are paid in case of a long-term disability that substantially reduces an individual's work or earnings capacity. Like in Germany, public DI benefits are a function of prior contributions in most countries, while lump-sum benefits are less common. Replacement rates vary, with Germany being at the lower end of public DI generosity. Nowadays, most public DI systems focus only on providing general DI, requiring claimants to be unable to work in any occupation. Interestingly, the evolution of public DI in several countries (e.g., Canada, the Netherlands, and the U.K.) closely mirrors the German setting, where own-occupation coverage was removed from public DI through reforms aimed at curbing public expenditure. In some cases, such as Austria and Spain, a subset of workers can still qualify for own-occupation DI.

Furthermore, the structure of private DI markets in other countries is largely similar to Germany. In all countries we surveyed, there are individual private DI markets; although in a few cases (e.g., Denmark and the U.S.), private DI is predominantly sold as group insurance. Insurers offer own-occupation DI in all countries. Sometimes, workers can choose between own-occupation and general DI. As in Germany, private DI benefits can be set individually, and public and private DI payouts are independent in most other countries.[10] Private DI markets differ substantially in size: overall take-up varies between 4% in Austria and 85% in Denmark. Interestingly, private DI markets tend to be larger in countries with less generous public DI, which may be indicative of the type of crowding-out effects we study in Section 3.

2.3 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.

[10] An exception is given by the U.S. and Canada, where private DI providers are secondary payers and require claimants to apply for public DI. In Denmark, public DI benefits are means-tested against private DI payouts.

Private Insurer Microdata. 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 market share between 3% and 6%.[11] 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 and some limited socio-demographic 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.[12] Similarly, we add education at the occupation level. Appendix Table A2 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, corresponding to a 35% replacement rate. 54% of contracts were sold as a stand-alone product.

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 many key dimensions. First, as we discussed above, private DI contracts are similar across providers regarding their primary features. Second, the pricing of private DI contracts follows common industry practice, assigning individuals to risk groups primarily based on occupations. As we show in Section 4.3, 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 workers in 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 many 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 has 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 4.3, which yield similar empirical patterns to the insurer microdata.

[11] For confidentiality reasons, we cannot name the insurer or specify its market share more precisely.
[12] See Seitz (2021) for a detailed description of the insurer microdata and the occupation matching procedure.

Administrative Data. Our second main data source is administrative data on the universe of public DI claims between 1992 and 2014 provided by the German State Pension Fund.[13] This data contains information on the timing and type of DI claims, benefit amounts, individual earnings histories, and some socio-demographics such as age, marital status, and gender. Appendix Table A3 shows summary statistics of the administrative data. 59% of all DI claimants are male, and the average claiming age is around 52. Monthly DI benefits are EUR 1075 on average. Claimants' monthly earnings were EUR 2295 over all periods and EUR 1306 in the year before claiming. Compared to all DI cases, own-occupation DI claimants are more likely to be male and married, and their age and income tend to be slightly higher.

Other Data Sources. As an additional source of information on private DI, we obtained aggregate data on the entire private DI market from a leading rating agency. The agency rates 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, contains time-series information on the total number of private DI contracts and a breakdown by contract type, risk group, and age group.

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 survey wave, which contains information on households' private DI take-up. We use this data for complementary analyses, particularly for the validation exercises presented in Section 4.3. Appendix Table A4 shows summary statistics of the survey data. 31% of households had private DI in 2013. Households' average labor income is 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.

3 Crowding-Out Between Public and Private DI

The 2001 reform removes public own-occupation DI for younger birth cohorts. Affected individuals could compensate for this by purchasing private DI, which covers 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-out effect, analogously to social insurance expansions studied in the literature (e.g. Cutler and Gruber, 1996; Brown and Finkelstein, 2008).

[13] 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.

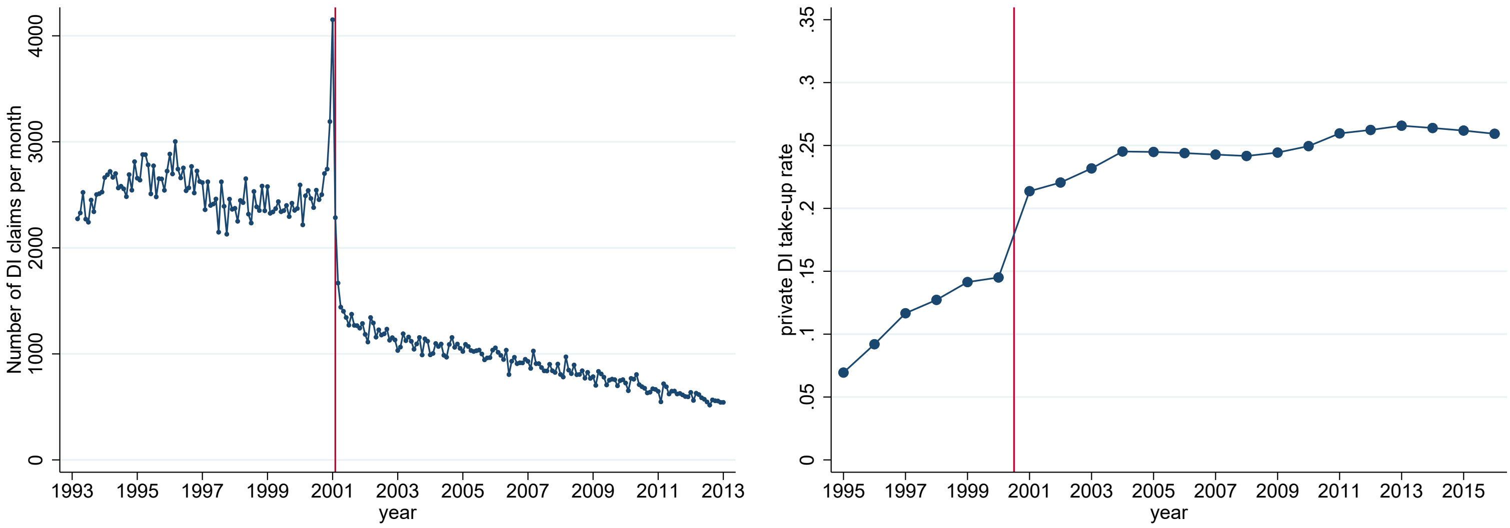
3.1 Overall Private DI Take-Up

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 per month in our administrative data. 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 is also 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 as the number of contracts in the entire market from the rating agency data, divided by 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 below 10% before the first reform announcement in 1997. The substantial growth of the private DI market provides first, suggestive evidence of crowding-out between public and private DI. Yet, the modest level of private DI take-up 15 years after the reform indicates that this crowding-out is far from complete.

Figure 1: Crowding-Out: 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 2001 reform.

3.2 Difference-in-Difference Estimation

The evidence above suggests a crowding-out effect of the 2001 reform, but overall growth in the private DI market could be due to general trends in insurance demand or other factors. 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 around the reform cutoff, comparing treated cohorts 1961-1962 to control cohorts 1959-1960.

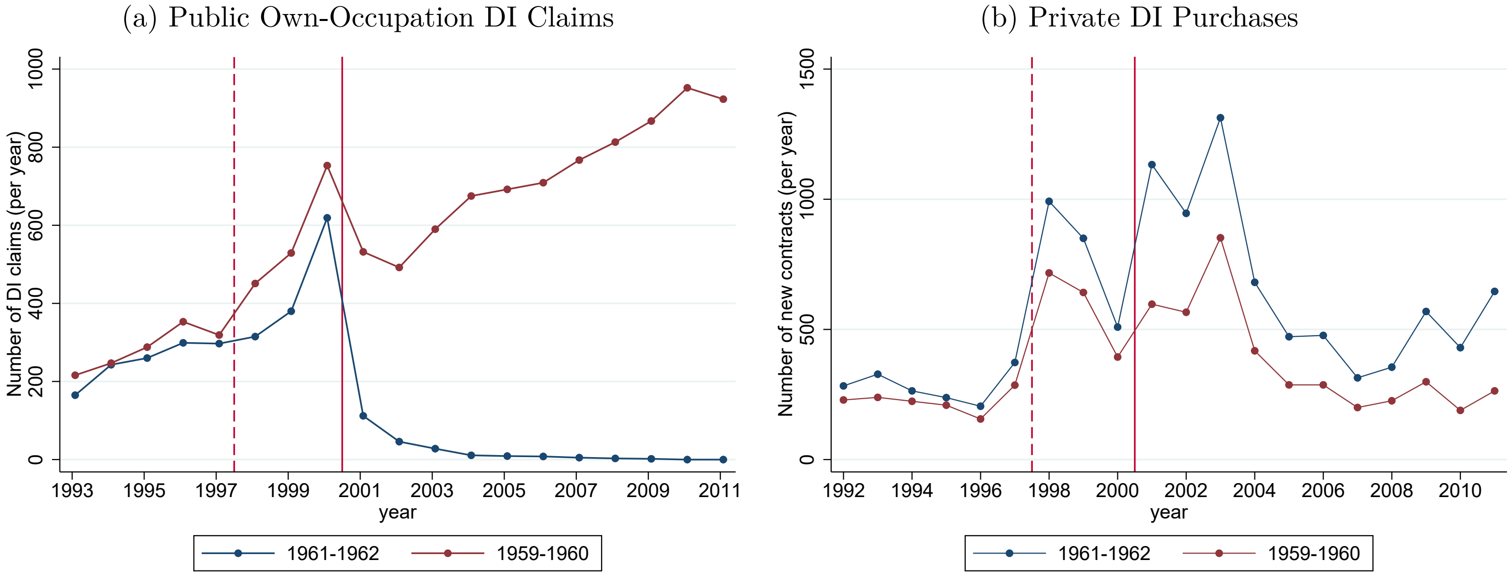
Figure 2 illustrates our difference-in-difference results. In order to ease visual interpretation, the figure depicts graphical patterns at yearly frequency, while estimation results at monthly frequency are shown in Table 2. We begin by investigating the effect of the reform on public own-occupation DI claims in Panel (a) of Figure 2. Before 2001, claims by treated and control cohorts follow a similar increasing trend. In 2001, there is a sharp differential drop in claims by treated cohorts virtually to zero, while claims by the control group continue to increase.[14] Column (1) of Table 2 shows a highly significant difference-in-difference coefficient of -53.4, corresponding roughly to the number of monthly claims by treated cohorts just before the reform. As expected, this result confirms that the 2001 reform immediately and completely removes public own-occupation DI coverage for younger workers. In addition, Column (2) of the table shows that the reform does not lead to an increased propensity to claim the other tier of public DI. The estimated effect on *any* type of public DI claims is in fact larger than the effect on own-occupation DI claims. This lack of benefit substitution towards general DI suggests that the disability screening process is able to distinguish between the two types of disability.[15]

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. Before the first announcement of the reform demarcated by the dashed vertical line, purchases by treated and

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

[15] If anything, the estimate in Column (2) would imply that general DI claims also decreased among treated cohorts. Potential reasons for such a negative spillover may include confusion about the reform or a general deterrence effect.

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



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) at yearly frequency. In both panels, the dashed vertical line demarcates the time when the reform was first announced (December 1997), and the solid vertical line demarcates the time when the 2001 reform took effect (January 2001). See Table 2 for corresponding difference-in-difference estimates at monthly frequency.

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.[16] The impact on private DI purchases peaks in the third year post-reform and persists until the end of our sample period. Column (3) of Table 2 presents the estimated effect on monthly private DI purchases, pooling over the post-reform period. The coefficient of 15.1 is highly significant and corresponds to a 64% increase relative to pre-reform purchases. Column (4) shows that the effect is almost exclusively driven by newly purchased stand-alone DI contracts. 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 new private DI contracts. We find no significant effect along this "intensive margin" of private DI. This motivates our focus on the extensive margin given by private DI take-up throughout the paper.[17]

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

[16] Interestingly, older workers born before 1961 also seem to purchase more private DI contracts after 2001. This could be due to other reform elements affecting all cohorts. Moreover, increased marketing and sales efforts by insurers may not perfectly distinguish between treated and control cohorts around the cutoff. In the presence of such positive spillovers on the control group, our difference-in-difference would yield a lower bound on crowding-out effects.

[17] In addition, Appendix Figure A1 presents graphical results corresponding to Columns (2), (4), and (5) of Table 2. Appendix Table A5 shows that our difference-in-difference results remain robust under various alternative specifications, including cohort-specific linear trends and a range of timing assumptions.

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

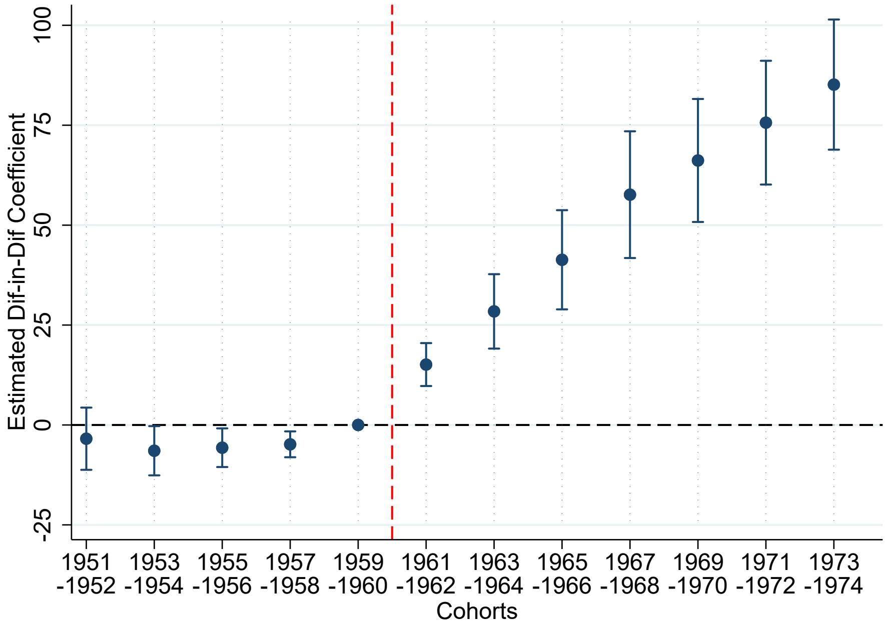
	(1)	(2)	(3)	(4)	(5)
	Public DI Claims		Private DI Contracts		
	Own-Occupation DI Claims	All Public DI Claims	Number of Purchases		Insured Benefits (All Contracts)
			All Contracts	Stand-Alone	
Treated×post	-53.37***	-116.3***	15.11***	13.22***	-462.2
	(1.677)	(5.734)	(2.739)	(1.676)	(384.1)
Observations	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
Month-by-year FE	yes	yes	yes	yes	yes

Notes: The table shows results from the main 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 the years 1992 to 1997 for Columns (3) to (5). Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

over time. However, this strategy likely leads 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 purchase private DI at younger ages. In the full sample, the average purchase age is around 31 (see Appendix Table A2). We repeat the difference-in-difference estimation for a broader set of cohorts to assess how the reform affects younger workers. 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 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.

Quantifying Crowding-Out. Our difference-in-difference analysis reveals a significant impact of the 2001 reform on private DI purchases. To understand how this maps into crowding-out effects on the level of private DI take-up, we can perform a simple back-of-the-envelope calculation. We compute the predicted number of contracts held by cohorts 1961-1962 in 2015 based on pre-reform mean purchases and add the cumulative causal impact over the post-reform period implied by our estimates. This results in a 26% increase in the stock of private DI contracts held by the baseline treatment group who

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 2001 reform, such that the cohorts to the right of the line are affected by the reform.

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%. Applying this estimate to the pre-reform take-up rate from Figure 1 yields a crowding-out effect of 18 percentage points, similar to the observed increase in overall take-up. This implies that much of the growth of the private market can be attributed to a causal effect of the reform, while confirming that the magnitude of crowding-out between public and private DI is modest.

Alternative Strategy: Regression Discontinuity Design. As an alternative empirical strategy, the cohort cutoff of the reform could be exploited to implement a regression discontinuity design (RDD). Our difference-in-difference strategy has the advantage of providing higher statistical power, particularly for subgroup analyses. Nevertheless, Appendix Figure A3 shows that an RDD would yield results similar to our main specification. The figure depicts a sharp jump in the number of private DI contracts held by individuals precisely at the January 1961 cutoff. The RDD estimate is highly significant and corresponds to an increase of 25% relative to average take-up among control cohorts. This is almost perfectly in line with the 26% increase in the stock of private DI contracts implied by our baseline difference-in-difference result.

The Welfare Reform of 2005. As we explained in Section 2.1, another important safety net reform occurred in 2005. The reform made social assistance substantially less generous, replacing the prior income-dependent welfare system with a lower, flat benefit. Moreover, strict means testing was introduced, and benefit receipt was made conditional on active job search (see e.g. Bradley and Kuegler, 2019). For our purposes, the 2005 reform presents a valuable opportunity to test the potential role of social assistance in determining private DI take-up. If social assistance served as a substitute for private DI, one might expect private DI take-up to increase after 2005, when benefit levels were reduced and many workers became ineligible for social assistance. However, Figure 1 suggests that much of the growth in private DI take-up occurs right around 2001, with no further change after 2005. Similarly, Figure 2 provides no indication that treated cohorts increase private DI purchases after 2005. To test this more formally, Appendix Table A5 performs a difference-in-difference estimation around the 2005 reform, resulting in a small and insignificant effect on private DI purchases. This suggests that the generosity of social assistance is not a major driver of private DI take-up.

4 Heterogeneity in Private DI Take-Up

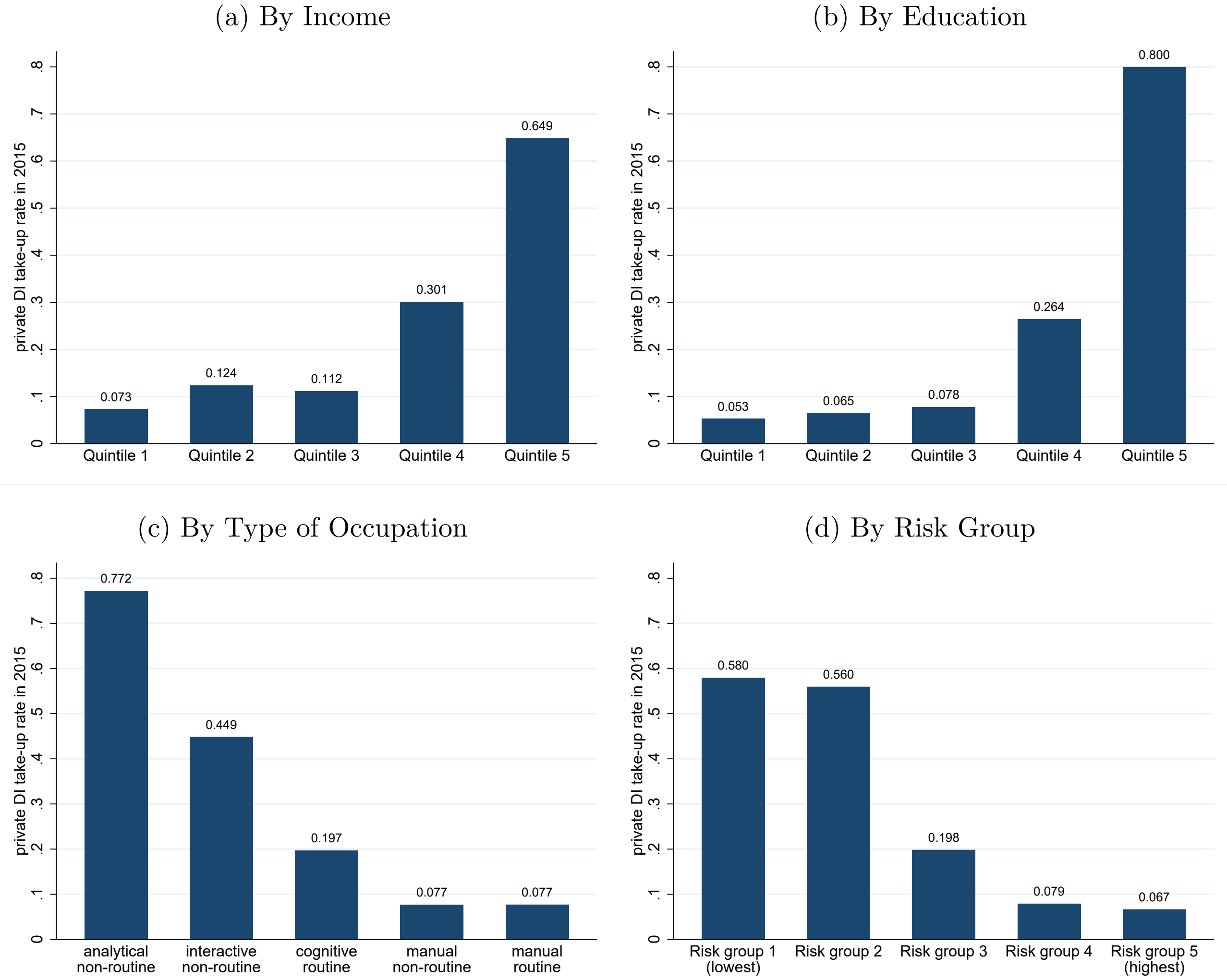
In this section, we study which types of individuals take up private DI. The main challenge in doing so is that comprehensive microdata on the overall private DI market is not available. This challenge is faced by much of the literature investigating private insurance markets, which often uses data from 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. Appendix B.1 describes in detail how we use this data in combination with administrative data and official social insurance statistics to calculate private DI take-up of subgroups. Importantly, our approach requires the assumption that the market share of the insurer is constant across subgroups (within contract type and year). This assumption is not innocuous and its validity hinges on how representative the insurer is for the overall market. In Section 2.3, 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 using representative household survey data and other independent data sources in Section 4.3.

4.1 Private DI Take-Up across Groups

In Figure 4, we begin by providing descriptive evidence on heterogeneity in private DI take-up in 2015. Panel (a) displays a strong 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 is

30% in the fourth quintile, 11% to 12% in the second and third quintiles, and only 7% in the bottom quintile. Panel (b) shows a similar gradient of private DI take-up by education. 80% of individuals in the highest education quintile have private DI, while take-up is 26% in the fourth quintile and only 5% to 8% in the bottom three quintiles.

Figure 4: Private DI Take-Up across Groups



Notes: The figure shows private DI take-up rates in 2015 by income quintile (Panel a), education quintile (Panel b), type of occupation (Panel c), and risk group (Panel d). In Panel (b), education is defined as years of schooling. In Panel (c), we use the task-based classification by Dengler et al. (2014) to group occupations. Take-up rates are calculated among all cohorts; see Appendix B.1 for details.

Panel (c) depicts private DI take-up by type of occupation. We use the task-based classification by Dengler et al. (2014) who adapt the method of Autor et al. (2003) and distinguish between cognitive (analytical or interactive) vs. manual tasks and routine vs. non-routine tasks. With 77% and 45%, respectively, workers in occupations performing analytical or interactive non-routine tasks display the highest private DI take-up rates. In cognitive routine occupations, 20% of individuals have private DI, while take-up in both routine and non-routine manual occupations is only 8%.

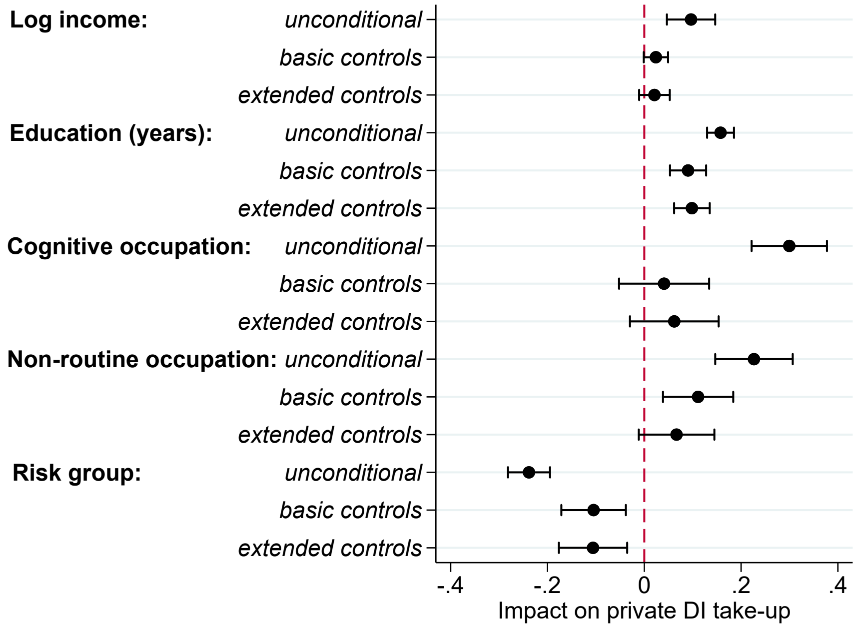
Panel (d) finally investigates private DI take-up by risk group. Recall that the insurer assigns individuals to one of five risk groups based on occupations, and these risk groups are the primary determinant of private DI premiums. We find that lower-risk workers facing lower insurance premiums are much 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 have private DI.

Heterogeneous Impact of the 2001 Reform. To understand how the 2001 reform affects private DI take-up across groups, we provide two additional pieces of evidence. First, Appendix Figure A2 shows private DI take-up rates before the reform (in 1997). Differences in take-up before the reform are qualitatively similar to Figure 4, but much less pronounced. For instance, 17% to 18% of individuals in the top two income quintiles have private DI, compared to 6% to 9% in the bottom three quintiles. Second, Appendix Figure A4 shows results from a causal analysis estimating heterogeneous effects of the 2001 reform. For this purpose, we repeat the difference-in-difference estimation from equation (1) separately for each subgroup. To increase statistical power, we extend the cohort window used in the estimation to 1957-1964. The relative effects by subgroup are very similar to the descriptive patterns from Figure 4. For instance, we estimate that the impact on private DI purchases of the top income quintile is about double that for the fourth quintile, while effects for the bottom three quintiles are very small. The impact of the reform on take-up also strongly increases with education and non-routine occupations, but decreases with risk groups. These results suggest that the causal impact of the 2001 reform by subgroup is closely in line with the observed post-reform heterogeneity in private DI take-up.[18]

Multivariate Heterogeneity. Our main heterogeneity analysis shows that private DI take-up exhibits strong unconditional correlations with income, education, type of occupation, and priced risk groups. To further unpack this heterogeneity, Figure 5 displays results from regressions of private DI take-up on these characteristics, controlling for varying sets of individual and occupational characteristics. One key result from these multivariate specifications is that income is not a significant determinant of private DI take-up once education and other characteristics are controlled for. Thus, while the unconditional take-up gradient by income is important for distributional considerations (see Section 7.2), income per se does not seem to drive heterogeneous private DI demand. On the contrary, Figure 5 shows that private DI take-up remains significantly correlated with education, risk groups,

[18] In addition, Appendix Table A2 shows summary statistics of private DI contracts by time of purchase. Characteristics of pre- vs. post-reform buyers align with the heterogeneity analysis presented here. Individuals who took up private DI between the first reform announcement and its final implementation (1998 to 2000) display similar characteristics to pre-reform buyers more broadly.

Figure 5: Determinants of Private DI Take-Up



Notes: The figure displays results from regressions of private DI take-up rates on individual characteristics at the three-digit occupation level. The coefficients show the estimated impact of the respective variable with 95% confidence intervals. "Basic controls" are the other main characteristics from the figure, i.e. log income, education (years), indicators for cognitive and non-routine occupations, and risk groups. "Extended controls" include these variables plus gender, marital status, an indicator for economic training and residence in East Germany. See Appendix Table A7 for full regression results.

and working in a non-routine occupation in all specifications.

4.2 Private DI Take-Up, Disability Risk, and Risk Protection Benefit

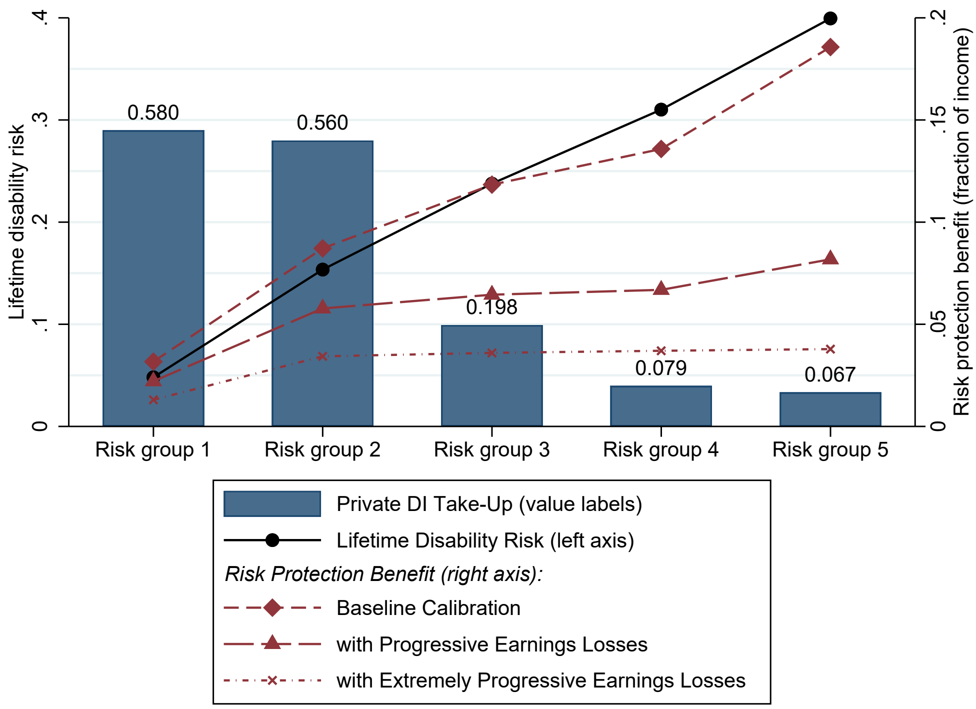
Both descriptive patterns and difference-in-difference results suggest that private DI take-up *decreases* with risk groups. This raises a potential puzzle, as, in principle, one would expect higher-risk individuals to place a higher valuation on insurance. Note that risk-rated premiums alone cannot explain this finding. Private DI premiums increase across risk groups in a manner not far from actuarially fair. Thus, while one may not necessarily expect private DI take-up to increase with risk groups, the pricing scheme cannot explain the decreasing pattern.[19] To explore what could explain low private DI take-up among high-risk workers, we calibrate a comprehensive measure of the potential insurance value of private DI. Our *risk protection benefit* measure takes into account a variety of factors beyond lifetime disability risk, including heterogeneity in the timing and sub-risk composition of disability events, other safety net programs, and consumption drops upon disability.

Building on existing approaches in the insurance literature, particularly Mitchell et al. (1999) and Finkelstein and McKnight (2008), we set out an expected lifetime utility framework in Appendix B.3. In

[19] This discussion is closely related to our test for risk-based selection in Section 5. Once we control for insurance prices, we find that the correlation between private DI take-up and disability risk becomes flat but does not turn positive, as one would expect under standard models of adverse selection.

this framework, individuals face some risk of disability in each period, and they may qualify for public DI benefits or social assistance in case of disability. We use the model to calibrate the certainty equivalent utility gain that risk-averse individuals would derive from private DI. To perform the calibrations, we combine the information on dynamic disability risk paths, income, and private DI parameters contained in our various data sources, and we rely on a range of assumptions about consumption drops upon disability and the probability of receiving public DI benefits.[20] In all specifications, individuals can receive basic social assistance if their income is sufficiently low. We initially assume that consumption losses and risk preferences are homogeneous across groups, but relax these assumptions later. Figure 6 displays the calibrated risk protection benefit by risk group under selected specifications, along with private DI take-up and lifetime disability risk. Full calibration results are shown in Appendix Table A10.

Figure 6: Private DI Take-Up, Disability Risk, and Risk Protection Benefit



Notes: The figure shows private DI take-up rates (in 2015), disability risk, and the risk protection benefit of private DI by risk group. The blue bars depict private DI take-up rates for each group, calculated among all cohorts. The solid red line shows lifetime disability risk by group. The dashed red lines show the risk protection benefit of private DI as a fraction of income under three selected calibration scenarios, namely (i) under our baseline assumptions, (ii) in a scenario where income losses upon own-occupation disability increase somewhat progressively with income, and (iii) in a scenario with extremely progressive income losses. See Appendix Table A10 for detailed calibration results.

Under the baseline calibration scenario, which assumes a coefficient of relative risk aversion of three, we find that the expected utility gain from private DI increases monotonically from 3.2% of income for risk group 1 to 19% for risk group 5. These relative magnitudes are roughly aligned with

[20] Since no estimates of consumption losses upon disability are available in the German context, we rely on results from the U.S. by Meyer and Mok (2019) and results from Denmark by Humlum et al. (2023) in the calibration.

the simple risk measure, which implies that taking into account full dynamic disability risk paths and the composition of claims does not substantially change the relative utility gain from private DI.[21] In Appendix Table A10, the gradient of the risk protection benefit across groups remains similar under alternative assumptions about risk aversion, public DI rejections, and the size of consumption losses.

Next, the availability of other safety net programs has been shown to play a role for insurance choices, e.g., in long-term care insurance (Braun et al., 2019). In our setting, two key programs could matter for private DI take-up. First, basic social assistance pays a flat benefit, which could provide some implicit insurance particularly for high-risk groups, given their lower average income (see Fischer et al., 2024). In Figure 6, the calibrated risk protection benefit indeed increases less steeply than the simple risk measure for the highest risk groups 4 and 5, but this effect is quantitatively small. A limited role of social assistance is in line with the low implicit replacement rate of the program and with the evidence from Section 3.2, where we show that a large welfare reform hardly affects private DI take-up. Second, the availability of public DI benefits could influence private DI take-up. However, post-reform public DI only covers general disability risk and pays an approximately constant replacement rate to all groups. Thus, it is unlikely to induce differential private DI demand. This is confirmed by Appendix Table A10, where varying the probability of qualifying for public DI (rejection rates) hardly impacts the relative benefit of private DI across risk groups.

Our baseline calibration assumes that consumption losses upon disability are a constant percentage of income for all risk groups. However, the consequences of own-occupation disability may vary. In particular, low-risk occupations are more likely to perform cognitive non-routine tasks, which tend to require specialized skills (see Dengler et al., 2014). It is thus possible that workers in low-risk groups experience larger earnings losses if an own-occupation disability necessitates switching to a different occupation.[22] Unfortunately, we do not know of any existing estimates of heterogeneous consumption losses upon disability across occupations or risk groups. Hence, we consider two calibration scenarios to examine this channel. As a benchmark, we make the extreme assumption that in the event of own-occupation disability, all individuals are only able to work in a basic low-skill occupation where they earn the average bottom-quintile income. We also consider an intermediate scenario in between this extreme case and our baseline specification with proportional consumption losses. Figure 6 shows that such "progressive" earnings losses can substantially modify the relative benefit of private DI.

[21] Two key calibration inputs illustrate why this occurs. Appendix Figure A6 shows that the timing of disability events is similar across risk groups. Table 1 shows that, in addition to overall disability risk, the share of own-occupation claims also increases with risk groups.

[22] This would be consistent with evidence from the literature on earnings losses upon job displacement. For instance, Huckfeldt (2022) documents particularly large losses for workers with specific human capital who find reemployment in a different occupation with lower skill requirements.

Under the intermediate scenario, the risk protection benefit increases less steeply with risk groups, and under the extreme scenario, it becomes virtually flat.

Finally, observed private DI take-up patterns could be explained by heterogeneous risk preferences. In particular, high-risk workers may have lower risk aversion. One potential reason behind a negative correlation between disability risk and risk aversion could be that workers select into more or less risky occupations based on their risk tolerance. To assess whether plausible variation in risk preferences could explain heterogeneous private DI take-up, we calibrate the degree of risk aversion that would make individuals indifferent between lifetime expected utility with and without private DI at market premiums. This yields an implied coefficient of relative risk aversion for the marginal buyer in each risk group. Details of the calibration are shown in Appendix B.4, and results are displayed in Appendix Table A10. Across calibration scenarios with proportional consumption drops, the implied coefficient of risk aversion is between 1.09 and 4.96 for risk group 1 and between 0.66 and 2.87 for risk groups 4 and 5. Even when allowing for progressive earnings losses, implied risk aversion of higher-risk groups remains below that of risk group 1.[23] This suggests that lower risk aversion among high-risk groups could indeed explain their lack of private DI demand. Our risk aversion estimates for these groups are low but not implausibly far from results in the literature.[24]

Implications for Welfare Analysis. Our baseline calibrations suggest that, given the size and structure of disability risk and the low level of social assistance in the German context, workers in high-risk groups should benefit substantially from private DI. However, low take-up among these workers could be explained by heterogeneous earnings losses upon own-occupation disability or by heterogeneous risk preferences. A key advantage of the revealed preference approach we follow later on is that the underlying reasons behind individual choices will not matter for the welfare implications, as long as observed private DI take-up reflects workers' true insurance valuations. Besides the factors discussed above, behavioral biases could be another potential reason for low insurance take-up among certain groups. Studying such biases is outside the scope of this paper. We briefly return to this discussion in our conclusion.

[23] Interestingly, calibrated risk aversion does not 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. This likely occurs due to a combination of social assistance providing more sizable implicit insurance and relatively high private DI premiums charged to this group.

[24] Studies on insurance choices typically yield estimates of relative risk aversion ranging between 1 and 8 (e.g. French, 2005; Lockwood, 2018; Jacobs, 2023; Landais and Spinnewijn, 2021). Some work implies larger values (e.g. Cohen and Einav, 2007; Sydnor, 2010).

4.3 Validation Checks

Our empirical results on heterogeneity rely on the insurer microdata, as individual-level data on the entire market is not available. As we discussed before, the validity of these findings depends on how representative the insurer is of the overall market. In this section, we present several validation checks using additional, independent data sources.

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 had private DI in 2015, corresponding precisely to our main take-up rate estimate for the same year from Section 3.1. In the representative EVS survey data, overall private DI take-up by German households was 31% in 2013. Household-level take-up is naturally higher than our individual-level estimate since the average household has around two members (see Appendix Table A4).

Other data sources also suggest qualitatively similar private DI take-up patterns by subgroups. Appendix Figure A5 shows that take-up rates clearly increase with income in the household survey, albeit with a somewhat flatter gradient. We match take-up rates by gender well, considering that the survey figures are at the household level. To validate private DI take-up rates by risk group, we use the rating agency data, which includes a breakdown 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 groups correspond roughly to the risk groups used by the insurer providing our microdata, but the insurer additionally differentiates among the highest risks. Our main take-up estimates for the largest risk groups 2 and 3 are virtually the same as those from 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, we present 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. Appendix Figure A5 plots the average monthly premium by risk group for the insurer providing our microdata and four large competitors. Relative prices charged to different occupations are fairly similar across insurers. This suggests that different risk groups should have little reason to select specifically into the insurer providing our microdata, as its pricing reflects the overall market.

5 Risk-Based Selection: Positive Correlation Test

A crucial question for the efficient functioning of private DI markets is whether and how individuals select into purchasing insurance based on their disability risk. Standard adverse selection models 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 formally test for risk-based selection, we implement a *positive correlation test* (Chiappori and Salanié, 2000) in this section. Later, we provide additional evidence from a cost curve test (see Section 6.2).

Our aim is to test for a positive correlation between private DI take-up and disability risk, which would indicate adverse selection. Specifically, we run the following regression:

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

where Q_j denotes private DI take-up of individuals in three-digit occupation j in 2015, π_j is lifetime disability risk measured in administrative data, and $\mathbb{1}(riskgroup_j = k)$ is an indicator for occupation j being assigned to risk group k by the insurer.[25] Note that we define π_j as total risk (including both own-occupation DI and general DI top-up payouts), as this is the relevant risk measure from the perspective of insurer cost.

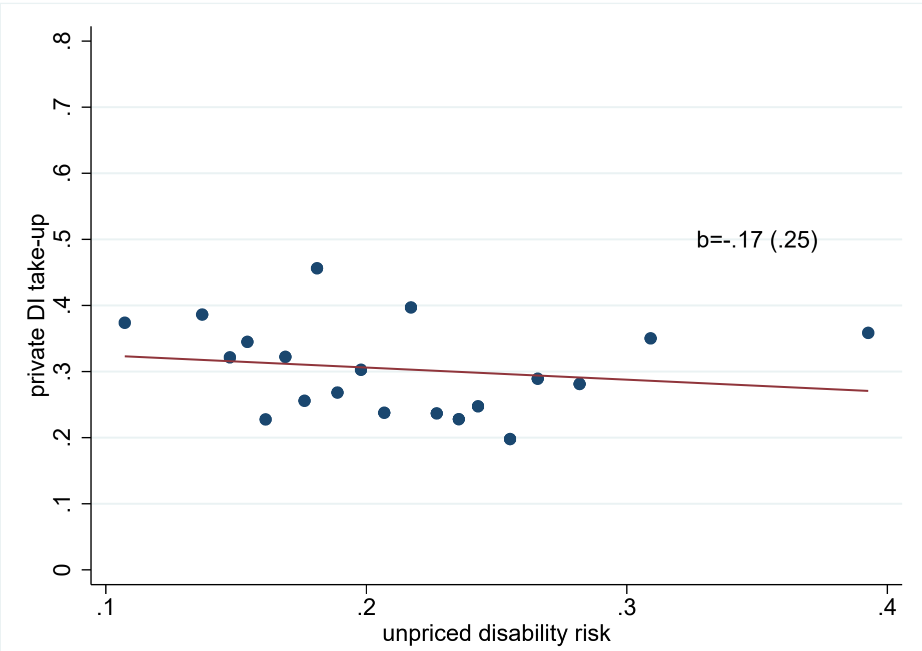
Our setting and data enable us to address two key challenges often faced by similar positive correlation tests in the literature. First, in assessing whether there is adverse selection, it is important to estimate the correlation between private DI take-up and risk within groups of individuals facing the same insurance prices. Indeed, we found a strong negative correlation between 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. In equation (2), 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). To address this challenge and isolate risk-based selection, we calculate take-up among the treated cohorts 1961 and younger but measure disability risk π_j as

[25] 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 (see Section 6.2).

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 DI coverage.

Figure 7 depicts the estimation results in a binned scatter plot. There is considerable residual unpriced variation in disability risk along the horizontal axis. Crucially, the estimated relationship between occupation-level private DI take-up and unpriced risk is quite flat, and the estimated slope coefficient corresponding to β_1 in equation (2) 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 risk are no more likely to select into purchasing insurance. The point estimate on risk is negative, which would imply slightly advantageous selection into private DI, if anything.

Figure 7: Risk-Based Selection: Positive Correlation Test



Notes: The figure shows a binned scatterplot depicting the correlation between private DI take-up and residual (unpriced) disability risk, controlling for private DI premiums. We run the regression at the level of three-digit occupations. As explained in Section 5, take-up rates are calculated among treated cohorts in 2015, while disability risk is measured only among control cohorts. The figure also includes the estimated slope coefficient b with its standard error in parentheses. See Appendix Table A8 for details of the corresponding regression results.

At first glance, the lack of adverse selection may seem surprising, as insurance should in principle be more valuable to higher-risk individuals. However, some of the factors we discussed in Section 4.2 could explain this empirical finding. Evidence from other insurance markets points to heterogeneity in non-risk related components of individual insurance valuations. If these correlate negatively 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 are more likely to purchase private DI could, for instance, reflect heterogeneous risk aversion or earnings losses that are negatively correlated with risk. Appendix Table A8 presents further suggestive evidence along these lines by exploring how risk-based selection changes conditional on different sets of observables. In particular, we find that the coefficient turns positive (but remains insignificant) once we control for education. This suggests that not conditioning prices on education induces some advantageous selection, countering potential adverse selection within risk groups. Hence, even though it is somewhat coarse, the pricing scheme devised by insurers seems to be an important factor in preventing adverse selection.[26]

6 Value and Cost of DI

6.1 Basic Conceptual Framework

Next, our aim is to quantify the value and cost of the DI coverage offered by the private market. These two are the main components entering our welfare analysis later on. Our conceptual approach builds on Einav et al. (2010), who show that in order to evaluate welfare in insurance markets, the key sufficient statistics are given by insurance demand and cost curves. Similar frameworks have been used in several related social insurance settings (Hendren et al., 2021; Einav and Finkelstein, 2023).

We consider a population of heterogeneous individuals indexed by θ_i, where $F(\theta_i)$ denotes the distribution of types. Heterogeneity may include variation both in individual disability risk and in other factors influencing DI valuations, such as risk aversion. The first key component for our welfare analysis is demand for DI. Denote by $v(\theta_i)$ the utility of consumer i from 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 their willingness to pay exceeds the premium, $v(\theta_i) \geq p_k$. Aggregate demand for private DI in group k can be written as

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

The second component we require is the cost of providing DI. We denote by $c(\theta_i)$ the expected cost of insuring individual i's risk. The average cost at price p_k is

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

In addition, we can write marginal cost as $MC_k(p_k) = \mathbb{E}_k\left(c(\theta_i)|v(\theta_i) = p_k\right)$.

Before we proceed to the empirical implementation, three aspects are worth noting. First, we assume that individuals make a discrete choice whether to buy insurance (if such choice is permitted),

[26] In line with this argument, Bundorf et al. (2012) show that risk-rated premiums can improve efficiency by limiting risk-based selection into health insurance.

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. Second, our main analysis follows the literature regarding the cost of providing DI and abstracts from any other cost incurred by insurers. We discuss the potential role of administrative cost later on in Section 7.3. Third, since insurance prices depend on risk groups to which insurers assign 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 apply within risk groups where individuals vary only in unpriced characteristics.

6.2 Estimating Demand and Cost

Our post-reform setting with insurance choice provides a unique opportunity to implement a revealed preference approach and to directly measure individual valuations of the DI coverage offered by the private market. In order to estimate private DI demand, we exploit discrete price changes due to periodic updates in insurers' "risk tables", which determine the mapping of occupations to risk groups. According to conversations with industry experts, such reclassifications typically occur when an insurer gains access to improved data or analysis tools, or they can be induced by competitive pressure. In our insurer microdata, this occurs relatively infrequently: 2.5% of occupations are reclassified into a different risk group per year.[27] We exploit this price variation to implement an event study design, pooling reclassifications that occur in the post-reform period. We estimate the causal effect of price changes on private DI purchases, which we can translate into demand elasticities. We also analyze the effect on the probability of claiming DI benefits, which allows us to perform a *cost curve test* for risk-based selection complementing the positive correlation test from Section 5.

We set up a standard event study model, regressing outcome $Y_{j,t}$ of three-digit occupation j in year t on leads and lags of dummy variables indicating a price change due to reclassification. We consider both price increases and decreases as events. Restricting the sample to occupations with at most one reclassification yields 57 events, of which 33 are price decreases. When analyzing price decreases, we exclude occupations that experience a price increase from the sample, and vice versa – hence, we always use the same control group of never-treated individuals. We define an event window with three lags and three leads, and bin event indicators at the endpoints of the window, capturing average long-run impacts (Schmidheiny and Siegloch, 2023). Let $D_{j,t}$ be an indicator for a price increase or decrease as

[27] Note that these reclassifications only apply to new private DI contracts. Premiums charged to existing contracts are unaffected.

a result of reclassification. Then, the empirical model is

$$Y_{j,t} = \beta_{-3} \sum_{s=-\infty}^{-3} D_{j,t-s} + \sum_{\ell=-2}^{2} \beta_\ell D_{j,t-\ell} + \beta_3 \sum_{s=3}^{\infty} D_{j,t-s} + \mu_j + \theta_t + \epsilon_{j,t}. \tag{3}$$

where θ_t and μ_j are event-year and occupation fixed effects. Equation (3) specifies a two-way fixed effects (TWFE) model in a staggered-adoption design. This strategy requires two identification assumptions. The first is the standard parallel trends assumption: In the absence of the price change, average outcomes for treated and control occupations would have evolved similarly over time. The second identification assumption is that treatment effects are constant over time. Recent literature cautions against possible violations of this constant-effects assumption, which can lead to biased TWFE estimates. Hence, we use the heterogeneity-robust estimator by de Chaisemartin and D'Haultfoeuille (2020, 2024) as our baseline method and show standard TWFE estimates as additional results.

Figure 8 and Table 3 display results. Due to the discreteness of private DI pricing across risk groups, price changes implied by reclassifications are large: on average, prices change by 36.8%. Panel (a) of Figure 8 shows that yearly private DI purchases respond sharply and quite symmetrically to price increases and decreases. Pooling across all price changes, the estimated impact on private DI demand is -39.2%, which implies a demand elasticity of -1.06. When estimated separately, the elasticity is -1.22 for price increases and -0.92 for price decreases, but the two estimates are statistically indistinguishable. Both de Chaisemartin and D'Haultfoeuille (2024) and TWFE estimators yield very similar point estimates. Furthermore, the figure displays only quantitatively small pre-treatment trends in purchases under the de Chaisemartin and D'Haultfoeuille (2024) estimator, which suggests that differential trends in insurance demand across occupations do not drive reclassifications.

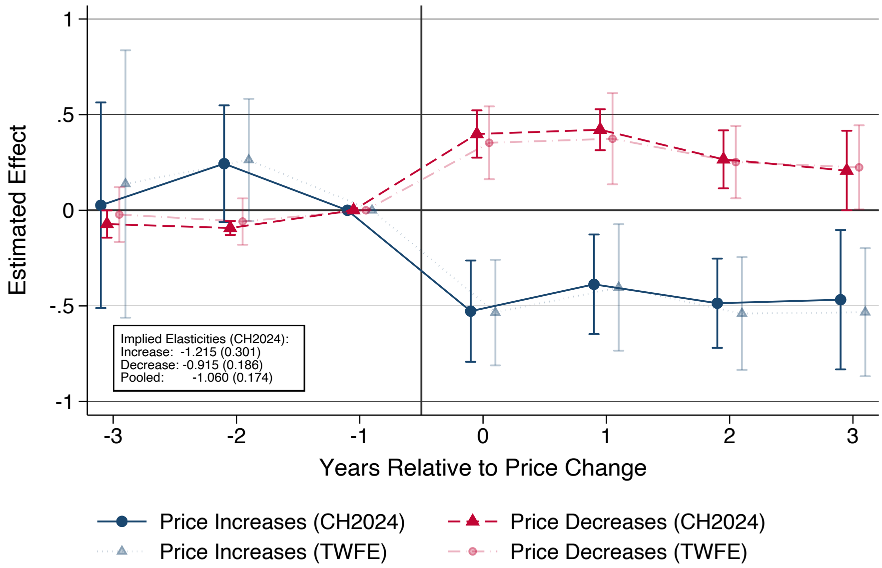
Table 3: Demand Elasticity Estimation

	(1) Pooled	(2) Groups 1-2	(3) Groups 2-3	(4) Groups 3-4	(5) Groups 4-5
dp/p	0.368	0.279	0.496	0.391	0.434
	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)
dQ/Q	-0.392	-0.350	-0.444	-0.375	-1.246
	(0.066)	(0.029)	(0.034)	(0.046)	(0.485)
Elasticity	-1.060	-1.256	-0.895	-0.961	-2.873
	(0.174)	(0.104)	(0.069)	(0.117)	(1.117)
Observations	4022	1605	1988	2476	1423

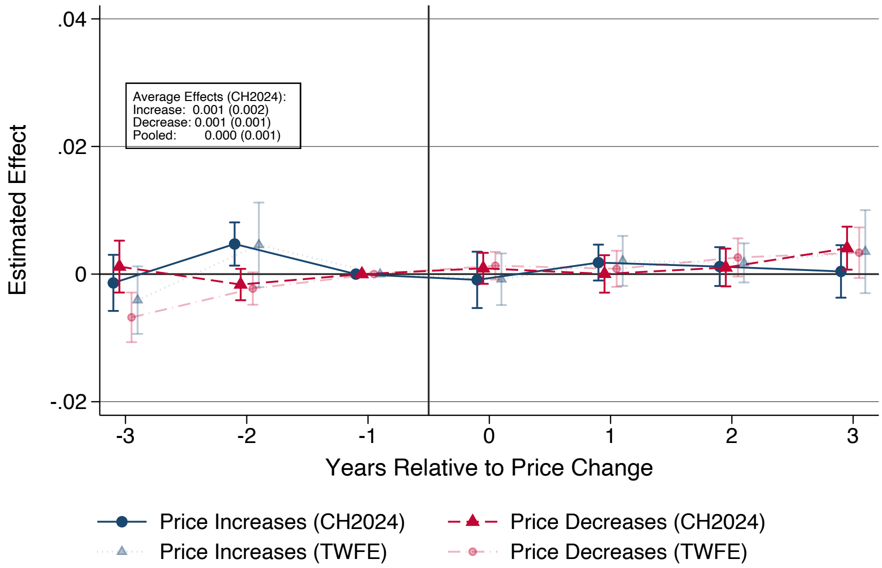
Notes: The table displays results from our main demand elasticity estimation based on the event study approach. The first row shows the variation in private DI premiums between adjacent risk group pairs. The second row displays the estimated response of private DI take-up. The third row shows demand elasticities relating the estimated percentage change in take-up to the percentage change in price. For each outcome, Column (1) shows estimates pooling all risk groups, and Columns (2) to (5) show results separately for each risk group pair. Standard errors based on the delta method are shown in parentheses.

Figure 8: Demand and Cost Estimation: Event Study Approach

(a) Private DI Purchases



(b) Probability of Ever Claiming DI Benefits (by Purchase Year)



Notes: The figure shows results from an event study around price changes due to occupation reclassifications. Panel (a) displays estimated dynamic effects on private DI purchases (relative to baseline purchases). Panel (b) shows the estimated impact on the probability of ever claiming DI benefits within the sample period by year of purchase. In both panels, effects are shown separately for price increases (blue lines) and price decreases (red lines). In addition to the baseline estimates using the method by de Chaisemartin and D'Haultfoeuille (2024), we also show estimates from a standard two-way fixed effects (TWFE) specification in lighter color. Point estimates are displayed along with 95% confidence intervals for all specifications. In Panel (a), the text box shows demand elasticities implied by the average effect on purchases for price increases, decreases, and pooling all price changes, with standard errors in parentheses. In Panel (b), the text box shows average effects, with standard errors in parentheses.

Columns (2) to (5) of Table 3 additionally report results separately by risk groups. For instance, the estimates in Column (2) only use reclassifications from risk group 1 to risk group 2 or vice versa. Demand responses of different groups translate into relatively constant elasticities, even though the estimates are obtained across a wide range of baseline private DI take-up levels (except the larger but imprecisely estimate for risk groups 4 to 5). This pattern, which also arises under our alternative estimation strategy described below, motivates the assumption of a constant elasticity along the demand curve that we make later on.

Next, we examine how private DI claims respond to price changes. Our outcome measure is the probability of ever claiming private DI benefits among individuals who purchased a contract in the event year. Note that this measure is not limited to claims during the time horizon of our event study itself, but takes into account all future claims occurring within our sample period. Panel (b) of Figure 8 depicts results. We find that despite the large observed demand response, there is no significant change in claims. The pooled point estimate is a precisely estimated zero effect, and we can exclude effects larger than 0.2 percentage points based on the confidence interval.[28] Separate estimates for price increases and decreases are also insignificant and close to zero. Again, we find no significant pre-trends in claims, supporting the parallel trends assumption.

Estimating the effect on DI claims corresponds to the cost curve test for risk-based selection (Einav et al., 2010). Intuitively, the impact of a price change on claims is informative about the cost associated with insuring marginal individuals induced to buy private DI compared to inframarginal buyers. Thus, the slope of the marginal cost curve can be derived from the estimated effect on claims. Our finding of a zero effect implies that the marginal cost curve is flat, i.e., no significant risk-based selection. This result is consistent with the positive correlation test from Section 5, reinforcing our conclusion of no adverse selection in the private DI market.

Alternative Strategy: Quasi-Discontinuity Approach. To complement these results, we implement a second demand estimation strategy, which relies on a different source of identifying price variation. Our alternative strategy directly exploits the discreteness in the pricing of private DI contracts, which creates jumps (”quasi-discontinuities”) in premiums between risk groups. As we explain in detail in Appendix B.2, this results in large price differences between occupations with virtually the same underlying disability risk. Empirically observed changes in private DI take-up at the risk group boundaries can be interpreted as a response to local variation in insurance premiums. Results from this estimation strategy are shown in Appendix Table A9. The average price difference between adjacent risk groups is 42.0%, and the average conditional jump in private DI take-up corresponds to a 48.4% reduction in insurance demand. This implies an average demand elasticity of -1.11, which is reassuringly close to our estimate from the event study approach in Table 3.

[28] The point estimate for the third post-event year after price decreases, which is the binned endpoint capturing purchases three or more years after the event, is small and positive. Like the point estimate of our positive correlation test, this would, suggest slightly advantageous selection, if anything.

6.3 Constructing Demand and Cost Curves

Demand. We construct risk-group-specific demand curves based on two empirical moments. First, their slope is pinned down by our demand elasticity estimates from above. Second, the level of demand is anchored by observed post-reform private DI take-up. We assume a constant elasticity of demand within risk groups, which is motivated by the relatively similar elasticity estimates we find across different take-up levels.[29] For our main welfare analysis, we use the pooled elasticity estimate from the event study approach, but the results remain very similar when considering group-specific elasticities instead.

We scale willingness to pay and prices in terms of expected insurance premiums paid by individuals and received by the insurer:

$$p_{i,k} = \sum_{t=0}^{T_i} (1 - \Pi_{k,t}) \tilde{p}_k \delta_t \tag{4}$$

where T_i is the contract end date relative to a start date normalized to zero, $\tilde{p}_k$ is the per-period premium charged to risk group k, $\Pi_{k,t}$ is cumulative disability risk in period t, 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 total claiming risk in the administrative data. Appendix Figure A6 shows empirical risk paths for each risk group. As we know from Table 1, lifetime disability risk increases strongly with risk groups. Risk paths by age evolve quite similarly across groups, with most DI claims occurring between ages 45 and 60. 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 and the welfare measures described below are expressed in terms of certainty equivalents.

Cost. In an Einav et al. (2010)-type framework, the shape of cost curves is determined by the nature of risk-based selection in the insurance market. We found no significant risk-based selection in the positive correlation test and the cost curve test. In fact, our cost curve test directly implies a flat marginal cost curve. Moreover, as marginal costs are constant, marginal and average cost curves coincide.

We calculate the expected cost of providing the DI coverage offered by the private market to individual i in risk group k as

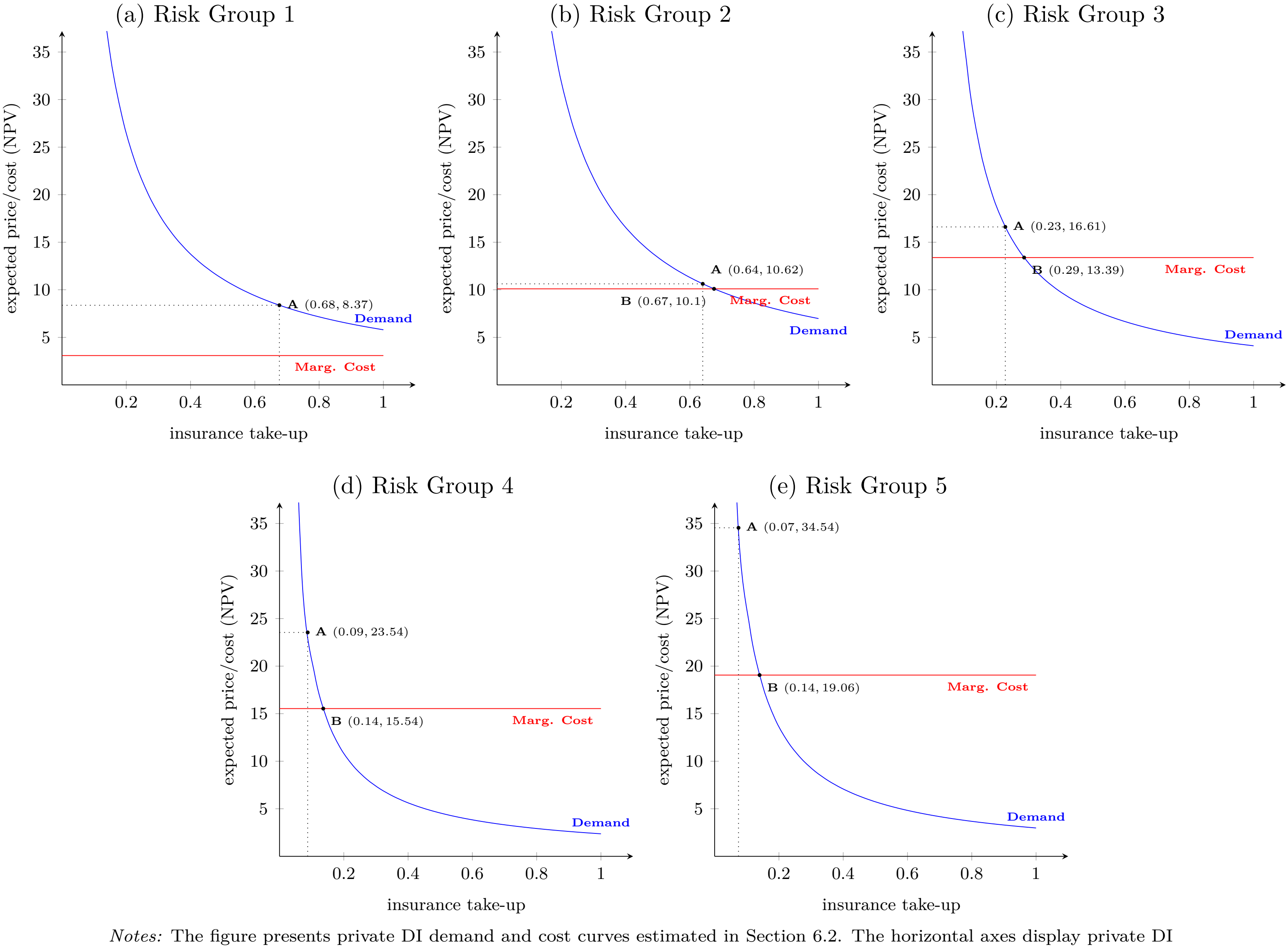
$$c_{i,k} = \sum_{t=0}^{T_i} \Pi_{k,t} b_i \delta_t \tag{5}$$

where b_i is the level of insured benefits. Again, we calculate $c_{i,k}$ for each individual in the insurer

[29] Alternatively, the literature often assumes a linear demand curve (e.g. Einav et al., 2010; Landais et al., 2021). In our case, demand responses estimated across different take-up levels suggest that a constant elasticity is a better approximation than a linear curve.

microdata and then take the average expected cost within risk groups. 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 since our risk measure is based on ex-post observed claims. Second, we assume that the cost of providing a given level of insurance coverage is the same across private and public DI systems.[30]

Figure 9: Demand and Cost Curves



Notes: The figure presents private DI demand and cost curves estimated in Section 6.2. 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 (4) and (5). 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.

[30] Unfortunately, the insurer microdata does not provide information on claims over a sufficiently long period to fully compare private and public DI claims. However, some aggregate calculations on private DI claiming risk are provided by the German Actuarial Society (DAV 2018). Appendix Figure A6 includes 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 similar to observed public DI claims, suggesting that our assumption of equal cost is a good approximation.

Results. Figure 9 plots empirical demand and cost curves by risk group. In each panel, the horizontal axis denotes the fraction of the group covered by private DI, ranging from zero to one. Demand curves rank individuals from high to low willingness to pay along the horizontal axis. Cost curves show the marginal/average cost associated with insuring the set of individuals willing to purchase insurance at a given price. In each panel, point A denotes empirically observed private DI take-up, and B denotes the intersection of demand and cost curves.[31] 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 at any level of take-up. Panel (b) shows corresponding results for risk group 2, for whom the cost is substantially higher. The demand curve also indicates a higher willingness to pay for DI, but demand and cost curves intersect at a take-up rate of 67%. Thus, willingness to pay is below cost for 33% of individuals. In Panel (c), the cost of insuring risk group 3 is 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 the estimated willingness to pay is below cost for around 86% of individuals.

We further quantify estimated demand and cost in Appendix Table A11. We calculate both for a private DI contract insuring a 30% gross income replacement rate and scale magnitudes relative to income. Across all groups, median willingness to pay for the coverage offered by the private DI market is around 0.9% of income, and expected cost is 1.5% of income. In line with strongly varying disability risk, we estimate group-specific insurance costs between 0.3% of income in risk group 1 and 2.1% in risk group 5. In contrast, valuations do not increase with risk. Our estimates suggest a willingness to pay for private DI of 1.2% of income in risk group 1 and 1.5% in risk group 2, but only between 0.5% and 0.9% for risk groups 3 to 5. These quantitative results echo the large differences in observed private DI take-up across risk groups.

Conceptually, our analysis is closely related to Cabral and Cullen (2019), who use a similar framework to estimate workers' willingness to pay for supplemental private DI coverage at a U.S. firm. One key difference is that in their setting, private DI is a pure top-up insurance covering exactly the same risk as public DI, whereas German private DI covers a different sub-risk since the 2001 reform. Yet, Cabral and Cullen (2019) find that workers are willing to pay 0.3% of annual earnings per 10% replacement rate which is quite similar to our median private DI valuation estimate from above.

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

7 Welfare Effects of Privatizing DI

7.1 Baseline Welfare Calculations

Based on the estimated demand and cost curves, we can assess welfare in the private DI market. As our baseline welfare measure, we define the *net value* of DI as its value to the insured relative to the cost to the insurer. Net value in the private market is

$$NV^{priv} = \frac{\sum_k n_k \big[\int v(\theta) \mathbb{1}(v(\theta) \geq p_k) dF_k(\theta) \big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) \geq p_k) dF_k(\theta) \big]} \tag{6}$$

where n_k denotes the size of risk group k. In the private market, the net value is given by the value to those who choose to purchase DI, 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.[32] Starting from the private market equilibrium, the net value of introducing the mandate is

$$\Delta NV^{mand} = \frac{\sum_k n_k \big[\int v(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]} \tag{7}$$

Individuals with willingness to pay 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 price.

Based on this welfare measure, a reform is welfare-improving if its net value is greater than one; that is, it generates value exceeding its cost. For our counterfactual, $\Delta NV^{mand} > 1$ would imply that mandating private DI coverage is welfare-improving. In contrast, $\Delta NV^{mand} < 1$ would mean that leaving this coverage to the voluntary private market is preferable.

Our baseline welfare analysis follows Einav et al. (2010) and focuses on the direct value and cost of providing extra DI. However, various types of indirect effects could be associated with DI provision. To account for these as much as possible, we also calculate a marginal value of public funds (MVPF) measure (Hendren and Sprung-Keyser, 2020; Finkelstein and Hendren, 2020). To do this, we augment

[32] While there might be alternative policies of interest, e.g., mandating parts of private DI coverage, we focus on this counterfactual for two reasons. First, the fairest comparison is arguably between two policies providing the same insurance coverage, so it is 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 the most empirically credible.

equation (7) and include relevant fiscal externalities in the denominator.[33] As a first externality, mandating private DI coverage is likely to impose indirect moral hazard costs onto public DI, since top-up insurance in case the worker also qualifies for public (general) DI benefits is included. To quantify this channel, we use the estimate of Seitz (2021), who finds that private DI increases public DI claims by 8.6%. Second, a fiscal externality may arise because additional DI claims entail reductions in labor supply, which in turn lower tax revenue. Unfortunately, empirical estimates of the labor supply effects of DI are not available in the German context, so we use an average of estimates from the literature. Third, covering all workers with private DI may reduce their propensity to claim social assistance if they become unable to work, implying a positive fiscal externality. Appendix B.5 provides full details on how we calibrate each channel based on our data and estimates from the literature.

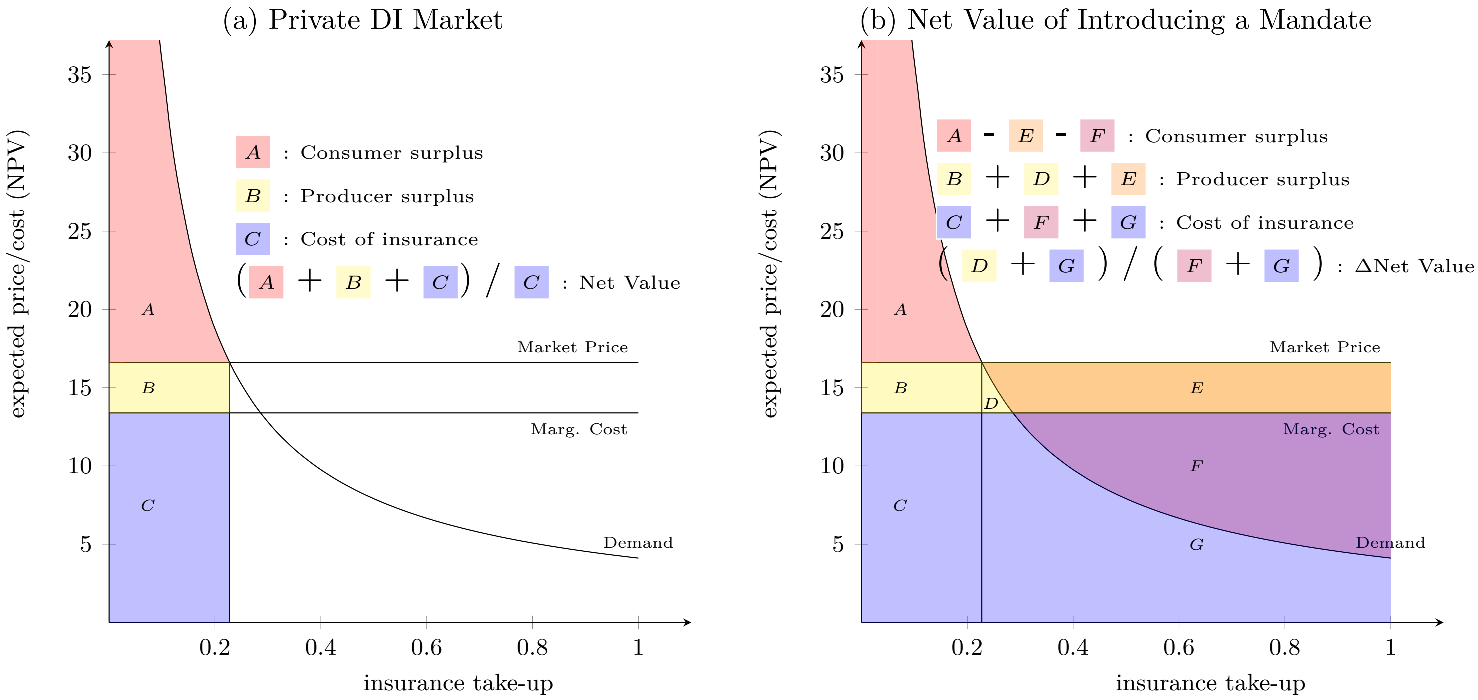
Welfare in the private DI market can be graphically illustrated using our estimated demand and cost curves. Panel (a) of Figure 10 depicts net value in the private DI market for the case of risk group 3. The total area under the demand curve up to equilibrium take-up corresponds to the numerator in equation (6), and the area under the marginal cost curve corresponds to the denominator. In addition, the figure shows a decomposition of willingness to pay into consumer surplus (area A), producer surplus (B), and cost (C). Appendix Figure A8 shows analogous graphs for all risk groups. Overall, the private DI market generates a large surplus, as individuals with the highest willingness to pay choose to purchase private DI. Consumer surplus is particularly sizable 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 over marginal cost are highest (see Section 7.3).

Panel (b) of Figure 10 illustrates the welfare effects of a mandate, again for the case of risk group 3. Starting from the private market status quo, insuring all individuals entails additional costs given by the area under the cost curve between equilibrium take-up and mandated take-up of 100% (areas $F + G$). Expanding insurance yields additional value ($D + G$), but this is exceeded by additional premium payments ($D + E + F + G$), implying a net loss in consumer surplus. Insurers, on the other hand, gain surplus ($D + E$). Thus, the overall net value of the mandate is given by $D + G$ over $F + G$, which is clearly below one. Appendix Figure A9 shows that the net value of a mandate is below one for all risk groups except group 1.

The first row of Table 4 quantifies these welfare results. We find an overall net value of introducing a private DI mandate of 0.705. This implies that partial DI privatization, similar to the 2001 reform,

[33] We continue using the entire estimated demand and cost curves when calculating the MVPF, as in equations (6) and (7). This is important because our counterfactual is a large reform moving insurance take-up to 100%, such that the approximation of willingness to pay based on the envelope theorem often used in MVPF calculations would not be appropriate.

Figure 10: Welfare Calculations



Notes: The figure illustrates our welfare calculations for the case of risk group 3. Panel (a) depicts welfare in the private DI market, 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, the net value can be further decomposed, as explained in the respective legend. Appendix Figures A8 and A9 show corresponding graphs for all risk groups.

is welfare-improving compared to a full public DI mandate. Similarly, we find an MVPF of a mandate of 0.617. This reflects that the joint effect of fiscal externalities increases the net cost of providing extra DI, reinforcing our conclusion that the private DI market is welfare-improving.[34]

7.2 The Social Value of a DI Mandate

As an extension of the welfare analysis, we introduce distributional concerns. Recall that the private DI market disproportionately covers high-income and low-risk individuals. A mandate would thus extend coverage to more low-income and high-risk individuals, on whom a social planner concerned with equity would place particular weight. We write the social net value of introducing a mandate as

$$\Delta SNV^{mand} = \frac{\sum_k n_k \Big[\lambda_k \overbrace{\int (v(\theta) - p_k)\, \mathbb{1}(v(\theta) < p_k) dF_k(\theta)}^{\text{Consumer surplus}} + \overbrace{\int p_k \mathbb{1}(v(\theta) < p_k) dF_k(\theta)}^{\text{Insurer revenue}} \Big]}{\sum_k n_k \big[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \big]} \tag{8}$$

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 change in consumer

[34] As a point of comparison, Hendren and Sprung-Keyser (2020) report similar MVPF estimates for marginal reforms providing additional DI benefits between 0.74 and 0.96.

Table 4: Welfare Effects of Insurance Mandates

	(1)	(2)	(3)	(4)
	Private DI Mandate (Risk-Based Premiums)		Public DI Mandate (Income-Based Contributions)	
	Net Value	MVPF	Net Value	MVPF
Baseline value	0.705	0.617	0.705	0.617
Social value by risk aversion σ				
σ=1	0.634	0.553	1.215	1.057
σ=2	0.575	0.499	1.547	1.343
σ=3	0.527	0.456	1.750	1.518
σ=5	0.459	0.393	1.936	1.679
σ=8	0.395	0.333	2.010	1.742

Notes: The table shows the welfare effects of mandating the DI coverage offered by the private insurance market. Column (1) presents net value estimates for a private DI mandate and Column (3) presents estimates for a full public DI mandate financed by income-based social insurance contributions. Columns (2) and (4) present marginal value of public funds (MVPF) estimates for the same mandates, taking into account fiscal externalities. The first row shows the baseline value calculated as in equation (7). The remaining rows show the social value calculated as in equations (8) and (9), using welfare weights from a Utilitarian social welfare function under different values of the coefficient of relative risk aversion σ.

surplus among risk group k is multiplied by λ_k, the social welfare weight of individuals in this group. The second term in the numerator reflects additional revenue to the insurer. The social net value then relates the sum of these two terms to the additional cost of providing insurance.[35]

Equation (8) 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 2001 reform, where individuals are mandated to participate and pay social insurance contributions. To evaluate such a public DI mandate, we have to consider that contributions can differ from risk-rated private DI premiums p_k. Formally, the social net value of a public DI mandate is given by

$$\Delta SNV^{pub} = \frac{\sum_k n_k \left\{ \lambda_k \left[\int (v(\theta) - p_k)\, \mathbb{1}(v(\theta) < p_k) dF_k(\theta) + \overbrace{\int (p_k - p_k^{pub}) dF_k(\theta)}^{\text{Pricing effect}} \right] + \int p_k^{pub} \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \right\}}{\sum_k n_k \left[\int c(\theta) \mathbb{1}(v(\theta) < p_k) dF_k(\theta) \right]} \tag{9}$$

where p_k^{pub} denotes contributions paid by individuals in risk group k. Compared to equation (8), a public DI mandate thus entails an additional pricing effect entering consumer surplus. Specifically, we

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

suppose that contributions are levied as a proportion of an individual's gross income, as is the case in our setting and other social insurance systems. 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 marginal utility from consumption. Moreover, we assume constant relative risk aversion utility. We calculate social welfare weights for each risk group based on expected lifetime income. Appendix Table A12 shows information on income and resulting social welfare weights by 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 the coefficient of relative risk aversion σ between 1 and 8, where a higher σ implies stronger equity concern and thus larger welfare weights on higher-risk groups.

Results from the social net value calculations are shown in Table 4. Column (1) suggests that a private DI mandate would lower welfare under any degree of equity concern. 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 A9, forcing all individuals 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 willingness to pay. Column (3) shows the welfare effects of a public DI mandate with income-based contributions. In our baseline net value calculations shown in the first row of the table, the welfare impact of a public DI mandate is the same as that of a private DI mandate because the difference in pricing does not affect total surplus. However, in the presence of equity concerns, a public DI mandate improves 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 prices below risk-rated premiums. This redistribution is highly valued by the social planner. Even under low risk aversion of σ=1, the social net value is already 1.215. As expected, the social net value rises with the degree of equity concern; for instance, it becomes 1.750 under σ=3 and 2.010 under σ=8.

We also calculate an analogous "social" MVPF measure. To this end, we augment equations (8) and (9) and include the various fiscal externalities described in Section 7.1. Table 4 shows that the social MVPF is generally somewhat lower than the social net value. As before, this occurs because the joint effect of fiscal externalities increases net cost. However, our main welfare results remain similar: the social MVPF of a private DI mandate is far below one, whereas the social MVPF of a public DI mandate is between 1.057 and 1.742.

Extensions and Robustness. Appendix Table A14 shows results from three extensions to our welfare analysis. First, we separate the effects of the different types of indirect costs included in our MVPF calculations. As expected, moral hazard spillovers onto public DI and the fiscal externality due to reduced labor supply lower the value of a mandate, but the positive externality due to reduced social assistance claims increases its value. Second, we check whether our results are robust to relaxing the assumption of a constant demand elasticity across risk groups. We find that results are qualitatively unaffected when using the point estimates for each risk group instead. Third, we allow for some risk-based selection in the private DI market. To quantify the potential range of cost curve slopes, we use the 95% confidence interval around the claim effect from Panel (b) of Figure 8. Converted into lifetime claiming probabilities, the confidence interval ranges from adverse selection with a 6.9% difference in costs between insured and uninsured individuals to advantageous selection with a -11.1% difference. Adverse selection somewhat increases the net value of a mandate, and advantageous selection somewhat decreases it, but again, results remain similar.

7.3 Supply-Side Factors: Market Power and Administrative Costs

Our welfare analysis relies on the sufficient-statistics framework by Einav et al. (2010), which takes insurance supply and the characteristics of insurance contracts as given. Evidence from other insurance markets, in particular long-term care insurance, suggests that the supply side can matter for take-up and welfare (Braun et al., 2019). Key supply-side factors emphasized by prior literature include the degree of market power and the extent of administrative costs.

Several empirical observations suggest that both market power and administrative costs are less critical issues in our setting. First, the German private DI market is relatively competitive: the top 3 providers have a combined market share of 34.2%. This is substantially lower than in other markets, e.g. Braun et al. (2019) report a top-3 market share of 66% in U.S. long-term care insurance. Second, administrative costs are modest in German private DI. According to Fischer et al. (2024), fixed and variable administrative costs amount to 3% and 10% of premiums, respectively, compared to 20% and 13% in Braun et al. (2019). Third, coverage denials, which can result from administrative costs, are infrequent in our setting. The overall denial rate is only 3% (see Section 2.1), versus 56% in U.S. long-term care insurance (Braun et al., 2019) and up to 64% in U.S. private DI (Hendren, 2013).

These empirical facts translate into modest insurance loads, a commonly used metric combining insurer profits and administrative costs.[36] Across all risk groups, we find an average load of 0.27,

[36] We follow Brown and Finkelstein (2008) and calculate insurance loads as $1 - (\mathbb{E}(c_{i,k})/\mathbb{E}(p_{i,k}))$, where $c_{i,k}$ are

implying that insured individuals can expect to receive 73% of premiums in benefits. This is considerably lower than the average load of 0.42 reported in Braun et al. (2019). Note that these loads are already implicitly incorporated in our main welfare analysis. Market power and administrative costs can lead to inefficiently low private DI take-up, which policy interventions aimed at increasing take-up such as a mandate can address. However, our welfare results imply empirical insurance loads are not sufficiently large to justify a mandate.

To shed more light on the role of administrative costs for private DI take-up and welfare, we nonetheless perform an additional counterfactual simulation building on Braun et al. (2019) and Fischer et al. (2024). Some proponents of regulatory tools such as minimum benefit ratios argue that these could reduce administrative costs. In the counterfactual, we set administrative costs to zero and assume that this cost reduction is fully passed through to consumers. As it is unlikely that such an extreme reduction can be achieved in practice, we interpret the results from this simulation as an upper bound on the potential impact of administrative costs. Appendix Table A13 shows that the decrease in private DI premiums due to the removal of administrative costs leads to a modest rise in private DI take-up to 33%. The positive impact on consumer surplus and insurer profits exceeds the additional (direct) costs of providing DI, such that the net value of the counterfactual is 1.359, indicating an improvement in overall welfare. While these results are qualitatively unsurprising, the small implied impact of administrative costs confirms that supply-side factors do not play a crucial role in our setting.

8 Conclusion

In this paper, we provide novel empirical evidence on the functioning of private DI markets. We document significant crowding-out after a reform that cut public DI coverage. Yet, private DI take-up remains far from complete, especially among low-income, low-educated and high-risk individuals. Our welfare analysis highlights the policy implications of these findings. Our baseline welfare result is that leaving private DI coverage to the voluntary market is welfare-improving. This is closely related to our main empirical findings. 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, the value of extra DI coverage revealed by insurance choices is low for many individuals, especially in higher-risk groups, and our sizable demand elasticity estimates imply that insurance valuations decline fast among the uninsured. Third, market power and administrative costs are of

expected DI benefits (corresponding to the direct cost of providing insurance) from equation (5) and $p_{i,k}$ are expected insurance premium payments from equation (4).

insufficient magnitude to justify a mandate. In other words, the private DI market covers the majority of individuals whose willingness to pay is above marginal cost.

However, equity concerns 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 income-based contributions as in real-world social insurance systems. Such a mandate redistributes not only from high- to low-income groups but also from low- to high-risk groups. Importantly, this analysis takes the design of other tax and transfer schemes as given. If the government aims at redistributing across income levels, there are likely more efficient ways to achieve equity gains. Nevertheless, redistribution across disability risk types is a distinctive feature of public DI. It may be worthwhile for future research to explore these trade-offs further.

Throughout the welfare analysis, we follow the literature on mandates vs. markets in social insurance settings and maintain the assumptions of the revealed preference approach (Einav et al., 2010; Finkelstein et al., 2019; Landais et al., 2021; Cabral et al., 2022). Crucially, this includes the assumption that individuals make optimal private DI purchase decisions, such that observed demand reflects individuals' true insurance valuations. As discussed in Section 4.2, observed private DI take-up could be explained by several factors consistent with revealed preferences. However, if behavioral biases lead to inefficient under-insurance for some workers, this could potentially provide an alternative rationale for a mandate beyond the classic market failures considered by the revealed preference approach. Studying such biases is outside the scope of this paper, but this may be another area where future work is needed to inform policy.[37]

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[37] In an earlier version of this paper (Seibold et al., 2022), we considered behavioral biases as an alternative rationale for a mandate more explicitly. As it is difficult to directly quantify such biases in our data, we defer this topic to future work.

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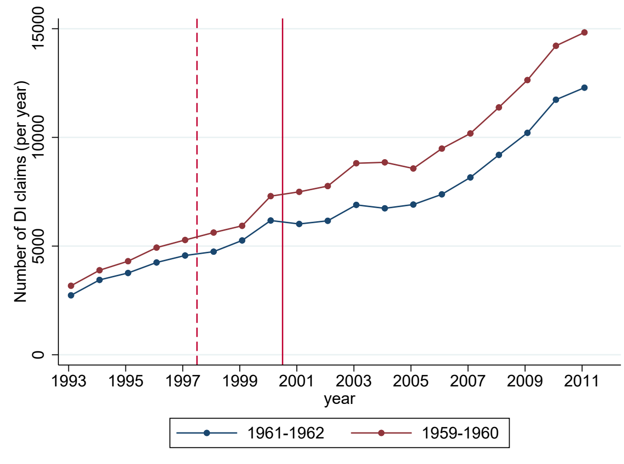
Appendix

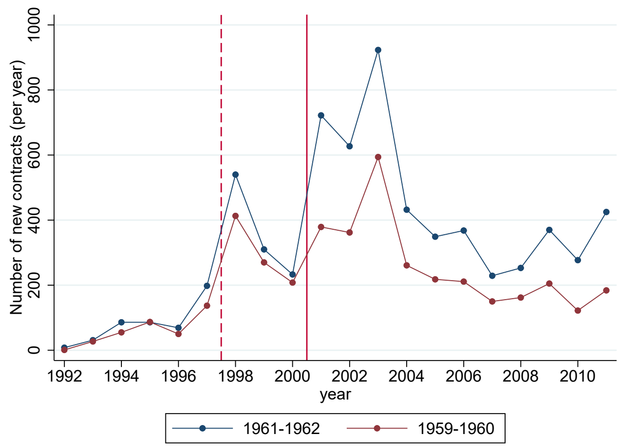
A Additional Figures and Tables

Figure A1: Additional Difference-in-Difference Results

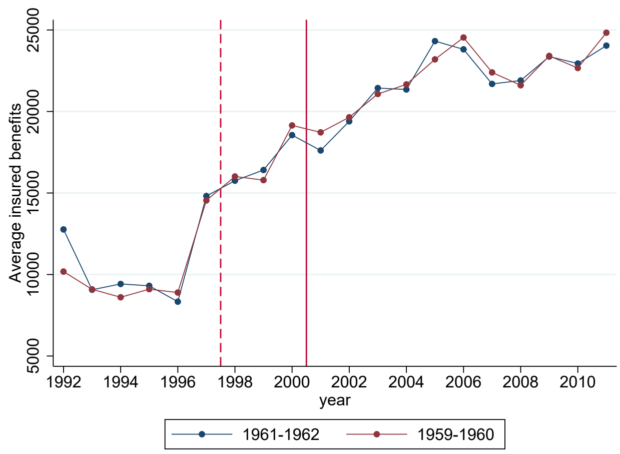
(a) All Public DI Claims



(b) Private Stand-Alone DI Purchases

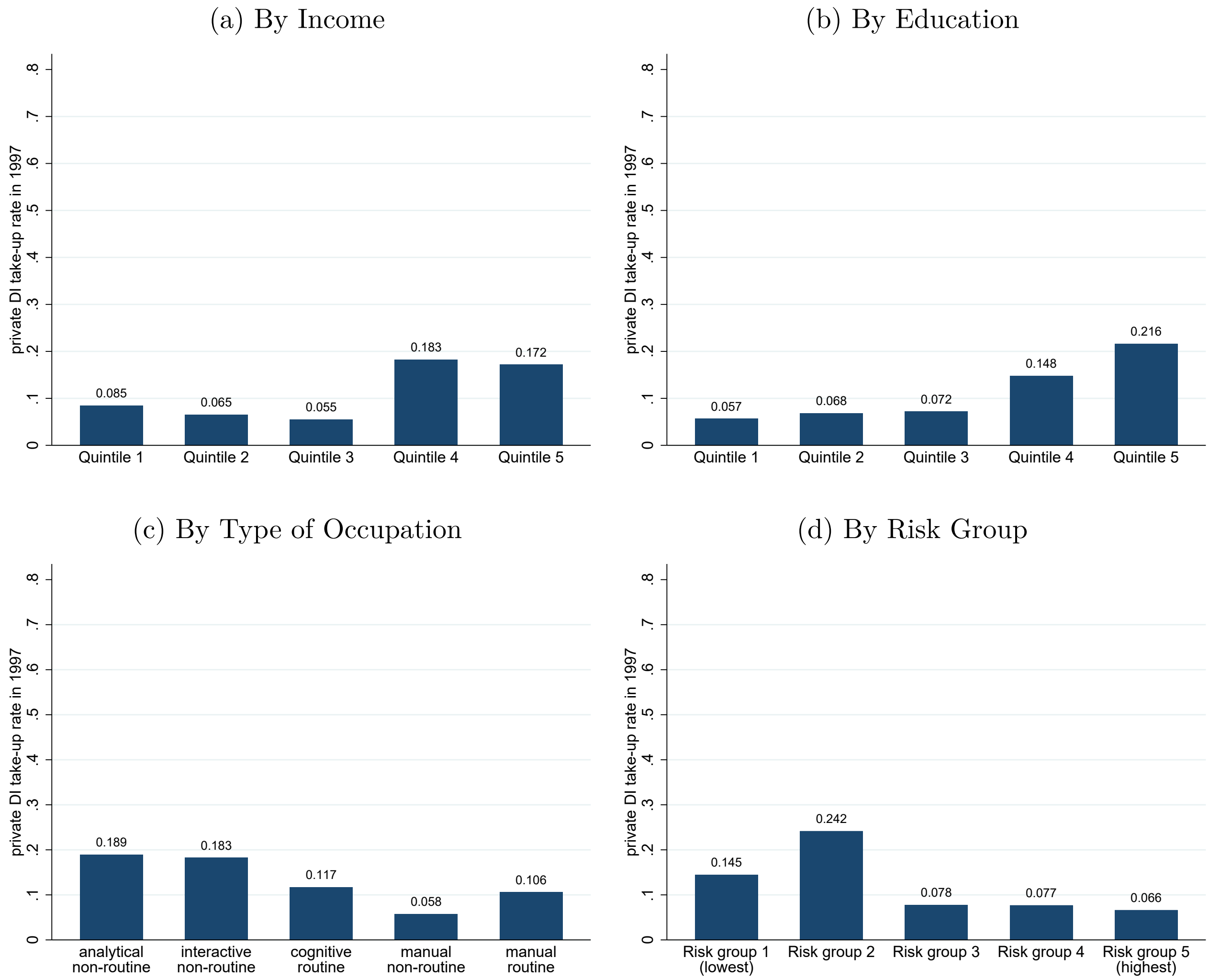


(c) Private DI Benefits



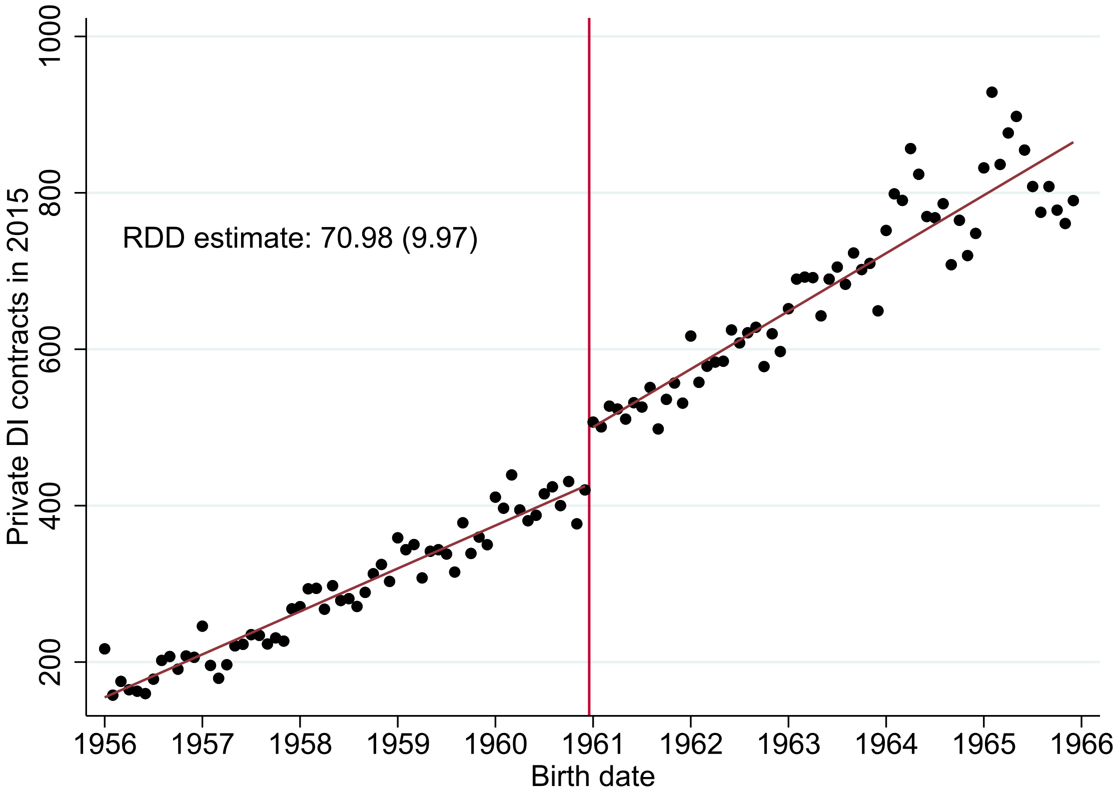
Notes: The figure shows the number of public DI claims (Panel a), stand-alone private DI purchases (Panel b) and insured benefits in private DI contracts of individuals born in 1961-1962 (treated cohorts) vs. 1959-1960 (control cohorts) at yearly frequency. In all panels, the dashed vertical line demarcates the time when the reform is first announced (December 1997), and the solid vertical line demarcates the time when the 2001 reform takes effect (January 2001).

Figure A2: Private DI Take-Up across Groups, Pre-Reform



Notes: The figure shows private DI take-up rates in 1997 by income quintile (Panel a), education quintile (Panel b), type of occupation (Panel c), and risk group (Panel d). In Panel (b), education is defined as years of schooling. In Panel (c), the we use the task-based classification by Dengler et al. (2014) to group occupations. Take-up rates are calculated among all cohorts, see Appendix B.1 for details.

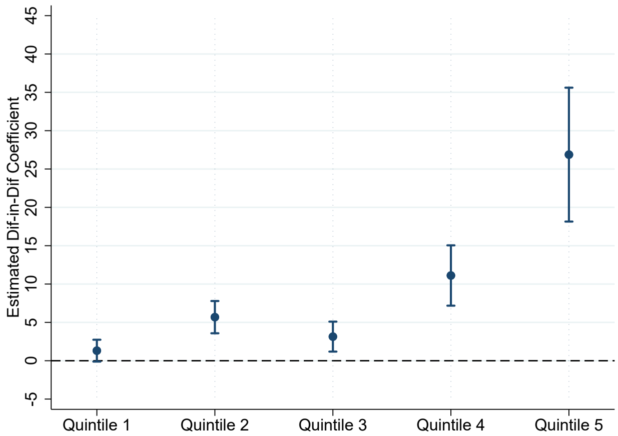
Figure A3: Alternative Strategy: Regression Discontinuity Design



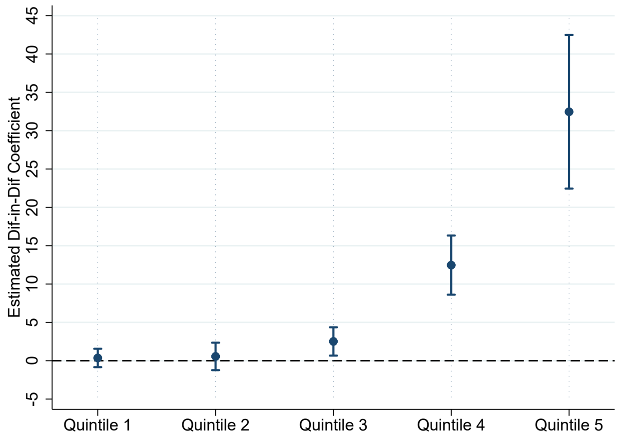
Notes: The figure shows alternative results from a regression discontinuity design (RDD) strategy. Black dots show the number of private DI contracts held by each monthly birth cohort in 2015, residualized for calendar month fixed effects. The vertical line denotes the birth cohort cutoff of the 2001 reform, above which individuals are treated. Red lines show fitted values from a linear regression, allowing for different slopes on the two sides of the cutoff. The figure also shows the estimated RDD coefficient, obtained from a specification using a linear fit and a bandwidth of 10 years as in the graph, with its standard error in parentheses. The estimated RDD coefficient corresponds to a 24.5% increase in the number of private DI contracts relative to the control group mean.

Figure A4: Heterogeneous Effects of the 2001 Reform on Private DI Purchases

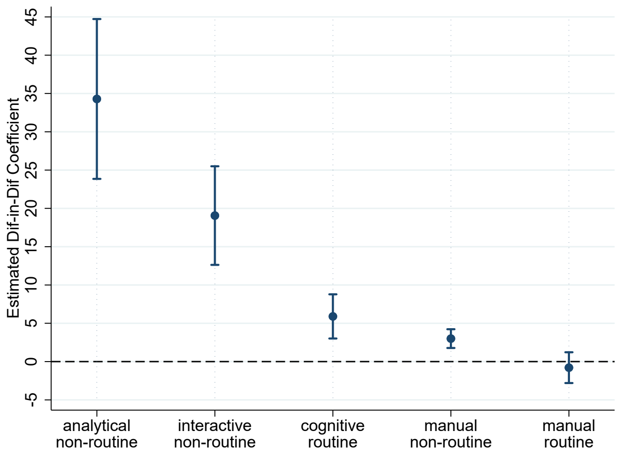
(a) By Income



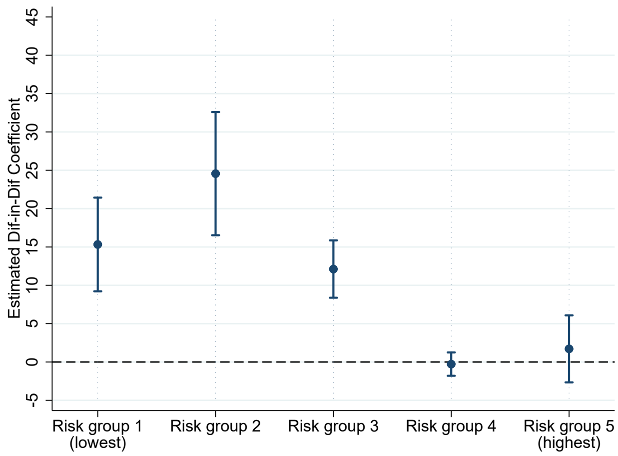
(b) By Education



(c) By Type of Occupation

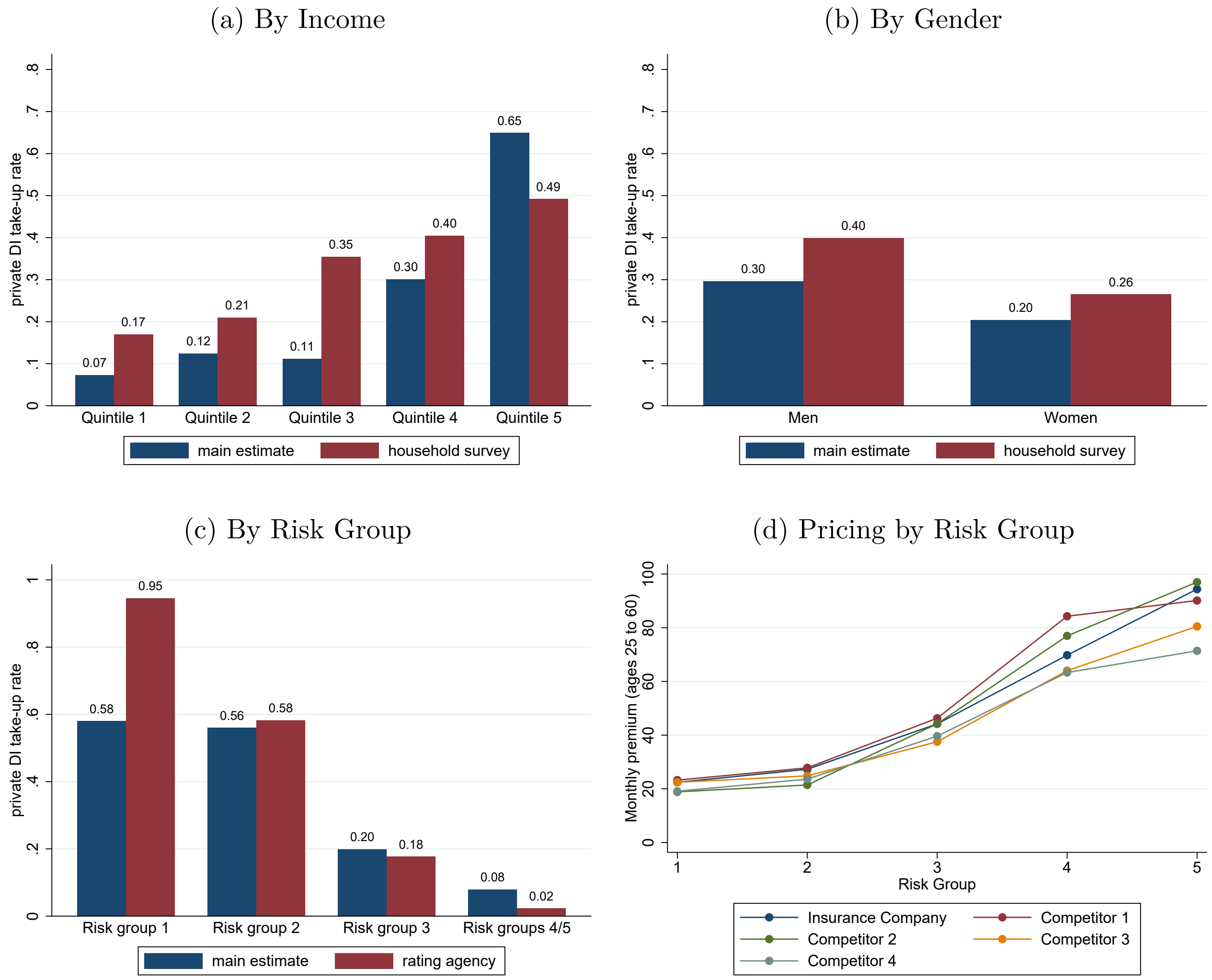


(d) By Risk Group



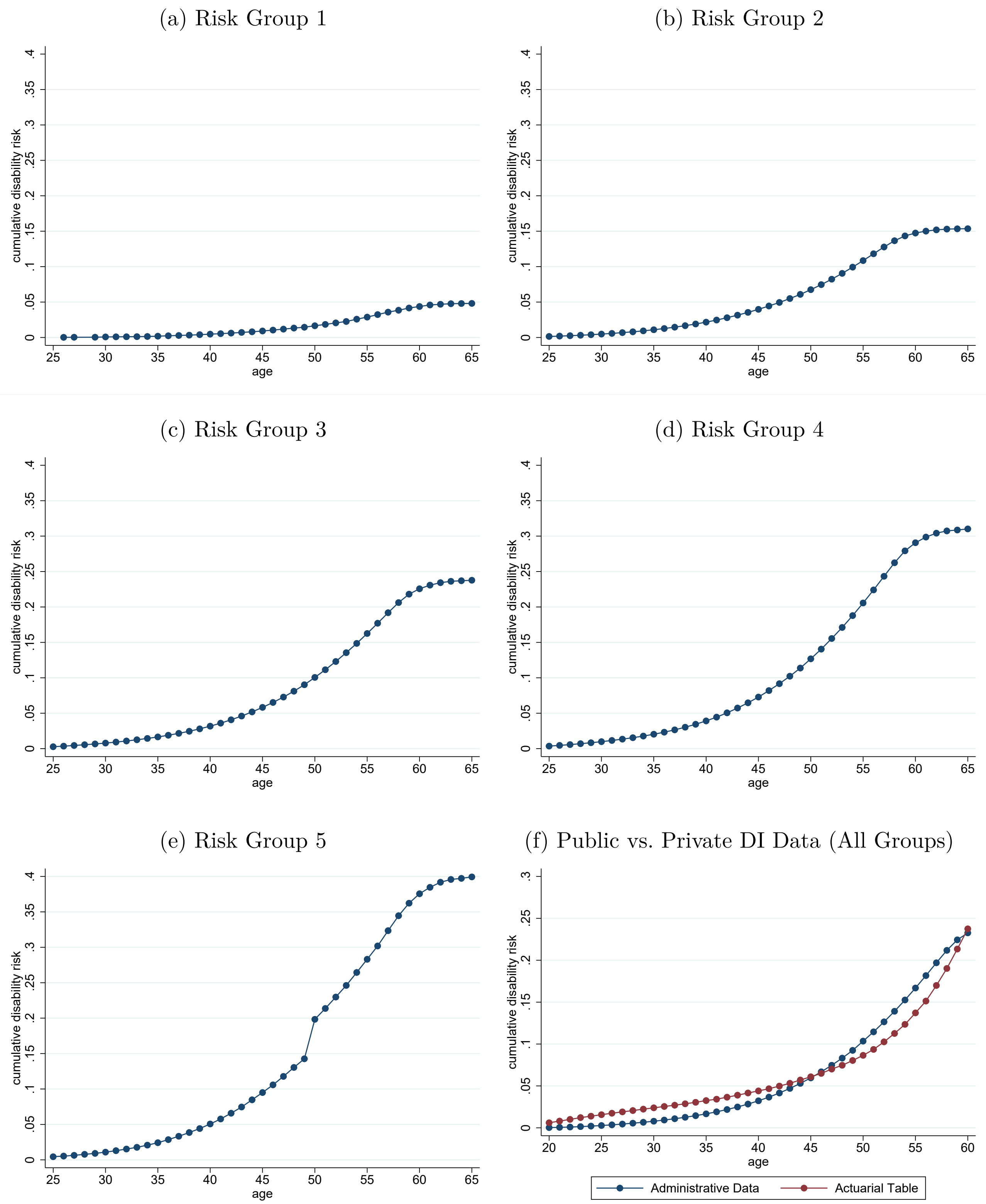
Notes: The figure shows difference-in-difference estimates of the effect of the 2001 reform on private DI purchases by subgroup. The estimates correspond to coefficient β_2 from equation (1), run separately for the subgroups indicated on the horizontal axis of each panel. In Panels (c) and (d), purchases are re-scaled proportional to relative group sizes. Point estimates are shown along with 95% confidence intervals. See Appendix Table A6 for full regression results.

Figure A5: Validating Private DI 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 private DI premiums charged to the ten most frequent occupations in each risk group by the insurer providing our microdata and four large competitors.

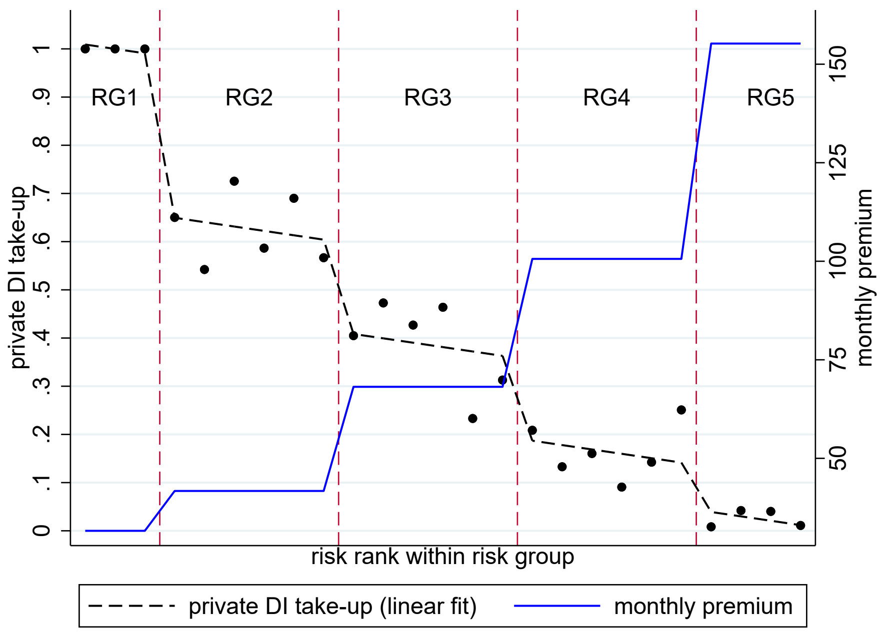
Figure A6: Disability Risk Paths



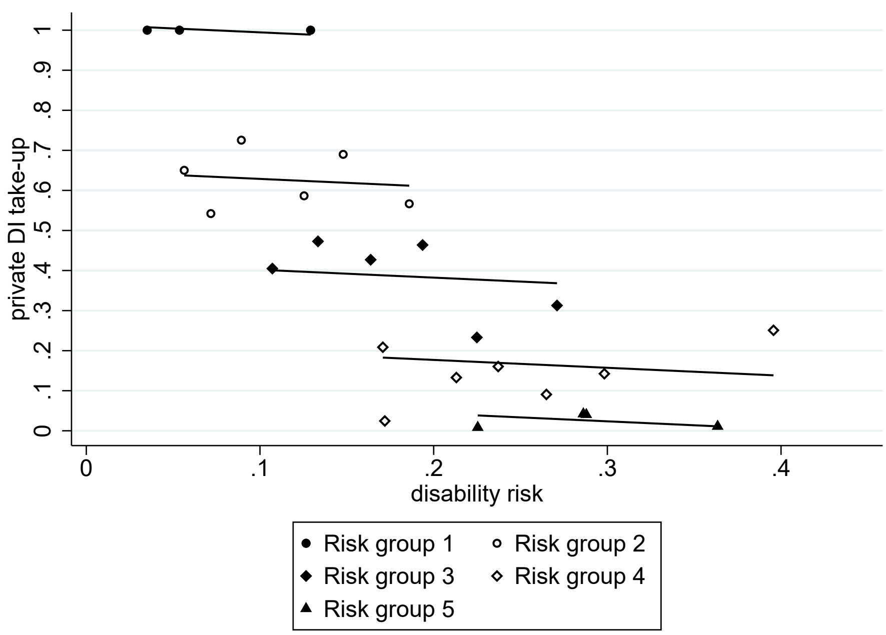
Notes: The figure shows the cumulative fraction of individuals claiming DI benefits. Panels (a) to (e) show the fraction claiming public DI benefits by age for the risk group indicated by the panel title. Panel (f) shows a comparison of claims among all risk groups in the administrative data to DI claiming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

Figure A7: Alternative Demand Estimation: Quasi-Discontinuity Approach

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

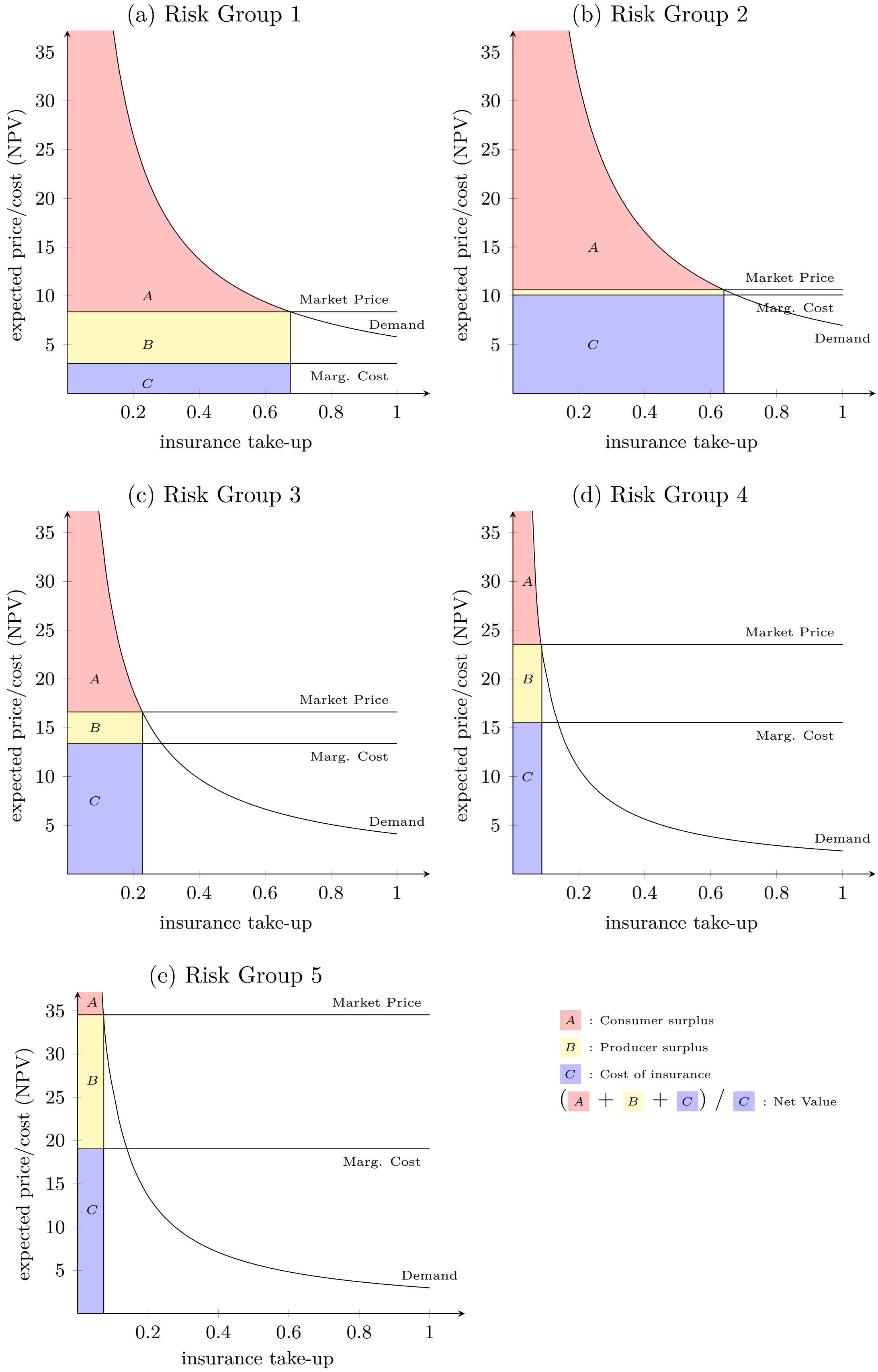


(b) Take-Up by Actual Risk



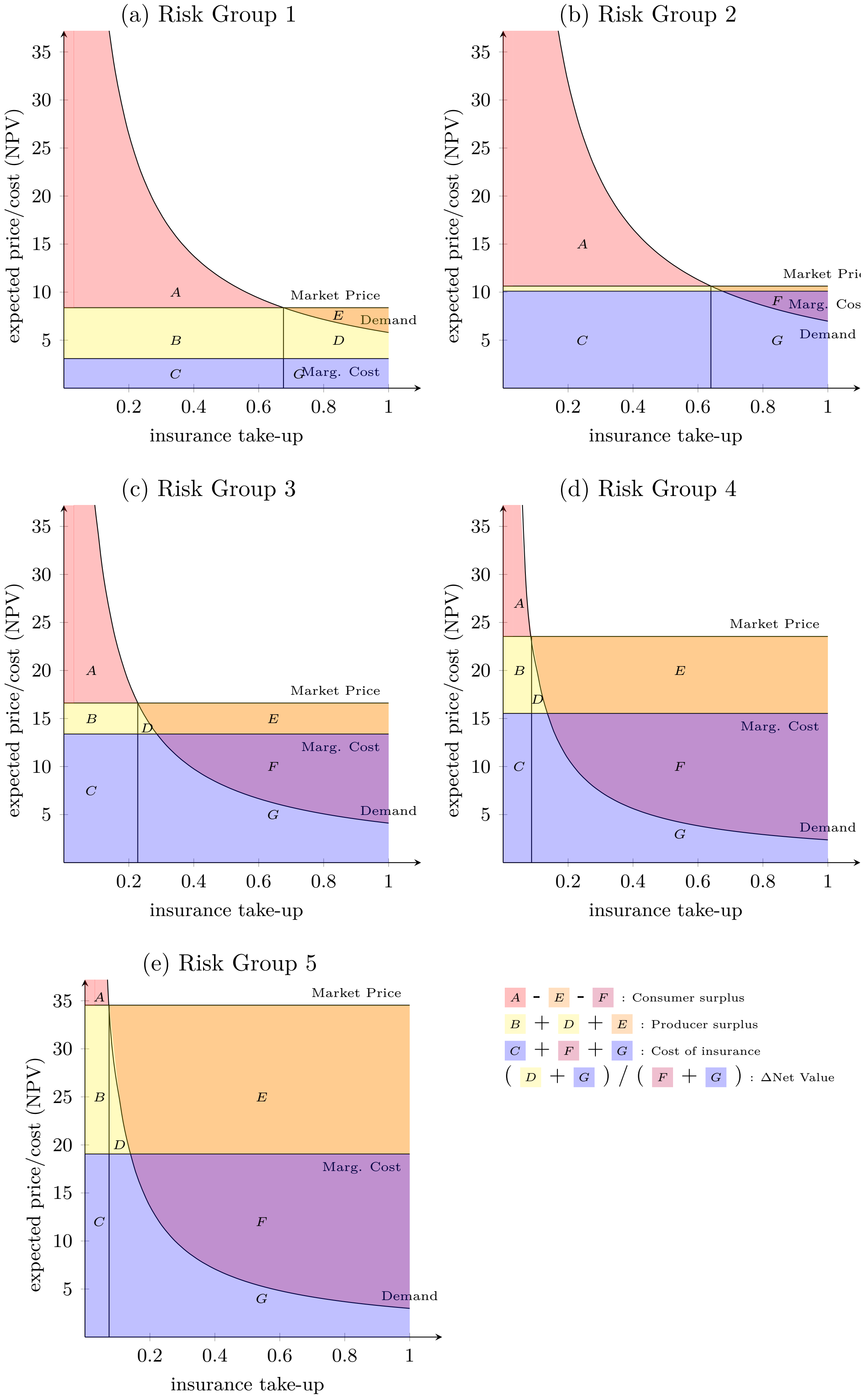
Notes: The figure illustrates our alternative demand estimation strategy exploiting the discrete pricing of private DI across risk groups. Panel (a) shows a stylized depiction of jumps in premiums and take-up rates between risk groups, ranking three-digit occupations by disability risk within risk group. 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 (B.2).

Figure A8: Welfare in the Private DI Market



Notes: The figure depicts welfare in the private DI market 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 A9: 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 of the Private Insurer Microdata

	(1)	(2)	(3)	(4)	(5)
		By Time of Purchase			
	Full Sample	Pre-reform (1997 or earlier)	In-between (1998-2000)	Post-reform (2001 or later)	Cohorts 1959-1962
Male	0.60	0.69	0.73	0.58	0.71
	(0.49)	(0.46)	(0.44)	(0.49)	(0.45)
Income (monthly)	4232.53	3966.97	4044.53	4275.41	4422.10
	(1382.31)	(1235.03)	(1293.07)	(1399.02)	(1364.61)
Education (years)	12.42	11.63	11.71	12.57	12.22
	(1.97)	(1.91)	(1.77)	(1.96)	(2.03)
Risk Group	2.42	2.81	2.81	2.35	2.55
	(0.86)	(0.98)	(0.89)	(0.83)	(0.92)
Age at Purchase	31.54	29.88	31.17	31.71	40.79
	(7.44)	(5.97)	(6.78)	(7.60)	(4.95)
Age at Contract End	61.33	58.27	58.86	61.87	60.18
	(3.55)	(3.75)	(3.26)	(3.32)	(2.77)
Insured Benefits (monthly)	1494.34	805.59	1267.20	1572.88	1553.75
	(1009.46)	(902.28)	(976.10)	(997.80)	(1242.95)
Insurance premium (monthly)	85.98	53.53	87.18	88.06	106.67
	(58.93)	(54.94)	(68.66)	(57.17)	(77.50)
Stand-Alone DI contract	0.54	0.27	0.39	0.58	0.57
	(0.50)	(0.44)	(0.49)	(0.49)	(0.50)
Observations			*confidential*		18,659

Notes: The table presents summary statistics of the insurer microdata, which contains information on private DI contracts. Column (1) summarizes the full sample. Columns (3) to (5) split the sample by year of purchase, showing summary statistics separately for contracts purchased in the pre-reform period (1997 or earlier), the "in-between" period when the reform was first announced but then retracted (1998 to 2000), and the post-reform period (2001 or later). Column (5) 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 A3: 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 A4: Summary Statistics of the 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 4.3.

Table A5: 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
Month-by-year 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)	(5)
	Number of Private DI Purchases (All Contracts)				
	baseline (post-2001)	control for 1998-2000	omit 1998-2000	post-1998	post-2005 (welfare reform)
Treated × post	15.11***	19.04***	16.96***	17.48***	1.411
	(2.739)	(2.539)	(2.456)	(2.202)	(3.055)
Observations	480	480	384	480	480
R-squared	0.939	0.940	0.944	0.940	0.932
Month-by-year FE	yes	yes	yes	yes	yes
Mean (pre-reform)	23.49	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. Column (5) shows results from an alternative specification around the welfare reform of 2005. 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 A6: Difference-in-Difference Results by Subgroup

	(1)	(2)	(3)	(4)	(5)
	Panel A: Private DI Contracts by Income				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Treated × post	1.313*	5.683***	3.143***	11.11***	26.88***
	(0.727)	(1.073)	(0.998)	(2.008)	(4.454)
Observations	480	480	480	480	480
R-squared	0.880	0.869	0.811	0.852	0.874
Mean (pre-reform)	6.560	5.720	5.830	13.96	18.22
Month-by-year FE	yes	yes	yes	yes	yes
	Panel B: Private DI Contracts by Education				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Treated × post	0.360	0.561	2.515***	12.47***	32.46***
	(0.612)	(0.915)	(0.943)	(1.968)	(5.112)
Observations	480	480	480	480	480
R-squared	0.823	0.842	0.821	0.858	0.880
Mean (pre-reform)	4.190	6.440	7.250	10.40	23.21
Month-by-year FE	yes	yes	yes	yes	yes
	Panel C: Private DI Contracts by Type of Occupation				
	analytical non-routine	interactive non-routine	cognitive routine	manual non-routine	manual routine
Treated × post	34.29***	19.06***	5.899***	3.001***	-0.792
	(5.323)	(3.283)	(1.471)	(0.625)	(1.025)
Observations	480	480	480	480	480
R-squared	0.870	0.876	0.838	0.883	0.843
Mean (pre-reform)	20.50	16.71	9.070	5.340	7.310
Month-by-year FE	yes	yes	yes	yes	yes
	Panel D: Private DI Contracts by Risk Group				
	Risk group 1	Risk group 2	Risk group 3	Risk group 4	Risk group 5
Treated × post	15.33***	24.56***	12.12***	-0.276	1.713
	(3.116)	(4.098)	(1.909)	(0.778)	(2.230)
Observations	480	480	480	480	480
R-squared	0.838	0.862	0.862	0.876	0.602
Mean (pre-reform)	13.18	19.85	7.980	6.690	5.830
Month-by-year 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 panel and column titles. The outcome in all specifications 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 A7: Determinants of Private DI Take-Up

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Dependent Variable: Private DI Take-Up			
Log income	0.0966***					0.0240*	0.0210
	(0.0255)					(0.0128)	(0.0161)
Education (years)		0.158***				0.0905***	0.0984***
		(0.0142)				(0.0190)	(0.0188)
Cognitive occupation			0.300***			0.0409	0.0620
			(0.0397)			(0.0475)	(0.0467)
Non-routine occupation				0.227***		0.111***	0.0667*
				(0.0408)		(0.0370)	(0.0399)
Risk group					-0.238***	-0.105***	-0.106***
					(0.0222)	(0.0340)	(0.0360)
Female							-0.301***
							(0.0780)
Married							-1.394***
							(0.462)
Economic training							0.157
							(0.0963)
East Germany							0.159
							(0.151)
Observations	286	286	286	286	286	286	286
R-squared	0.044	0.325	0.177	0.102	0.269	0.390	0.428

Notes: The table shows regression results on the determinants of private DI take-up at the three-digit occupation level. "Cognitive occupation" and "non-routine occupation" is based on the occupational classification by Dengler et al. (2014). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A8: Positive Correlation Test – Extended Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Unconditional correlation	Correlation test	Adding (unpriced) control variables				
	Dependent Variable: Private DI Take-Up						
Disability Risk	-1.374***	-0.168	-0.136	0.406	0.411	0.284	-0.0645
	(0.263)	(0.250)	(0.249)	(0.295)	(0.297)	(0.287)	(0.246)
Risk Group 2		-0.332***	-0.320***	-0.150	-0.147	-0.180	-0.204
		(0.0568)	(0.0580)	(0.145)	(0.145)	(0.150)	(0.128)
Risk Group 3		-0.590***	-0.568***	-0.255*	-0.250*	-0.276*	-0.289**
		(0.0488)	(0.0503)	(0.150)	(0.150)	(0.155)	(0.138)
Risk Group 4		-0.791***	-0.762***	-0.411***	-0.404**	-0.394**	-0.390***
		(0.0496)	(0.0518)	(0.156)	(0.157)	(0.162)	(0.147)
Risk Group 5		-0.937***	-0.928***	-0.555***	-0.559***	-0.554***	-0.561***
		(0.0501)	(0.0509)	(0.156)	(0.156)	(0.163)	(0.158)
Log income			0.0476***		0.0288**	0.0240*	0.0209
			(0.0158)		(0.0136)	(0.0130)	(0.0163)
Education (years)				0.123***	0.120***	0.0985***	0.0968***
				(0.0203)	(0.0203)	(0.0213)	(0.0214)
Cognitive occupation						0.0515	0.0665
						(0.0538)	(0.0526)
Non-routine occupation						0.104***	0.0690*
						(0.0383)	(0.0403)
Female							-0.313***
							(0.0830)
Married							-1.419***
							(0.480)
Economic training							0.155
							(0.0983)
East Germany							0.159
							(0.153)
Observations	286	286	286	286	286	286	286
R-squared	0.125	0.274	0.284	0.371	0.374	0.394	0.430

Notes: The table shows extended results from our positive correlation test. Column (1) displays the unconditional correlation between private DI take-up and risk. Column (2) shows our main positive correlation test, controlling for priced risk groups. Columns (3) to (7) include additional unpriced characteristics in the regression in order to study how these interact with risk-based selection. All specifications are run at the three-digit occupation level. "Cognitive occupation" and "non-routine occupation" is based on the occupational classification by Dengler et al. (2014). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A9: Alternative Demand Estimation: Quasi-Discontinuity Approach

	(1) Pooled	(2) Groups 1-2	(3) Groups 2-3	(4) Groups 3-4	(5) Groups 4-5
dp/p	0.420	0.246	0.439	0.370	0.536
dQ/Q	-0.484	-0.297	-0.182	-0.383	-0.985
	(0.121)	(0.210)	(0.160)	(0.180)	(0.360)
Elasticity	-1.106	-1.205	-0.415	-1.034	-1.833
	(0.274)	(0.852)	(0.366)	(0.485)	(0.670)
Observations	286	43	136	240	147

Notes: The table displays results from our alternative demand estimation strategy, the quasi-discontinuity approach exploiting discrete price variation between risk groups. The first row shows the variation in private DI premiums between adjacent risk group pairs. The second row displays the estimated response of private DI take-up. The third row shows demand elasticities relating the estimated percentage change in take-up to the percentage change in price. For each outcome, Column (1) shows estimates pooling all risk groups, Columns (2) to (5) show results separately for each risk group pair. Bootstrapped standard errors are shown in parentheses. No standard errors are shown in the first row because the cross-sectional price variation across risk groups is deterministic.

Table A10: Calibration Results: Risk Protection Benefit and Risk Preferences

	(1)	(2)	(3)	(4)	(5)
	Risk Groups				
	Group 1	Group 2	Group 3	Group 4	Group 5
Panel A: Risk Protection Benefit of Private DI					
Baseline (σ=3)	0.032	0.087	0.118	0.136	0.186
Lower risk aversion (σ=1)	0.007	0.023	0.031	0.035	0.047
Higher risk aversion (σ=5)	0.163	0.273	0.313	0.326	0.360
No public DI rejections	0.017	0.047	0.072	0.088	0.145
Higher public DI rejections	0.046	0.121	0.155	0.172	0.216
Lower consumption drop	0.007	0.021	0.029	0.034	0.048
Alternative consumption drop	0.007	0.021	0.028	0.032	0.043
Progressive earnings losses	0.022	0.058	0.064	0.067	0.082
Extremely progressive earnings losses	0.013	0.034	0.036	0.037	0.038
Panel B: Revealed Risk Aversion of Marginal Buyer					
Baseline	1.853	0.299	0.605	0.822	0.946
No public DI rejections	2.531	0.507	0.907	1.131	1.186
Higher public DI rejections	1.529	0.197	0.451	0.660	0.797
Lower consumption drop	4.956	1.981	2.480	2.802	2.866
Alternative consumption drop	5.603	1.774	2.511	2.978	3.405
Progressive earnings losses	2.133	0.347	0.802	1.182	1.555
Extremely progressive earnings losses	2.898	0.484	1.467	2.398	4.243

Notes: The table shows calibration results. Panel A displays the calibration risk protection benefit of private DI by risk group, scaled as a fraction of workers' income. Panel B shows the calibrated coefficient of relative risk aversion σ of the marginal buyer in each risk group. In each panel, different rows display results under varying assumptions about consumption drops upon disability and public DI rejections. In Panel A, results are additionally shown for different levels of risk aversion. See Appendix B.3 and B.4 for details of the calibrations.

Table A11: Estimated Value and Cost of Private DI

	(1)	(2)	(3)	(4)	(5)	(6)
	All	Risk Groups				
		Group 1	Group 2	Group 3	Group 4	Group 5
Median Willingness to Pay (% of Income)	0.860	1.180	1.452	0.867	0.504	0.642
Median Cost (% 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 A12: Social Welfare Weights

	(1)	(2)	(3)	(4)	(5)
	Risk Groups				
	Group 1	Group 2	Group 3	Group 4	Group 5
Income (annual)	64,605	54,998	40,648	35,202	31,546
Income (net present value)	1,524,573	1,269,563	926,151	794,701	702,268
Social welfare weights by risk aversion σ					
σ=1	0.585	0.710	1.015	1.217	1.408
σ=2	0.326	0.480	0.982	1.412	1.889
σ=3	0.176	0.314	0.915	1.579	2.444
σ=5	0.047	0.124	0.741	1.838	3.806
σ=8	0.006	0.028	0.487	2.083	6.675

Notes: The table shows average income and social welfare weights by risk group. "Income (net present value)" denotes the net present value of expected lifetime income calculated at age 25. Social welfare weights are calculated under a Utilitarian social welfare function and the relative risk aversion coefficient σ indicated by the row titles. Social welfare weights are scaled such that the average weight in the population equals one.

Table A13: The Role of Administrative Costs

	(1) Private DI Market Status Quo	(2) Counterfactual: Zero Administrative Cost
Private DI Take-Up	0.288	0.333
Private DI Premiums (NPV)	17.509	15.233
Insurance Load	0.268	0.159
Consumer Surplus	63.608	64.142
Producer Surplus	0.933	0.505
Profits	0.436	0.505
Admininistrative Costs	0.497	0.000
Direct Insurer Costs	2.890	3.349
Net Value of Reform		1.359
Social Net Value of Reform		1.332

Notes: The table shows results from a counterfactual simulation removing administrative costs. Column (1) shows outcomes under the private DI market status quo, and Column (2) shows outcomes under the counterfactual setting administrative costs to zero. The net value and the social net value of the counterfactual reform are calculated analogously to equations (7) and (8).

Table A14: 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	0.650	0.650
Social Net Value, σ=1	0.585	1.121
Social Net Value, σ=3	0.487	1.615
Social Net Value, σ=5	0.425	1.787
Panel B: Fiscal Externality due to Labor Supply Reduction		
Net Value	0.650	0.650
Social Net Value, σ=1	0.576	1.103
Social Net Value, σ=3	0.481	1.589
Social Net Value, σ=5	0.420	1.759
Panel C: Reduction in Social Assistance Claims		
Net Value	0.737	0.737
Social Net Value, σ=1	0.658	1.260
Social Net Value, σ=3	0.538	1.807
Social Net Value, σ=5	0.460	1.998
Panel D: Heterogeneous Demand Elasticities		
Net Value	0.806	0.806
Social Net Value, σ=1	0.757	1.167
Social Net Value, σ=3	0.693	1.666
Social Net Value, σ=5	0.660	1.859
Panel E: Some Adverse Selection		
Net Value	0.726	0.726
Social Net Value, σ=1	0.656	1.262
Social Net Value, σ=3	0.551	1.824
Social Net Value, σ=5	0.483	2.019
Panel F: Some Advantageous Selection		
Net Value	0.674	0.674
Social Net Value, σ=1	0.602	1.148
Social Net Value, σ=3	0.494	1.644
Social Net Value, σ=5	0.425	1.817

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 at the end of Section 7.2. 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.

B Empirical Methodology

B.1 Calculating Private DI Take-Up of Subgroups

The main challenge in studying heterogeneity in private DI take-up 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

$$C_{g,t} = \sum_j \frac{c^j_{g,t}}{marketshare^j_t} \tag{B.1}$$

where $c^j_{g,t}$ is the number of contracts of type $j \in \{\text{stand-alone}, \text{bundled}\}$ in the microdata 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 $marketshare^j_{g,t} = marketshare^j_t \;\; \forall g$. As we discuss in Section 4, this assumption is not innocuous but its validity in our context is supported by a range of empirical evidence.

B.2 Alternative Demand Estimation Strategy: Quasi-Discontinuity Approach

Our main demand estimation strategy in Section 6.2 uses an event study approach around occupation reclassifications. Here we present an alternative demand estimation strategy that relies on a different source of identifying price variation. Namely, we directly exploit the discreteness in insurers' pricing of private DI contracts, which creates large jumps in prices between risk groups. As we explain below, this price variation can be interpreted as "quasi-discontinuities" at the risk group boundaries. We run the following regression:

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

where Q_j denotes private DI take-up by three-digit occupation j in 2015, π_j is lifetime 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. The key idea behind this regression is that occupations are assigned to discrete risk groups based on a continuous running variable, namely disability risk π_j. Thus, around the boundaries between risk groups, similar occupations with virtually the same disability risk 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 variation in insurance premiums.[1]

The identification assumption behind this empirical strategy is that conditional on underlying risk and other observable characteristics, the assignment of occupations to risk groups is unrelated to unobserved demand differences. In addition to our risk measure from administrative data, we control for a large set of characteristics (income, education, indicators for type of occupation, gender, marital status, economic training and residence in East Germany). Thus, we arguably capture much of the information insurers could use to determine the assignment of occupations to risk groups. Consistent with this argument, we find very similar demand elasticities in the event study design where occupation fixed effects absorb any cross-sectional demand differences.

Appendix Figure A7 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 private 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 take-up within risk group, revealing large jumps in demand at the risk group boundaries. We can then calculate a demand elasticity by relating these responses 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 (B.2). There is 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 ample price variation. Indeed, Panel (b) also indicates clear, large jumps in private DI take-up conditional on underlying risk across all adjacent risk group pairs.

Appendix Table A9 shows quantitative results. The average price difference between adjacent risk groups is 42.0%, and the average conditional jump in private DI take-up at the risk group boundaries corresponds to a 48.4% reduction in insurance demand. This implies an average demand elasticity across all risk groups of -1.11, which is remarkably similar to the main estimate from the event study approach shown in Table 3. Demand responses at the different cutoffs provide no indication that elasticities systematically increase or decrease with risk groups. This pattern arising under both empirical strategies motivates the assumption of a constant elasticity along the demand curve we make below.

B.3 Calibrating the Risk Protection Benefit of Private DI

In the first set of calibration exercises described in Section 4.2, our goal is to quantify the potential risk protection benefit private DI offers to different groups of workers. To this end, we calibrate the expected utility gain risk-averse individuals derive from the availability of private DI benefits. Our method builds on similar approaches used in the literature to quantify the risk protection benefit of other types of insurance, such as health insurance (e.g. Finkelstein and McKnight, 2008; Engelhardt and Gruber, 2011; Shigeoka, 2014) and pension annuities (e.g. Mitchell et al., 1999).

[1] While the conceptual aim is different, the regression specification (B.2) itself is similar to the positive correlation test from Section 5. Econometrically, the main difference to equation (2) is that we now include a large set of characteristics as control variables Z_j, including income, education, and gender. In the correlation test, we do not control for these characteristics because they are not used by insurers to price contracts. However, it is important to add these controls in equation (B.2) since they may confound responses to insurance prices.

We set out a stylized framework that allows us to compare lifetime expected utility across situations with and without private DI. We define the *risk premium* as the maximum amount a risk-averse individual would be willing to pay with certainty per period in order to completely avoid the risk entailed by each scenario. For the situation without private DI, the risk premium π_0 is defined by

$$\sum_{t=0}^{T} \delta^t u(y - \pi_0) = \underbrace{\sum_{t=0}^{T} \delta^t \left[(1 - \Pi_t)u(c_H) + \Pi_t(\eta_t u(c_L^{0,0}) + (1 - \eta_t)u(c_L^{0,1}))\right]}_{\text{expected utility without private DI}} \tag{B.3}$$

where T is the end date of the potential insurance contract relative to a start date normalized to zero, y is the individual's income, 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.

The right hand side of equation (B.3) is the individual's expected lifetime utility in a situation without private DI, while baseline public DI coverage is available. In each period, consumption depends on whether the individual is disabled and whether they qualify for public DI benefits. We denote c_H consumption when not disabled, $c_L^{0,0}$ consumption when disabled and qualifying for public DI, and $c_L^{0,1}$ consumption when disabled and not qualifying for public DI, whereby the first superscript *0* indicates that these consumption levels are defined for the situation without private DI. The left hand side of the equation defines the risk premium π_0 as the maximum amount that would make the individual indifferent between making this payment with certainty in each period and the consumption lottery entailed by disability risk on the right hand side.

For the situation with private DI benefits, the risk premium π_1 is defined by

$$\sum_{t=0}^{T} \delta^t u(y - \pi_1) = \underbrace{\sum_{t=0}^{T} \delta^t \left[(1 - \Pi_t)u(c_H) + \Pi_t(\eta_t u(c_L^{1,0}) + (1 - \eta_t)u(c_L^{1,1}))\right]}_{\text{expected utility with private DI benefits}} \tag{B.4}$$

The right hand side of equation (B.4) is expected lifetime utility with private DI. All variables are defined analogously to equation (B.3), where consumption levels now carry the first superscript *1* to indicate that the individual receives private DI benefits in case of disability.

We can then calculate the risk protection benefit of private DI as the difference in risk premiums across scenarios, which we denote by $\Delta\pi$. To obtain an intuitive scaling of magnitudes, we additionally normalize $\Delta\pi$ relative to annual (non-disabled) income y:

$$\frac{\Delta\pi}{y} = \frac{\pi_0 - \pi_1}{y} \tag{B.5}$$

Thus, the risk protection benefit measure $\frac{\Delta\pi}{y}$ reflects what share of their income a risk-averse individual would be willing to give up with certainty in order to receive private DI benefits in case of a disability, relative to a situation with baseline public DI only. A decrease in risk exposure due to private DI appears as a decrease in risk premiums, $\pi_1 < \pi_0$. Accordingly, a positive value of $\frac{\Delta\pi}{y}$ corresponds to an expected utility gain from private DI.

We calibrate the risk protection benefit of private DI for each risk group. Throughout, we assume constant relative risk aversion (CRRA) preferences $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$. In the baseline specification, we follow the most common assumption in the literature and use a coefficient of relative risk aversion of $\sigma = 3$. In additional specifications, we consider lower risk aversion of $\sigma = 1$ or higher risk aversion of $\sigma = 5$.

One crucial input into the calibrations is given by the relative consumption levels across disabled and non-disabled states. It is useful to begin by writing income levels in different states as

$$
\begin{aligned}
y_H &= y \\
y_L^{0,0} &= \underline{y} \\
y_L^{0,1} &= \max(b^{pub}, \underline{y}) \\
y_L^{1,0} &= \max(b, \underline{y}) \\
y_L^{1,1} &= \max(b + b^{pub}, \underline{y})
\end{aligned}
$$

where all superscripts and subscripts are defined analogously to equations (B.3) and (B.4). Earnings in the non-disabled state are y. If the individual becomes disabled and qualifies for public DI, they receive benefits b^{pub}. If the individual is disabled and does not qualify for public DI, they receive basic social assistance $\underline{y}$. Moreover, basic social assistance provides an income floor in case DI benefits are below $\underline{y}$. If the individual has private DI, they receive benefits b in case of disability, which can serve as a top-up if they also qualify for public DI.

Table B1 summarizes key calibration input parameters. For each group, we calculate average income, insured benefits, contract duration, and lifetime disability risk paths in the data. As public DI benefits replace a proportional share of income, we use the observed average replacement rate of 39% for all groups. Private DI replacement rates, which we take directly from the insurer microdata, vary between 31% and 36% of income. For $\underline{y}$, we use the average annual basic social assistance payment, which was EUR 5632 in 2015.[2] As Table B1 shows, this corresponds to an implicit replacement rate of between 9% of income for risk group 1 and 18% of income for risk group 5. 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 each group, which are not covered by public DI. 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 assume a marginal propensity to consume out of non-disabled income of 80%, and we use a discount rate of 3%.

We consider a range of scenarios allowing for different values of the consumption drop upon disability in order to simulate relative consumption across disabled and non-disabled states. In the baseline scenario, we assume that relative to their non-disabled consumption c_H, all individuals experience the same proportional consumption drop upon disability. Denote d_0 as the consumption drop without additional transfers, and d_1 the consumption drop if they qualify for public DI. With proportional consumption drops, $c_L^{0,0} = (1 - d_0)c_H$ and $c_L^{0,1} = (1 - d_1)c_H$. To obtain $c_L^{1,0}$ and $c_L^{1,1}$, we need to add private DI benefits. Finally, we also consider scenarios where own-occupation disability entails greater earnings losses for high-income individuals. For instance, such "progressive" losses may arise because these workers have specialized human capital, making it costlier to be unable to work in their previous occupation. To capture this sort of heterogeneity, we let d_0 vary across groups. Note that under all scenarios and in all states, consumption remains bounded from below by social assistance $\underline{y}$.

Unfortunately, we cannot directly estimate consumption drops upon disability due to a lack of consumption data available in the German context. More generally, there are very few explicit estimates

[2] We calculate this number based on total social assistance expenditure and the number of recipients, as reported by IAQ (2022). Note that this includes both cash payments and housing benefits.

of these consumption drops: We are only aware of one study, namely Meyer and Mok (2019), who report such estimates based on U.S. survey data. We thus calibrate proportional consumption drop magnitudes based on their findings. In our baseline ”high consumption drop” scenario, we assume a change in consumption of 41% upon disability, and a “lower consumption drop” scenario assumes a drop of 25%.[3] For an alternative calibration scenario, we consider estimated income losses after workplace injuries reported by Humlum et al. (2023). They find a 40% drop in earnings and a 30% drop in income including public DI benefits. For our ”alternative consumption drop” scenario, we directly use these magnitudes.[4]

Moreover, we do not know of any existing empirical evidence on heterogeneity of earnings or consumption losses upon disability across different risk groups or occupations. Thus, we consider two scenarios to calibrate progressive earnings losses. As a benchmark, we calibrate an “extremely progressive earnings losses” scenario where, upon own-occupation disability, all workers can only work in a basic, low-skill occupation (regardless of their previous income and occupation). We set earnings in this basic occupation to the average income in the bottom income quintile, which was EUR 27,313 in 2015. In addition, we consider an intermediate scenario where $c_L^{0,0}$ and $c_L^{1,0}$ are given by the average between this extreme scenario and the baseline calibration with proportional consumption drops.

Results from selected calibration scenarios are included in Figure 6. Appendix Table A10 shows results based on the full range of specifications with varying assumptions on risk aversion, public DI rejections, and consumption drops.

B.4 Calibrating Revealed Risk Preferences

In the second set of calibration exercises described in Section 4.2, we we ask what level of risk aversion would be implied by observed private DI purchase decisions. We write expected lifetime utility without private DI as

$$V_0 = \sum_{t=0}^{T} \delta^t \left[(1-\Pi_t)u(c_H^0) + \Pi_t(\eta_t u(c_L^{0,0}) + (1-\eta_t)u(c_L^{0,1})) \right] \tag{B.6}$$

Expected lifetime utility with private DI is

$$V_1 = \sum_{t=0}^{T} \delta^t \left[(1-\Pi_t)u(c_H^1) + \Pi_t(\eta_t u(c_L^{1,0}) + (1-\eta_t)u(c_L^{1,1})) \right] \tag{B.7}$$

where variables in equations (B.6) and (B.7) are defined as in equations (B.3) and (B.4). In these expressions, the only major change relative to our prior calibrations is that we now take into account actual private DI premiums in determining non-disabled consumption levels, rather than calibrating

[3] 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 public DI replacement rate in the U.S. than in Germany, we consider the estimate of 25% for our “lower 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 “lower consumption drop” in the absence of any transfers 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.

[4] Note that the average injury in the data used by Humlum et al. (2023) is rather light, reducing earnings capacity only by 37%. This is below the threshold used for own-occupation and general DI assessments in Germany. Thus, we interpret the Humlum et al. (2023) estimates as another lower bound on consumption drops, similar to our ”lower consumption drop” scenario.

implied risk premiums. Because premiums have to be paid until a disability event, net income and consumption in the non-disabled state depend on whether the individual has private DI, such that $y_H^0 = y$ and $y_H^1 = y - p$, where p is the private DI premium charged to the individual.

Individuals buy private DI if expected utility V_1 exceeds V_0. The marginal individual purchasing private DI can be characterized by the indifference condition

$$V_0 = V_1 \tag{B.8}$$

This condition enables us to calibrate the implied risk preferences of the marginal buyer in each risk group, who is indifferent between buying and not buying at the market premium. In particular, we again assume CRRA preferences and calibrate the coefficient of relative risk aversion for marginal buyers. As before, we combine all available information on income, private DI benefits, premiums, contract duration and lifetime disability risk paths from the data. We consider the same range of assumptions about consumption drops upon disability, public DI rejections and other parameters as in Appendix B.3. All results are shown in Panel B of Appendix Table A10.

B.5 Externalities and the Marginal Value of Public Funds

In this section, we provide details of our marginal value of public funds (MVPF) calculations, which take into account various externalities from private DI provision. Hendren and Sprung-Keyser (2020) define the MVPF of a policy as

$$MVPF = \frac{WTP}{Net\ Cost} \tag{B.9}$$

where WTP is the total willingness to pay of recipients for the policy, and $Net\ Cost$ is the sum of its direct cost and any indirect effects of the policy on the government budget.

In our context, the policy of interest is a reform mandating private DI coverage. Our baseline net value measure from equation (7) is defined analogously to the MVPF, but only takes into account the direct cost of providing extra DI, as is typically done in the social insurance literature (Einav et al., 2010). Since the reform we consider entails a large change in private DI take-up, we have to take into account the entire demand and cost curves in order to quantify total WTP and direct cost. Section 6.2 describes how we estimate demand and cost curves empirically, and Section 7.1 explains these curves enter our net value measure.

As in the main text, the direct cost of insuring benefit level b is given by

$$c = \sum_{t=0}^{T} \delta^t \Pi_t \cdot b \tag{B.10}$$

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, and δ is a discount factor. Note that relative to the main text, we drop individual and risk group subscripts in this appendix for simplicity.

In order to derive the MVPF of DI mandates, we have to augment our cost measure to include indirect effects on the government budget. We consider three main types of indirect fiscal effects discussed in the social insurance literature, (i) additional moral hazard effects onto public DI due to top-up insurance provided by private DI, (ii) a decrease in tax revenue because of labor supply reductions in response to private DI, and (iii) cost savings in other safety net programs that workers claim less as a result of private DI, in particular basic social assistance. We calibrate the cost entailed by each of these channels as accurately as possible, using a combination of our data and estimates from the literature. in The first type of indirect cost is given by potential moral hazard spillovers onto public DI. Workers may become more likely to claim baseline public DI, since private DI can serve as a top-up insurance increasing the overall replacement rate. We can write the additional cost to the public DI system as

$$\Delta c_{pub} = \sum_{t=0}^{T} \delta^t m(1 - \eta_t)\Pi_t b^{pub} \tag{B.11}$$

where $1 - \eta_t$ is the share of general DI claims out of all disability cases, and b^{pub} is the benefit level in the public DI system. The factor m denotes the proportional increase in public DI claims as a result of private DI coverage. In order to quantify c_{pub} empirically, besides the information on disability risk and benefit levels contained in our various data sources, we crucially require an estimate of m, the moral hazard externality of private DI onto public DI. We use the estimate from Seitz (2021), who finds that the private DI increases public DI claims by 1.9 pp. (8.6%) in the German setting. Using these inputs, we calibrate equation (B.11) for workers in each risk group. Scaled relative to the direct cost of providing private DI, we find that this channel increases cost by a factor $\frac{c+\Delta c_{pub}}{c}$ of 1.085 on average.

The second type of fiscal externality arises because workers may reduce their labor supply in response to private DI. The resulting change in government tax revenue can be written as

$$\Delta R = \sum_{t=0}^{T} \delta^t (1 - \eta_t) m \Pi_t y_t \tau + \sum_{t=0}^{T} \delta^t \Delta L \eta_t \Pi_t y_t \tau \tag{B.12}$$

where τ is the average tax rate income level y_t is subject to. The potential impact of private DI on tax revenue has two components. The first term of equation (B.12) captures labor supply reductions among the additional workers claiming public DI, i.e. an additional fiscal cost of the moral hazard channel described above. The second term of the equation reflects that private DI pays benefits in case of an own-occupation disability, and workers who would otherwise be without any DI benefits decrease their labor supply in response. Empirically, besides our main data sources, we use the German tax and transfer microsimulation model ZEW-EviSTA (Buhlmann et al., 2022) to calculate average tax rates faced by individuals in each risk group. For m, we can again use the Seitz (2021) estimate. In addition, we require an estimate of ΔL, the reduction in labor supply in response to being awarded own-occupation DI benefits. We are not aware of any such estimate from the German setting, nor of any estimate specifically for own-occupation DI from other settings. Hence, we use an average effect across studies estimating labor supply responses to receiving DI benefits in the U.S. (Chen and van der Klaauw, 2008; Maestas et al., 2013; French and Song, 2014; Autor et al., 2016). On average, these studies find that DI receipt causes a reduction in labor force participation of 21.7 pp. Ultimately, calibrating this channel results in an average cost factor of $\frac{c+\Delta R}{c}$ of 1.104.

Third, a positive fiscal externality can arise when additional workers covered by private DI become less likely to claim other safety net programs. As we discuss in Section 2.1, the main alternative program to DI in the German context is basic social assistance. The potential fiscal effect of a reduction in social assistance claims is given by

$$\Delta SA = -\sum_{t=0}^{T} \delta^t \eta_t \Pi_t \underline{y} \tag{B.13}$$

where $\underline{y}$ is the annual social assistance payment a worker would be eligible for in the absence of private DI. This effect is relatively straightforward to calculate, using our data and the information on average social assistance payments we previously used in Appendix B.3. Across all groups, we find an average cost factor associated with this externality of $\frac{c+\Delta R}{c}$ of 0.945.

To calculate the MVPF of private and public DI mandates, we augment the denominator of equation (7) to include all three indirect fiscal effects. Similarly, we can augment the denominator of equations (8) and (9) to calculate the MVPF including social welfare weights. All MVPF results are shown in Columns (3) and (4) of Table 4. In addition, Appendix Table A14 shows results from incorporating the different types of fiscal externalities separately.

Table B1: Calibration Inputs

	(1)	(2)	(3)	(4)	(5)	
	Risk Groups					
	Group 1	Group 2	Group 3	Group 4	Group 5	*Source*
Lifetime disability risk	0.048	0.154	0.238	0.310	0.399	Administrative data
Share of own-occupation DI claims	0.109	0.081	0.126	0.157	0.320	Administrative data
Income (annual)	64,605	54,998	40,648	35,202	31,546	Administrative data
Public DI benefits (share of income)	0.390	0.390	0.390	0.390	0.390	Administrative data
Social assistance benefits (share of income)	0.087	0.102	0.139	0.160	0.179	IAQ (2022), own calculation
Private DI benefits (share of income)	0.359	0.358	0.356	0.317	0.308	Insurer microdata
Consumption drop upon disability (by scenario):						
Baseline, with public DI	0.41	0.41	0.41	0.41	0.41	Meyer and Mok (2019), own calculation
Baseline, without public DI	0.77	0.77	0.77	0.77	0.77	Meyer and Mok (2019), own calculation
Lower consumption drop, with public DI	0.25	0.25	0.25	0.25	0.25	Meyer and Mok (2019), own calculation
Lower consumption drop, without public DI	0.47	0.47	0.47	0.47	0.47	Meyer and Mok (2019), own calculation
Alternative consumption drop, with public DI	0.30	0.30	0.30	0.30	0.30	Humlum et al. (2023)
Alternative consumption drop, without public DI	0.40	0.40	0.40	0.40	0.40	Humlum et al. (2023)
Progressive earnings losses	0.33	0.31	0.26	0.23	0.20	Own calculation
Extremely progressive earnings losses	0.58	0.50	0.33	0.22	0.13	Own calculation

Notes: The table shows key parameters used as inputs into the calibrations described in Appendix B.3 and B.4.

C Literature on Risk-Based Selection in Social Insurance

In this appendix, we provide a review and a simple meta analysis of the literature on risk-based selection in social insurance settings. Studies are included based on the following criteria: (1) they are published in leading, peer-reviewed journals in economics (top general interest or top field) from 2000 onward, (2) they focus on one or several types of social insurance (health insurance, pension annuities, disability insurance, long-term care insurance, unemployment insurance, accident insurance/workers' compensation), and (3) they apply at least one of the state-of-the art empirical methods to test for risk-based selection. With these criteria, we limit the scope of the analysis to a manageable set of papers and we ensure that all results are directly comparable. They imply that we do not consider some older studies as well as work on other insurance markets not intersecting with government-provided social insurance. There are a number of review articles providing more comprehensive surveys of risk-based selection, including Cohen and Siegelman (2010), Einav, Finkelstein and Levin (2010), and Chetty and Finkelstein (2013), as well as surveys of older work by Cutler and Zeckhauser (2000), Cutler (2002) and Chiappori and Salanié (2003). Recently, Einav and Finkelstein (2023) provide a review focusing on papers that use their Einav et al. (2010) framework to study selection.

Our review is summarized in Table C1, which includes 34 published articles. References to all listed studies are provided in a separate bibliography immediately after the table. For each article, we report the country studied, the type of insurance, the type of selection test applied, and the main findings regarding risk-based selection. In terms of methods, we differentiate five types of empirical tests for risk-based selection: (i) the positive correlation test proposed by Chiappori and Salanié (2000) and (ii) the cost curve test by Einav et al. (2010), both of which we use in this paper; furthermore, (iii) the unused observables test by Finkelstein and Poterba (2014), (iv) the subjective probability elicitation test by Hendren (2013), and (v) tests based on various structural models. Note that both unused observables and subjective probability elicitations methods do not directly test risk-based selection, but rather test for the presence of private information about risk, which is a prerequisite for adverse selection. For this reason, Table C1 refers to the results of those two methods as indirect evidence on risk-based selection.

Our review reveals several noteworthy patterns in the literature. First, a large majority of 22 out of 34 papers study health insurance. Besides health insurance, there are 5 papers on long-term care insurance, 5 on pension annuities, 2 on unemployment insurance and one on workers' compensation (a few include more than one type of insurance). Importantly for this paper, there is only one existing study on DI by Hendren (2013), who provides indirect evidence on risk-based selection through the subjective probability elicitations test. Thus, one of our key contributions to the literature is to provide the first direct evidence on risk-based selection in DI.

Second, most studies (25 out of 34) find adverse selection, but there are important differences in results across types of insurance. While the majority of papers on health insurance (16 out of 22), pension annuities (5 out of 5) and unemployment insurance (2 out of 2) find adverse selection, evidence is more mixed in other markets. For instance, 3 out of 5 papers on long-term care insurance find advantageous rather than adverse selection, and the only paper on workers' compensation finds no significant selection. Interestingly, the latter two types of insurance share key characteristics with disability insurance: workers' compensation insures individuals against the loss of earnings capacity due to workplace accidents, and long-term care insurance also insures against health shocks occurring later in life. Like DI, long-term care insurance is also characterized by strong risk-rating in the private market and the co-existence of private and public schemes. This suggests that our novel result of no significant risk-based selection is in line with evidence from the most closely related types of insurance.

Furthermore, we note that a large majority of 26 out of 34 papers study insurance in the U.S. Out of the 8 non-U.S. studies, four are situated in the U.K., and one each in India, Pakistan, Canada and Sweden. Finally, there is an apparent trend in methods. While earlier studies predominantly use the positive correlation test, more recent work tends to employ the cost curve test. The other three methods are in general less frequently used.

Table C1: Literature on Risk-Based Selection in Social Insurance

Study	Country	Insurance Type	Selection Test	Selection Result
Cardon and Hendel (2001)	U.S.	Health	Structural Model	None
Finkelstein and Poterba (2002)	U.K.	Annuity	Positive Correlation	Adverse
Finkelstein and Poterba (2004)	U.K.	Annuity	Positive Correlation	Adverse
Finkelstein and McGarry (2006)	U.S.	Care	Positive Correlation	Advantageous
Fang et al. (2008)	U.S.	Health	Positive Correlation	Advantageous
Einav et al. (2010)	U.S.	Health	Positive Correlation, Cost Curve	Adverse
Einav, Finkelstein and Schrimpf (2010)	U.K.	Annuity	Structural Model	Adverse
Oster et al. (2010)	U.S.	Care	Positive Correlation	Adverse
Bundorf et al. (2012)	U.S.	Health	Structural Model	Adverse (weak)
Einav et al. (2013)	U.S.	Health	Structural Model	Adverse
Handel (2013)	U.S.	Health	Positive Correlation, Structural model	Adverse
Krueger and Kuziemko (2013)	U.S.	Health	Positive Correlation	Adverse (weak)
Hendren (2013)	U.S.	Care, Disability, Life	Subjective Probability Elicitations	Adverse (indirect)
Bajari et al. (2014)	U.S.	Health	Structural Model	Adverse
Banerjee et al. (2014)	India	Health	Unused Observables	None
Finkelstein and Poterba (2014)	U.K.	Annuity	Unused Observables	Adverse (indirect)
Hackmann et al. (2015)	U.S.	Health	Structural Model	Adverse
Fitzpatrick (2015)	U.S.	Annuity	Cost Curve	Adverse
Handel et al. (2015)	U.S.	Health	Structural Model	Adverse
Yao et al. (2017)	Pakistan	Health	Positive Correlation	Adverse
Dardanoni and Donni (2016)	U.S.	Care, Health	Cost Curve	Care: advantageous, health: none
Keane and Stavrunova (2016)	U.S.	Health	Positive Correlation	Advantageous
Cabral (2017)	U.S.	Health	Positive Correlation, Structural Model	Adverse
Hendren (2017)	U.S.	Unemployment	Subjective Probability Elicitations	Adverse (indirect)
Cabral et al. (2018)	U.S.	Health	Cost Curve	Advantageous (weak)
Finkelstein et al. (2019)	U.S.	Health	Cost Curve	Adverse
Panhans (2019)	U.S.	Health	Cost Curve	Adverse
Boyer et al. (2020)	Canada	Care	Cost Curve	Advantageous (weak)
Jaffe and Shepard (2020)	U.S.	Health	Structural Model	Adverse
Landais et al. (2021)	Sweden	Unemployment	Positive Correlation, Cost Curve	Adverse
Cabral et al. (2022)	U.S.	Workers' Compensation	Cost Curve	None
Shepard (2022)	U.S.	Health	Positive Correlation, Cost Curve	Adverse
Fischer et al. (2023)	Pakistan	Health	Cost Curve	Adverse
Tebaldi (2024)	U.S.	Health	Positive Correlation	Adverse

Notes: The table summarizes existing studies of risk-based selection in social insurance settings.

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D Institutional Survey: Public DI and Private DI across Countries

In this appendix, we present a systematic review and comparison of public DI systems and private DI markets across selected countries. Our survey includes OECD countries whose DI systems are studied in leading, peer-reviewed journals in economics (top general interest or top field), namely Austria, Canada, Norway, the Netherlands, Spain, and the U.S. In order to broaden the scope of the survey, we add Denmark, France, and the U.K., for whom institutional information is available from other sources, such as policy reports or government websites. See also Wise (2012) and Burkhauser et al. (2016) for detailed reviews of public DI systems across countries.

A key result of our survey is that the German setting shares many key characteristics with other countries. German public DI is quite representative in terms of coverage, benefit calculation, and eligibility criteria. Like Germany, most countries nowadays only provide general DI benefits via public systems, but many have or used to have elements akin to own-occupation DI. Over the last decades, a common direction of reform was tightening access to public DI benefits, for instance by moving towards a general DI system that requires being unable to work in any job. In most countries included in our survey, private DI markets work similarly to the German one, too. Own-occupation DI is available via the private market in all countries. Moreover, private DI is sold as individual insurance in all countries, and in a few cases there are also large group insurance markets. Private DI benefit rules and eligibility criteria are similar across countries, and private DI assessments are usually conducted independently of public DI.

D.1 Public DI Systems across Countries

Table D1 shows information on public DI systems across countries. We summarize public DI coverage and funding structure, benefit calculation rules, eligibility criteria in terms of contributions and medical conditions, and whether the system provides general DI or own-occupation DI. We also briefly describe selected public DI reforms, focusing in particular on reforms to screening and work capacity assessment criteria.

In all countries included in our survey, public DI is a mandatory social security program for private-sector employees. Sometimes, other workers, such as public-sector employees and self-employed individuals, are included as well. Contributions are paid via payroll taxes in all countries except for Denmark where funding is via general tax revenue and the Netherlands where DI is provided by employers. Most countries calculate public DI benefits as a function of prior earnings or contributions, while some provide lump-sum benefits or a combination of income-dependent and flat components. Effective replacement rates vary substantially, whereby the majority of countries have more generous public DI benefits than Germany. Benefit eligibility criteria are qualitatively similar across countries, but details vary. Most countries impose a minimum period of social insurance contributions in order to be eligible for public DI benefits, typically between one and five years. As an exception, the Danish universal system only uses a residence criterion.

When contribution and waiting time criteria are satisfied, the applicant's medical condition is assessed. This process is fairly similar across countries. In order to qualify for public DI benefits, the applicant must suffer from a health condition leading to a lasting and substantial reduction in work or earnings capacity. This is usually evaluated in terms of hours of work or in terms of potential earnings, relative to a comparison group of healthy individuals.

Like Germany, most countries nowadays provide only general DI, requiring claimants to be unable to work in any occupation. Some countries, including Austria and Spain, have a mixed system, where own-occupation DI benefits are available to at least some workers. Moreover, some countries, such as the U.S. and Norway, implicitly consider occupations in the DI application process by taking into account claimants' education, skills or experience in the work capacity assessment. In terms of major public DI reforms, most countries have moved in the same direction as Germany, tightening access to public DI. These reforms were typically motivated by similar concerns about rising public DI claiming rates threatening the fiscal sustainability of public DI programs. Interestingly, a number of countries implemented changes similar to the German 2001 reform, moving from own-occupation DI towards general DI. For instance, Canada, the Netherlands, and the U.K. historically provided own-occupation DI, but switched to general DI in the 1990s. In countries where own-occupation DI is still provided such as Austria, access became more limited over time.

D.2 Private DI Markets across Countries

Table D2 compares private DI markets across countries. We describe the type of insurance offered, private DI take-up rates (where this information is available), how private DI benefits are set, medical eligibility criteria and whether private insurers offer general DI or own-occupation DI. In addition, we summarize rules governing the interaction between public and private DI in terms of disability assessment and simultaneous claims.

In all countries we reviewed, individual private DI markets similar to the German one exist. In a few cases, including Denmark and the U.S., private DI is predominantly sold as a group insurance (via employers). Private DI markets vary substantially in size. For instance, 85% of Danish workers have private DI, but just 4% of Austrian workers. Private DI take-up likely depends on some of the factors we analyze in this paper. In those cases with the highest take-up rates, some groups of workers are mandated to purchase private DI (e.g. Denmark), and in cases of low private DI take-up, public DI coverage tends to be generous (e.g. Austria). Like in Germany, private DI benefits can be set individually in most other countries. Medical eligibility criteria are qualitatively similar across countries, relying on one or several thresholds in terms of work capacity reduction. The details of these criteria vary somewhat, and these differences are often in line with disability definitions used by the respective public DI systems.

Private insurers offer own-occupation DI in all countries we surveyed. In some cases, individuals can choose between private general DI and private own-occupation DI. Private DI providers have their own disability assessment and award procedures independent of public DI assessments in most countries. Furthermore, public and private DI benefit payouts are mutually independent in most countries. Only in a few cases, including the U.S. and Canada, private DI providers are secondary payers who require individuals to apply to public DI. Only in Denmark, public DI benefits are means-tested against private DI payouts.

Table D1: Public DI Systems across Countries

Country	Coverage and Funding	Benefits	Benefit Eligibility		General or Own-Occupation DI?	Reforms	Sources
			Contribution Criteria	Medical Criteria			
Germany	Mandatory program for private-sector employees, funded via payroll taxes.	Earnings-history dependent; formula similar to old-age pension benefits; replacement rate approx. 39%.	Contributions for at least 5 years, and 3 out of last 5 years.	Long-term disability, unable to work for more than 3 hours per day in any occupation.	General DI	2001: Own-occupation DI abolished for cohorts 1961 and younger.	own research
U.S.	Mandatory program for private-sector employees, funded via payroll taxes	Earnings-history dependent; formula similar to old-age pension benefits.	40 credits from contributions, 20 credits in last ten years; 6 months out of work before application	Earnings capacity below substantial gainful activity level (avg. monthly earnings below $1,550 in 2024); medical condition likely persistent or terminal	General DI (but occupations implicitly considered education, skills, experience in earnings capacity assessment)	1984: assessment criteria changed from "medical listing" to "functional", i.e., assessing the residual work capacity. Made the assessment process more lenient and more discretionary.	SSA (2024); Strand and Trenkamp (2015); Milligan (2012)
Canada	Mandatory program for private-sector employees, funded via payroll taxes	3 components: flat benefit + earnings-related component + child benefits; average benefit (2023): $1,176.98	Contribution for at least 4 out of last 6 years	Severe medical condition preventing substantial gainful employment, condition terminal or likely permanent	General DI	1989: relaxed screening criteria for ages 55 and above, effectively introducing own-occupation DI). 1995: repeal of reform, reverting to general DI.	Government of Canada (2024); Baker and Milligan (2012); Millard (2023); Government of Canada (2022)
Austria	Mandatory program for private-sector employees, funded via payroll taxes.	Earnings-history dependent; replacement rate approx. 70%, capped at €4,500.	Contributions for at least 5 out of the last 10 years.	Work capacity reduced by more than 50% relative to a healthy person in any reasonable occupation, disability lasts for at least 6 months	Mixed system. "Reasonable occupation" criterion is any occupation under age 60. For 60 and older, it is similar (own) occupation.	Several reforms to "relaxed screening" (general vs. own-occupation DI) age cutoff: from 55 to 57 for men (women) in 1996 (2000) and to 58, 59, and 60 in 2013, 2015, and 2017 respectively. Potential own-occupation DI coverage also prolonged via some old-age pension reforms.	Haller et al. (2024); Mullen and Staubli (2016); Staubli (2011); Staubli and Zweimüller (2013)
Denmark	Universal program, tax-funded.	Flat benefit, means-tested (including spousal income); max. monthly benefit (2024) for singles (couples): DKK 20,370 (17,315)	Citizens: resident in Denmark for at least 3 years after age 15; Non-citizens: resident in Denmark for the last 5 years and for at least 10 years after age 15.	Residual work capacity in any occupation negligible and recovery unlikely.	General DI	2003: 4 different DI programs consolidated; work capacity cutoff tightened and generosity reduced. 2013: Access to public DI removed for people younger than 40 (exceptions for most severe conditions).	Bingley et al. (2012); STAR (2024b,a); borger.dk (2024)
France	Universal program, funded via payroll taxes and other taxes	Earnings-history dependent; replacement rate depends on disability category: 30% in cat. 1, 50% in cat. 2, & 50% + surcharge in cat. 3; min. benefits: €328.07; max. benefits €1,159.20/ €1,932/ €1932 + €1,266 for the 3 categories.	Insurance contributions for at least 12 months + worked at least 600 hours or paid contributions of at least 2.03 times the minimum wage in last 12 months	Work or earnings capacity reduced by at least 66% relative to a healthy person.	General DI	1971: qualifying work capacity limitation reduced from 100% to 50%, minimum number of contribution years lowered, benefits increased.	ameli.fr (2024b,a); Behaghel et al. (2012)

Table D1: Public DI Systems across Countries

Country	Coverage and Funding	Benefits	Benefit Eligibility		General or Own-Occupation DI?	Reforms	Sources
			Contribution Criteria	Medical Criteria			
Norway	Mandatory program for private-sector employees, funded via payroll taxes.	2 components: flat basic benefit + earnings-history dependent benefit; average replacement rate approx. 66%	Contributions for at least 5 years.	Work capacity reduced by at least 50% in any substantial gainful activity.	General DI (but occupations implicitly considered via education, skills, experience in work capacity assessment)	2003: Introduction of temporary DI awards. 2005: return-to-work program providing more generous benefits if claimants take up work.	Hemmings and Prinz (2020); Autor et al. (2019); Kostol and Mogstad (2014); Rege et al. (2009); Dahl et al. (2014); NAV (2024)
Spain	Mandatory program for private-sector employees, funded via payroll taxes.	Function of ”regulatory base” (depends on source of disability) and replacement rate (depends on degree of disability): 55 to 75% for ”total” disability, 100% for ”absolute” disability; 100% + 50% for ”severe” disability.	Depends on source of disability and age. For non-work related illness, age $\geq$ 31: contributions for at least 5 years and for 25% of the time since 20th birthday; age $<$ 31, contributions for 1/3 of time since 16th birthday. For accidents/occupational illness: no contribution requirement.	Work capacity reduced by at least 33% compared to a healthy person.	Mixed system. Total disability defined relative to ”usual occupation” similar to own-occupation DI, absolute disability is general DI, severe disability additionally requires help with daily activities.	1997: medical eligibility criteria for sick pay tightened, assessment relative to ”usual occupation” instead of only current job; assessment carried out by examiner panel instead of own doctor.	García-Gómez et al. (2012); La Seguridad Social (2024); Marie and Vall Castello (2012)
Netherlands	Mandatory program for private-sector employees, employer-provided (contributions paid by employers and employees)	Earnings-history dependent; replacement rate approx. 70% to 75%	Ever employed.	Full (partial) disability if work capacity reduced by at least 80% (35%).	General DI (but occupations implicitly considered via skills, experience in work capacity assessment).	Until 1987: own-occupation DI. 1987: assessment broadened to set of regular jobs. 1993: assessment further broadened towards general DI, benefits reduced. 1996, 2002, 2004, 2006: employers made increasingly responsible for cost of DI.	Koning and Lindeboom (2015); Koning and van Sonsbeek (2017); Koning et al. (2022); Burkhauser et al. (2016); Borghans et al. (2014)
U.K.	Mandatory program for private-sector employees, funded via payroll taxes.	Flat benefit; £484 (317) per month for ”support” group (”activity” group); average replacement rate approx. 15%.	Contributions for 1 out of the last 3 years.	Assessment of functional limitations: if unable to participate in work-related activities, assigned to the support group; otherwise assigned to activity group.	General DI	1995: work limitation criterion changed from own-occupation DI to general DI; earnings-related benefit replaced by flat benefit; assessment carried out by examiners instead of own doctor.	Low and Pistaferri (2020); Banks et al. (2015, 2012)

Notes: The table compares public DI systems across selected countries, including information on (1) who is covered by public DI and how it is funded, (2) how benefits are calculated, (3) who is eligible for benefits both in terms of contributions and medial criteria, and (4) whether there is a general DI or an own-occupation DI system. The second-to-last column summarizes selected reforms to public DI, focusing in particular to reforms to screening and general vs. own-occupation DI. The last column shows the main sources on which the information in the table is based.

Table D2: Private DI Systems across Countries

Country	Type	Take-up	Benefits	Medical Eligibility Criteria	General or Own-Occupation DI?	Interaction with Public DI	Sources
Germany	Individual insurance	26% of private-sector workers (31% of households) in 2015 (2013)	Set individually, average replacement rate 35%	Earnings capacity reduced by at least 50% in current occupation.	Own-occupation DI	Independent assessment and award process; no benefit reductions for mutual claims.	own research
U.S.	Group insurance (via employer) or individual insurance	35% of private-sector employees covered (90% of those group insurance), strong income gradient	Set individually, most common contract replaces 60% of earnings.	Severe and likely persistent work capacity reduction in current or similar occupation	Mostly own-occupation DI	Independent assessment and award processes; private DI providers are secondary payers and require applying to public DI; 41% of claimants receive both private and public benefits.	Autor et al. (2014); Bureau of Labor Statistics (2020)
Canada	Group insurance (via employer) or individual insurance	46% of labor force has group insurance, 5% have individual Insurance	Replaces 60-70% of income (up to some cap)	Severe and prolonged medical condition preventing substantial gainful employment	Mostly own-occupation DI	Independent assessment and award processes; private DI providers are secondary payers and require applying to public DI	CLHIA (2021); Stepner (2021); Government of Canada (2024); FCAC (2024); Torjman (2002)
Austria	Individual insurance	4% of private-sector employees	Set individually	Earnings capacity reduced by at least 50% in current occupation.	Own-occupation DI	Independent assessment and award processes; no benefit reduction for mutual claims	Kaniovski and Url (2019)
Denmark	Group insurance (via employer) or individual insurance	85% of Danish working population covered by mandatory group insurance, no information available for individual insurance.	Group insurance benefits earnings-related, no information on individual insurance.	Residual work capacity in any occupation negligible and recovery unlikely.	General DI	Some private providers conduct independent health and work assessment, others award private DI only conditional on public DI. Moreover, public DI benefits means-tested, including on private DI benefits.	Andersen et al. (2022)
France	Individual insurance, often bundled	75% of labor force	Set individually	Work or earnings capacity permanently reduced by at least 66%. Partial benefits available for reduction of at least 33%. Medical condition resulting from work-related injuries/illnesses excluded.	Both own-occupation DI and general DI available.	Independent assessment and award processes; no benefit reduction for mutual claims.	Montaut and Adjerad (2019); AG2R LA MONDIALE (2024)
Norway	Individual insurance	Private DI described as rare, no explicit statistics available.	Set individually	Work capacity reduced by at least 40-50%.	No information.	Independent assessment and award processes; no benefit reduction for mutual claims.	Autor et al. (2019); DNB (2024); Nuf (2024)
Spain	Group insurance (via employer) or individual insurance	At least 29% of labor force (19% individual insurance, 10% group insurance)	Set individually.	Permanent disability reducing work capacity. Severity criterion depends on specific insurance.	Mostly general DI, own-occupation DI also available	Some private providers conduct independent health and work assessment, others award private DI only conditional on public DI. No benefit reductions for mutual claims.	Münchener Rück (2007); Acierto.com (2024)

Table D2: Private DI Systems across Countries

Country	Type	Take-up	Benefits	Medical Eligibility Criteria	General or Own-Occupation DI?	Interaction with Public DI	Sources
Netherlands	Individual insurance, mainly for self-employed	21% of self-employed	Set individually.	Work capacity reduced by at least 25%, contracts with higher thresholds available at lower premiums.	Both own-occupation DI and general DI available.	Independent assessment and award processes; no benefit reduction for mutual claims.	CBS (2023); Leensma (2022)
U.K.	Individual insurance	3% of female and 6% of male private-sector employees	Set individually.	Unable to work in current occupation for at least 6 months.	Own-occupation DI	Independent assessment and award processes; no benefit reduction for mutual claims	Statista (2019); HMRC (2023); Conner (2022)

Notes: The table compares private DI markets across selected countries, including information on (1) the type of insurance available, (2) private DI take-up rates, (3) how benefits are set, (4) medical eligibility criteria, and (5) whether general DI or own-occupation DI is provided. The second-to-last column describes the interaction between private DI and public DI regarding medical assessment procedures and benefit rules. The last column shows the main sources on which the information in the table is based.

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