

The Interaction of Private and Public Disability Insurance: Moral Hazard, Insurance, and Welfare

Sebastian Seitz*

University of Manchester and ZEW

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Abstract

I study the interaction between private and public disability insurance (DI). Using comprehensive contract data from a major German insurer combined with representative administrative and survey data, I estimate a dynamic life-cycle model of insurance, savings, and labor supply choices. I find that private DI imposes significant fiscal costs on public DI by increasing public DI claims. As public DI becomes more generous, private DI reduces welfare gains and eventually reduces welfare. Conversely, private DI can offset welfare losses from public cuts, allowing for welfare-enhancing and cost-reducing reforms.

JEL codes: D14, G22, J28, I38

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* University of Manchester and ZEW, Arthur Lewis Bldg., M13 PL9, Manchester, UK, sebastian.seitz@manchester.ac.uk

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1 Introduction

Lifetime disability risks are substantial and the consequences of work-limiting disabilities for individuals of working age are important, for individuals and policymakers alike. Private disability insurance (DI) markets already exist in many countries and are sizeable - for instance, covering over one-third of employees in the US and Germany. Aging populations and rising retirement ages mean that understanding DI markets' structure and functioning, especially the use of private DI as an addition or alternative to public DI, is increasingly important.

Allowing private disability insurance (DI) alongside a public program entails a fundamental trade-off: Private DI offers more insurance to those who want it, potentially having positive implications for the design of public DI programs. However, private DI also changes labor supply incentives for people experiencing a disability shock, thus affecting public DI claims and costs. While there are papers quantifying similar trade-offs between private and public insurance in the context of health, unemployment, and long-term care insurance¹, the evidence to date in the area of DI is sparse.

In this paper, I provide novel insights by building a structural model of labor supply choice to quantify the trade-offs involved, and in particular the role of moral hazard concerning labor supply choices in the presence of private DI. I estimate the model using moments from two administrative datasets – insurance contracts from a major German insurer and social security records – coupled with household survey data on private DI take-up, savings, and earnings. I find a significant moral hazard response to private DI - private DI is estimated to reduce the labor force participation of the disabled by 7.2 percentage points (35%) and these individuals, either immediately or ultimately, end up claiming public DI as well. This effect is driven by the high take-up of private DI among high-income individuals with low disability risks.

The empirical estimates of the structural model suggest that in the absence of private DI an increase in public DI generosity is unambiguously welfare-enhancing. However, in the presence of private DI this is no longer the case due to interactions between the two systems— a decrease in generosity could increase welfare as well. The model is built for the German context where there is no conditionality between the two benefits, i.e., they are awarded independently of each other without benefit reductions. My estimate of the moral hazard effect underlying the interaction would actually be an underestimate for systems such as the US or Canada where there is conditionality and private DI is a secondary payer to public DI.

This paper makes a broad contribution to the risk and insurance literature which studies the interactions between private and public insurance. To the best of my knowl-

¹For an overview of this literature in the context of health insurance see Einav and Finkelstein (2018), Landaïs et al. (2021) for unemployment insurance, and Weissert et al. (2005) for long-term care insurance.

edge, it is the first paper to quantify the trade-offs and moral hazard in the case of DI². In addition, my results provide a more specific contribution to what is known about DI program design. An emerging literature focuses on crowding out and (adverse) selection (Seibold et al., forthcoming; Abdulhadi, 2022; Fischer et al., 2023) or employer moral hazard (Prinz and Ravesteijn, 2020; Koning and van Lent, 2022) but this is the first paper to quantify the moral hazard channel on labor supply and the resulting consequences for public DI design. In contrast, papers studying labor supply incentives have done so with public DI only (e.g., Low and Pistaferri (2015)). I show that private DI significantly alters the insurance-incentive trade-off and thus, the design of public DI policies.

The challenge in assessing the importance of the interaction between private and public DI is that one needs comprehensive data on private DI contracts, disability risk, and (non-)buyers. I overcome this challenge by using three data sets that complement each other. First, I obtain novel contract data from a top-10 German private insurer. The private insurer data has detailed information on private DI contracts, owners, and prices. The data is representative of the private DI market (Seibold et al., forthcoming), but it has no information on people who do not buy private DI. Hence, I complement the insurer data with four waves of the Income and Consumption survey - a large household survey representative of the German population with detailed information on income, savings, and from 2013 on, private DI take-up. Finally, I use administrative social security records from the Institute of Employment Research to recover the population disability risk distribution based on the insurer's risk assessment.

The data displays two stylized facts, which guide the structural estimation. First, private DI take-up is significant and increases in income. Second, high-income people pay lower premiums due to their lower risk of disability. Therefore, the model is set up to allow the moral hazard effect to differ by income groups, which potentially affects the redistributive properties of (public) DI and welfare.

I use a structural model to match the observed data patterns and estimate the underlying behavioral parameters allowing me to quantify the trade-off between insurance (welfare) and labor supply distortions (moral hazard) from private DI and, therefore, to discuss counterfactual policies. The model includes private DI purchases, self-insurance via savings, and a detailed approximation of the German social security system. Individuals differ in their observable disability risk³ and income, which both affect the private DI purchase and labor force exit choice at disability onset. Individuals' disability status evolves stochastically depending on their observable risk group and age. The model allows for permanent and temporary disability (so people can recover from disability). At disability onset, an individual can choose to retire and claim public and if purchased

²Stepner (2019) finds similar results for short-term private DI in Canada (benefits expire after 20 weeks on average) which increased public DI inflow leading to additional costs. In this paper, I study long-term DI which pays benefits up to the contract end which is usually the retirement age.

³My model abstracts from unobservable risk heterogeneity following the results in Seibold et al. (forthcoming) who find no evidence for risk-based selection.

private DI, or keep working but then forgo the benefits.

I use the method of simulated moments to estimate my model. The risk group distribution, disability transition probabilities by risk group and age as well as the income process accounting for the correlation between income and risk enter the model exogenously. I estimate the remaining preference parameters by relating private DI take-up by income quartile, labor force participation (full-time, part-time), and mean and median assets over the life cycle to their empirical counterparts. I confirm the performance of my estimation by comparing simulated distributions to their empirical counterparts not used in the estimation, e.g., the distribution of private DI benefits.

I provide several important results. First, I document significant moral hazard from private DI take-up: The labor force participation of the disabled is 7.2 p.p. lower with private DI (35%). The composition of public DI claimants also changes: high-income individuals claim public DI more frequently once covered by private DI. As a result, the public DI system is more expensive once a private market exists (€11 per person-year⁴).

Second, I study two commonly discussed policies – local changes in benefit generosity and rejection rates – to investigate the implications of private DI for welfare and public DI design. I find that without private DI, only increasing benefit generosity is welfare-enhancing relative to the current system. However, with private DI, *both increasing and sufficiently decreasing* benefit generosity leads to welfare gains, while the welfare gains for more generous public benefits are smaller compared to the same policy without private DI.

The difference in welfare responses arises from the change in public DI claimants due to private DI. For more generous public DI benefits, only high-income people keep buying private DI, strengthening the selection on income into private DI take-up. Since they exhibit a stronger moral hazard to private DI take-up, they impose a significant fiscal externality on public DI increasing its costs, while also redistributing income via public DI to themselves. Thus, welfare gains are dampened with private DI. Vice versa, for less generous public benefits, low-income individuals start to buy private DI for the additional insurance it offers. Their expanded insurance cover increases their welfare, which can compensate the welfare loss stemming from the decrease in public DI benefits such that total welfare increases again.

The results for rejection rates are similar: Increasing rejection rates enhances welfare, but welfare gains are smaller with private DI. The selection on income into private DI take-up strengthens for higher rejection rates, so only high-income individuals buy private DI. Absent private DI, the higher rejection rate induces them to stay employed, reducing public DI costs and better targeting public DI to low-income people. Conversely, lowering the rejection rate weakens the selection on income, and the marginal public DI claimant (and private DI owner) buys private DI mostly for the insurance it offers. While

⁴This amounts to additional cost of €416.4 million per year for the German labor force (without self-employed) in 2013 (Statistisches Bundesamt, 2024) due to benefit payments and lost income tax revenue.

this enhances their welfare, it cannot offset the negative welfare effects from less strict screening, only dampening the welfare loss.

Third, I find that a dual insurance system (private + public) does not uniformly enhance welfare. A dual insurance system can enhance welfare if public benefits are low or rejection rates are moderate, i.e., cases where the expansion in individual insurance dominates the moral hazard from private DI. However, for more generous public benefits or stricter screening, the dual system reduces welfare as the fiscal externality from private DI is significant under these policies. In these cases, abolishing private DI increases welfare.

Overall, this paper highlights the important interactions between private and public DI with significant consequences for individual welfare, and public DI costs and policies. The results show that while private DI expands individual insurance, it imposes a fiscal externality on public DI affecting public DI outcomes, exacerbated by the selection on income. Existing policy evaluations that abstract from private DI likely overestimates the welfare effects of public DI while underestimating the cost, even when focusing on groups with low take-up (e.g., Low and Pistaferri, 2015; Deshpande and Lockwood, 2021).

These findings generalize beyond the German context. Private DI markets exist in many countries and can be large. The German system – where private DI only covers earnings loss due to disability, is not linked to public benefits (DI, universal health insurance, etc)⁵, and without a waiting period before applying for public DI – is well-suited to study the interaction between private and public DI. In contrast, systems where private DI is bundled with other insurance products (e.g., pensions like in Denmark) or sold as group insurance (employer provided) likely exhibit stronger moral hazard and selection on income.⁶ Likewise, the fiscal externality and distributional effects documented here are likely amplified in settings where private DI acts as a secondary payer, requiring public DI application when applying for private DI and offsetting benefits dollar-for-dollar as in the US and Canada. In this regard, my results constitute a conservative estimate when private DI is employer-provided, bundled with other insurance, or a secondary-payer.

This article focuses on the demand side, quantifying how private DI take-up affects public DI claims and costs, taking the supply side and policy environment as given. My results highlight the critical trade-off for the insurance-incentive effects of private DI: while private DI expands individual insurance, it imposes a fiscal externality on public DI, thus affecting its properties. These results are key inputs for welfare analysis such as sufficient statistics approaches (Haller et al., 2024) or the marginal value of public funds (e.g. Hendren and Sprung-Keyser (2020); Seibold et al. (forthcoming)). Understanding demand is a necessary first step toward a complete general equilibrium (GE) framework,

⁵Importantly, private and public DI are independent of each other with independent assessment and award processes and no benefit reductions for mutual claims.

⁶For instance, 75% of people in France and 85% in Denmark are covered by private DI bundled with private pension and occupational accident insurance. 34% of the labor force in the US and 44% in Canada are covered by group insurance.

and my results complement recent GE approaches.⁷ While building a full dynamic model of the insurance market is beyond the scope of this paper – requiring different data and an entirely different model– incorporating supply-side responses and regulatory design is a promising avenue for future work.

This paper contributes to the extensive literature on the interaction of public and private insurance, with a particular focus on moral hazard. A vast literature documents how private coverage affects behavior and imposes fiscal externalities on public programs, e.g. in unemployment insurance (Schmieder et al., 2012; Landais et al., 2021; Kolsrud et al., 2018), health insurance (Chandra et al., 2010; Einav et al., 2013; Finkelstein et al., 2012; Shepard, 2022; Finkelstein et al., 2019; Anderson et al., 2024) and long-term care insurance (Konetzka et al., 2019; Brown and Finkelstein, 2008). For instance, supplementary private health insurance for the elderly in the U.S. (Medigap) increases public Medicare cost by 22.2% per year (Cabral and Mahoney, 2018) and moral hazard accounts for over half of the higher unemployment risk among privately insured workers in Sweden (Landais et al., 2021). I provide the first (structural) estimate of moral hazard in long-term private DI, reinforcing the broader lesson that supplemental private increases public DI claims and costs with consequences for public program design. In addition, I highlight the importance of selection on income into private insurance. While prior works has highlighted this selection on income in health (Hurd and McGarry, 1997) and long-term-care insurance (Goda, 2011), I quantify how income-based selection amplifies the fiscal externality of private DI and distorts the welfare impact of public DI reforms.

This paper also extends the vast and growing literature on public DI (see Low and Pistaferri (2020) for a review). This literature focuses on the effects of public DI on labor supply, claiming behavior, and the value of insurance (e.g., Diamond and Sheshinski, 1995; Low and Pistaferri, 2015; Meyer and Mok, 2019; Haller et al., 2024; Deshpande and Lockwood, 2021; Bound et al., 2004; Bound, 1989; Autor and Duggan, 2003, 2006, 2007; Staubli, 2011; Kostol and Mogstad, 2014; Borghans et al., 2014; Autor et al., 2016; Deshpande, 2016a,b; Mullen and Staubli, 2016; Gelber et al., 2017; Ruh and Staubli, 2019). All of these papers abstract from private DI, despite sizable and growing private DI markets across OECD countries. The emerging literature on private DI studies crowd-out and selection (Seibold et al., forthcoming; Fischer et al., 2023; Abdulhadi, 2022), employer moral hazard (Prinz and Ravesteijn, 2020; Koning and van Lent, 2022), effect of claim deferral on claiming (Autor et al., 2014), and the valuation for public DI using private DI (Cabral and Cullen, 2019).

I make three contributions to this literature. First, I show that the moral hazard of private DI increases public DI claims and costs. These effects alter the insurance-incentive trade-off in public DI (Diamond and Sheshinski, 1995; Low and Pistaferri, 2015), and I

⁷Braun et al. (2019); Fischer et al. (2023) solve a GE model in overlapping private and public insurance focusing on administrative costs and private information. However, they do not formally estimate their model citing the high computational intensity involved. In contrast, I estimate a richer demand-side model to focus on moral hazard at the expense of not endogenizing the supply side.

provide the first structural estimate of moral hazard of private DI, which can be used to inform welfare calculations such as in sufficient statistics or marginal value of public funds approaches (e.g., Hendren and Sprung-Keyser, 2020; Seibold et al., forthcoming; Haller et al., 2024). Second, I show that private DI systematically alters the incidence of public DI by shifting benefit claims toward higher-income individuals. This income-based selection shifts the fiscal burden of public programs, affecting the redistributive properties of public DI, with important implications for program design. Third, building on the largely theoretical dual-insurance literature (Pauly, 1974; Golosov and Tsyvinsky, 2007; Chetty and Saez, 2010), I show that while a dual insurance system is not universally welfare-enhancing, it can mitigate welfare losses from less generous public programs, expanding policymakers’ policy options.

Finally, this paper is closely related to Seibold et al. (forthcoming), which studies crowding out and selection into private DI following the abolition of public own-occupation DI in Germany. Whereas that paper focuses on crowding out and the welfare effects of this reform, the present paper analyzes the ongoing interaction of private and public DI in a dual system. I show that while private DI expands insurance, it also increases public DI claims and costs, with the magnitude of these effects affected by selection which itself varies with the public DI schedule. These results extend our earlier evidence on selection by quantifying how private DI alters the insurance–incentive trade-off in public DI, and by incorporating moral hazard explicitly into the analysis.

The paper is structured as follows. Section 2 explains the institutional settings for public and private DI in Germany before presenting the data. Section 3 presents the model. Section 4 details the estimation procedure. The estimation results and counterfactual exercises are discussed in sections 5 and 6 respectively. Section 7 concludes.

2 Institutional Setting and Data

2.1 Institutional Setting

Public DI: The German public DI system closely resembles DI systems in other countries. It is a mandatory social insurance program for private sector employees, administered by the public pension fund and financed through payroll taxes (pension contributions). Civil servants and the self-employed are excluded from social insurance and thus omitted from this study.

An individual must meet certain criteria to claim public DI. First, she has paid contributions in three of the past five years. Second, she has a persistent health impairment severely limiting her work capacity.⁸ Medical evaluations are conducted by pension fund

⁸There is no mandatory waiting period before an individual can apply for public DI, e.g., contrary to the US or the Netherlands. Since unemployment spells have a limited benefit period and are not a necessary requirement to access public DI, my model abstracts from them.

physicians, and approximately 44% of applications are rejected at this stage. Successful applicants receive benefits proportional to past earnings, with imputed contributions up to the early retirement age (63). Full benefits are awarded if work capacity is limited to less than 3 hours per day in *any* occupation.⁹ The average gross replacement rate is 35%. Benefits continue until recovery or conversion to old-age pensions at the statutory retirement age. 25% of German workers experience at least one disability spell before retirement (Table 1).

Private DI: Germany has a long-standing private DI market, dating back to the 1920s, with over 70 providers currently operating. Most private DI contracts are purchased individually (85%) and the remainder are purchased via the employer (FAZ, 2012).

Private DI differs from public DI in several key dimensions. First, insurers screen applicants based on their full medical history, verified by a physician. They must report any major bad health episode including chronic diseases, physical, and mental health conditions. Incomplete or false statements result in denial of benefits at the time of disability onset. Insurers deny coverage to 4% of applicants (GDV, 2016). Given the low number of rejections, my model abstracts from them. Second, premiums are experience-rated and primarily determined by occupation at application, categorized into five risk groups. Premium adjustments for medical conditions or hazardous hobbies are rare (4% of contracts). Premiums are priced as annuities and actuarially adjusted based on contract duration.

Third, individuals select benefit levels, capped at 70% of gross income; in my data, people insure 36% of their past gross income on average. Fourth, private DI covers "own-occupation" disability: an individual is eligible for private DI if she is persistently unable to work for more than 50% of her usual hours in her *own* occupation. This is more generous than public DI's "any-occupation" criterion. As a result, only 11% of private DI claims are rejected on medical grounds (GDV, 2014). I capture the different assessment criteria in the model by assuming all work-limiting disabilities qualify for private DI, while public DI remains subject to rejection.

Private and public DI operate independently: applications, assessments, and payouts are separate, and private (public) benefits are not offset by public (private) claims.

Other Programs: Several other social insurance programs are available to individuals unable to participate in gainful employment. The most relevant alternative to public DI is social assistance (*Arbeitslosengeld II*), which provides a means- and income-tested consumption floor for an extended period. Other alternatives such as sickness benefits, accident insurance, and unemployment insurance have a maximum benefit duration of at most two years. Hence, they are inadequate to insure individuals against persistent health shocks.

Individuals are eligible for social assistance if household assets do not exceed €5,000

⁹More than 90% of claims (Bund, 2017) are full claims, so I abstract from partial claims.

for singles (€ 10,000 for couples). If household income exceeds € 100 per month, benefits are withdrawn at a rate of 80%. Social assistance benefits are low; for instance, the average benefit level in 2013 was € 5438.63 per year (€ 453.22 per month). Social assistance recipients face active job search requirements. Public DI recipients with benefits below the social assistance level can also claim social assistance for disabled individuals. Given their health impairment, the job search requirement is waived but the means and income test still applies. Overall, given the strict means tests and the job search requirement, social assistance is most likely not a meaningful substitute for (public) DI for the majority of workers, and only low-income, low-asset individuals benefit from social assistance for disabled individuals.

Comparison to other Countries: The German DI system closely resembles those in other OECD countries and offers a clean setting to study the interaction between public and private DI¹⁰. Public DI is mandatory for private sector employees across and provides earnings-linked benefits in cases of severe and likely permanent disabilities that limit work capacity in any occupation. Lump-sum benefits are rare.

Private DI markets are also structurally similar across countries. Individuals can purchase standalone contracts specifying benefit levels, contract duration, and the definition of disability (own- vs. any- occupation DI). Sometimes private DI is bundled with other products such as pensions or life-insurance. While some countries rely more on group policies via employers or unions, most offer individual insurance as well. In most countries, private and public DI operate independently. Private and public DI are awarded separately, and benefits are not offset for mutual claims. Notable exceptions include the U.S. and Canada, where private DI is a secondary payer, and private benefits are reduced dollar-for-dollar by public DI.

Germany’s institutional features make it particularly well-suited for this analysis. Health insurance coverage is universal, private DI is purchased individually (as standalone insurance), not tied to employment, and private and public DI operate independently. This allows for the clean identification of individual behavioral responses to private DI take-up. Moreover, because employer provided DI, bundled insurance, and secondary-payer arrangements likely amplify moral hazard, my estimates likely provide a lower bound on the fiscal externalities of private DI in settings such as the U.S. and Canada. I return to this in Section 6.3.

2.2 Data

I combine three complementary data sources to estimate the model parameters in Section 3. First, I use proprietary data from a major German private insurer to analyze the private DI market. Second, I draw on four waves of the German Income and Consumption Survey

¹⁰Seibold et al. (forthcoming) provide a detail survey of DI systems across ten OECD countries. The discussion here highlights their main findings.

(EVS), a nationally representative household survey with detailed information on assets and private DI take-up. Third, I use the SIAB, a 2% random sample of German social security records provided by the Institute for Employment Research (IAB), containing rich information on earnings, program participation, and occupations. Since the SIAB and insurer data use the same occupation classifications, I can merge insurer-based risk groups to the SIAB to recover population-level disability risk.

In all datasets, I restrict the sample to men aged 25 and older who are neither in education nor retired. I exclude civil servants and the self-employed, who are not eligible for public DI. All monetary values are expressed in 2013 Euros. Data Appendix S1 provides details on data construction.

Private Insurer Data: I use novel and unique contract data from a major German insurer, ranked among the top ten in DI market share. The data contains all active private DI contracts as of January 1, 2013, as well as all new contracts issued through 2018. For each contract, I observe detailed characteristics, including risk group, benefit level, and purchase date, along with basic demographics (age, gender, and detailed occupation titles). I also observe outcomes such as disability onset, recovery, death, and contract cancellations from 2013 to 2018.

I augment the dataset in three ways. First, I match each occupation to its 2010 occupational classification code using the official classification table from the Federal Employment Agency. This allows me to apply the insurer’s occupation-risk mapping to the social security data to recover the population disability risk distribution. Second, I impute individual income, unavailable in the insurer data, using age, gender, and occupation-specific earnings from the Verdienststrukturhebung, a large representative income survey. This enables construction of the replacement ratio (annual DI benefit relative to income). Third, since premiums are calculated externally and not included in the data, I scraped premium schedules by age and risk group from the insurer’s website.¹¹ Data Appendix S1.1 and S2 detail the data construction and cleaning, and the occupation code matching respectively.

Appendix Table A.1 presents summary statistics. In the full sample, the average age at purchase is 29.68 and contracts expire at 62.55, covering the bulk of the working life.¹² The average annual benefit is €16,487, with a replacement ratio of 34%. The average risk group is 2.27 (low risk). Restricting the sample to employed men aged 25 and older, excluding miners (who fall under legacy public schemes), policies bundled with life insurance, and contracts issued prior to the 2001 public DI reform, has limited impact on the distribution of key variables. The average replacement ratio increases to 36% while the average risk group decreases to 2.22. Only the average age at purchase and expiration increase to 34.6 and 65.6 years, respectively, which is expected given that 26% of people

¹¹Premiums vary modestly across years, primarily reflecting changes in capital market assumptions.

¹²Private DI is purchased until contracted expiration date. No annual renewal is required and there are no updates to existing contracts.

buy private DI before the age of 25.

While the data cover a single insurer, Seibold et al. (forthcoming) demonstrate its broad representativeness in terms of occupational and regional coverage, pricing, underwriting practices, and market trends using representative data sources from a leading rating agency.

Income and Consumption Survey: The Einkommens- und Verbrauchsstichprobe (EVS) is a large and nationally representative household survey conducted by the German Federal Statistical Office. It contains detailed information on income sources, expenditures, and private DI take-up (from 2013).

I pool the 1998, 2003, 2008, and 2013 waves to construct the estimation sample, applying the same sample restrictions as in other datasets: I exclude civil servants, the self-employed, individuals under 25, those still in education, and retirees. Due to limited sample sizes, I also exclude households with female heads (see Data Appendix S1.2 for details). The final sample consists of 87,286 households. Appendix table A.2 summarizes the data.

Private DI take-up is 25% in the full sample but rises to 48% among individuals aged 25–35, i.e., those entering the labor market after the 2001 public DI reform (Seibold et al., forthcoming). The average labor income of household heads is € 23,395, and their average age is 53 years. The average household size is 2.39, and mean financial assets amount to € 170,810. I use all waves to estimate the asset moments, while private DI take-up is estimated using the 2013 wave, the first wave to report this information. Section 4 details the estimation strategy.

Social Register Data: The Sample of Integrated Labor Market Biographies (SIAB) is a 2% random sample of administrative social security records in Germany, compiled by the Institute for Employment Research (IAB). It covers 1,875,439 individuals between 1975 and 2017, excluding civil servants, the self-employed, and pensioners. The data report detailed employment and benefit histories, including daily wages, occupations, full- vs. part-time status, and transitions into public DI, enabling the identification of public DI spells.

I construct an annual panel of employment and benefit histories from the spell-level data. For multiple spells within a year, I retain the longest spell. I use spells from 1992 to 2017 to assign the risk groups to each occupation code from the insurer data.¹³ I match risk groups to all observations with valid occupation codes – 97.2% of observations in the raw data and 99.8% in the cleaned data – allowing me to estimate the population risk distribution and the joint distribution of risk and income (see Data Appendix S1.4).

To construct the estimation sample, I apply the following restrictions: I retain men aged 25 to 65 with non-zero income in standard employment (excluding apprenticeships,

¹³While the estimation sample spans 2001–2017, including earlier years allows me to assign risk groups to individuals not employed in 2001 based on prior occupation.

early retirement, and marginal jobs)¹⁴. I focus on the period after the 2001 pension reform, dropping observations before 2001. The final sample consists of approximately 12.5 million person-year observations. Appendix table A.3 summarizes the key variables.

The average age is 40, average annual income is €38,507, and the mean risk group is 3.36. Among employed individuals, 93% work full-time and 7% part-time. I use the SIAB to estimate the wage process, labor market moments, disability probabilities by risk group, and the risk group distribution in the population (see Section 4).

2.3 Positive analysis: observable characteristics and selection into private DI

This section presents descriptive evidence on the relationship between income, disability risk, and insurance prices. These facts reveal systematic heterogeneity in private DI take-up, which informs both the model structure and the targeted moments in the estimation.

Figure 1 shows that 50% of German and 34% of US private-sector workers own a private DI contract. In both countries, there is a steep income gradient in private DI take-up: In Germany, individuals in the top income quartile are twice as likely to own private DI as those in the bottom quartile; in the US, the gradient is even steeper, at a factor of six. Yet, private DI take-up is substantial even among below-median-income individuals, contrary to much of the DI literature, which often abstracts from private coverage in evaluating public DI programs and reforms (e.g., Deshpande and Lockwood, 2021; Low and Pistaferri, 2015). Appendix Table A.4 reports further summary statistics by private DI take-up for the EVS sample. Besides earning substantially higher incomes, individuals with private DI hold more assets, are more likely to be married, and have higher educational attainment than those without¹⁵.

Table 1 links insurance prices, income, and disability risk to the occupation-based risk groups insurers use. Lifetime disability risk in Column (1) rises non-linearly with risk group, from 4.81% in group 1 (very-low-risk occupations, e.g., accountants, computer scientists) to 39.92% in group 5 (very-high-risk occupations, e.g., firefighters)¹⁶. Column (2) shows that premiums track risk closely: annual premiums range from €353 in group 1 to €1,736 in group 5 for a contract purchased at age 25 insuring €12,000 per year until age 65.

Importantly, income and risk are negatively correlated (Column (3)). Average annual

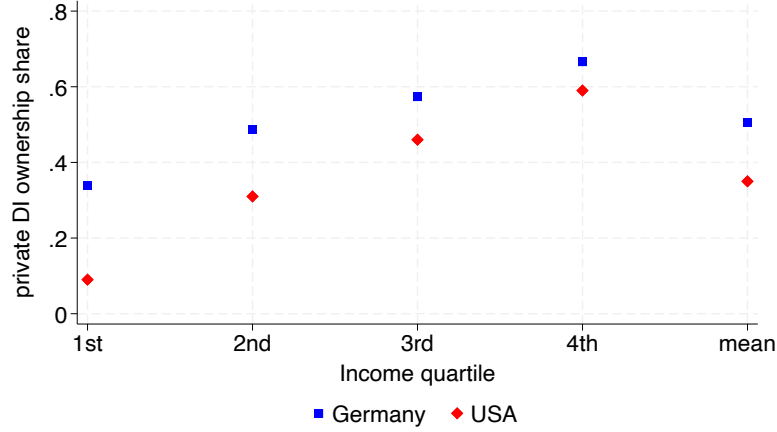
¹⁴Transfer income is reported and different from zero. Thus, zero-income spells contain missing information.

¹⁵Note this is inconsistent with the notion that assets or intra-household insurance, i.e., spousal income, are crowding-out private DI take-up.

¹⁶Occupations in risk group 2 display mild risk exposure (mostly analytical and cognitive tasks, e.g., lawyers). Occupations in risk group 3 are characterized by a fair amount of physical strain and work outside (e.g., physiotherapist or social workers). Occupations in risk group 4 are even more physically demanding (heavy lifting, handling sharp/heavy tools, etc., e.g., carpenters, nurses.). Risk group 5 contains the most hazardous occupations (e.g., firefighters).

Figure 1: Average private DI take-up by income quartile

The figure below presents the average private DI take-up by income quartile for the US (diamonds) and Germany (squares). The US data reports private DI take-up for all private sector employees in 2020 (Source: BLS (2020)). The German data summarizes private DI take-up of all private sector employees, 35 years and younger who entered the labor market after the 2001 pension reform (Source: EVS 2013).



income is €71,285 in group 1 versus €30,879 in group 5, while lifetime disability risk is lowest in group 1 and highest in group 5. Since premiums scale with disability risk, individuals in higher risk groups face both higher absolute and relative insurance costs. Consequently, private DI is most affordable for high-income individuals who face the lowest disability risk.

Column (4) documents the occupational risk distribution using SIAB data. Most male private-sector workers are concentrated in medium- and high-risk groups: 45.39% in group 4 and 28.90% in group 3. Only 4.81% and 19.95% work in very-low-risk (group 1) and low-risk (group 2) occupations, respectively, while hazardous occupations (group 5) account for 0.4%.

In sum, a substantial number of people across the income distribution buy private DI. However, high-income individuals are overrepresented among buyers, despite facing low lifetime disability risk. In contrast, low-income and high-risk individuals, the majority of the population, face steep premiums and lower take-up rates. The model accounts for these patterns by allowing income and risk to be correlated, moral hazard to vary by income group, and targeting take-up across the income distribution.

3 Model

I develop a dynamic life-cycle model in which heterogeneous individuals choose their consumption, labor supply, savings, and, at entry into the model, private disability insurance (DI) take-up. They face exogenous income, disability, and public DI admission risk. Each period is one year. The model is designed to quantify how private DI take-up

Table 1: Risk group distribution, disability risk, and private DI premiums

The table below shows lifetime disability risk, private DI premiums, and average annual income by risk group, and the population risk group distribution. Column (1) shows the lifetime disability risk for each risk group (Source: Seibold et al. (forthcoming)). Column (2) reports the annual private DI premiums (in EUR) for insuring €12,000 per year from age 25 up until age 65. Column (3) displays the average annual income (in EUR), and Column (4) displays the risk group distribution for men in the German workforce based on the social security records (Source: SIAB, estimation sample).

Risk Group	(1) Lifetime disability risk	(2) Annual insurance premium (in €) for contract start at age 25	(3) Average income (€/year)	(4) Share of workforce
1 (best risks)	4.81%	353	71,285.13	5.3%
2	15.35%	467	57,644.87	19.95%
3	23.77%	762	39,174.89	28.90%
4	31.01%	1,125	31,751.92	45.39%
5 (worst risks)	39.92%	1,736	30,878.75	0.4%
Population	25.06%	849.68	41,294.66	100%

alters public DI claiming behavior, capturing the moral hazard of private on public DI, and to study the implications for public DI system design¹⁷.

3.1 The individual problem

An individual maximizes her expected discounted lifetime utility, choosing consumption, savings, labor supply, and whether to purchase private disability insurance (DI) subject to the constraints below:

$$\max_{\{c_k, A_{k+1}, l_k\}_{k=1}^T, pDI_0} V_{i0} = \sum_{t=0}^T \beta^t \mathbf{E}_t[U(c_t, A_{t+1}, l_t; S_{it})] \quad (1)$$

where, t denotes age, T is the terminal age, and β is the discount factor. $\mathbf{E}_t$ the expectation operator over the information available to an individual at t . Choices include consumption c_{it} , next-period assets A_{it+1} , and leisure l_{it} . Labor supply is chosen until mandatory retirement at $T_{retire} = 40$ (age 65); after that, leisure l_{it} equals the time endowment. Individuals enter the model at age 25 ($t = 0$) and die with certainty at age 95 ($T = 70$). There is no bequest motive.

The state vector S_{it} includes current assets A_{it} , income y_{it} , disability status H_{it} , private DI take-up $pDI_{it} \in \{0, 1\}$, observable disability risk group $rg_i \in \{1, \dots, 5\}$ (following the discrete risk mapping insurers use to price private DI), and public DI admission status

¹⁷While the model is in the spirit of Low and Pistaferri (2015), I abstract from unemployment–DI interactions (less relevant in the German context) and include all income groups to control for income-correlated risk heterogeneity. This structure suits the institutional focus on private DI and moral hazard better.

$DIS_{it} \in \{0, 1\}$ if disabled and not working.

The intratemporal budget constraint is specified as:

$$\frac{A_{it+1}}{1+r} + c_{it} + pDI_{it} \cdot p_{it} = A_{it} + y_{it} - SSC(y_{it}) - TAX(y_{it}) \quad (2)$$

where A denotes assets, and r the real interest rate net of capital taxes. pDI_{it} is an indicator for private DI take-up ($pDI_0 \in \{0, 1\}$). If insured, individuals pay the private DI premium p_{it} while not claiming. Individuals pay income tax $TAX(\cdot)$ and social security contributions $SSC(\cdot)$ on their income y_{it} according to the German system (Appendix C). Section 3.4 describes the different income sources.

The second constraint an individual faces is the time constraint:

$$l_{it} = L - l_{it}^w - \theta \mathbf{1}[l_{it}^w > 0] \quad (3)$$

Time endowment $L = 3$ ¹⁸ is split between work l_{it}^w and leisure l_{it} . The term θ captures the disutility from labor force participation ($\mathbf{1}[l_{it}^w > 0]$). Labor supply is discrete: it takes the value 1 if an individual works full-time, 0.5 for part-time, and to 0 otherwise.

Finally, I assume $A_{it} \geq 0$ so individuals cannot borrow.

At model entry ($t = 0$), individuals make a one-time decision to buy private DI.¹⁹ They pay the private DI premium each period while not claiming, and receive private DI benefits upon claiming. Private DI expires at retirement. Section 3.3 provides more details on private DI contracts. Individuals choose consumption and savings in every period, and labor supply prior to mandatory retirement, thereafter consuming their entire time endowment as leisure. Disabled individuals may claim public DI (and if purchased) private DI by exiting the labor force ($l_{it}^w = 0$). She can use her savings to finance consumption in any period, particularly to smooth consumption over income fluctuations or during disability spells and retirement.

The per-period utility takes the form of CRRA preferences similar to the preferences in Low and Pistaferri (2015):

$$U(c_t, l_t; H_t) = \frac{(c_{it}^\kappa l_{it}^{1-\kappa} e^{-\varphi \mathbf{1}[H_t=bad]})^{1-\gamma}}{1-\gamma} \quad (4)$$

where γ is risk aversion, κ governs the weight on consumption relative to leisure, and φ captures the (dis-)utility from disability. Intuitively, φ informs us about how individuals would move consumption across health states if fully insured. A positive value of φ implies that individuals value one Euro of consumption moved from the good to the bad health state at more than this one Euro in the bad state, consistent with disability being a 'bad'. The model parameters $(\gamma, \kappa, \varphi, \theta)$ are estimated from the data (see Section 4).

My model accounts for exogenous household composition with age-varying household

¹⁸Since a standard work contract specifies 8 hours a day as full-time work, $L = 3$ implies that a full-time worker spends 8 hours working out of 24 hours a day

¹⁹In the baseline model, I allow people to only choose from a single contract. I relax this assumption in a robustness exercise, where people choose from a menu of private DI contracts $pDI_0 \in \{0, \dots, L\}$ indexed by the replacement rate. $pDI_0 = 0$ denotes no private DI.

size matched to the data, by equalizing consumption in (4) using the OECD scale²⁰. I abstract from spousal income in the baseline like Low and Pistaferri (2015), though I allow for exogenous spousal income in robustness checks (Section 6.4).

In the next sections, I discuss the key elements of my model: disability risk, the public and private DI system, and the income process.

3.2 Disability risks

Disability is central to the model, directly affecting utility and labor productivity. It enters the utility function non-separably and reduces labor productivity via the income process, thereby influencing consumption and labor supply. I discuss the disability transition probabilities here and the implications for income in Section 3.4.

Disability evolves according to a three-state Markov-process: individuals transition between good health, mild disability or severe disability ($H_{it} \in \{\text{good, mild, severe}\}$). Transition probabilities $\Pi_{it}(H_{it+1}; H_{it}, rg_i)$ depend on current age t , disability status H_{it} , and the risk group rg_i .²¹ This specification allows for recovery, and all individuals enter the model in good health.

Disability transitions are exogenous conditional on age and risk group. Thus, the model abstracts from within-group heterogeneity in health, e.g., due to different investments in health, and from adverse selection. This is consistent with empirical evidence from the German private DI market, where selection operates exclusively on priced observables (risk groups), despite remaining disability risk heterogeneity within each risk group (Seibold et al., forthcoming).

Finally, I abstract from medical expenditure risk. In Germany, universal health insurance covers most direct medical costs, rendering out-of-pocket expenses negligible.

3.3 Private and public disability insurance

At model entry ($t = 0$), individuals observe their risk group and income and make a one-time, irreversible decision to purchase private DI.²² A private DI contract is characterized by a replacement ratio, $RR^{private}$, and a risk-group-specific price per insured Euro, $ppE(rg_i)$. The insured benefit is proportional to full-time income in good health $Y_{it}(H_{it})$:

$$b^{private} = RR^{private} \cdot Y_{it}(H_{it} = \text{good}).$$

²⁰I refrain from endogenizing family composition and spousal responses to disability shocks due to data limitations, especially as the literature is inconclusive (Lee, 2020; Autor et al., 2019; Gallipoli and Turner, 2009).

²¹Since rg_i also enters the wage process, disability risk and earnings are correlated, allowing for low productivity individuals to be also more likely to become disabled like in Low and Pistaferri (2015).

²²As contracts are purchased until an expiration date – usually the retirement age – there are no updates to existing contracts and no annual renewal decision.

The annual premium is then²³:

$$p_{it}(rg_i) = ppE(rg_i) \cdot b^{private}.$$

Individuals pay the premium while working and receive benefits when she is (at least mildly) disabled and has exited the labor force. Benefit payments end upon recovery, re-entry into employment, or at the old-age pension age.

Public DI is available to all disabled individuals who choose to exit the labor force, whereby individuals apply for public (and private) DI at labor force exit. Upon application, public benefits are granted with probability depending on disability severity and age. Successful applicants immediately receive public DI benefits which mirror the private DI scheme:

$$b^{public} = RR^{public} \cdot Y_{it}(H_{it} = good)$$

defined as a fixed replacement ratio RR^{public} of full-time income in good health.

Applicants denied public DI may reapply after one year and can receive means-tested social assistance income during this period. The probability of rejection is:

$$Prob(DI_{sit} = 0 | DI_{sit-1} = 0, H_t, t) = \begin{cases} \pi_H^{Young} & \text{if } t < 20 \\ \pi_H^{Old} & \text{if } t \geq 20 \end{cases}$$

where $DI_{sit} \in \{0, 1\}$ indicates public DI status. The rejection probabilities depend on disability severity H_t , capturing the eligibility criterion of public DI, and age t , following Fehr and Fröhlich (2022). Two assumptions are imposed: (i) healthy individuals are always rejected;²⁴ (ii) severely disabled individuals face (weakly) lower rejection rates than mildly disabled individuals.

This implies that while the public DI provider can verify the existence of a disability, it still makes Type I (rejection of deserving claimants) and Type II (admission of undeserving claimants) errors due to imperfect verification of disability severity.²⁵ Once admitted, recipients remain on public DI while disabled. Recovery or re-employment triggers exit, and future re-entry requires a new application. At the old-age pension age, public DI is transformed into a regular old-age pension.

3.4 Income Process

Individuals receive income either from labor or from transfers, if eligible. Transfers include public and private DI benefits (if disabled) or means-tested social assistance. This section

²³This is in line with insurers' premium calculations: They compute the price to insure one Euro by age and risk group, then multiply it by the benefits to determine the annual premium.

²⁴Including low-productivity but healthy claimants feigning disability to enter DI, as in Deshpande and Lockwood (2021); Low and Pistaferri (2015) would result in stronger labor supply distortions. In this regard, the results presented here constitute a conservative estimate.

²⁵The definition of deserving and undeserving claimants is relative to the eligibility criterion enforced by the government, i.e. the retained productivity after suffering a verifiable disability shock.

describes each income source in detail.

Labor income is modeled as a reduced-form function of observable characteristics and stochastic shocks:

$$\log Y_{it} = \beta_0 + \sum_{k=1}^4 \beta_k * age_{it}^k + \beta_5 \mathbf{1}[l_{it}^w = 1] + \sum_{j=2}^5 \beta_6^j * \mathbf{1}[rg_{it} = j] + \varepsilon_{it} + \epsilon_{it}. \quad (5)$$

where Y_{it} is the annual income. The reduced-form specification controls for a quartic polynomial in age age_{it}^k , $k = 1, \dots, 4$, a full-time dummy $\mathbf{1}[l_{it}^w = 1]$, and individual risk group dummies $\mathbf{1}[rg_{it} = j]$, $j = 2, \dots, 5$. Including the disability risk in the income process is essential to allow income to vary with disability risk – i.e., to capture the negative correlation between income and risk documented in Section 2.3– with implications for selection into private DI take-up and thus welfare in Section 6.

Labor income is subject to two i.i.d. shock processes. The persistent component ε_{it} follows an AR(1) process (Güvenen, 2009; Low et al., 2010) capturing lasting productivity shocks unrelated to health, e.g. wage changes due to technological change:

$$\varepsilon_{it} = \rho \varepsilon_{it-1} + \eta_{it}, \quad \eta_{it} \sim N(0, \sigma_\eta^2), \quad (6)$$

where ρ denotes the shock persistence. The transitory shock $\epsilon_{it} \sim N(0, \sigma_\epsilon^2)$ reflects short-term wage fluctuations. Parameters $\{\rho, \sigma_\eta^2, \sigma_\epsilon^2\}$ are estimated from data as described in Section 4.2.

Disability status is not directly observed in the income data, as individuals are only recorded as disabled after labor force exit. Thus, I either observe benefit receipt (disability) or labor income but not both. Instead, I assume the productivity loss from a severe (mild) disability reduces productivity to 38% (50%) of productivity in good health corresponding to the public and private DI eligibility thresholds. Sensitivity checks confirm the robustness of my results to alternative retained productivity values.

Upon disability-induced labor force exit, individuals may receive transfer income from public DI, and private DI (if insured). The total benefit is:

$$B_{it} = b^{public} \cdot \mathbf{1}[DI_{sit} = 1] + b^{private} \cdot \mathbf{1}[pDI_0 = 1], \quad (7)$$

where b^{public} and $b^{private}$ are replacement-rate-based benefits tied to full-time income in good health; $\mathbf{1}[DI_{sit} = 1]$ and $\mathbf{1}[pDI_0 = 1]$ indicate public DI admission and private DI coverage, respectively. As described in section 3.3, private and public benefits can be claimed simultaneously without benefit reductions.

The social safety net guarantees a minimum consumption floor (SSI) for people out off the labor force, including DI recipients and retirees. To qualify, household income Y_{it}^{HH} and assets A_{it} fall below eligibility thresholds:

$$y_{it} = SSI \quad \text{if} \quad \min\{0, Y_{it}^{HH}\} \leq SSI \quad \text{and} \quad A_{it} \leq \bar{A}. \quad (8)$$

Retirement income is modeled as a fixed pension based on lifetime earnings; see Appendix C.4 for the formula.

3.5 Solution Method

The model does not have an analytical solution and is solved numerically by backward induction, starting from the terminal condition at $t = T + 1$, when death occurs with certainty.²⁶

In each period, I compute the value function conditional on work status and the full set of state variables S_{it} . Assets are discretized using the Tauchen method and value functions are interpolated between grid points through piecewise splines.

I solve for optimal consumption for each state and work status. At model entry ($t = 0$), individuals make an irreversible choice whether to purchase private DI. Thereafter, private DI take-up becomes a state variable. Individuals buy private DI if and only if it yields weakly greater expected lifetime utility at $t = 0$ than without private DI:

$$V_{i0}(pDI = 1; S_{i0}) \geq V_{i0}(pDI = 0; S_{i0}) \quad (9)$$

Appendix B provides the details of the numerical solution.

4 Estimation

I estimate the model from section 3 in a three-step procedure. First, I take some values from the literature, e.g. tax rates and social security contributions. Second, I estimate some processes in a reduced form fashion outside the model, like the population risk-group distribution or the income process. Finally, I apply the method of simulated moments (MSM) to estimate the utility parameters of my model by minimizing the weighted distance between data moments and the corresponding moments simulated in the model.

4.1 Values from the literature

Table 2 displays the parameters I take from the literature. The first panel shows three model parameters I set to values commonly used in the literature. The terminal age is 95 years so the final period is $T = 70$. I set the real interest rate to 3%. Applying the linear capital tax rate of 25%, the net-of-tax rate r amounts to 2.25%. I assume that β takes the value 0.987, so people are patient.

The second panel summarizes the values of the tax and transfer system, which I model according to its rules in 2013 (cf. Appendix C for details). Income is taxed based on the statutory income tax schedule. Social Security contributions are paid via payroll taxes. The payroll tax rates were $\{0.015, 0.0995, 0.0775, 0.01025\}$ for unemployment insurance, public pension, health insurance, and long-term-care insurance in 2013 respectively. So-

²⁶Work-limiting disability is only relevant before retirement, while mortality mostly matters after retirement. Hence, I abstract from mortality as it affects outcomes only indirectly via the length of the retirement period.

Table 2: Parameters from literature

The table below shows the parameter values set outside the model. These parameters include model parameters not estimated in the model, the German tax and benefit schedules, disability risk, as well as private insurance premiums by risk group. Monetary values are deflated to 2013 prices.

Parameter	Value	Source
<i>Model parameter:</i>		
-Final period T	70 (age 95)	-
-Interest rate r (net-of-tax)	0.0225	-
- β	0.987	-
<i>Tax schedule and social security contributions</i>		
-Income tax schedule	Appendix C	Income tax code 2013
-Health, long-term care insurance	0.0775, 0.01025	SSC code in 2013
-pension, unemployment insurance	0.0995, 0.015	SSC code in 2013
<i>Social security contribution: income caps</i>		
-Health and long-term care insurance	4000 €/month	SSC code in 2013
-Pension and unemployment insurance	5800 €/month	SSC code in 2013
<i>Public Benefit programs</i>		
-Social Assistance	€5438.63	Income tax code 2013, IAQ (2022)
-Social Assistance, means test $\bar{A}$	€5,000 (per adult)	SSC code in 2013
-Public DI rejection rate	0.50 (age < 45); 0.41 (age ≥ 45)	German Pension Fund, Fehr and Fröhlich (2022)
-Replacement ratio (public)	0.35	German Pension Fund
<i>Risk processes</i>		
- Health Transitions	Aktuarvereinigung (1997, 2018)	German Actuarial Society
- Share mild disability (by risk group)	0.1085, 0.0806, 0.1257, 0.1574, 0.3195	Seibold et al. (forthcoming)
<i>Annual private DI premium for an annual benefit of €12k, by risk-group</i>		
-Risk-group 1	€353	Company website
-Risk-group 2	€467	Company website
-Risk-group 3	€762	Company website
-Risk-group 4	€1125	Company website
-Risk-group 5	€1736	Company website

cial security contributions are capped at an income threshold and stay flat for income exceeding these caps. In 2013, the income thresholds were €5800 (€4000) per month for the pension and unemployment insurance (health and long-term-care insurance). Public benefits also stay flat at the maximal amount after these thresholds.

The parameters governing the public benefit programs are presented in the third panel. I set the consumption floor offered by social assistance (Hartz-IV + additional transfers) to €5438.63 per year. This number is based on the total social assistance expenditures and the number of recipients in 2013 as reported by IAQ (2022).²⁷ To qualify for social assistance, household income must be below this value and household assets cannot exceed €5,000 per adult. Otherwise, the household is not eligible.

²⁷Like consumption, this consumption floor is scaled by the equivalence scale to account for household composition.

The public DI program is characterized by two parameters, the replacement ratio and the rejection rate of applications. The replacement ratio is set to 35% of individual gross income, its average in the public pension data (Seibold et al., forthcoming). The rejection rate is set to 50% for applicants younger than 45, and to 41% for ages 45 and above (DRV, 2019; Fehr and Fröhlich, 2022). Contributions to public DI are included in the public pension contributions (cf. section 2).

The health transition probabilities are from the disability table by the German Actuarial Society (Aktuarvereinigung, 1997, 2018). The share of mild disabilities by risk group is from Seibold et al. (forthcoming).

The last panel of table 2 presents the web-scraped prices for private DI by risk group. The prices are calculated under the assumption that a 25-year-old (healthy) individual purchases insurance until the age of 65 insuring €12,000 per year. The price to insure one Euro of income is the ratio of the price reported in the table divided by 12,000 Euro.

4.2 Parameters estimated outside the model

I estimate three inputs outside the structural model: the distribution of risk groups, the disability probabilities by risk group, and the labor income process (equation (5)). The sample period covers 2001–2017; estimation sample construction is detailed in Section 2.2. Table 3 reports the parameter estimates.

Panel A shows the distribution of men across the five risk groups, assigned based on insurers’ occupation-risk (group) mapping. The majority (45.3%) fall into risk group 4 (high risk), while only 5.3% are in the lowest-risk group, risk group 1. I assume risk group assignment is fixed over the working life. Although individuals can update their contracts when changing jobs or receiving promotions, such reclassifications are infrequent. Abstracting from this margin likely yields conservative estimates, particularly since high-income individuals are overrepresented in private DI and use it as a pathway to public DI.

To account for group-specific disability risk, I adjust the age-based disability probabilities from the German Actuarial Society’s risk table (Aktuarvereinigung, 1997)²⁸ using probit estimates of disability incidence by risk group (rg_{it}) in the SIAB:

$$disabled_{it} = \Phi(\zeta_0 + \zeta_1 * rg_{it}) \quad (10)$$

Panel B displays the predicted probabilities. Risk groups and disability risk are positively correlated and highly nonlinear: individuals in risk group 5 are 5.6 times more likely to become disabled than those in group 1. These estimates are used to scale transition probabilities across disability states (equation 11) relative to the population median risk group (group 3)²⁹:

²⁸This table serves as a baseline for insurance companies’ risk premium calculations.

²⁹Seibold et al. (forthcoming) validate that this approach leads to similar probabilities as estimating the disability probabilities from public DI claims data.

Table 3: Parameters estimated outside the model

The table below shows parameter values estimated outside the model. Panel A shows the discrete risk group distribution in the population as population shares. Panel B displays the predicted disability probabilities (eq. (10)) (Source: SIAB, Estimation Sample). Panel C reports the estimation results for the income equation (5) (Source: SIAB, labor income > 0).

Parameter	Value	Source
<i>Panel A: Risk Group Distribution</i>		
Risk Group 1	0.0530	SIAB
Risk Group 2	0.1995	
Risk Group 3	0.2891	
Risk Group 4	0.4539	
Risk Group 5	0.0045	
Risk Group NA	0.0011	
Num. Obs.	4,696,325	
<i>Panel B: Health Risk adjustment</i>		
$Prob(disabled(rg = 1))$	$2.722 * 10^{-4}$	SIAB, eq. (10)
$Prob(disabled(rg = 2))$	$4.227 * 10^{-4}$	
$Prob(disabled(rg = 3))$	$6.476 * 10^{-4}$	
$Prob(disabled(rg = 4))$	$9.787 * 10^{-4}$	
$Prob(disabled(rg = 5))$	$14.592 * 10^{-4}$	
Num. Obs.	4,696,325	
<i>Panel C: Income Process</i>		
β_0	0.7522	SIAB, eq. (5)
β_1 (age)	0.0374	
β_2 (age ²)	-0.0011	
β_3 (age ³)	$1.22 * 10^{-5}$	
β_4 (age ⁴)	$-4.76 * 10^{-8}$	
β_5 (full-time)	0.8300	
β_6^k (risk group):		
2	-0.2119	
3	-0.5570	
4	-0.7449	
5	-0.7834	
σ_η^2	0.0206	
σ_ζ^2	0.1296	
σ_ϵ^2	0.0478	
ρ	0.9438	
Num. Obs.	4,580,880	
Replacement ratio	0.36	contract data

$$\Pi_{it}(H_{it+1}; H_{it}, rg_i) = \pi(H_{it+1} = J | H_{it} = j) * \frac{\hat{disabled}(rg_{it})}{\hat{disabled}(rg = 3)} \quad (11)$$

for $J, j = \{\text{good, mild, severe}\}$.

Panel C Panel C reports the coefficients from the labor income regression (5) estimated on employed men in the SIAB. The stochastic earnings components are derived following Guvenen (2009) (Appendix D for details). The estimated income-risk gradient aligns with Table 1, with income declining in risk group coefficients (β_6^k).³⁰ Together

³⁰Since changes in risk group occur infrequently over the working life, I cannot simultaneously include risk groups and individual fixed effects in eq. (5). Given the importance for selection on income into private DI take-up, I estimate the risk-income gradient.

Table 4: Moments targeted in the method of simulated moments approach

The table below shows the moments targeted in the estimation. The first column presents the group of moments and the second column reports the data sets from which they are derived. The third column shows the number of moments in each group. See appendix table A.5 for the data and simulated values.

Data Moment	Source	Number moments
<i>private DI moments</i>		
Mean take-up	EVS 2013	1
Mean take-up by income quartile	EVS 2013	4
<i>Labor moments, age 29-53 (every 4yrs)</i>		
Participation	SIAB	7
Full-time	SIAB	7
Part-time	SIAB	7
<i>Asset moments, age 25-69 (3yrs-bins)</i>		
Mean assets	EVS98 - EVS2013	15
Fraction with below median assets	EVS98 - EVS2013	15
Total Moments		56

with the positive income gradient in private DI take-up (Figure 1), the negative income-risk gradient highlights an important selection margin into private DI, shaping public DI claimant composition and welfare consequences of public DI reforms.

In the baseline model, individuals can only buy a single private DI contract insuring 36% of gross income. A robustness exercise allowing choice over multiple coverage levels (replacement ratios) confirms the results, albeit at significantly higher computational cost (Section 6.4).

4.3 Method of Simulated Moments Approach

I apply the method of simulated moments (MSM) to estimate the four preference parameters of interest: risk aversion γ , consumption weight κ , the fixed cost of labor force participation θ , and (dis-)utility from disability φ . The MSM minimizes the weighted distance between simulated and data moments for given parameter values. I weigh each moment by the inverse of its variance (Altonji and Segal, 1996). A detailed description is provided in Appendix B.3.

Table 4 summarizes the 56 targeted moments, grouped into three categories: private DI take-up, labor supply, and asset accumulation. Appendix Table A.5 lists all moments and weights. Private DI moments include overall take-up and take-up by income quartile, estimated from the 2013 EVS wave, the first to record private DI take-up. To minimize confounding effects of the 2001 pension reform, I restrict the sample to men aged 25–35 in 2013, i.e., the cohort that enter the labor market after the reform.

The second set of moments comprises labor supply moments which measure labor

force participation and the share of full- and part-time employment across ages 29 to 53, in four-year intervals. I estimate these moments from SIAB data pooled over 2001 to 2017 for men who are employed, on social assistance, or receiving public DI.³¹

The third set of moments contains mean and median assets by age, estimated from the pooled EVS estimation sample (Section 2.2). I group ages 25 to 69 into 15 three-year bins to increase precision. This yields 30 moments, capturing the life-cycle asset profile.

Each set of moments contributes to the identification of a specific preference parameter. Risk aversion (γ) governs intertemporal and across-state consumption smoothing and thus is identified by the shape of the asset profiles. Consumption weight (κ) affects the trade-off between consumption and leisure. κ will be larger the more people value consumption over leisure, which also implies they care more about consumption insurance in low-income states. Hence, κ is identified from the variation in labor supply (full-time, part-time, no participation) and private DI take-up. The fixed cost of labor force participation (θ) is primarily identified from labor force participation moments, as individuals participate in the labor force only when the utility gains from higher consumption exceeds the fixed utility cost of supplying labor. Finally, the disutility from disability (φ) determines the value of consumption in the disabled state. A greater value of φ raises the value of an additional Euro of consumption in the disabled state thus increasing the demand for formal (private DI) and, to some extent, informal insurance (assets). Together, the moments allow me to pin down the preference parameters that govern labor supply, savings, and insurance decisions over the life cycle.

5 Results

This section presents the estimation results of the preference parameters from the model in section 3. It includes a discussion of the model’s performance by evaluating the estimation precision with respect to preference parameters and model fit. Overall, the parameter estimates are in line with values in the literature and precisely estimated. Moreover, the simulated moments match targeted and non-targeted data moments well.

5.1 Estimation Results

Table 5 presents the estimation results. The second column displays the parameter estimates from the method of simulated moments and the third column shows the standard errors for each parameter following Lockwood (2018). The fourth column reports which moments identify each parameter (see section 4.3). Overall, the estimates are in line with

³¹I exclude unemployment insurance recipients, as the model does not allow for involuntary unemployment. Given the annual frequency of my model, the exclusion has limited impact since UI spells are typically short and followed by either reemployment or transition to social assistance. Besides, there is no mandatory waiting period without work before applying for public DI unlike in the US, so unemployment is less relevant in the German context.

Table 5: Parameters estimated using the method of simulated moments

The table below shows the model parameter estimates from the method of simulated moments (second column). The third column reports the estimated standard errors for each parameter. The fourth column presents the moments that contribute to identifying each utility parameter as discussed in section 4.3.

Parameter	Value	Standard Error	Identification
Risk aversion γ	3.877	0.131	Mean and median assets
Consumption weight κ	0.688	0.033	full-time and part-time shares, LF participation
Labor force participation cost θ	0.383	0.070	LF participation, full-time and part-time shares
Disutility from bad health φ	0.127	0.006	mean private DI, mean and median assets

the related literature and precisely estimated. I discuss the robustness of my parameter estimates and counterfactual results to several extensions to this model in Section 6.4.

The coefficient of relative risk aversion γ is 3.877. Estimates in the related literature range from 2 to 7 (French, 2005; Lockwood, 2018; Jacobs, 2023). The estimated value for γ lies in the middle of this interval. The standard error in the third column shows that γ is precisely estimated (s.e. 0.13).

The consumption weight κ is precisely estimated with a value of 0.688 (s.e. 0.033). The estimate is greater than the values in (Jacobs, 2023) and the one assumed in Low and Pistaferri (2015), and closer to French (2005) albeit still greater. The high consumption weight is explained by the high labor force participation of (prime-age) men and the high share of private DI purchases among high-income earners. Only if (high-income) people sufficiently value consumption insurance in low-income states after experiencing a disability shock, are they willing to buy unfairly priced insurance instead of working despite their disability.

The parameter for the labor force participation cost θ takes the value 0.383 equal to 12.8% of the total time endowment. It is similar to the values in Jacobs (2023) and French (2005) and below the value in Low and Pistaferri (2015). The parameter is precisely estimated (s.e. 0.07). Given that prime-age men in good health exhibit large labor force participation shares (over 90% in the data), labor force participation cannot be very costly to them, resulting in this small estimate.

Finally, the disutility of bad health is estimated to be 0.127 (s.e. 0.006). A positive value of φ implies disability is a "bad" given the utility function in eq. (4), so people want to transfer additional consumption to the bad health state. The parameter estimate lies between the estimates of French (2005) and Low and Pistaferri (2015). This is most likely explained by differences in health measures and study focus. French (2005) uses a broader measure of bad health³², which includes more moderate conditions, thus finding

³²French (2005)'s measure is the answer to the question: "Do you have any physical or nervous condition

a lower 'penalty'. Low and Pistaferri (2015) focus on low-income earners, who might suffer from more severe disabilities than the average individual, explaining their higher disutility term. Instead, I study the whole population and apply the statutory work-limitation cutoffs. Therefore, my model is between the model of French (2005) and Low and Pistaferri (2015), so my disutility from bad health is also between their estimates.

In sum, the estimated model parameters are in line with values in the related literature. They are precisely estimated, so the targeted moments identify these parameters³³. Appendix table A.7 reports the sensitivity of each parameter with respect to the included moments following Andrews et al. (2017). The next subsection presents the model's performance regarding the targeted moments and non-targeted moments, i.e. the in-sample and out-of-sample fit.

5.2 Model Fit

This section evaluates the model's ability to replicate both targeted and non-targeted moments. Since the model was estimated on targeted moments, a good fit is expected here. Matching non-targeted moments provides an out-of-sample check corroborating the model's performance.

Figure 2 compares simulated (red) and data (black) moments, with 95% confidence intervals plotted as black lines. The model closely matches the private DI take-up rates by income quartile (Panel a), capturing the positive income gradient in private DI take-up, a key feature of the data. The labor supply moments are also well captured (Panel b), though the model slightly overpredicts full-time and underpredicts part-time employment. This is probably a consequence of how part-time work is defined: the data treat 10–29 hours per week as part-time, while the model permits only 20 or 40 hours. Some observed part-time workers may fall between these two discrete choices such that an individual working 40 hours in my model might move to 29 hours if this option was available.

Panels (c) and (d) show that the model replicates the life-cycle trends in mean and median asset holdings well, though it tends to underpredict asset levels. Two factors account for this gap. First, the model assumes zero assets at entry into the model (age 25–27), consistent with the empirical median (€16,910, 95% confidence interval: €5,000–€29,000) but understating mean assets. Second, the empirical asset moments include net housing wealth, which I abstract from in my model. Since most households accumulate housing wealth in their 30s and 40s, omitting housing dampens asset levels during these years.

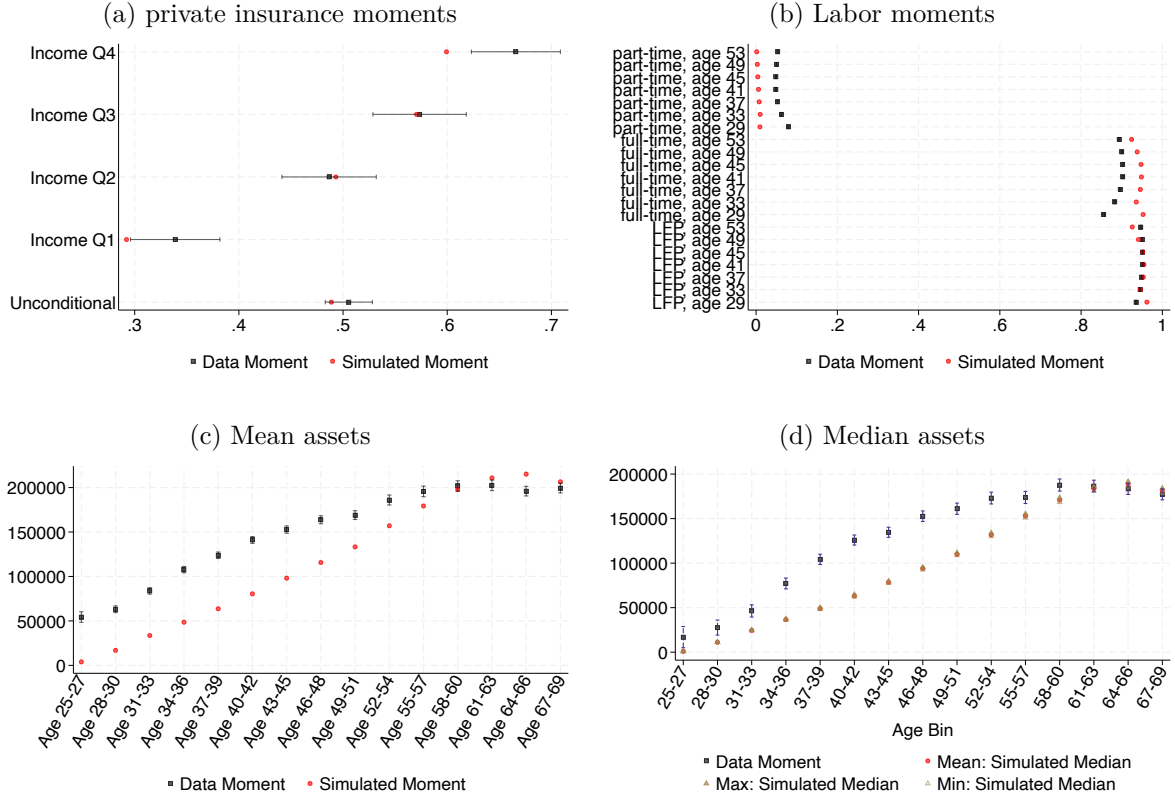
While explicitly modeling housing decision would improve asset level fit, it would not change the model's main conclusions. Housing wealth is not used to self-insure against

that limits the type of work or the amount of work that you can do?"

³³The estimated standard errors imply that the objective function is steep around the optimal values for each parameter. Since small variations in each parameter value produce a substantially lower model fit, the moments are also informative concerning the parameters that are to be estimated.

Figure 2: Model fit of data to simulated moments

The figure below presents the in-sample fit for the simulated moments (red) with the corresponding data moments (black). Panel (a) displays the private DI moments from the EVS2013 wave, panel (b) the labor moments estimated on the SIAB, and panel (c) and (d) show the mean and median asset profiles over the life cycle from the EVS98-2013 waves respectively. The simulated moments are obtained from 25 populations with 16,000 individuals each. The displayed moments are the average across these populations. The 95% confidence intervals are shown.



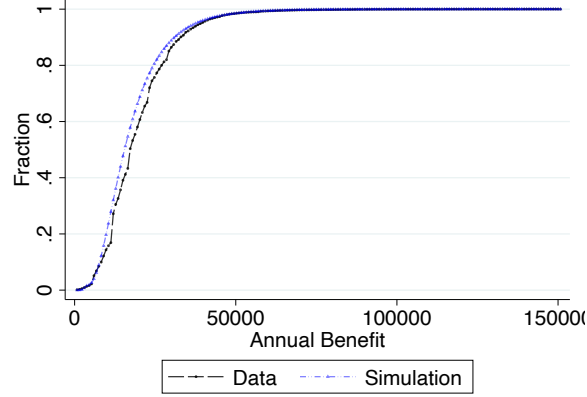
disability, and in Germany, mortgage approval often requires private DI coverage to secure mortgage repayment, reinforcing the relevance of insurance over precautionary savings in this context.³⁴

Second, disability is a rare but catastrophic risk. It is inefficient to self-insure via savings alone given that people would have to put aside large sums of money for a low-probability event. Even without private DI, the model predicts only a modest increase in precautionary savings ($\approx \text{€}10,000$), with households relying primarily on public DI or retained productivity instead. Third, the life-time asset profiles are determined by risk

³⁴Although housing wealth is not primarily used for insuring against disability, it constitutes a substantial share of retirement wealth. While retirement is not the focus of this paper, it remains an important savings motive since individuals seek to smooth consumption over retirement. Disability shocks draw down some of these savings, but at the cost of reduced resources later in life. Including net housing wealth in the asset measure helps capture this intertemporal trade-off and consumption over retirement more accurately.

Figure 3: Out-of-sample fit - Private DI benefit distribution

The figure below shows the cumulative distribution of private DI benefits in the model (blue) and the data (black) which was not targeted in the estimation. Appendix figure A.3 shows additional out-of-sample fit graphs.



aversion. The underprediction of asset levels implies that I currently underestimate risk aversion. Since a higher risk aversion also raises the valuation of formal insurance, my results constitute a lower-bound estimate for the welfare effects of private DI.

For these reasons, the model's underprediction of asset levels, especially at younger ages, has limited implications for counterfactual results, which depend more critically on labor supply and private DI take-up, both of which the model fits well.

Figure 3 shows the out-of-sample fit of the private DI benefit distribution. The model closely replicates the empirical cumulative distribution function of private DI benefits, conditional on take-up. Additional out-of-sample fits for income and labor supply in Appendix figure A.3 further support the performance of the model.

6 Counterfactuals

How does private DI affect public DI claims and what does this imply for public DI reforms? I address these questions by examining two widely debated policy levers: public DI benefit generosity and rejection rates. First, I analyze how private DI influences retirement behavior at disability onset and how this interaction shifts the welfare effects of public DI reforms (Section 6.1). Second, I assess when a dual system — combining public and private DI — improves welfare relative to a public-only mandate (Section 6.2). Policy lessons from the German case for other countries are discussed in Section 6.3. Section 6.4 presents robustness exercises.

A key element in this analysis is understanding who purchases private DI and why. Some individuals buy private DI for its insurance value — it smooths consumption across health states, enhancing welfare (insurance motive). Others are motivated by the addi-

tional income it provides at disability onset, which can lead to earlier labor force exit (retirement motive). Thus, private DI serves as a pathway to public DI increasing public DI enrollment and costs. Welfare effects depend on the relative strength of these motives, as discussed below.

I evaluate all counterfactuals under revenue neutrality using a lump-sum tax. Welfare is measured by consumption-equivalent variation (CEV), defined as the constant share of consumption an individual would give up to switch to a new policy before individual uncertainty is revealed. Appendix E provides further technical details.

6.1 Welfare-improving public DI reforms with private DI

This subsection analyzes local changes in public DI generosity and rejection rates to assess the impact of private DI on the number and composition of public DI claimants and welfare. I first present the results with private DI, consistent with the existing system. I then analyze the same reform without private DI to examine the impact of private DI take-up on welfare, labor supply, and program cost. Welfare is normalized at the Status Quo—implying zero lump-sum taxes and welfare changes—allowing for within-scenario comparisons. However, this setup does not permit welfare comparisons across private DI regimes; I return to this in Section 6.2.

6.1.1 Alternative Benefit Generosity

Table 6 summarizes the results of varying public DI benefit generosity and rejection rates around the Status Quo. Column 1 shows the baseline outcomes under the current public system (Status Quo); Columns 2 and 3 present the results for a 20% increase and decrease in benefit generosity, respectively. Changes in rejection rates are discussed in subsection 6.1.2.

Panel A presents the results for the current dual system (public + private DI). The model predicts 48.5% of individuals take up private DI, and 13.2% of disabled individuals remain employed under the existing system. A 20% increase in public DI benefit generosity reduces private DI take-up and raises labor force participation (LFP) among the disabled, suggesting that those dropping private coverage are more likely to work post-onset rather than claim public DI. This policy is financed via a positive lump-sum tax. Conversely, a 20% benefit cut increases private DI take-up, reduces LFP, and results in a tax rebate. Both reforms raise welfare by €55.56 and €4.98 in annual consumption equivalents, respectively.

To isolate the impact of private DI coverage on welfare, labor supply, and government revenue, Panel B reports outcomes under an identical public system without private DI. Here, my model predicts that 20.4% of disabled individuals work post-onset.³⁵ Increasing

³⁵This figure is consistent with empirical estimates in the public DI literature. See Low and Pistaferri (2020); von Wachter et al. (2011); Maestas et al. (2013); French and Song (2014).

Table 6: Public DI reforms without and with private DI markets

The table below presents the results from the counterfactual exercise in Section 6.1. The first column summarizes, the current public DI system (the "Status Quo"). The second and third column report the results for a 20% public DI benefit increase and decrease, respectively. The fourth and fifth column report the results for a 10% increase and decrease in public DI rejection rates. Panel A shows the results for the current dual system (public + private DI). Panel B presents the results for an identical public DI system without private DI. Panel C summarizes the income and labor force participation of private DI buyers for each scenario. Welfare changes are reported in Euros of annual consumption. A positive (negative) value implies a welfare improvement (reduction). The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

	Status Quo	Benefit Generosity		Rejection Rate	
		+20%	-20%	+10%	-10%
Panel A: with private DI					
Share of private DI owners	0.485	0.171	0.856	0.462	0.575
LFP of disabled	0.132	0.184	0.051	0.144	0.104
Lump sum tax (€ per year)	0.000	77.152	-99.123	-9.522	8.196
Welfare change (€ of annual consumption)	0.000	55.566	4.977	4.365	-2.857
Panel B: without private DI					
Share of private DI owners	0.000	0.000	0.000	0.000	0.000
LFP of disabled	0.204	0.202	0.259	0.215	0.194
Lump sum tax (€ per year)	0.000	82.902	-131.125	-9.452	8.269
Welfare change (€ of annual consumption)	0.000	68.036	-5.589	6.255	-5.357
Panel C: Private DI buyers					
Avg. Income of private DI buyers (age 25, €)	34608.874	38849.479	32614.708	34897.778	32669.422
LFP of disabled (covered by private DI)	0.002	0.000	0.002	0.002	0.002
LFP of disabled (absent private DI)	0.207	0.186	0.258	0.224	0.195

benefit generosity lowers the LFP of the disabled, and results in higher taxes, yet still improves welfare. Vice versa, reducing benefits raises LFP and lowers taxes, but leads to a welfare loss.

Comparing the results with private DI to the results without private DI reveals two central effects of private DI. First, private DI take-up reduces the LFP of disabled individuals (moral hazard) consistently – e.g., by 7.2 p.p. under the existing system – increasing public DI claims and imposing a fiscal externality on the public DI system. Since the taxes needed to balance the government budget are broadly distributed, the additional claimants only partially bear the cost, and use private DI to effectively redistribute income to themselves via the public system.

Second, private DI take-up changes the composition of public DI claimants. Panel C shows private DI is predominantly purchased by higher-income individuals. Many of them continue working absent private DI, but all exit the labor force once insured — suggesting a strong retirement motive. This shifts the composition of public DI claimants toward higher-income individuals, exacerbating the redistribution from low- to high-income

groups via public DI.

Public DI generosity interacts with both moral hazard and selection on income. When benefits are more generous, fewer individuals purchase private DI, but the selection on income strengthens (mean income: €38,849 vs. €34,609 at the Status Quo), intensifying the fiscal externality and regressive redistribution. In contrast, benefit cuts induce more low-income individuals to purchase private DI (mean income: €32,615), primarily for its insurance value. These individuals already exit the labor force when disabled given their low productivity, so private DI allows them to compensate for public DI cuts, increasing their consumption without altering their labor supply.

This shift in moral hazard responses and pool of public DI claimants affects welfare outcomes. With private DI, generous public DI reforms become more costly due to the fiscal externality and intensifying selection on income, muting welfare gains (€55.56 vs. €68.04 without private DI). In contrast, private DI can offset the negative welfare effects of public DI cuts: while benefit reductions lower welfare without private DI (-€5.59), they raise welfare with private DI (+€4.98), as more low-income individuals buy private DI to compensate for the lost public coverage. Given their low income, this substantial boosts their consumption and thus welfare in the disabled state. Moreover, more low-income individuals buying private DI limits both the fiscal externality and regressive redistribution imposed by high-income individuals, further improving welfare.

Overall, private DI increases public DI claims and changes the income composition of claimants. While this mutes welfare for more generous public benefits, private DI also enables cost-saving reforms without sacrificing welfare, thus expanding the policy space. Appendix Figure A.1 confirms that these findings hold across benefit changes in the range $[-20\%, 20\%]$, conditional on private DI availability. Section 6.3 discusses implications for addressing rising public DI expenditures.

6.1.2 Alternative Rejection Rates

Column 4 and 5 of Table 6 presents the results for a 10% increase and decrease in public DI rejection rates respectively, in comparison to the Status Quo in Column 1.

Panel A reports the results for the current dual system (public + private DI). Raising the rejection rate by 10% reduces private DI take-up, increases labor force participation (LFP) among the disabled, lowers public program costs, and yields a welfare gain of €4.365 of annual consumption. Conversely, lowering the rejection rate by 10% increases private DI take-up, reduces disabled LFP, raises taxes, and leads to a welfare loss of €2.857.

Panel B reports results for an identical public system without private DI. Qualitatively, results are similar: higher rejection rates increase LFP and welfare, while paying a tax rebate; lower rates reduce LFP and welfare, while taxes are higher. The welfare responses are greater (in absolute terms) compared to responses with private DI.

As for benefit changes, these differences stem from the effect of private DI on the number and composition of public DI claimants, i.e., the moral hazard of private DI and selection on income into private DI. Public rejection rates interact with both of them: Higher rejection rates reduce private DI take-up, but intensify income-based selection (mean income of buyers: €34,898 vs. €34,610 at the Status Quo), amplifying the redistribution to high-income individuals via public DI. In contrast, lower rejection rates expand private DI take-up, especially among lower-income individuals (mean income: €32,669). Given their low incomes, they have higher marginal utility of consumption and buy private DI for its insurance value rather than the retirement motive.

These fiscal externality and compositional changes shape welfare outcomes. With private DI, higher rejection rates lead to higher-income marginal public DI claimants as only high-income people keep buying private DI. The resulting fiscal externality and intensified regressive redistribution dampen welfare gains compared to the no-private-DI case (€4.365 vs. €6.255). Conversely, lower rejection rates lead to lower-income marginal public DI claimants because of the increased private DI take-up among low-income individuals. Their higher valuation of insurance, in addition to the lessened redistribution to high-income groups when private DI is present, limit the welfare loss relative to the no-private-DI scenario (-€2.857 vs. -€5.357).

In sum, while the direction of welfare effects from changing rejection rates remains the same, private DI attenuates these effects due to its impact on public DI claims and the income composition of claimants. Appendix Figure A.2 confirms these findings across a broader range of rejection rates changes $[-50\%, 50\%]$.

6.2 When is a dual insurance system welfare-enhancing?

The previous section highlighted how private DI alters the composition of public DI claimants and affects welfare under various public DI policies. This section turns to another core policy question: under which public DI schedules does allowing a private DI market improve welfare compared to a system with only public DI?

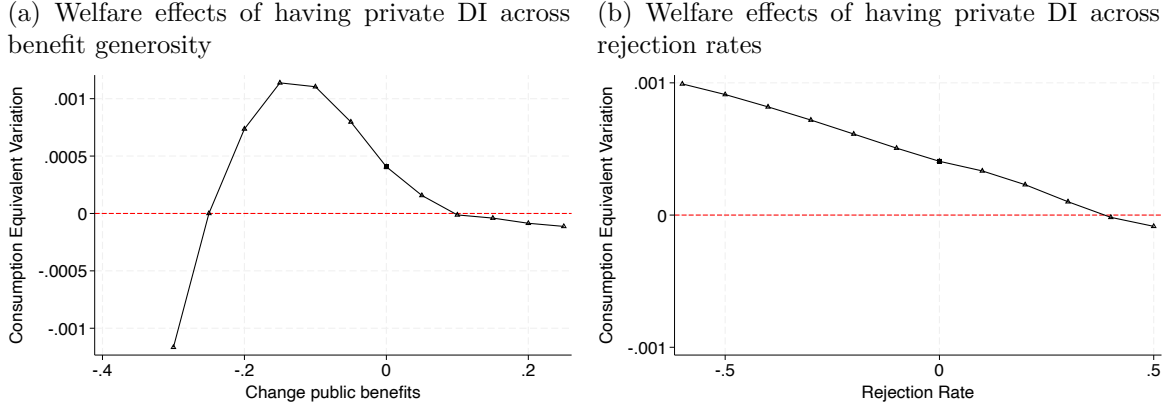
As before, all policies are revenue-neutral, financed through lump-sum taxation. Welfare is measured in terms of consumption equivalent variation (CEV), defined as the percentage of annual consumption individuals would forgo to move from the no-private-DI regime to one with a private DI market. A positive CEV indicates that private DI enhances welfare.

Figure 4 plots the CEV across public policy parameters. Panel (a) considers variation in benefit generosity. Private DI improves welfare relative to a public-only system for benefit levels between -25% and +10% relative to the Status Quo. Outside this range, particularly at higher benefit levels, welfare is lower with private DI.

This pattern reflects the effect of private DI take-up on the number and composition of public DI claimants. As public benefits rise, high-income individuals predominantly

Figure 4: Welfare effects of private DI markets

The figure below presents the consumption-equivalent variation (CEV) for having private DI markets under alternative policy DI policies (benefit generosity $\in [-25\%, 25\%]$, rejection rates $\in [-50\%, 50\%]$). The CEV reflects the percent of annual consumption an individual would forgo to have a private DI market relative to only a public mandate, holding the public DI schedule fixed. Positive values indicate welfare gains from having a private DI market. The results are based on $N = 16,000$ agents and impose revenue neutrality.



buy private DI. Many of them would have continued working in the absence of private DI, but with coverage, they exit the labor force and claim public DI. This imposes a fiscal externality and regressive redistribution via public DI that erodes the welfare gains from more generous public insurance. At generous benefit levels, abolishing private DI can reduce the fiscal externality and eliminate the regressive redistribution to high-income individuals via public DI, thus improving welfare.

Conversely, when public benefits are reduced, private DI take-up broadens, especially among low-income individuals. Since private DI offers them meaningful additional insurance, while hardly distorting their labor supply incentives once disabled, welfare improves. In addition, the weakening selection on income implies that the fiscal externality and regressive redistribution to high-income individuals via public DI are limited, further boosting welfare. However, if benefits fall too much, even these channels cannot offset the welfare loss from public DI cuts.

Panel (b) shows the CEV for changes in rejection rates. Private DI enhances welfare for most of the rejection rate changes considered. Only at very high rejection rates does abolishing the private market improve outcomes.

The mechanism is identical to before: higher public rejection rates deter public DI applications and claims but strengthen selection on income into private DI. Private DI take-up becomes concentrated among high-income individuals with a stronger retirement motive, who subsequently attempt to access public DI. This spillover raises public costs despite fewer approved applicants. In contrast, in a public-only system, these same

individuals would remain in the labor force. Hence, when rejection rates are high enough, the fiscal externality from private DI outweighs its insurance value and the welfare gains from a stricter public system.

The moral hazard effects documented here are in line with other settings where public and private insurance overlap. For example, Cabral and Mahoney (2018) find that Medigap coverage raises U.S. Medicare costs by 22%, and Landais et al. (2021) show that moral hazard explains over half of higher unemployment risk among privately insured Swedish workers. In private long-term care insurance, there is significant moral hazard in home care use (Brown and Finkelstein, 2008; Konetzka et al., 2019). This paper provides the first structural estimate of moral hazard in long-term private DI, reinforcing the broader lesson that supplemental private insurance imposes a significant fiscal externality on public programs with consequences for their design.

In conclusion, a dual insurance system does not uniformly enhance welfare. It improves outcomes when public benefits are modest or when rejection rates are moderate, cases where the fiscal externality stemming from private DI remains contained. However, under generous public benefits or strict eligibility rules, private DI imposes a significant fiscal externality undermining the welfare gains from the reform to the public system. In such cases, restricting private DI access may be welfare-enhancing.

6.3 Policy Lessons

This paper documents three critical channels through which private DI interacts with public DI systems, each having important fiscal and distributional implications for policy design.

First, private DI induces moral hazard that raises public DI claims and costs. Based on my estimates, private DI increased German public DI expenditures by approximately €416 million in 2013, due to both increased program uptake and lower income tax revenue. Similar effects have been found in Canada, where employer-provided short-term DI increased long-term public DI enrollment by over 18,000 individuals, raising costs by \$230 million (Stepner, 2019). Failing to account for this interaction leads to underestimating the true fiscal burden of public DI.

Second, private DI alters the composition of public DI claimants. High-income individuals – more likely to hold private DI – are also more likely to use private DI as a pathway to public DI. This amplifies fiscal externalities and redistributes public DI resources regressively, as low-income workers effectively subsidize higher-income claimants. Policymakers designing public DI schedules must therefore internalize how private DI take-up responds to and reshapes the public claimant pool.

Third, these effects fundamentally change the outcomes of public DI reforms. Accounting for private DI, the welfare improvements from public DI reforms are muted, especially for low- and middle-income individuals. Strong income-based selection further

concentrates benefits among high-income insured, limiting redistributive effectiveness and constraining the planner’s policy space. For the same reasons, a dual insurance system does not uniformly improve welfare and restricting private DI access may enhance welfare.

These findings generalize beyond Germany. Private DI markets exist in most OECD countries, and the German system – where individual private DI only covers earnings loss due to disability and is not linked to public benefits (DI, health insurance, etc.) – is relatively clean for identification (see Section 2). In systems with bundled (e.g., with pensions) or employer-provided DI³⁶, or where private DI is a secondary payer – requiring public DI application and offsetting benefits dollar-for-dollar as in the U.S. and Canada – moral hazard and regressive redistribution are likely stronger. Hence, my results likely constitute a conservative lower-bound estimate for these settings.

As a result, existing policy evaluations that abstract from private DI likely overstate the net welfare gains of generous public DI schemes while underestimating the program cost. For instance, Low and Pistaferri (2015) and Deshpande and Lockwood (2021) show substantial welfare gains from public DI for low-income, low-education, or low-productivity individuals in the U.S. However, given the 34% private DI take-up rate in the U.S. and its strong income-based selection (BLS, 2020), my model suggests that these welfare estimates may be upward-biased while public DI costs and the impact of regressive redistribution due to high-income individuals’ private DI take-up are underestimated.

While estimating a GE model – incorporating supply-side responses to public DI schedules and alternative institutional settings – would be ideal, the available data do not allow for joint estimation of supply- and demand-side behavior. Despite covering several public reforms which increased private DI take-up, the insurer did not respond to these reforms. However, observing supply-side responses is crucial to discipline a GE model, especially because realistic (risk) pricing of endogenous DI contracts under rich heterogeneity poses a complex computational challenge.³⁷

Hence, I focus on the demand side to credibly estimate private DI take-up and its externalities on public DI programs. Understanding demand is a necessary first step toward a complete GE framework. My results highlight the critical trade-off for the insurance-incentive effects of private DI: while private DI expands individual insurance, it imposes a fiscal externality on public DI, thus affecting its outcomes. These results are key inputs for welfare analysis such as sufficient statistics approaches (Haller et al., 2024) or the marginal value of public funds (e.g. Hendren and Sprung-Keyser (2020); Seibold et al. (forthcoming)). Incorporating supply-side responses and regulatory design

³⁶While (individual) take-up responses to public DI reforms might be weaker for employer-provided DI, the income gradient is usually steeper (e.g. in the US), as mostly high-income jobs come with private DI coverage. Since high-income individuals exhibit stronger moral hazard, the fiscal externality is still substantial.

³⁷While Braun et al. (2019) and Fischer et al. (2023) solve general equilibrium models of private long-term care and disability insurance, respectively – focusing on administrative costs, private information, and means-tested transfers – they do not formally estimate these models, citing the high computational intensity involved.

is a promising avenue for future work³⁸.

In conclusion, private DI imposes a fiscal externality on public DI that distorts public DI's intended insurance functions. Depending on the policy environment, a dual system can improve or reduce welfare. When benefits are modest or screening stringency is moderate, private DI expands the space for cost-saving public reforms without harming welfare. For instance, Figure 5 shows that cutting public DI by 20% reduces average costs by €99 per person-year while still improving welfare – even under a dual insurance regime – highlighting that cost-saving reforms remain feasible despite the externalities induced by private DI. However, at high public benefit generosity or under tight screening, private DI can undermine reform goals. Policymakers must therefore account not only for direct costs and benefits, but also for how private DI reshapes incentives, fiscal burdens, and distributional outcomes.

6.4 Robustness Exercises

The main results are robust to alternative modeling assumptions. Appendix Table A.6 presents estimates under three key extensions: (i) correcting for selection into employment following French (2005), (ii) allowing individuals to choose among multiple private DI contracts offering different replacement ratios, and (iii) incorporating spousal income as an exogenous household insurance mechanism. Parameter estimates remain largely stable across specifications, except when spousal income is included, which raises estimated risk aversion. This is consistent with added intra-household insurance reducing the value of private insurance³⁹.

I also re-run all counterfactuals with linear instead of lump-sum taxes and under the spousal income extension. Welfare effects (Appendix Figures A.4, A.5, A.8), labor supply, and private DI take-up (A.6, A.7) remain qualitatively and quantitatively similar to the baseline.

7 Conclusion

This paper provides novel evidence on the interaction between private and public DI. I show that while private DI expands individual insurance choice, it also introduces moral hazard, reducing labor supply, and increasing public DI claims, especially among high-income individuals who are more likely to have private DI. The moral hazard of private DI raise the fiscal cost of public DI and alter the welfare impact of policy reforms: Under generous public benefits or strict screening, private DI reduces welfare gains; but private

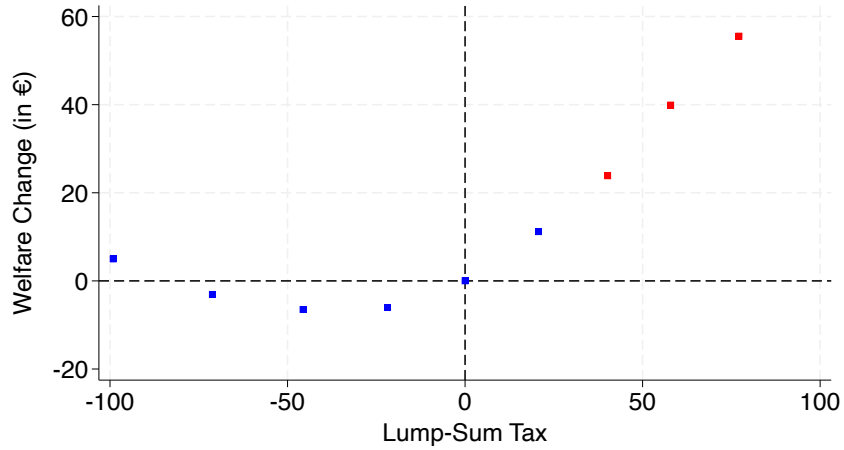
³⁸The focus on the demand side also explains why I refrain from studying alternative institutional designs that could limit the fiscal externality, for instance, by introducing an income test in public DI. Any such policy will affect the profitability of insurers, eliciting some response to maximize profits again. Keeping the supply side fixed, I cannot study the effect of such policies in my model.

³⁹Since private insurance is also unfairly priced, this is even more true.

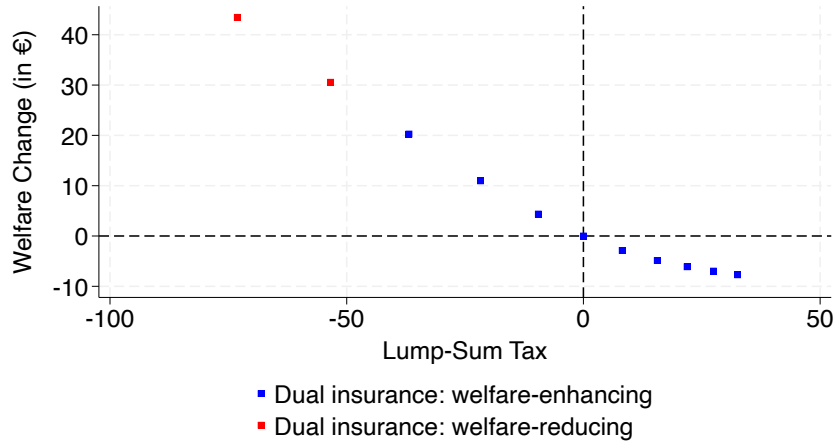
Figure 5: Cost-Welfare Comparison of private DI

The figure below presents the cost (€ of tax per person-year) and the welfare (€ of annual consumption an individual is willing to forgo to move to the new policy relative to the Status Quo) for the public DI reforms from Section 6.1 and 6.2. Positive welfare values imply that the policy change enhances welfare represented by the squares above the horizontal '0'-line (Section 6.1). If a dual insurance system is welfare-enhancing over only a public mandate (Section 6.2), the square is blue and red else. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

(a) Changes in benefit generosity



(b) Changes in rejection rates



DI mitigates and can even offset welfare losses from benefit cuts or looser screening by providing additional insurance, especially to lower-income individuals. As a result, whether private DI complements or undermines public DI depends critically on the policy environment.

These results generalize beyond Germany. As many OECD countries seek to contain rising public DI expenditures, private DI may offer a valuable tool to support fiscal consolidation while limiting welfare losses. However, failure to account for its moral hazard may exacerbate rather than alleviate public costs, especially in systems with

generous benefits or secondary payer rules, as in the US and Canada. Policy evaluations that abstract from private DI likely overstate the net welfare gains of generous public DI schemes while underestimating the program cost.

This paper takes a first step to advance our understanding of the interaction between private and public DI by estimating demand side behavior and quantifying the externalities imposed by private DI, which serve as critical inputs for welfare calculations in sufficient-statistic or marginal value of public funds approaches (e.g. Haller et al., 2024; Hendren and Sprung-Keyser, 2020; Seibold et al., forthcoming). Embedding this analysis within a general equilibrium framework – endogenizing contract pricing and insurer behavior – would be ideal but is precluded by data limitations. Extending this framework to include endogenous contracts and supply-side responses remains a promising direction for future work.

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A Appendix: Additional Tables and Graphs

Table A.1: Private DI data: Summary statistics

The table below shows summary statistics for the private insurance data under alternative sample restrictions. Column (1) displays the sample means for the full sample. Column (2) presents the cleaned sample, column (3) the baseline sample for men and column (4) the corresponding estimation sample. The corresponding sample selection criteria is shown in the lower panel. The sample window is 1966 to 2017 in column (1), (2), and (3) and 2001 to 2017 in column (4). Data Appendix [S1.1](#) provides further details on the cleaning steps and data preparation.

	(1)	(2)	(3)	(4)
Age	40.02	39.83	41.01	43.29
Age: Purchase	29.68	31.54	32.54	34.63
Age: Purchase (Median)	29.00	30.00	32.00	34.00
Age: Contract end	62.55	62.79	62.68	62.60
Benefit	16486.74	17579.70	19157.66	20558.52
Income	52805.83	51033.95	56237.01	59602.74
Replacement ratio	0.34	0.36	0.35	0.36
Risk Group	2.27	2.34	2.34	2.22
Share: Disabled	0.02	0.01	0.01	0.01
<i>Sample selection criteria</i>				
Stand-alone DI	0.55	1.00	1.00	1.00
Male	0.61	0.57	1.00	1.00
Share: Cancel	0.10	0.10	0.10	0.00
Share: Bought before 2001	0.14	0.01	0.01	0.00
Share: Age Purchase < 25	0.26	0.18	0.15	0.00
Share: Miners	0.00	0.00	0.00	0.00
# Obs.	Confidential	42.11%	23.96%	99,441

Table A.2: EVS: Summary Statistics

The table presents summary statistics of the Income and Consumption Survey (EVS). The first column shows the statistics for the pooled sample after dropping self-employed, civil servants, people in education, or younger than 25. The second column summarizes the estimation sample, which I use to construct the moments for the method of simulated moments approach. The third column shows statistics for the estimation sample used to compute the private DI moments, i.e., the 2013 wave for people aged 25 to 35. Monetary values are converted to 2013 prices. Data Appendix [S1.2](#) provides further details on the cleaning steps and data preparation.

	Pooled Sample	Estimation Sample	Estimation Sample 2013
Gross labor income (€/year)	22672.40 (23165.15)	23395.63 (24415.87)	33811.75 (18261.06)
Assets (€)	150264.69 (249916.51)	170810.07 (266554.50)	78861.11 (164288.30)
Age	51.13 (15.90)	52.79 (15.71)	30.85 (2.96)
private DI owners	0.24 (0.43)	0.25 (0.43)	0.48 (0.50)
Family Size	2.20 (1.06)	2.39 (1.05)	2.25 (1.14)
Male HH heads	0.76 (0.43)	1.00 (0.00)	1.00 (0.00)
Married	0.74 (0.44)	0.86 (0.35)	0.68 (0.47)
Observations	112,918	87,286	1,963

Table A.3: Sample Restriction and Composition

The table below summarizes the key variables for the SIAB under different sets of sample selection criteria. Column (1) displays the summary statistics for the full sample of benefit recipients or employed individuals. Column (2) presents the baseline sample after imposing some sample selection criteria (age, no non-standard work) and column (3) shows the estimation sample for the labor moments. Column (4) presents the summary statistics for the subsample of employed individuals and column (5) summarizes the key variables for the estimation sample (men) with non-missing risk-group information. The sample window is 1992 to 2017 for Column (1) and (4), and 2001 to 2017 for Column (2), (3), and (5). Data Appendix [S1.3](#) provides further details on the cleaning steps and data preparation.

	(1)	(2)	(3)	(4)	(5)
Age	39.15	39.90	39.91	41.15	41.44
Spell-duration	187.26	172.42	169.97	294.47	300.38
Annual income	32816.41	32822.24	38506.84	34565.07	38351.23
Male	0.55	0.55	1	0.55	1
Risk Group	3.21	3.22	3.36	3.04	3.14
<i>Sample selection criteria</i>					
Share: Occ. merged from risk-table	0.97	0.98	1	1	1
19 < age < 66	0.98	1	1	0.99	1
Temporary worker	0.01	0	0	0.01	0
Military personal	0	0	0	0	0
Time period	1992-2017	2001-2017	2001-2017	1992-2017	2001-2017
# Obs.	33,952,157	23,195,801	12,510,926	10,794,985	5,079,427

Table A.4: Summary Statistics by private DI take-up

The table summarizes the estimation sample for the private DI moments. Column (1) shows the summary statistics for people who do not buy private DI. Column (2) reports the respective statistics for people who have private DI. The sample is restricted to male household heads, who are 25 to 35 years old and work in the private sector. All monetary values are converted to 2013 values. (Source EVS 2013).

	(1) w/o private DI	(2) with private DI
Gross labor income (€/year)	28450.67 (17300.05)	39591.33 (17498.82)
Assets (€)	59115.59 (168035.42)	100148.04 (157488.61)
Age	30.70 (3.02)	31.01 (2.88)
Family Size	2.18 (1.18)	2.33 (1.09)
Some College	0.38 (0.49)	0.49 (0.50)
Married	0.62 (0.48)	0.74 (0.44)
Observations	952	1011

Table A.5: Targeted data moments, Variances (weights) and Simulated Moments from the Model

The table below shows the targeted moments (data), their variance (data), and the corresponding simulated moments from the model estimation. The difference between the data moment and the simulated moment is weighted by the inverse of the variance in the estimation. The final column also shows the standard errors for each moment from the data. The standard error for the median is computed via bootstrapping (250 populations, $N = 85,605$ each). Abbreviations are as follows: pDI = private DI, LFP = Labor Force Participation, FT = Full-time, PT = Part-Time.

Moment	Data	Variance	Simulation	Standard Error
pDI mean	0.5055	0.0002	0.4888	0.0115
pDI, 1	0.3389	0.0006	0.2922	0.0219
pDI q2	0.4866	0.0007	0.4930	0.0231
pDI q3	0.5735	0.0005	0.5706	0.0229
pDI q4	0.6659	0.0006	0.5993	0.0218
LFP 29	0.9352	0.0000	0.9621	0.0007
LFP-FT 29	0.8556	0.0000	0.9526	0.0010
LFP-PT 29	0.0796	0.0000	0.0094	0.0008
LFP 33	0.9451	0.0000	0.9460	0.0006
LFP-FT 33	0.8827	0.0000	0.9359	0.0009
LFP-PT 33	0.0624	0.0000	0.0100	0.0007

continued

Table A.5 continued

Moment	Data	Variance	Simulation	Standard Error
LFP 37	0.9490	0.0000	0.9533	0.0006
LFP-FT 37	0.8964	0.0000	0.9458	0.0008
LFP-PT 37	0.0527	0.0000	0.0076	0.0006
LFP 41	0.9516	0.0000	0.9547	0.0006
LFP-FT 41	0.9026	0.0000	0.9486	0.0008
LFP-PT 41	0.0490	0.0000	0.0060	0.0006
LFP 45	0.9514	0.0000	0.9519	0.0005
LFP-FT 45	0.9024	0.0000	0.9476	0.0008
LFP-PT 45	0.0490	0.0000	0.0043	0.0005
LFP 49	0.9506	0.0000	0.9412	0.0006
LFP-FT 49	0.9002	0.0000	0.9382	0.0008
LFP-PT 49	0.0505	0.0000	0.0030	0.0006
LFP 53	0.9469	0.0000	0.9259	0.0006
LFP-FT 53	0.8936	0.0000	0.9243	0.0009
LFP-PT 53	0.0533	0.0000	0.0016	0.0006
Mean Assets 25-27	54352.7100	10600000	3893.8106	3008.9840
Mean Assets 28-30	63104.5800	5759191	16893.9721	1942.5970
Mean Assets 31-33	83752.0700	5970413	33583.2274	1842.4670
Mean Assets 34-36	107676.0000	4444191	48585.3495	1838.5780
Mean Assets 37-39	123851.2000	4931617	63654.3609	1862.8580
Mean Assets 40-42	141030.0000	6029934	80449.3448	1930.3220
Mean Assets 43-45	152744.8000	6329157	98114.6752	2105.5640
Mean Assets 46-48	163755.1000	7277397	115676.5843	2300.3550
Mean Assets 49-51	169032.0000	8348281	133295.2436	2505.9750
Mean Assets 52-54	186003.6000	12800000	156998.9677	2866.2310
Mean Assets 55-57	195703.9000	13200000	179320.3878	3050.5460
Mean Assets 58-60	201794.1000	12700000	197789.0023	2978.2300
Mean Assets 61-63	202461.0000	12900000	210806.1951	3035.4440
Mean Assets 64-66	195975.4000	10900000	215155.8184	2760.5610
Mean Assets 67-69	199461.3000	10100000	206470.9001	2807.3580
Median Assets 25-27	0.5000	0.0002	0.1815	0.0010
Median Assets 28-30	0.5000	0.0001	0.3393	0.0007
Median Assets 31-33	0.5000	0.0001	0.3770	0.0006
Median Assets 34-36	0.5000	0.0001	0.3620	0.0005
Median Assets 37-39	0.5000	0.0001	0.3458	0.0005
Median Assets 40-42	0.5000	0.0001	0.3436	0.0005
Median Assets 43-45	0.5000	0.0001	0.3670	0.0005
Median Assets 46-48	0.5000	0.0001	0.3769	0.0005
Median Assets 49-51	0.5000	0.0001	0.3906	0.0006
Median Assets 52-54	0.5000	0.0001	0.4221	0.0006
Median Assets 55-57	0.5000	0.0001	0.4550	0.0006

continued

Table A.5 continued

Moment	Data	Variance	Simulation	Standard Error
Median Assets 58-60	0.5000	0.0001	0.4655	0.0006
Median Assets 61-63	0.5000	0.0001	0.4943	0.0006
Median Assets 64-66	0.5000	0.0001	0.5101	0.0006
Median Assets 65-69	0.5000	0.0001	0.5081	0.0005

Table A.6: Robustness of parameter estimates to model assumptions

The table below shows the model parameter estimates derived under different assumptions relative to the baseline model. The second column presents the baseline estimates. The third column shows the parameter estimates controlling for selection into employment following French (2005). The fourth column shows the parameter estimates if people can choose from five different private DI contracts, i.e. five different replacement ratios [0.30, 0.33, 0.36, 0.39, 0.42]. Note that this increases the computational time by a factor of 19. The fifth column presents the parameter estimates when spouses contribute to the household income (and thus act as informal intra-household insurance).

Parameter	Baseline	Selection into employment	Menu of contracts	With spousal income
Risk aversion γ	3.877	3.413	3.199	7.011
Consumption weight κ	0.688	0.684	0.612	0.707
LFP cost θ	0.383	0.502	0.354	0.237
Disutility from bad health φ	0.127	0.159	0.159	0.066

Table A.7: Parameter sensitivity to targeted moments

The table below shows the sensitivity of each utility parameter estimate concerning the moments used in the method of simulated moments approach. They are computed following Andrews et al. (2017). The values document how mismeasuring a given moment alters the parameter estimate by $\delta = \text{value} \times \text{measurement error}$, such that the correct value would be parameter + δ . Besides, the sensitivity estimates are informative about the relative importance of each moment for identifying the respective parameter. Abbreviations are as follows: pDI = private DI, LFP = Labor Force Participation, FT = Full-time, PT = Part-Time.

Moment	γ	κ	θ	φ
Mean pDI	-0.0387	0.6843	1.3714	0.0032
q0	-0.2371	0.0649	0.0952	0.0038
q25	-0.1192	-0.1639	-0.3523	0.0121
q50	3.9417	-0.3217	-0.6789	-0.1827
q75	-3.3440	1.2073	2.5148	0.1565

continued

Table A.7 continued

Moment	γ	κ	pc	hc
LFP1	-1.6237	-0.0445	-1.7980	-0.2353
FT1	-0.9048	-0.0139	-0.9452	-0.1249
PT1	0.1159	-0.0150	0.0334	0.0064
LFP2	-1.6109	0.2686	-0.2252	-0.0679
FT2	-1.3474	0.2759	0.0622	-0.0306
PT2	0.0180	-0.0883	-0.4146	-0.0429
LFP3	-1.1765	0.0555	-0.8649	-0.1239
FT3	-0.8068	0.0274	-0.6442	-0.0903
PT3	0.2299	0.0082	0.2602	0.0336
LFP4	-0.8590	0.1524	-0.0670	-0.0301
FT4	-0.7526	0.1335	-0.0602	-0.0266
PT4	0.3356	-0.0595	0.0293	0.0123
LFP5	-0.3965	0.0791	0.0123	-0.0093
FT5	-0.3564	0.0612	-0.0366	-0.0133
PT5	0.3014	-0.0366	0.1037	0.0188
LFP6	-0.3581	0.0202	-0.2434	-0.0354
FT6	-0.2807	0.0253	-0.1447	-0.0229
PT6	0.1786	-0.0297	0.0253	0.0076
LFP7	-0.3532	0.0040	-0.3198	-0.0434
FT7	-0.2425	0.0044	-0.2103	-0.0287
PT7	0.0104	-0.0027	-0.0058	-0.0005
Mean1	-0.0000	0.0000	-0.0000	-0.0000
Mean2	-0.0000	0.0000	-0.0000	-0.0000
Mean3	-0.0000	0.0000	-0.0000	-0.0000
Mean4	-0.0000	0.0000	-0.0000	-0.0000
Mean5	-0.0000	0.0000	-0.0000	-0.0000
Mean6	-0.0000	0.0000	-0.0000	-0.0000
Mean7	-0.0000	0.0000	-0.0000	-0.0000
Mean8	-0.0000	0.0000	-0.0000	-0.0000
Mean9	-0.0000	0.0000	-0.0000	-0.0000
Mean10	-0.0000	0.0000	-0.0000	-0.0000
Mean11	-0.0000	0.0000	-0.0000	-0.0000
Mean12	-0.0000	0.0000	-0.0000	-0.0000
Mean13	-0.0000	0.0000	-0.0000	-0.0000
Mean14	-0.0000	0.0000	-0.0000	-0.0000
Mean15	-0.0000	0.0000	-0.0000	-0.0000
Median1	-0.0024	-0.0001	-0.0028	-0.0004
Median2	-0.0066	0.0007	-0.0032	-0.0005
Median3	-0.0039	0.0003	-0.0021	-0.0003
Median4	-0.0081	0.0018	0.0009	-0.0001

continued

Table A.7 continued

Moment	γ	κ	pc	hc
Median5	-0.0063	0.0015	0.0013	-0.0000
Median6	-0.0038	0.0008	0.0006	-0.0000
Median7	-0.0101	0.0009	-0.0046	-0.0007
Median8	-0.0061	0.0010	-0.0009	-0.0002
Median9	-0.0081	0.0015	0.0002	-0.0002
Median10	-0.0094	0.0014	-0.0019	-0.0004
Median11	-0.0104	0.0013	-0.0032	-0.0006
Median12	-0.0105	0.0016	-0.0019	-0.0005
Median13	-0.0104	0.0015	-0.0021	-0.0005
Median14	-0.0117	0.0018	-0.0017	-0.0005
Median15	-0.0123	0.0021	-0.0010	-0.0004

Figure A.1: Welfare, labor force participation, and private DI take-up for changes in public DI benefit generosity

The figure below presents the consumption-equivalent variation (CEV, panel (a)), the mean labor force participation of disabled individuals (panel (b)), and mean private DI ownership (panel (c)) for changes in public DI benefit generosity of $[-20\%, 20\%]$. The CEV measures the change in expected lifetime utility relative to the Status Quo in the share of annual consumption an individual is willing to forgo to move to the new system. A policy enhances welfare if the CEV is positive. All values are expressed in average (per period) consumption in 2013 Euros. Positive values imply a welfare improvement. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

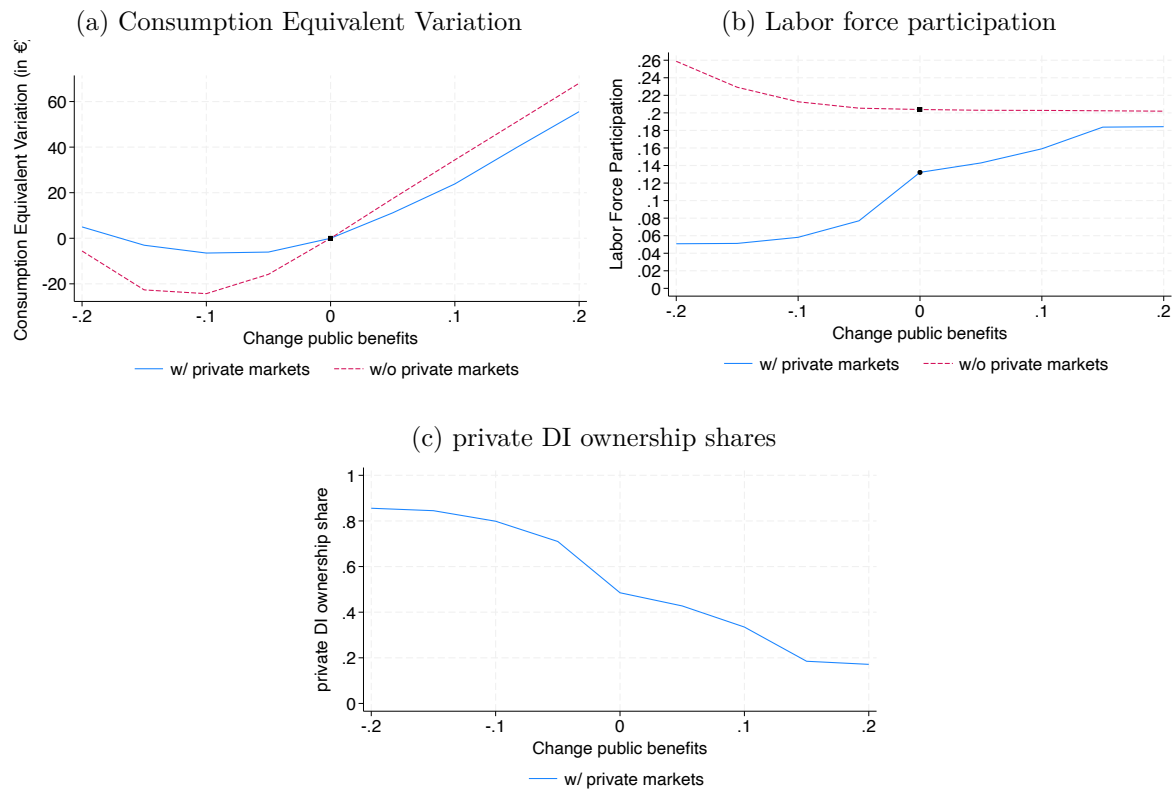


Figure A.2: Welfare, labor force participation, and private DI take-up for changes in public DI rejection rates

The figure below presents the consumption-equivalent variation (CEV, panel (a)), the mean labor force participation of disabled individuals (panel (b)), and the mean private DI ownership shares (panel (c)) for changes in the public DI rejection rates of $[-50\%, 50\%]$. The CEV measures the change in expected lifetime utility relative to the Status Quo in the share of annual consumption an individual is willing to forgo to move to the new system. A policy enhances welfare if the CEV is positive. All values are expressed in average (per period) consumption in 2013 Euros. Positive values imply a welfare improvement. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

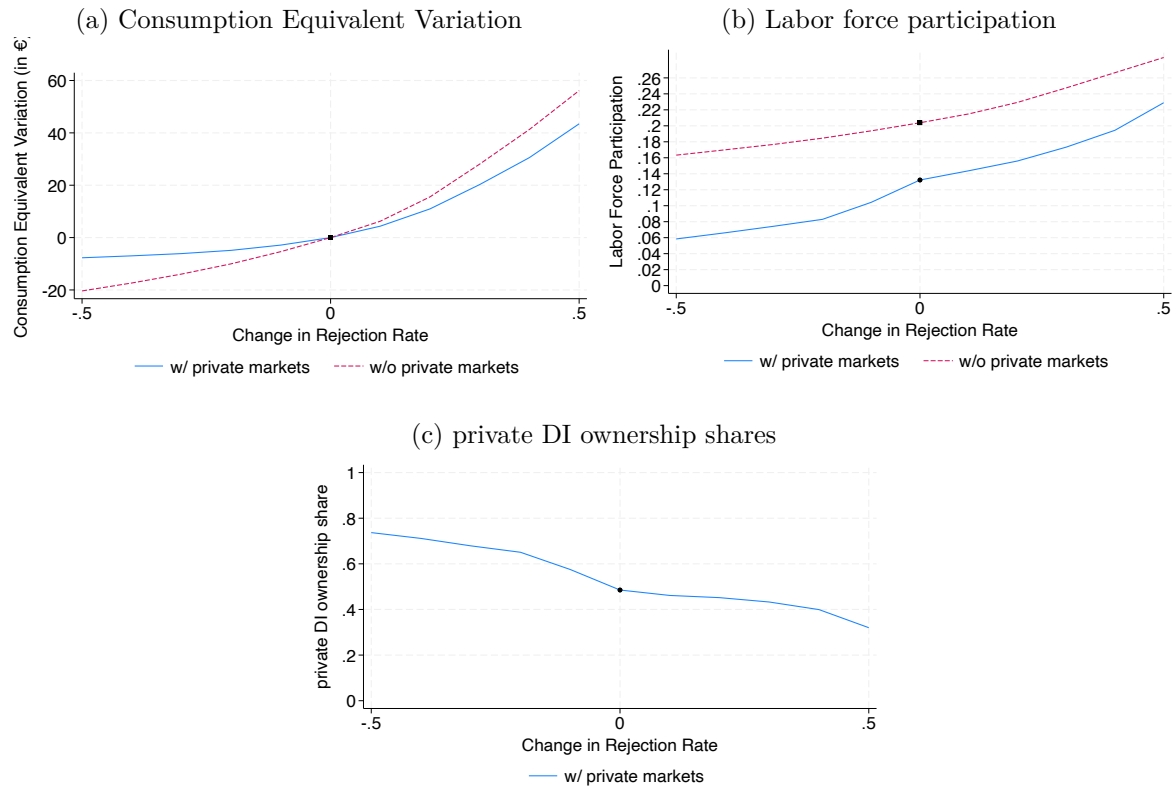


Figure A.3: Out-of-sample fit of model

The figure below presents the out-of-sample fit of simulated (blue) and data (black) moments not targeted in the estimation. Panel (a) shows the cumulative distribution of private DI benefits in the model and the data (Source: insurer data). Panel (b) shows the profile of full-time and part-time work between the ages of 25 to 60 (Source SIAB). Targeted moments are plotted in red. Panel (c) shows the mean income by age for the baseline sample from the data (black) and the simulations (blue)(Source: SIAB).

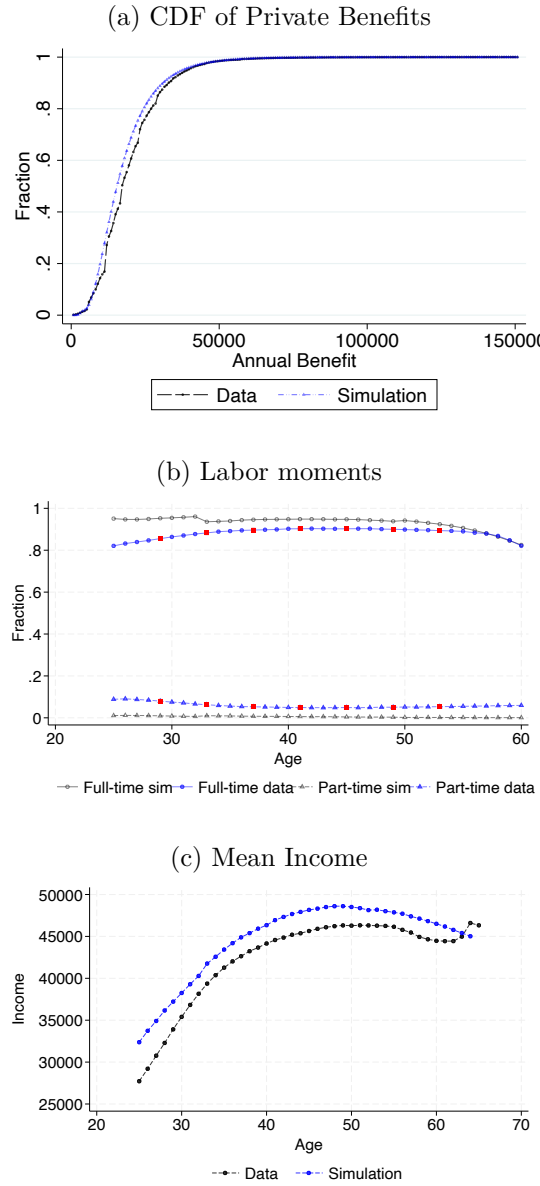


Figure A.4: Consumption - equivalent variation for changes in benefit generosity

The figure below presents the consumption-equivalent variation (CEV) for changes in the benefit generosity of $[-20\%, 20\%]$ for the baseline specification (a), for linear taxes (b), and when spouses contribute to the HH income (c). The CEV measures the change in expected lifetime utility relative to the baseline level (percentage change = 0) in the percentage of lifetime consumption an agent is willing to forgo to move to the alternative policy. Positive values imply a welfare improvement. All values are expressed in 2013 Euros. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

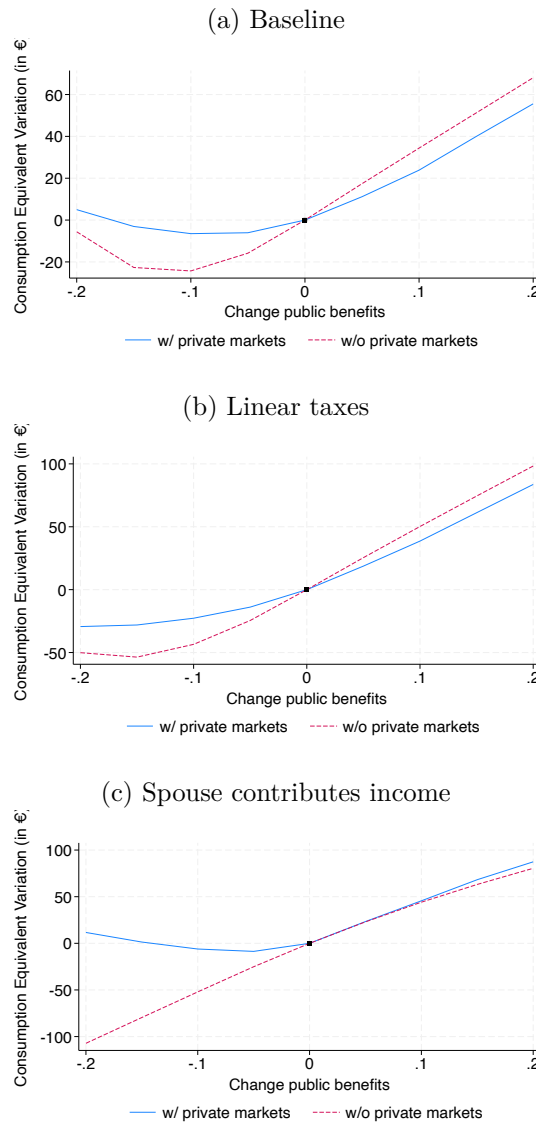


Figure A.5: Consumption - equivalent variation for changes in rejection rates

The figure below presents the consumption-equivalent variation (CEV) for changes in the rejection rate of $[-50\%, 50\%]$ for the baseline specification (a), for linear taxes (b), and when spouses contribute to the HH income (c). The CEV measures the change in expected lifetime utility relative to the baseline level (change in rejection rate = 0) in the percentage of lifetime consumption an agent is willing to forgo to move to the alternative policy. Positive values imply a welfare improvement. All values are expressed in 2013 Euros. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

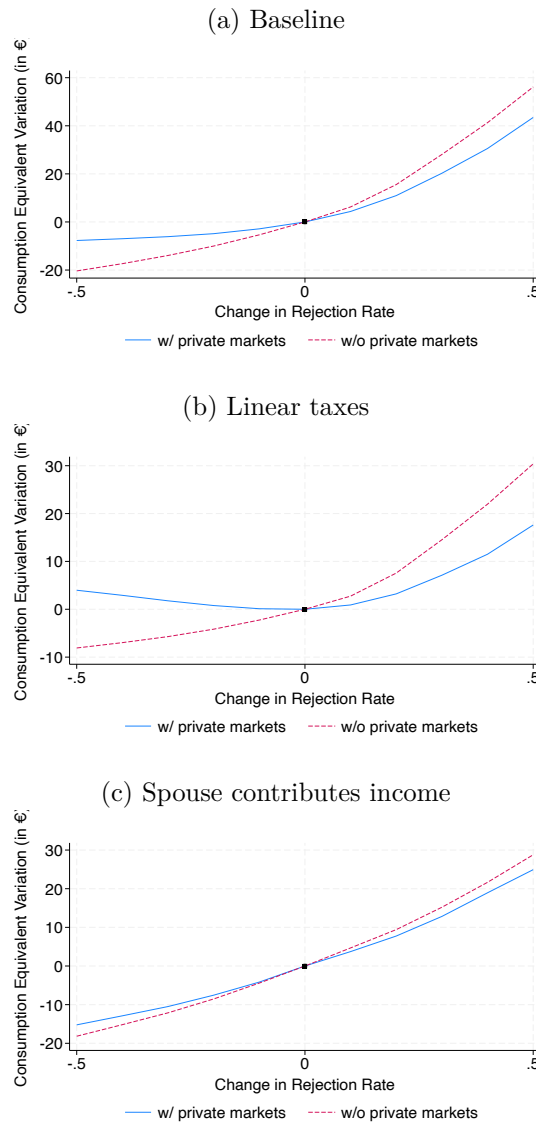


Figure A.6: Labor force participation and mean private DI shares for changes in benefit generosity

The figure below presents the mean labor force participation of disabled individuals and the mean private DI ownership shares for changes in the public DI benefit generosity of $[-20\%, 20\%]$. Panel (a) and (b) show the baseline results from the main text for the mean LFP and mean private DI shares respectively. Panel (c) and (d)/ Panel (e) and (f) present the results for the mean LFP and mean private DI shares if the government levies linear taxes to balance the budget/ when spouses contribute to the HH income. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

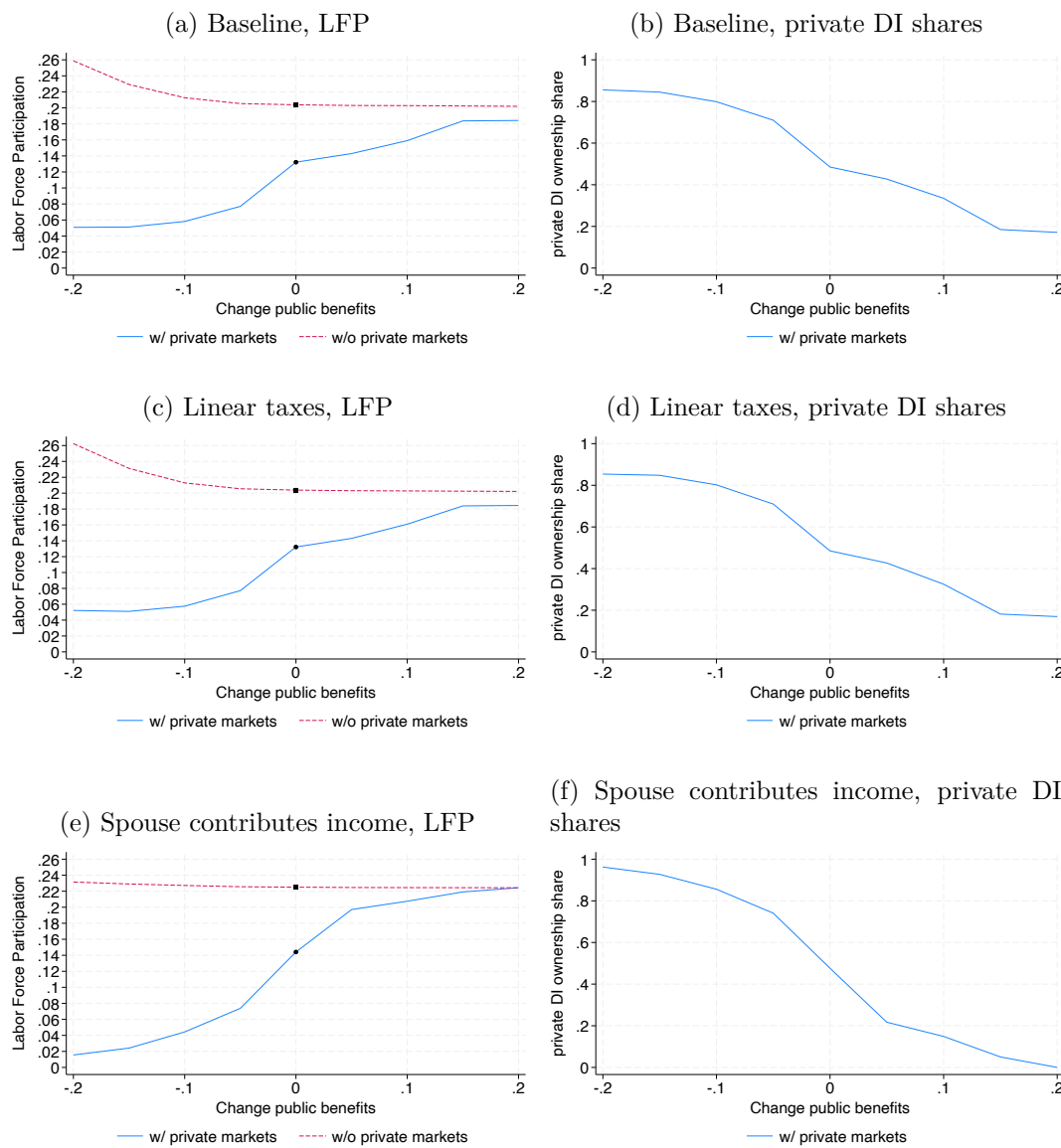


Figure A.7: Labor force participation and mean private DI shares for changes in the rejection rate

The figure below presents the mean labor force participation of disabled individuals and the mean private DI ownership shares for changes in the public DI rejection rates of $[-50\%, 50\%]$. Panel (a) and (b) show the baseline results from the main text for the mean LFP and mean private DI shares respectively. Panel (c) and (d)/ Panel (e) and (f) present the results for the mean LFP and mean private DI shares the government levies linear taxes to balance the budget/ when spouses contribute to the HH income. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.

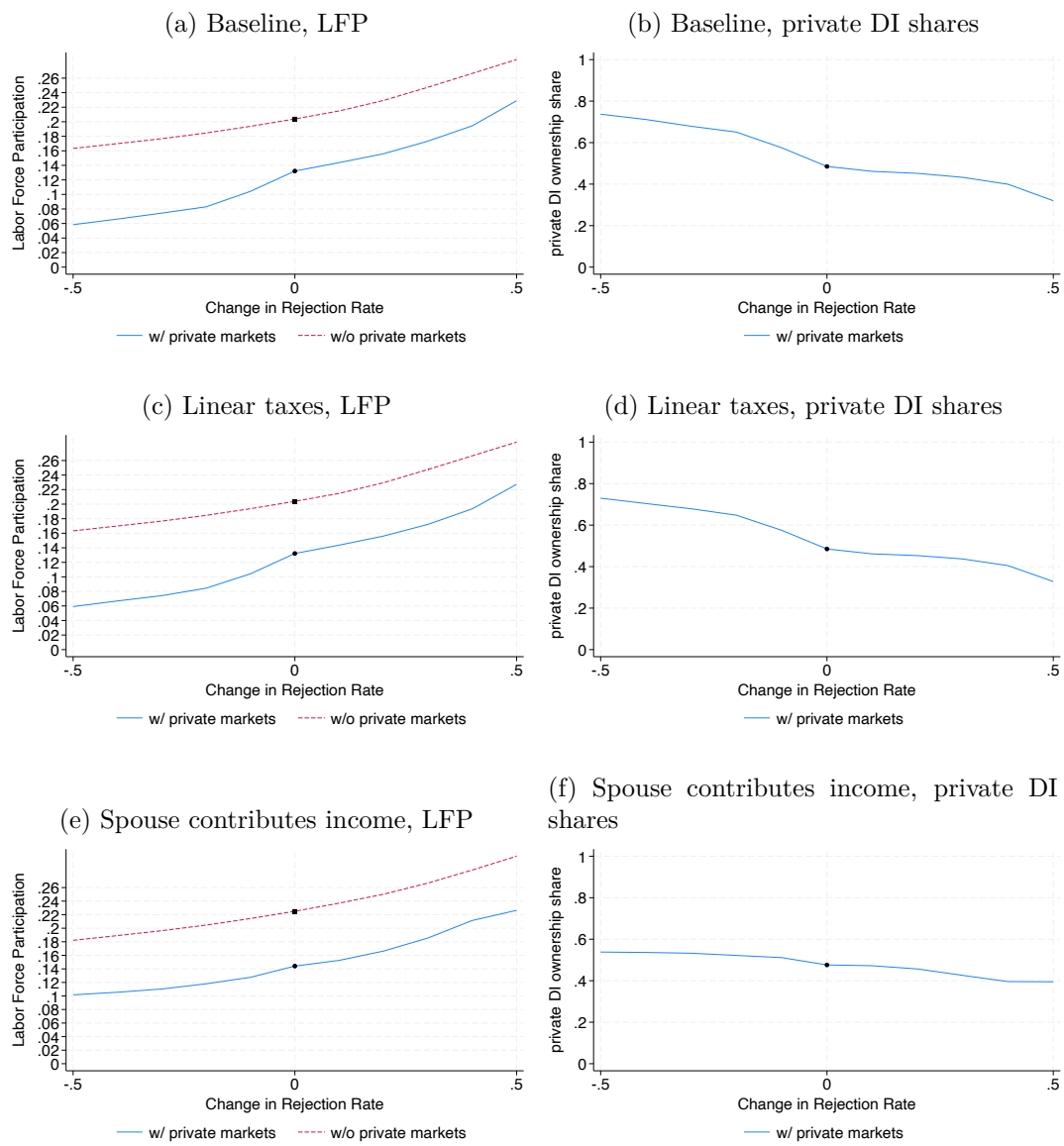
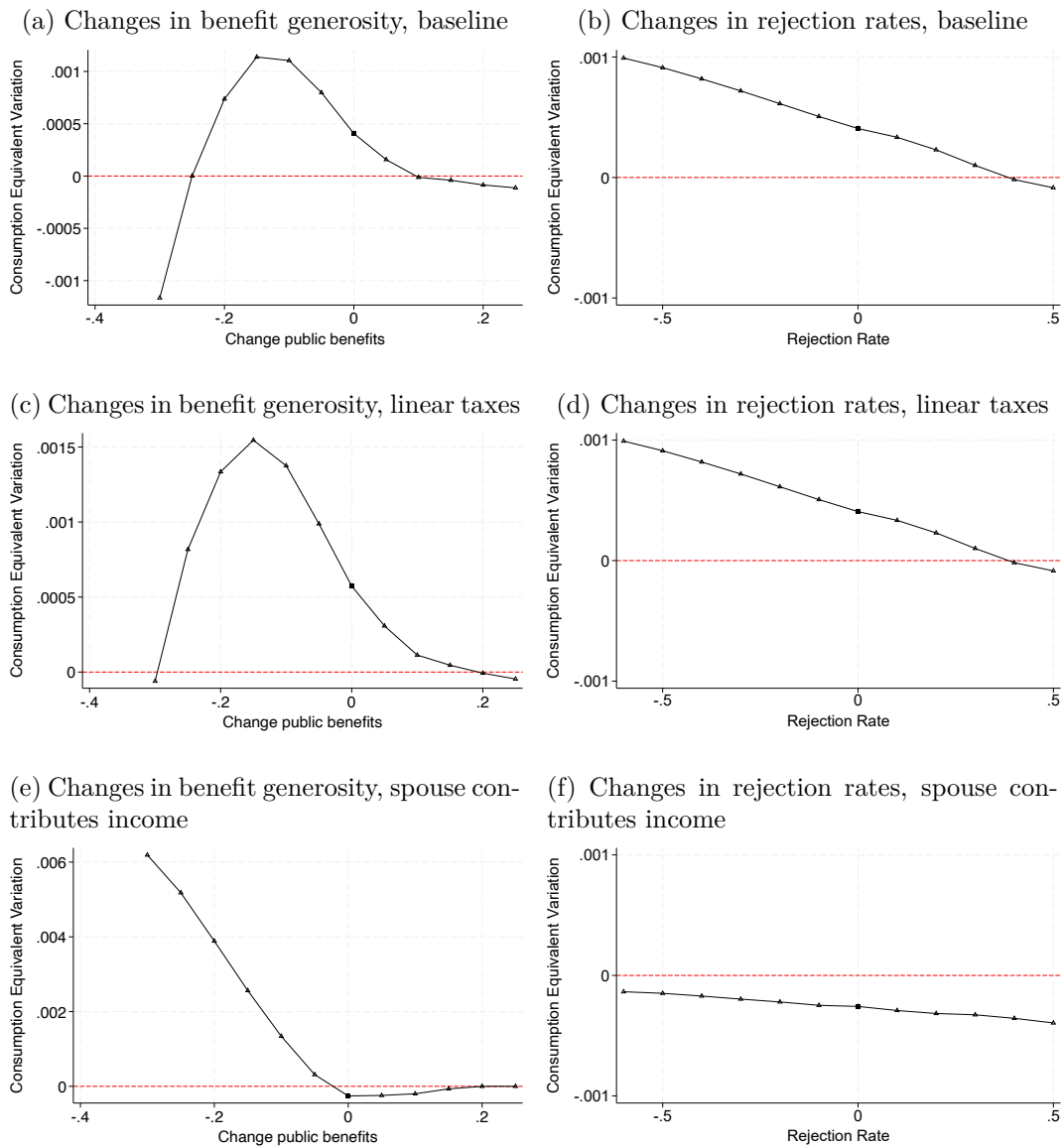


Figure A.8: Welfare effects of private DI markets

The figure below presents the consumption-equivalent variation (CEV) for allowing for private DI markets under alternative policy schedules. The first (second) column depicts the CEV for changes in public benefit generosity (rejection rates). The first row shows the results derived under the baseline model. The second and third rows show the results for when the government uses linear taxes to balance its budget and when spouses contribute to the HH income respectively. The CEV is expressed as the percent change of per-period consumption an agent is willing to forgo to have a private market by comparing the expected lifetime utility from having a private market to the one without a private market under the same public DI schedule. Positive values imply that private DI markets are welfare-enhancing under the considered policy schedule visually presented by the blue line being above the red '0'-line. The results are computed for a population of $N = 16,000$ individuals and under revenue neutrality.



B Appendix: Numerical Methods

This appendix gives details on the numerical approaches applied to estimate the fundamental preference parameters. I discuss the solution approach to the individual problem, the simulation of the individual profiles based on the model solution, and the method used to estimate the preference parameters - the Method of Simulated Moments approach.

B.1 Solution

The model described in section 3 needs to be solved numerically as no analytical solution exists. I apply a backward iteration approach: By backward iterating on the value function starting in the final period of the model (T), I obtain the value of the value function in T . I use this value to solve the maximization problem in period $T - 1$, and so on. Formally, the individual decision problem (eq. (1)) in T simplifies to the following problem (as death occurs with certainty in $T + 1$ leaving the individual with zero utility):

$$V(S_T) = \max_{c_T, A_{T+1}} U(c_T, L) \quad (\text{B.1})$$

where S_T is the set of state variables at time T . Given the per-period utility function $U(\circ)$ (eq. 4), I derive the policy functions $c_T(S_T)$ and $A_{T+1}(S_T)$ that maximize the value function $V(S_T)$ for any given values of state variables S_T . As detailed below, the maximization method relies on discretized state space grids. To obtain the value of $V(S_T)$ at any point in S_T , including off-grid points, an approximation approach is needed (detailed below), which yields the approximation $\hat{V}(S_T)$. The approximation is then used to solve the decision problem in period $T - 1$ and derive the corresponding policy functions $c_{T-1}(S_{T-1})$ and $A_T(S_{T-1})$:

$$V(S_{T-1}) = \max_{c_{T-1}, A_T} U(c_{T-1}, L) + s_{T-1} * \beta * \hat{V}(S_T | S_{T-1}) + (1 - s_{T-1}) * 0 \quad (\text{B.2})$$

where s_t denotes the survival probability conditional on having survived till period t .⁴⁰

This procedure is iterated backward to $t = 0$. For all ages below the statutory retirement age of 65 ($t < 40$), individuals also choose their labor supply. The state space expands to include (i) income risk from transitory and persistent shocks and (ii) the initial purchase decision of private DI at $t = 0$. I compute value functions separately by insurance status, and derive the take-up policy by comparing expected lifetime utility with and without private DI at $t = 0$: individuals purchase private DI iff the value with private DI exceeds that without, conditional on affording the premium.

To solve this model, I have to make some choices regarding (a) the discretization of the state space, (b) the integration over stochastic variables, (c) the approximation of the value function at each point of the state space, and (d) the implications for optimization.

(a) Discretization of the state space

The six state variables in my model are current assets, persistent and transitory income

⁴⁰In my baseline model, I abstract from mortality, so $s_t = 1 \forall t$.

shock realizations, current health, individual risk group, and (if disabled) public DI admission status. The first three variables are continuous, and need to be discretized.

Assets are placed on an equidistant grid with 64 grid points, bounded below by 0 (borrowing constraint), and above by the minimum of the maximal feasible lifetime income up to period t or €2,000,000 (ten times average retirement savings). The continuous stochastic income processes are discretized using the Tauchen method (Tauchen, 1986), with 21 and 19 equally spaced grid points for the persistent and transitory shocks, both normally distributed. The persistent shock process accounts for path dependency.

The remaining three state variables are discrete: disability status take three values, public DI admission is binary, and risk groups consist of five mutually exclusive categories.

The three choice variables are savings, labor supply, and the insurance decision (only at $t = 0$).⁴¹ Labor supply and insurance choice are already discrete, while savings is continuous but requires no discretization, as the optimal choice is obtained directly by maximizing the individual problem each period.

(b) Integration over stochastic values:

Solving the individual maximization problem requires evaluating the expected utility by integrating over the four stochastic variables during the working life – persistent and transitory income shocks, disability shocks, and public DI admission status – and over disability and survival shocks during retirement. All of these shocks are discrete: Disability, survival, and public DI admission shocks are discrete random variables, while persistent and transitory income shocks are discretized using the Tauchen method (Tauchen, 1986). Consequently, the integration of the value function over the discrete realizations of these stochastic outcomes is equivalent to computing the weighted sum over the value functions at these realizations. The weights correspond to the probability of each realization.

(c) Approximation of the value function

The results of the individual optimization problem are only derived for the subset of the discretized state space. However, solving the problem requires evaluating the value function for the entire state space. Thus, the value function is approximated at these off-grid points by applying multidimensional spline-evaluation for equidistant grids.⁴²

(d) Optimization

I solve the problem separately by private DI take-up. For each point of the discrete state space, I compute the optimal decision rules conditional on (not) having private DI.

Within each period, I compute the optimal savings choice separately for each labor supply decision. The resulting decision problem is then continuous in assets and solved using the Brent-Method. I evaluate which labor supply-asset choice maximizes the value function in that period (at fixed state-space points). The maximizing pair defines the policy functions (labor, assets) and value function for this state space point.

⁴¹Consumption is redundant since it is pinned down by the budget constraint in every period.

⁴²The routine is provided by Fehr and Kindermann <https://www.ce-fortran.com/toolbox/>

B.2 Simulation

After deriving the optimal decision rules for consumption $c_t(S_t)$, assets $A_{t+1}(S_t)$, leisure $l_t(S_t)$, and private DI take-up, I simulate the decisions of 16,000 households. I follow Eisenhauer et al. (2015) and simulate 25 different data sets to reduce the idiosyncratic errors introduced into the model by drawing from random distributions. The simulated moments are computed by averaging the respective moments across runs.

Within each run, I simulate the behavior of each individual as follows:

1. Initialize the simulations by setting decision paths for consumption, purchase decision, assets, labor supply to zero. Individuals enter in good health with no assets.
2. The risk group realizations are drawn from a uniform distribution.
3. The shock realizations (disability, persistent and transitory income, public DI admission) are drawn for all individuals in each period from the corresponding distributions (normal for continuous variables; uniform for binary variables).
4. The continuous gross income is computed based on the deterministic income process (eq. (5)) and the persistent and transitory shock realizations.
5. For the discrete disability and public DI admission shocks, an individual is assigned to a specific state if the shock realization does not exceed the probability of being in that state - e.g., an individual is in "good health" if the shock realization does not exceed the risk group-specific probability of being in good health⁴³.
6. After these initial steps, the simulation starts by determining if an individual buys private DI at $t = 0$. I evaluate the policy function given their assets and persistent and transitory shock realization using a spline evaluation for equidistant grids. If the resulting evaluation exceeds 0.5⁴⁴, the individual buys private DI, which determines the policy functions for the rest of their life.
7. The remaining decision profiles for $t = 0, \dots, 70$ are computed by repeating the following steps:
 - (a) (Only during working life:) Given risk group, current assets, income shock realizations, and disability status, I solve the individual labor supply decision by applying a spline evaluation for equidistant grids to interpolate the labor supply policy function. Individuals are assigned to the nearest neighbor (in absolute values) labor supply. Based on the labor supply decision, I compute the gross income and, conditional on bad health, benefit receipt. I pool all these incomes to compute the tax liability and the disposable income (net of taxes and social security contributions).

⁴³For instance, assume that the probability of being in good health in $t = 10$ is 0.8. An individual is assigned to the "good health" state in $t = 10$ if her shock realization is ≤ 0.8 .

⁴⁴The results are robust to other cutoffs between 0.4 and 0.6

- (b) I compute assets (and by the property of the budget constraint consumption). I apply the same spline interpolation approach conditional on current assets and income shock realizations. I verify that this amount of assets is feasible (i.e., the optimal assets do not exceed current savings plus disposable income).
- (c) Consumption is computed as the difference between disposable income, this period's savings, and the private DI premium (if bought and not claiming).

B.3 Estimation of preference parameters

The preference parameters – risk aversion γ , consumption weight κ , (dis-)utility from bad health φ , and labor force participation cost θ – are estimated via the Method of Simulated Moments (MSM) approach. The procedure minimizes the distance between data and simulated moments denoted by $\mathbf{G}$:

$$G(\gamma, \kappa, \varphi, \theta) = \Sigma^{data}(\gamma_0, \kappa_0, \varphi_0, \theta_0) - \Sigma^{sim}(\gamma, \kappa, \varphi, \theta) \quad (\text{B.3})$$

where $\Sigma^j, j = \{data, sim\}$, is an $N \times 1$ vector of the stacked moment conditions.

Two types of moments are used: (i) mean comparisons (M_t and $\hat{M}_t$) and (ii) median comparisons following French (2005).

$$\begin{aligned} M_t - \mathbf{E}[\hat{M}_t(\gamma, \kappa, \varphi, \theta)] &= 0 \\ 0.5 - \mathbf{E}[\mathbf{1}[A_{ia} \leq \text{median}(\hat{A}_{ia}(\gamma, \kappa, \varphi, \theta))]] &= 0 \end{aligned} \quad (\text{B.4})$$

where A_{it} denotes individual i 's assets in age bin a in the data. $\text{median}(\hat{A}_{ia}(\hat{\Upsilon}))$ denotes the median assets in age bin a from the simulated asset profiles $\hat{A}_{ia}(\hat{\Upsilon})$. $\mathbf{1}(\cdot)$ is an indicator function that takes the value 1 if the assets from the data are below the median assets in the simulations. The corresponding data moment is 0.5, i.e. 50% of assets are below the median assets (in the data).

The optimal preference parameters are then determined by solving:

$$\min_{\gamma, \kappa, \varphi, \theta} G(\gamma, \kappa, \varphi, \theta)'WG(\gamma, \kappa, \varphi, \theta) \quad (\text{B.5})$$

where W denotes the weighting matrix. I use the inverse of the variance matrix as the weighting matrix (Altonji and Segal, 1996), estimated from the data using bootstrapping. To put more weight on the private DI moments - the key moments in my estimation - I adopt the block-weighted adjustment of (Finkelstein et al. (2019)). This adjustment is necessary because private DI take-up is observed only in the 2013 EVS, while the sample size for the asset moments is 4 times (4 waves pooled), and for the labor supply moments (SIAB) almost 20 times as large. The block-weighting ensures that there enough weight is put on private DI take-up - the key moments - while preserving efficiency⁴⁵.

The optimization uses the Nelder-Mead simplex algorithm (Nelder and Mead, 1965), initialized with 150 random draws from the parameter space. The starting value is a

⁴⁵I re-scale by dividing the asset and labor market moments by their number of moments in each block (21 for labor market moments; 51 for the asset moments).

convex combination of the best-performing draws (smallest function value). To reduce the risk of local minima, I repeat the procedure across multiple subspaces, seeding each run with previous optima. This iterative search consistently recovers the global minimum.

C Appendix: German Institutional Setting

C.1 Income Taxation (2013 Tax Code)

The 2013 German tax schedule consists of five brackets with increasing marginal tax rates. The tax liability is rounded down to the next euro.

Income up to €8,130 is tax free. From €8130 to €13,469, the tax liability is:

$$Liability = (933.70 * \frac{(y_{it} - 8130.00)}{10,000} + 1,400.00) * \frac{(y_{it} - 8130.00)}{10,000},$$

where y_{it} denotes annual labor income. For €13,470 to €52,881.00, the tax liability is⁴⁶:

$$Liability = (228.47 * \frac{(y_{it} - 13,469.00)}{10,000} + 2,397.00) * \frac{(y_{it} - 13,469.00)}{10,000} + 1,014.00$$

For annual incomes between €52,881.00 and €250,730.00, tax liability is linear:

$$Liability = 0.42 * y_{it} - 8,196.00$$

Above €250,730.00, the marginal tax rate is 45% and the liability is:

$$Liability = 0.45 * y_{it} - 15,718.00$$

Married couples are assessed jointly. Their incomes are pooled, halved, taxed, and the resulting tax liability is doubled to yield the final household tax liability. Joint assessment is the default. In addition, a solidarity surcharge of 5.5% of the tax liability applies.

Pension and public DI benefits are partially tax-exempt, with the non-taxable fraction determined by the year of first receipt. For cohorts retiring in 2005 or earlier, 50% is exempt. For younger cohorts, the share declines by 2 p.p. per year until 2020 and by 1 p.p. thereafter, reaching zero in 2040. The taxable share is entered into the tax formula. Most pensions are small so most pensions remain in the lowest brackets.

Likewise, private DI benefits are partially taxable. The taxable fraction is increasing in the length of the benefit period (see section C.3). When both private and public DI benefit are received, the taxable shares are pooled to determine the tax liability.

C.2 Social Security Contributions

Social Security contributions (SSC) are levied at the individual level and split equally between employee and employer. Employers deduct contributions directly from gross

⁴⁶The formulas ensure that the tax liability is continuous at the upper bracket, and that the marginal tax rates are increasing in income.

wages and pay them to the relevant funds.

Employees contribute to the pension fund (18.9%), unemployment insurance (3%), health insurance (15.5%), and long-term care insurance (2.05%), amounting to roughly 40% of gross wages (20% paid by the employee). Pension and unemployment contributions apply only to workers, whilst all individuals pay health and long-term care contributions, including pensioners and DI recipients. Thereby, they pay SSC on their gross benefits and not only on the taxable share. Therefore, the taxable fraction only matters for income tax but not for SSC.

All SSC are subject to caps. In 2013, pension and unemployment insurance contributions were capped at €5,800 of monthly income and health and long-term-care insurance at €4000 per month. Above these thresholds, individuals pay the maximum contribution, regardless of additional income. These caps are adjusted annually.

A key distinction between public and private DI is that private DI recipients pay the full health and nursing insurance contributions, whereas public DI recipients only pay half (like employees). Individuals with both benefits only pay health and nursing insurance contributions on their public benefits. I account for these distinct cases.

C.3 Annuity Taxation

Private DI benefits are taxed according to the annuity taxation rules. The taxable income share depends on the length of the benefit receipt specified in the contract and is almost linear in it. The taxable fraction of private benefits is treated as regular labor income, and the income tax code applies. Social security contributions are paid on gross benefits, and not only the taxable fraction. The rules from the previous section apply: private DI recipients pay the full contribution rate for health and long-term-care insurance, while people receiving public DI or both benefits only pay the employee contribution.

C.4 Public DI and Pension Formula

Public DI and pension benefits are determined by four factors: (i) The sum of actual and hypothetical pension points, (ii) the discount factor, (iii) the pension value, and (iv) the claim size.

Pension points: Pension points are the sum of actual ($actPP$) and hypothetical pension points ($hypPP$). The actual pension points are the ratio of individual to average earnings ($\bar{y}$), capped at the earnings threshold y_{it}^{max} (€5800/month in 2013):

$$actPP_{it} = \min \left\{ \frac{y_{it}}{\bar{y}}, \frac{y_{it}^{max}}{\bar{y}} \right\}$$

Hypothetical points capture future contributions foregone due to disability. They equal the average of accumulated (monthly) pension points up to disability onset (T^k), multiplied by the remaining months until age 62 (the early retirement age):

$$hypPP_i = \left(\frac{1}{(T^k - T^0) * 12} * \sum_{j=0}^{T^k - T^0} actPP_{ij} \right) * (62 * 12 - T^k * 12) \quad (C.1)$$

where T^0 is the age at which an individual entered the labor force. Thus, younger DI claimants – who have lower past earnings and forgo higher wages at higher ages – accrue fewer points.

Discount factor: Pension benefits are reduced by 0.3% for each month claimed before age 63 years and 7 months, up to a maximum of 10.8%:

$$Disc_{it} = 1 - \min\{0.108, (63 * 12 + 7 - T^k * 12)\} \geq 0.892 \quad \forall t \quad (C.2)$$

Pension value: Pension points are converted into euros using a region-specific multiplier $PensVal_{it}$ (€28.14 in West, €25.74 in East Germany in 2013). I abstract from such distinctions.

Claim Size: Fully work-impaired individuals receive full benefits ($HM_{it} = 1$) while partially impaired receive half ($HM_{it} = \frac{1}{2}$).

The complete formula is:

$$DIb_{it} = \left(\sum_{j=0}^{T^k - T^0} actPP_{ij} + hypPP_i \right) * Disc_{it} * PensVal_{it} * HM_{it} \quad (C.3)$$

Pensions: Pension benefits are computed using the same formula as DI, but only actual pension points enter (C.3) and there are no partial claims ($HM_{it} = 1$). Pensions are discounted for claiming before the statutory retirement age using the same discount factor as DI benefits. Pensions are taxed identically to public DI benefits.

Conversion from DI to pension: At the statutory retirement age, DI benefits are converted into regular pensions. Benefits are recomputed, reflecting three adjustments: (i) the partial-claim factor is dropped, (ii) the discount factor is set to one (if previously less than one), and (iii) DI benefits are treated as labor income, which typically increases the accrued pension points. Hence, individuals usually experience an increase in benefits at retirement. In the model, pension benefits are recomputed at retirement and then held constant over the claiming period.

D Appendix: Estimation of stochastic earnings components

The earnings process in equation (5) is governed by two i.i.d. stochastic processes: An AR(1) persistent shock (ε_{it}) and a transitory shock (ϵ_{it}). The AR(1) process depends on the persistence term ρ and the innovation variance σ_η^2 ; the transitory shock only on its innovation variance σ_ϵ^2 .

I estimate $(\rho, \sigma_\eta^2, \sigma_\epsilon^2)$ following Guvenen (2009) and Low et al. (2010) by minimizing the distance between the variance-covariance matrix of the residuals ($\hat{\Sigma}$) estimated from

the SIAB (data moment) and its theoretical counterpart (Σ), which contains the sum of the persistent and transitory error component ($u_{it} = \varepsilon_{it} + \epsilon_{it}$)

Under the assumption that ε_{it} and ϵ_{it} are i.i.d., the variance and covariance of u_{it} are then defined as (dropping the i index for clarity of presentation):

$$\text{var}(u_t) = \text{var}(\varepsilon_t) + \sigma_\epsilon^2 \quad (\text{D.1})$$

$$\begin{aligned} \text{cov}(u_t, u_{t+j}) &= \text{cov}(\varepsilon_t + \epsilon_t, \varepsilon_{t+j} + \epsilon_{t+j}) \\ &= \text{cov}(\varepsilon_t, \varepsilon_{t+j}) + \text{cov}(\epsilon_t, \epsilon_{t+j}) \end{aligned} \quad (\text{D.2})$$

Given the transitory nature of ϵ_t , $\text{cov}(\epsilon_t, \epsilon_{t+j}) = 0, \forall j > 0$ and $\text{cov}(u_t, u_{t+j}) = \text{cov}(\varepsilon_t, \varepsilon_{t+j})$

The persistent shock's variance and (auto-) covariance are time-dependent as captured by the persistence term ρ (I define them recursively later):

$$\text{var}(\varepsilon_t) = \rho^2 \text{var}(\varepsilon_{t-1}) + \sigma_\eta^2, \quad \text{cov}(\varepsilon_t, \varepsilon_{t+j}) = \rho \text{cov}(\varepsilon_t, \varepsilon_{t+j-1})$$

with $\text{cov}(\varepsilon_t, \varepsilon_{t+1}) = \rho \text{var}(\varepsilon_t)$. Following the literature, I allow $\text{var}(\varepsilon_0) = \sigma_\zeta^2$ with $\sigma_\zeta^2 \neq \sigma_\eta^2$.

Therefore, the theoretical variance-covariance matrix is $\Sigma(\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2)$. Stacking the elements of Σ and $\hat{\Sigma}$ into a $N \times 1$ -vector $\mathbf{vec}(\Sigma)$ (with N equal to the included moment conditions), let $\mathbf{G}$ denote the difference between the data and theoretical moment vector taking the parameters $(\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2)$ as arguments:

$$\mathbf{G}(\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2) = \mathbf{vec}(\Sigma)(\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2) - \mathbf{vec}(\hat{\Sigma}) \quad (\text{D.3})$$

The stochastic components are then estimated by solving the following problem by applying standard GMM methods (Gruenen, 2009):

$$\min_{\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2} \mathbf{G}(\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2)' \mathbf{W} \mathbf{G}(\rho, \sigma_\zeta^2, \sigma_\varepsilon^2, \sigma_\epsilon^2) \quad (\text{D.4})$$

where $\mathbf{W}$ denotes the weighting matrix. I choose the identity matrix $\mathbf{W} = \mathbf{I}$ following Altonji and Segal (1996). The resulting parameter estimates are reported in table 3.

E Appendix: Computation of counterfactuals

I compute counterfactuals for changes in rejection rates ($\pm 50\%$) and benefit generosity ($\pm 20\%$) around the Status Quo, (i) with and (ii) without a private DI market. Computing these counterfactuals requires two assumptions: how the government budget is balanced and how welfare is measured.

Revenue neutrality: All counterfactuals preserve government revenue relative to the Status Quo. Policy changes induce both mechanical and behavioral effects on revenue. To balance the government budget, I impose a non-distortionary lump-sum tax on labor income. The tax is constant until retirement and defined as:

$$LS = \frac{\hat{R} - R_0}{N_s} * \frac{(1+r)^{T_{retire}} * r}{(1+r)^{T_{retire}} - 1} \quad (\text{E.1})$$

where $\hat{R}$ is revenue under the new policy regime, R_0 baseline revenue, N_s the number of simulated individuals, and r the after-tax real interest rate. The revenue-neutral lump-sum tax is found iteratively: the program adjusts LS until behavioral changes (and thus revenue) converge across iterations.

Welfare metric: Welfare is evaluated using consumption-equivalent variation (CEV). I simulate 16,000 identical individuals across policy environments – i.e., these individuals have identical shocks and risk groups across simulations –, ensuring comparability. The CEV measures the (constant) fraction of lifetime consumption (α) an individual is willing to forgo in each period under the new policy to attain baseline expected lifetime utility (V_0) relative to the new regime ($\hat{V}$):

$$\hat{V}((1-\alpha)c, l) = V_0(c, l) \quad (\text{E.2})$$

I compute the CEV under "the-veil-of-ignorance", i.e., before individual risk is revealed. An analytical solution exists for α given CRRA per-period utility functions and $\gamma > 1$:

$$\alpha = 1 - \left(\frac{V_0(c, l)}{\hat{V}(c, l)} \right)^{\frac{1}{\kappa*(1-\gamma)}} \quad (\text{E.3})$$

For $\gamma > 1$ a positive α implies welfare gains, while a negative α implies welfare losses relative to the Status Quo.

The second counterfactual exercise compares the expected lifetime utility with and without private DI markets. In (E.3), V_0 denotes the regime without a private market and $\hat{V}$ to the regime with one. $\alpha > 0$ implies that access to private DI improves welfare.

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Data Appendix

Data Appendix S1. Data

I draw on three data sets to estimate the fundamental parameters of my model: (i) proprietary customer data from a major German private insurer, (ii) the Income and Consumption Survey (*Einkommens- und Verbrauchsstichprobe*, EVS), and (iii) the Sample of Integrated Labour Market Biographies (SIAB). This Data Appendix discusses the cleaning steps and sample construction for each data set in detail.

S1.1 Private Insurance Data

I use administrative microdata from a large German insurer covering all private DI contracts in force on January 1, 2013 or purchased thereafter through 2018. The data include basic demographics (age, gender, occupation), contract characteristics (risk group, insurance type [stand-alone DI vs. bundled with life insurance], annual benefits, purchase and expiration dates), and health outcomes (disability onset, recovery, death). Cancellations and health events are recorded at the month–year level between 2013 and 2018.⁴⁷

I add occupation classification codes to the private data based on the reported occupations using two approaches (detailed in Data Appendix S2.1 and S2.2 respectively): (i) "string matching" of titles to the insurer's internal risk table, and (ii) "line-by-line assignment" to the official occupation codebook of the Federal Employment Agency⁴⁸. Results rely on the latter, which yields a higher match rate, though both procedures generate highly consistent assignments (Appendix Table S.1).

I add two variables: replacement ratios and prices. Replacement ratios are the ratio of annual benefits to annual income. Since the insurer does not record income, I impute it

⁴⁷Ongoing disability spells starting before 2013 are also reported.

⁴⁸Due to different naming conventions in the insurance data, string matching is not feasible when using the official occupation codebook. Instead, I searched the code for each occupation title in the insurer data separately "line-by-line" to match titles to codes.

using the 2014 German "Verdienststrukturerhebung" (Labor Income Survey)⁴⁹, regressing income on a quartic in age, gender, full-time status, and 5-digit occupation codes, and predicting income conditional on these covariates. Prices are obtained from the insurer's website in 2020 for each risk group (see Appendix S1.5).

The sample is cleaned as follows. I drop civil servants, self-employed, people in education/training – identified based on their occupation e.g., "Entrepreneur" or "pupil" –, and observations with missing or unmatchable occupations (175 obs. including students with unspecified degrees)⁵⁰. Next, I drop contracts bundled with life insurance⁵¹, miners (covered by a special public scheme), contracts bought before 2001 (due to a major reform; see Seibold et al. (forthcoming) for details), and all observations canceling their insurance. To this sample, I apply the same sample restrictions as in all data sets, only retaining men purchasing after age 25 to align with my model. This yields 99,419 contracts.

Appendix table A.1 summarizes the data across the different construction steps. Column (1) contains the summary statistics for the full sample; Column (2) after dropping civil servants, self-employed, people in education, and all observations with missing occupation information or buying bundled contracts; Column (3) after restricting the sample to men; and Column (4) summarizes the estimation sample.

In the full sample, the average age at purchase is 29.68 years and contracts end typically around 62.55 years, so covering most of the working life. The average annual insured benefits are € 16,487.30, predicted income € 52,806.26, and the mean replacement ratio is 34%. The average risk group is 2.27 and 55% of the contracts are stand-alone DI. The mean outcomes look very similar for imposing the sample restrictions in Column (2) and (3). The estimation sample (Column (4)) is similar in replacement ratio and disability incidence, but older with a higher age at purchase, higher income, and insured benefits, reflecting the exclusion of younger individuals.

S1.2 Income and Consumption Survey (EVS)

The EVS is a large representative household-level survey conducted every 5 years by the German Federal Statistical Office. Participating households record over three months their total income from all sources (e.g. labor, transfer, capital, etc.) and expenditures (e.g., consumption/durable goods, rent, etc.). To account for varying sample sizes across waves (due to non-compulsory participation), weights based on the Micro-census are constructed. All presented numbers are weighted.

I pool the 1998, 2003, 2008, and 2013 waves (42,000 to 49,000 households each). I exclude all self-employed, civil servants (ineligible for public DI due to missing social

⁴⁹This is large and representative cross-section survey conducted by the German Federal Statistics Office with detailed employment and income information. The same sample selection criteria as in my analysis are applied (no civil servants, older than 24, not in education or training).

⁵⁰80% of the sample are assigned an occupation code. Section S2 provides details for assignment failures.

⁵¹Since the motives for purchasing life insurance with private DI are potentially different from buying stand-alone DI, I drop bundled contracts to focus on insuring labor earnings.

security contributions), household heads younger than 25, and those still in training or education. This leaves me with 112,918 observations, summarized in Column (1) of Table A.2. Further restricting the sample to male household heads – the dominant household type in Germany (76% of all respondents) – reduces the sample to 87,286 observations (Column (2)). Compared to the full sample, the estimation sample displays higher mean assets (€170,810 vs €150,265) reflecting differences in marital status composition⁵².

I use the EVS to construct two sets of moments for the Method of Simulated Moments approach. First, I compute private DI take-up overall and by labor income quartile from the 2013 wave – the first wave eliciting private DI take-up. Accounting for the 2001 public DI reform, I restrict to individuals born after 1961 (i.e. younger than 35 in 2013), who entered the labor market after the reform. Column (3) shows that this restrictions raises private DI take-up from 25% in the overall sample to 48% among post-reform cohorts.

Second, I estimate mean and median household assets (deflated to 2013 prices using the CPI) in 3-year age bins from ages 25–69, pooling all four waves. Following Adda et al. (2017), I drop the top and bottom 1% of the net income and asset distribution. Applying the suggest asset definition by the Federal Statistical Office ('EVS 2013 Codeverzeichnis' [German only]), assets comprise liquid assets (savings accounts, home loan or savings contracts, stocks, private loans, annuities, and 'other' liquid assets) and net housing wealth (housing value minus mortgage debt/credits/loans). The resulting mean and median savings are €170,810 and €69,482 (not shown), respectively.

S1.3 Sample of Integrated Labor Market Biographies (SIAB)

The SIAB is a random 2% sample of German social security records (managed by the Institut fuer Arbeitsmarkt- und Berufsforschung), covering all individuals who are employed, unemployed, or receive social assistance between 1975-2017; Civil servants and self-employed are excluded due to missing social security contributions. It contains the employment and benefit history of 1,875,439 individuals, comprising 66,961,520 spells, with detailed information on daily wage (third-party reported), occupation (2010 classifications), demographics (age, gender, citizenship), full-time vs. part-time work, sector, residence, benefits, and employment transitions, including public DI awards.

From the spell data, I construct an annual panel of individual employment and benefit histories for 1992-2017, splitting multi-year spells and retaining the longest spell within a year (for multiple spells). The estimation period is 2001–2017, with earlier years used to track prior work/benefit histories. I drop all observations outside employment, unemployment, non-participation, or poor health. Missing occupations (e.g., due to DI receipt) are imputed by individual mode occupation – i.e., the occupation this individual has worked in for the most years. Then, I merge the private-insurer risk groups to the SIAB by oc-

⁵²Most male household heads (HHH) are married, while only half of the female HHH are married. As single households have lower assets, this explains the lower mean assets for female HHH.

cupation codes. This procedure assigns risk groups to all observations with non-missing occupation codes, 97.2% of raw observations and 99.8% of the cleaned sample.

I convert daily wages to annual income (2013 prices) by multiplying the daily wage with the number of days worked in that year. Top-coded wages above the contribution ceiling are imputed following Dauth and Eppelsheimer (2020). Wages are third-party reported, so measurement error is negligible.

I apply the same sample restrictions as in the other data: men aged 25–65 in standard employment with positive income (excluding apprentices, early retirees, temporary contracts, and zero-income spells⁵³). Appendix Table A.3 documents the cleaning. The raw SIAB contains ~ 34 m person-year observations (Column (1); average age: 39, income: €32,816, average risk group: 3.21, 55% male). Restricting the sample to people in standard employment with positive income and to post-2001 observations yields ~ 20 m person-years (Column (2)). All averages remain the same, except the average spell duration which is slightly shorter. Further restricting to men results in ~ 12.5 m observations (average age 40, income €38,507, risk group 3.36). I use this sample to construct the labor market moments for the MSM, the disability probabilities by risk group, and the population risk group distribution.

Columns (4) and (5) of Table A.3 report the samples used for wage estimation (eq. (5)), obtained by additionally excluding non-employed spells. These samples are slightly older (mean age: 41) and have longer average spell durations but are otherwise similar.

S1.4 Merging Risk Groups to Public Data

The SIAB records occupation codes whereas the private insurer records the occupation titles.⁵⁴ Since occupation titles are more detailed, several titles can share the same code despite belonging to different risk groups. To address this, I compute the mean, median, and mode (min and max) risk group by occupation code (5 digits, 4 digits, and 3-digit code).⁵⁵ I choose the mean risk group by occupation code as my baseline, while the results are robust to using the other statistics.

I merge the aggregated risk group-occupation-code mapping from the insurer data to the SIAB based on the 5-digit occupation codes, which assigns a risk group to 96.40% out of 34 million observations. For 0.5% and 0.3% of observations, I assign the risk group based on the 4-digit and 3-digit occupation codes respectively. Overall, I match all observations in the SIAB with an occupation code to a risk group (97.2% of the sample); 2.8% of the sample cannot be matched because of missing occupation codes in all years (e.g., due to continuous benefit receipt).

Since the occupation titles in the insurer data are more detailed than the codes,

⁵³Benefits recorded and positive. Hence, zero income spells captures "non-eligible" individuals, e.g. those failing minimum contribution periods).

⁵⁴Appendix S1.3 describes the strategy to assign codes to individuals with missing occ. information.

⁵⁵3(4) digit code refers to the combination of the first 2(3) digits and the final digit (skill level).

the mean and median risk group by occupation code are no longer discrete. Hence, I discretize the risk-groups as follows: I assume individuals are uniformly distributed on the interval between the two nearest integers around the mean (median) risk group. Drawing from a uniform distribution, I assign an individual to the smaller risk group if the $\leq 1 - (\text{mean RG} - \text{next smaller integer})$, the probability of falling below the mean. For example, let the mean be 1.7. Then the probability of being in risk group 1 is equal to $(1 - (1.7 - 1) = 0.3)$. The individual will be assigned to risk group 1, if the random draw from the uniform distribution is ≤ 0.3 and to risk group 2 otherwise.

S1.5 Private DI Data - Validation

In Seibold et al. (forthcoming), we provided detailed validation checks for the representativeness of the data of the major insurer in this project for the market as a whole using various independent data sources. I mention the key points here: (i), private DI take-up in the population and by subgroups is very similar in data from a large rating agency to the private insurer data; (ii) the total stock of private DI contracts issued by the different insurers follows similar trends; (iii) insurers issue similar contracts with similar risk assessment and pricing, and (iv) the insurer is present in all regions. These exercises confirm that the insurer data used in this paper are representative of the German private DI market, and individuals have little incentives to select into a specific insurer, including the one in this paper.

Data Appendix S2. Occupation Code Assignment

The private insurer data records occupation titles, while the administrative data records occupation codes (2010 classification). I assign titles to codes in the insurer data using the code book of occupation classifications by the German Unemployment Agency and two approaches: (i) the insurer’s occupation–risk group table (“Risk Table”), which reflects insurers’ pricing categories but is more aggregated; and (ii) direct title-to-code matching (“Line-by-Line”), which yields higher coverage at finer occupational detail.

Both approaches produce highly consistent results: 73% of observations are assigned the same code, and only 6% differ (Appendix Table S.1). The remaining deviations reflect the higher aggregation of the risk table. 18.76% of contracts cannot be matched (mainly individuals in training, with missing titles, or self-employed), corresponding to the unmatched cases under the "Line-by-Line" approach (Appendix Table S.2). Overall, the results are robust to the chosen mapping.

Table S.1: Comparison between both Occupation Title to Code Mapping Strategies

Flag	Number of Observations	Percent
Perfect Overlap	-	73.06
Different Assignment	-	6.11
Only Line-by-Line Assignment	-	0.0
Match Line-by-line, not contained in Risk Table	-	1.22
Only Risk Table Assignment	-	0.23
Both: No Assignment	-	0.61
No Match Line-by-Line, not contained in Risk Table	-	18.76
Total	Confidential	100

The table presents the overlap in occupation code assignments based on the "Risk-Table Matching" relying on the company's risk table and the "Line-by-Line" matching.

S2.1 Risk Table Matching

The first procedure is based on the insurer's occupation-risk-group table, which assigns each occupation to a risk group. The insurer uses the official occupations as defined by the unemployment agency. Thus, using the official code book of the Unemployment agency, each occupation in the table is successfully matched to its code.

Merging the augmented table to the contract data based on occupations, 78% of contracts are match directly. For each matching failure, I checked whether the occupation from the insurer data is not in the risk table (e.g., change in naming conventions) or if I can find a similar occupation based on slight variations in the skill level (5th digit of the occupation code) or specialization (4th digit)⁵⁶. Correcting spelling and naming inconsistencies, and using almost identical occupations adds 3%.

19% of observations remain unmatched, mostly because individuals are in education (67%) or report no occupation (29%); a small share reflects military personnel, self-employed, and home producers, excluded from public DI and my analysis (10%).

S2.2 Line-by-Line matching

This approach directly matches occupations in the insurer data to codes in the code book by searching for the occupation in the Unemployment Agency's code book (2010 version). 69.84% of observations are matched directly, and 9.41% via their old occupation title (1988/1992 version)⁵⁷. I use the transformation table from the German Unemployment Agency to assign the 2010 code to the old titles. Sometimes an old title has several 2010 codes, in which case I drop occupation codes if the old occupation rules out certain matches or if the old occupation contains further details narrowing down potential

⁵⁶Very narrow specialization have similar codes, e.g., gardeners growing fruits (code: 12112) versus flowers (code 12122). I treat both as gardeners (code 12102).

⁵⁷Contracts use the occupation at time of purchase; thus contracts before 2010 use the 1988/1992 codes

Table S.2: Flags for Matching Procedure (Line-by-Line)

Flag	Number of Observations	Percent
Stay-At-Home Parent	-	2.79
Missing Occupation Title	-	27.39
Occupation: Employee, Home Producer	-	0.59
Community/ Military Service	-	0.17
Intern	-	0.02
Unemployed	-	0.01
In-Training/Education	-	41.96
High-School Student	-	21.99
Self-Employed	-	4.93
Unable to find matching occupation	-	0.15
Total	Confidential	100

The table presents the distribution of the occupation titles that could not be matched in the "Line-by-Line" approach.

matches in the 2010 version.⁵⁸ If several candidates remain, I document all possible 2010 candidates with their respective codes. 19.61 percent of contracts could not be assigned to a code (see Data Appendix S2.3).

4,543 occupations are assigned to a unique code (70.2% of the sample), 162 occupations to two possible codes (7.7%), and 154 occupations to three or more potential codes (2.5%). Multiple codes occur mainly as the new 2010 codes are more detailed than the 1988 and 1992 versions, usually because they are split into "specializations". 80.5 percent of the "non-unique" matches are due to these specializations within an occupation. The remaining 19.5 percent are explained by the insurer grouping similar occupations with different codes into one occupation. The results are robust to interchanging codes.

S2.3 Match failures - Reasons

Table S.2 explores the reasons for failing to match observations to classification codes. 66.9% of matching failures are caused by individuals currently "out-of-employment", - unemployed, not participating in the labor force, or in training and education - thus no occupation code can be assigned. 27.4% of matching failures are due to missing or corrupted occupation information. In 0.6% of cases, people stated "Employee", "Worker" or "Home Producer" as their occupation, which cannot be matched to a code. Likewise, I cannot match self-employed individuals to occupation codes as the data refers to them as "entrepreneurs" or "self-employed" (4.9% of matching failures). Finally, I am unable to match 174 observations (0.2%) reporting a specific occupation. The stated occupation does not exist in the occupation code handbook of the German Unemployment Agency, and they are likely the insurer's or the insurance holder's own creation.

⁵⁸E.g., "Sicherheitsberater" (Work Safety expert) has different potential codes, but only one "Sicherheitsberater" in the 1988 version has no additional details identifying the occupation as an engineer. Only one of the listed "Sicherheitsberater" in the 2010 code book is an engineer, a unique match.