Routes to Retirement: Health, Occupation, and Pension Design

Courtney Brell

Department of Economics, University College London (UCL)
Centre for Research and Analysis of Migration (CReAM)
ROCKWOOL Foundation Berlin (RFBerlin)

12th November 2026

Click here for the latest version

Abstract

For those who can no longer work at older ages due to poor health or a strenuous career, pension age increases will be ineffective at extending their working lives. I investigate potential targeted pension policies which aim to protect those incapable of work while extending the working lives of those who can. Estimating a dynamic structural model of occupational choice, health, and retirement on German microdata, I simulate counterfactual policy regimes, including health- or career-based exemptions from a pension age increase, finding that many of those who would not work longer are neither in poor health nor from strenuous careers and so are beyond the reach of either test, and that the cost of such a policy is set less by who it protects than by who it exempts by mistake. Protecting those a later pension age would not keep in work costs comparatively little, since the pension largely replaces disability or unemployment benefits they would otherwise have drawn, and for the poorest their entitlements are small. In contrast, exempting someone who would otherwise have worked costs far more, mostly in lost tax and social security contributions rather than pension payments themselves. Changes in career choices as a response to such policies are present but modest. Support for a health-based exemption depends on when people are asked. The largest welfare gains go to older cohorts, but it is most widely popular among middle-aged cohorts, for whom it still has insurance value.

1 Introduction

As life expectancy grows, and the old-age dependency ratio with it, the sustainability of pension systems around the world has come under strain. Many governments have increased pension eligibility ages in response, with the goal of keeping people in employment longer. The European Commission has long advised linking the pension age to life expectancy (European Commission, 2012), and Germany's recent pension commission has also recommended doing so (Alterssicherungskommission, 2026). But an increased pension age can only keep those people in work who are still capable of working. Those who can no longer work either simply suffer a benefit cut or fall into alternative social benefit systems such as disability pensions or unemployment insurance.

Incapacity to continue work in old age is commonly attributed to poor health, especially in physically demanding occupations, where years of strenuous work can wear down health until

This work was supported by the Economic and Social Research Council grant ES/P000592/1; and the ROCKWOOL Foundation. We gratefully acknowledge Jérôme Adda, Christian Dustmann, Eric Klemm, Ian Preston, and Uta Schönberg for valuable comments and discussions.

people can no longer do their jobs. Policies that condition pension eligibility on career history or health status could protect such people from pension age increases they can't respond to by working longer. The German pension commission's concrete answer along these lines is a hardship route to early pension access for those who can no longer work in their occupation for health reasons (Alterssicherungskommission, 2026).

But whether such policies can protect those who cannot work depends on how much of this non-work at later ages is actually caused by poor health or strenuous careers, and their cost depends on how many of those they exempt could have kept working. Introducing selective pension policies may also have unintended consequences, as people change their behaviour in response. The key questions we ask here are whether exempting people from a pension age increase on the basis of their health or career history can protect those the increase cannot keep in work, how many of them such an exemption reaches, and at what cost to the public finances. Answering these questions requires knowing whether people whose pension eligibility is delayed do not work because of their health, their career, or their circumstances, in a setting where occupation, health, and the route out of work are all endogenous.

In this paper we build and estimate a lifecycle model in which people choose and change occupations over their career, where strenuous work wears down health, and where poor health reduces capacity to work. The model is estimated on the German Socio-Economic Panel (SOEP), and allows agents to exit the labour force into the old-age pension, or into the disability or unemployment insurance systems Germany also provides. Using this model we perform counterfactual simulations under different potential policy regimes. We find that targeted exemptions to a pension eligibility age increase based on health or career history can help some of those who would not work when pension eligibility is taken away, and who would be left with no other source of income apart from the basic income support consumption floor, and cheaply. However, exemptions mistakenly granted to people who would otherwise work are an order of magnitude more expensive, and policies of this kind miss most of those in need of help, who are neither in poor health nor in strenuous careers, but nonetheless have weak labour market attachment and few assets. Even so, this kind of targeted exemption acts as insurance against future inability to work, and while this is not especially valued at labour market entry, by mid-career it can provide a substantial welfare gain.

In existing structural models of retirement in which health risks differ by occupation, this occupation is typically taken as either fixed (Grossmann et al., 2024; Jacobs, 2025; Wen, 2023) or as a one-time choice (Jacobs, 2023), which makes them unsuited to evaluating potential pension policies whose rules exempt people based on attributes like career history or health status. Evaluating such rules requires three things at once: (i) occupational choice, since eligibility varying with career history changes who chooses the careers it favours; (ii) health that limits the capacity to work, since that lost capacity is what these rules are proxying for; and (iii) disability pensions and unemployment insurance as substitutes for the old-age pension, since without them both the fiscal gain from a later pension age and its burden on those who do not keep working are misstated. Our paper allows occupation and health to coevolve over the whole career, as Strulik (2022) does in a calibrated model of health behaviour, but alongside the pension, disability, and unemployment routes out of work that retirement policy acts on.

The literature has also shown that the burdens of a pension age increase fall unevenly. Those who are able to continue work can adjust by extending their working lives, but those who have lost that ability suffer under a reform that removes their pension eligibility. Broadly, those in poor health (Wen, 2023) or strenuous careers (Giraldo Páez, 2023; Jacobs, 2025) have been found to be the most impacted. Theoretical work has studied pension rules that treat these groups differently (Cremer et al., 2007; Pestieau and Racionero, 2016a), and Vandenberghe (2021a) asks how far retirement ages would need to differ across groups to equalise expected health at retirement. Quantitative studies have evaluated how the effects of raising retirement ages vary for workers in different occupations (Jacobs, 2025) and considered replacement rates that differ

by occupation (Grossmann et al., 2024).

Germany's own experience suggests that pension designers need to be wary of unintended consequences. Its early pension for those with 45 years of contributions, introduced in 2014, was aimed at workers whose health had been worn out by hard jobs until they were unable to work further. In practice those eligible for it had longer and more stable careers and fewer months of sick pay in their fifties than those eligible for the standard long-term insured route (Börsch-Supan et al., 2015), and take-up does not appear to have been driven by differences in health (Dolls and Krolage, 2023). The rule's eligibility criterion, a long contribution history, was only loosely related to the inability to work it was meant to proxy for. The health- and career-based criteria we evaluate are different proxies for the same thing, since in our model health and occupation shape, but do not determine, whether people keep working.

Germany is a useful setting for these questions. Workers approaching retirement there may have the option to leave work through early old-age pension routes (some with deductions), through a disability pension if they are assessed as unable to work, or through unemployment insurance followed by basic income support. These substitute for one another when a reform restricts one route (Riphahn and Schrader, 2023), so they must be studied together. Their eligibility rules changed repeatedly across the cohorts we observe, these natural experiments providing variation to identify how people respond to pension policy. We use the SOEP to follow men born between 1935 and 1953 through their careers into retirement, observing their occupations, earnings, wealth, and health, and supplement it with administrative data on claims from the Deutsche Rentenversicherung (DRV), which administers Germany's statutory pension insurance. In the data we see that health declines faster in strenuous work, and once it deteriorates sufficiently it pushes people out of work, more strongly in strenuous jobs. Those in poor health rarely move to lighter work, and instead exit work through whichever routes are open to them.

Our model captures each of these features. Individuals make career choices over the whole lifecycle, choosing among occupations with different strenuousness or non-employment, and whether to claim any of the social benefits that they might be eligible for. Health deteriorates at a rate depending on the occupation held, and it shapes the value of work both by affecting the disutility of working and the wages a worker can command. Individuals choose whether to work full-time or part-time (or not at all) each period, and can change occupation at any point, though this comes at the cost of lost occupational tenure as well as explicit switching costs. They can also save in order to fund higher consumption during retirement. As workers approach retirement, they decide how they transition out of work and into their pension claim. They may apply for a disability pension, which they receive if found eligible, or claim the old-age pension through any early route for which they qualify. Alternatively they may adjust their working patterns by changing occupation or hours, or drop out of the labour market early with no pension, falling into the unemployment system. We estimate the model by indirect inference, matching the lifecycle profiles of employment, occupation, health, and pension claiming in the SOEP and the DRV data.

We use the estimated model to compare a number of pension reforms. The three we focus most on are: a uniform increase in the pension eligibility age by two years; an age increase with exemptions for people with careers in strenuous work; and an age increase with exemptions for people in poor health. The career-based policy is motivated by schemes for arduous work elsewhere, such as those in Austria (Republik Österreich, 2026), Spain (Gobierno de España, 2026), and Czechia (OECD, 2025), while the health-based policy is similar in spirit to the German pension commission's proposed hardship route for those who can no longer work for health reasons. We compare the total fiscal impacts of these policies, accounting for old-age pension, disability, and unemployment benefit spending as well as the effects on income tax and social security contributions.

We find that a uniform two year rise in the pension age delays pension claims by almost the full two years but lengthens working lives by only 0.64 years, and a substantial part of the resultant fiscal gains come from taxes and contributions on the extra work, not only from pensions

withheld. For those who lose pension years without working more, the reform is simply a benefit cut. Conditioning the pension age increase on career or health cuts the share in this category from 19.1% to 11.7% and 13.3% respectively, but the two policies retain only 65% and 74% of the uniform rise's net fiscal gain. The career-based rule also distorts career choices, drawing some people into the exempted occupations later in their careers in order to take advantage of the more generous eligibility rules.

We assess how accurately each policy targets its exemptions, and at what cost to the public finances. The exemptions we consider err in both directions. As well as missing some of those who lose pension years without working more, they exempt some who would have kept working if their exemption were withdrawn (5.9% of all men under the career-based policy, 2.5% for the health-based). These two kinds of error differ greatly in cost. Each worker wrongly exempted costs the public finances €71,718 under our career-based rule and €83,335 under the health-based one, most of it not in additional pensions but in forgone income taxes and social security contributions. On the other hand, protecting a person who would otherwise fall onto basic income support costs just €1,171 and €4,139 respectively.

Given these tradeoffs, we ask which policy different groups prefer. A fair comparison requires each policy to deliver the same net fiscal gain, so we compute the contribution increases or pension cuts needed to pay for the health- and career-based exemptions. When financed by a funded contribution rise, people at labour market entry value the uniform and the health-based policy about equally and the career-based policy least. By their mid-fifties, when people know more about whether they are likely to be able to benefit from the policy and when much of the cost of the exemptions is already behind them, the health-based policy is worth considerably more to them on average than the uniform rise, and far more to those already in poor health. The protection a targeted policy offers is insurance to those less likely to be able to continue work, paid for in contributions throughout the working life and collected, if at all, near its end. No majority at any age prefers the career-based rule. Between the uniform and the health-based policies the young prefer the uniform policy and those in mid-career the health-based one. A vote across the whole electorate is close, and which wins depends on how many cohorts already in mid-career the reform covers. Financing the exemptions through cuts to old-age pensions instead shifts their cost onto those near retirement, and they lose their appeal as retirement approaches.

Our analysis does have limits worth stating. We model men only, abstracting from household decisions, so the results speak most directly to older cohorts in which men were the primary breadwinners. Our fiscal accounting covers old-age pensions, unemployment benefits, disability benefits, taxes, and social security contributions, but not health or long-term care spending, and holds wages fixed in partial equilibrium rather than letting them respond to changes in labour supply induced by a policy reform.

Our results suggest that when designing pension eligibility rules, targeted exemptions based on health or career history can protect some of those who cannot work, and can do so cheaply, but that these rules fail to identify many such people and become very costly whenever they exempt people who could have continued to work. Whether such exemptions are on balance desirable depends on when people are asked and on how they are paid for. Any change to the pension age must also be costed on the whole interconnected system of benefits and taxes, not just the pension budget in isolation, because a pension reform moves people onto other benefits, and affects what they will pay in income tax and contributions as their employment changes.

Contribution and related literature Our model builds on the family of structural lifecycle models of work, savings, and retirement starting with French (2005) and French and Jones (2011) (see Blundell et al., 2016 for a survey of papers in this tradition). This literature finds that retirement responds strongly to the structure of pension incentives (French, 2005; Haan and Prowse, 2014). Health in these models can be a reason people work less, through lower

productivity and a higher disutility of work (Capatina, 2015), and workers with more human capital have a greater incentive to invest in health (Galama et al., 2013), while at the same time propensity to poor health is itself correlated with low productivity (De Nardi et al., 2025).

A second strand of models focuses on the different routes out of work, including disability insurance (Iskhakov, 2010; Low and Pistaferri, 2015), unemployment and partial retirement (Etgeton, 2018; Haan and Tolan, 2019), and re-entry after retirement (Jacobs and Piyapromdee, 2025). In a calibrated model of the German system, Fehr and Fröhlich (2024) find that raising the normal retirement age shifts retirement towards disability pensions, and that the expansion of disability pensions can neutralise the fiscal gain unless eligibility is tightened. Low and Pistaferri (2015) quantify the extent to which disability insurance is accurately targeted, with type I errors measuring how many of those unable to work are rejected and type II errors those who are awarded benefits without truly needing them. Our targeted exemptions make the same two kinds of error.

Typical models in this structural retirement literature do not consider the contribution of occupation, or at most take it as given. Occupational choice has its own structural literature, from Keane and Wolpin (1997), in which career paths are built up from yearly choices between occupations, to Michaud and Wiczer (2018), who find that disability insurance makes workers more willing to choose occupations with higher disability risk.

A handful of recent papers bring occupation, health, and retirement together. In an equilibrium model with a one-time binary choice of occupational sector, Jacobs (2023) finds that disability insurance leads more people to choose strenuous blue-collar work at older ages, and, by reducing precautionary saving, leads people to stop working later than they otherwise would. Extending this work (with occupation fixed), Jacobs (2025) shows that increases in the early eligibility age fall hardest on blue-collar workers and increase their applications for disability insurance. Wen (2023) also considers occupation to be fixed by the time retirement choices approach, and finds that poor physical health mainly keeps manual workers from delaying retirement. Looking at German pension design and again taking the occupational structure as given, Grossmann et al. (2024) consider the fairness of the pension system when health deteriorates faster in blue-collar work, shaping both retirement and mortality. In contrast to these, Strulik (2022) develops a calibrated lifecycle model of occupational choice and health evolution in which performing strenuous work accelerates the accumulation of health deficits, and workers change their choices as their health declines. Retirement enters only through a simplified pension system and is not a focus of the analysis. Our model combines occupational mobility throughout the career with the competing routes out of work that are key to understanding the impacts of pension policy.

It is well established that health declines faster in physically demanding work (Abeliansky and Strulik, 2023; Case and Deaton, 2005; Vandenberghe, 2026). Much of the association between occupation and health reflects selection, but a substantial causal effect remains (and grows with age) (Ravesteijn et al., 2018), so occupation and health must be modelled jointly as opposed to treating occupation as a fixed health hazard. Poor health (Blundell et al., 2016; French, 2005) and physically demanding work (Badarin et al., 2023; Lopez Garcia et al., 2021) predict earlier exit from work, but health only explains part of the decline in employment rates at older ages (Vandenberghe, 2021b). Many older people do have the health capacity to continue work for longer than they do (Coile et al., 2017; Jürges et al., 2017; Lopez Garcia et al., 2025; Vandenberghe, 2021b). Moving to less strenuous work can help extend the working lives and preserve the health of those whose health is declining (Badarin et al., 2022; Oh, 2023), but in the German data those in poor health rarely make such moves (see Section 2.4). Retirement itself affects health, improving it for those leaving physically demanding work (Abeliansky and Strulik, 2023; Eibich, 2015; Mazzonna and Peracchi, 2017), but possibly accelerating decline for others (Mazzonna and Peracchi, 2017), and early exit through some channels has been found to increase mortality (Kuhn et al., 2020).

Ceteris paribus, a pension system with a uniform claiming age redistributes from the short-lived to the long-lived, and because life expectancy rises with lifetime earnings (e.g. von Gaudecker and Scholz, 2007, in Germany), this is a regressive transfer mechanism (Sánchez-Romero et al., 2020; Sánchez-Romero and Prskawetz, 2017). In Germany it is enough to make the system regressive overall (Haan et al., 2020). Proposed solutions addressing this issue include making pension benefits less dependent on earnings (Fehr et al., 2013; Jones and Li, 2023), paying higher annual benefits to groups with shorter lives (Grossmann et al., 2024; Sánchez-Romero et al., 2020), or differentiating retirement ages by group (Ayuso et al., 2017).

Differentiating the retirement age is a form of what Akerlof (1978) calls tagging, which uses an observable characteristic correlated with need to target support, at the cost of misclassification and of incentives to acquire the characteristic (Parsons, 1996). Since work capacity cannot be observed directly, any screen admits some who could work and rejects some who cannot, and a theoretical literature studies how retirement and disability benefits should be designed around this (Cremer et al., 2004a,b, 2007; Diamond and Sheshinski, 1995; Golosov and Tsyvinski, 2006). Pestieau and Racionero (2016a,b) show that conditioning on occupation can improve welfare, and can outperform health testing when testing is costly and poor health is concentrated in arduous jobs, but take occupation as given. Whether this is effective in practice is less well established. Vandenberghe (2021a) asks directly whether retirement ages should be differentiated to compensate for health differences, and finds that characteristics like gender and education account for only a small fraction of the variation in individual health, so that a rule based on these would leave most of that variation uncompensated. Baurin (2021) reaches a similar conclusion for lifespan. Differentiating by career arduousness raises a further problem, since it rewards remaining in arduous work and so may keep workers in the jobs that wear their health down in order to preserve their eligibility (Vandenberghe, 2026).

Such rules are nonetheless common. A number of OECD countries offer early retirement for at least some arduous jobs (OECD, 2023, ch. 2); Germany has a statutory scheme specifically covering miners. These schemes command public support (Vermeer et al., 2016) and have been defended on grounds of equality (Mittlaender, 2023), while international bodies have argued that such risks are better handled outside the old-age pension system, for example through disability or unemployment insurance (OECD, 2023; Zaidi and Whitehouse, 2009). We provide a quantitative evaluation of these rules in an estimated model in which people can respond through their career choices and their routes out of work.

The paper is organised as follows. Section 2 describes the institutional context of the German pension system and what routes out of work this allows, as well as our data and the key descriptive facts motivating our structural model. Section 3 describes the model itself, and Section 4 its estimation, identification, and how the estimated model matches the trends in the data. Section 5 presents the counterfactual policy reforms we analyse and how they perform, before Section 6 discusses the political economy of people's preferences between them. Finally, Section 7 discusses the implications of our results for policy design and the tradeoffs revealed, and concludes.

2 Empirical context

Our empirical analysis will focus on men who are of potential retirement age in Germany over the period 2000-2018. Here we will describe the elements of the pension system and social safety net as they apply to our sample, before describing our data and presenting some motivating descriptive facts.

2.1 The German pension system

The three components of the German social insurance system that matter most for us are the old-age pension, disability insurance, and unemployment support, each of which is a potential support for people who are unable (or unwilling) to find suitable employment. For the most part in this paper, we will concentrate on those workers who are liable for social security contributions, which is the common situation excluding civil servants, who have a separate pension system, and most of the self-employed, for whom joining the pension system is voluntary (Börsch-Supan et al., 2021; Dustmann et al., 2009).

During their working lives, individuals accumulate *Entgeltpunkte*, or earnings points, based on their earnings relative to the national average salary. The cumulated earnings points are multiplied by a statutory euro value to compute one's old-age pension entitlement, which is set so that a standard pensioner earning the average wage over a 45 year career will be entitled to a pension at about half of average earnings. The normal retirement age (NRA) was 65 for those born before 1947, since which it has been slowly increasing to 67 for cohorts born in 1964 or later. Above this age workers are also allowed to work while drawing their pension, and those who delay claiming beyond the NRA gain a bonus to their pension entitlement of 0.5% per month.

However, there are also several other routes to draw a pension earlier than the NRA, with various eligibility requirements, summarised in Table 1 (following Börsch-Supan et al., 2021). The two main early pension pathways are the long-term insured route, by which workers with 35 years of contributions can choose to claim their pension from 63, subject to a deduction of 0.3% for each month they retire before the NRA, and the *especially* long-term insured route, known since a 2014 reform as the *Rente mit 63* (pension at 63), in which those with 45 contributing years can draw a full pension without deductions from age 63. Because it counts years of contributions rather than age alone, this route favours those who started work young and worked without long interruptions, as is more common in strenuous careers (Section 2.4). Those with a recognised severe disability can claim with deductions from 60, and for those born in 1951 or earlier, routes for the long-term unemployed and for those who had worked part-time also allowed claims from 60. If drawing an old-age pension before the NRA on any of these routes, one may not earn above a relatively low earnings limit before the pension is reduced or withdrawn.

Table 1: Routes to an old-age pension

Route	Earliest age	Contribution years requirement	Further conditions	Deduction
Regular route	65 → 67	5	—	none
Long-term insured	63	35	—	0.3%/mo
Especially long-term insured	63 → 65	45[a]	at 63 from July 2014	none
Severe disability	60 → 62	35	recognised disability	0.3%/mo
Unemployed	60 → 63	15[b]	≥ 52 weeks unemployed; cohorts to 1951	0.3%/mo
Part-time	60 → 63	15[b]	2 years part-time under an eligible agreement; cohorts to 1951	0.3%/mo

Notes: We omit the miners' route and women's routes.
[a] Excluding time in education, basic income support, and unemployment insurance in the two years before claiming.
[b] Of which 8 years in the last 10.

For those not yet eligible for the old-age pension, the disability pension provides support to people assessed as no longer able to work due to disability. Since 2001 the disability pension requires that a worker cannot work in any occupation, while prior to that they were eligible for a disability pension if unable to continue work in their own occupation. For all the cohorts in

our sample it remained possible to continue to claim a partial pension on these more generous grounds, but a full disability pension required the stricter test. The disability pension pays similarly to the old-age pension, at a rate determined by the earnings points accumulated during one's healthy working years, imputed until a statutory age.

Finally, for those eligible for neither old-age nor disability pensions, unemployment support is available when you leave work. The system is split in two parts, the first (*Arbeitslosengeld I*; ALG I), paying 60% of your previous average net pay for a period of around 12 months, and if you are above 50 then this period may be extended gradually (to a maximum of between 18 and 32 months, depending on the year). After ALG I is exhausted then an individual would fall into *Arbeitslosengeld II* (ALG II), which is paid at a means-tested basic income support level. We will generally refer to this whole system as unemployment support, to ALG I as unemployment insurance, and to ALG II as basic income support.

Each of these pensions or benefits provides a potential route from work to retirement. One may directly claim the old-age pension at the NRA, or choose one of the early claiming routes, or alternatively claim disability pension until eligible for old-age pension, or else fall out of the labour force into unemployment until pension eligibility. These form the choices of how to permanently exit the labour market. Changes to the pension system will see workers substitute between these channels depending on their eligibility.

Several reforms changed these available routes across the cohorts we observe. Policy changes in 1999 abolished the unemployment route and part-time pension routes for cohorts born after 1951. Deductions for early claiming were also finishing their phase-in, so that for almost all of our sample the unemployment and long-term insured routes paid a full pension only from 65, and the earliest age at which the unemployment route could be claimed rose from 60 to 63 for those born 1946–1948. The 2014 reform that created the *Rente mit 63* reached only the youngest cohorts in our sample, but was taken up widely, accounting for about 30 percent of new old-age pensions in 2015–2017 (Bundesregierung, 2018). As a result of these reforms, in our sample we have variation in eligibility for different routes, in the ages some routes can be accessed, and in the relative prices between routes. This will in part allow us to determine how individuals behave under different regimes and hence model how they might behave under proposed new pension policies.

For additional details, a more comprehensive discussion of the German institutional context is provided in Appendix A.

2.2 Potential policy choices

In order to improve the fiscal sustainability of a pension system, a government can increase contribution rates, reduce benefit rates, or tighten eligibility criteria. The first two are blunt tools, increasing the tax burden on the working population or reducing the adequacy of the pension to support people in old age. In this paper we focus on the third option, and specifically on raising the ages at which a pension can be claimed.

A tightening of pension eligibility criteria should fundamentally be designed to keep people in the workforce longer. If they instead exit the workforce on a different route, for example to the disability pension or unemployment support, they will no longer pay income taxes or contributions, and would still draw some kind of benefits from the state.

While the goal of such a reform should be to extend people's working lives, this may not be possible for all workers. Some workers may not be able to continue working if their health no longer permits it. This incapacity for work will not be uniformly distributed across the population, and as we will see in Section 2.4, workers with poor health permanently exit the labour market earlier, and this poor health is concentrated in particular career paths.

As such, in this paper we will consider several potential policy choices and examine their effects on the pension system, on the labour market, and on individuals' outcomes. The policies

on which we focus most are:

(i) Uniform increase in eligibility ages: we consider raising all old-age pension eligibility ages by two years.

(ii) Career-based eligibility ages: people in strenuous careers are assigned earlier eligibility ages than those in others.

(iii) Health-based eligibility ages: people in poor health are assigned earlier pension eligibility ages than those in good health.

Each exemption uses an observable characteristic as a proxy for inability to work, and so can fail in two ways, by leaving exposed people who cannot work or by exempting people who would have kept working. The two also differ in how they can be acquired. Career history is built up over decades and can be sought by choosing a career, while health is assessed only at the point of eligibility.

2.3 Data

We are primarily considering German men born between 1935 and 1953, and their late career decisions over the period from 1994 to 2018. Our main data source is the German Socio-Economic Panel (SOEP) (Goebel et al., 2019; Socio-Economic Panel (SOEP), 2021), a household panel running annually since 1984. Our primary sample consists of 58,696 observations of 6,823 men whom we observe not only in their late career but also their earlier outcomes back to 1984, from which we construct their histories of labour force status, occupation, and earnings. Our restriction to men abstracts from household formation, household incomes, and joint decision making. For the cohorts we consider, women's participation in the labour market was considerably lower than men's (Fitzenberger et al., 2004), so men were typically the main earners in their households and their earnings are a reasonable proxy for household income. Table 2 provides descriptive statistics of the sample, also split by career occupation.

The primary health information we consider is self-rated health (SRH), reported on a 5 point scale (bad, not so good, satisfactory, good, very good) and recorded every year since 1994. In prose we will typically aggregate the outcomes into three groups "good" (good, very good), "middling" (satisfactory), and "poor" (bad, not so good).

Health is a complex quantity and can be measured in numerous ways (Blundell et al., 2016; French and Jones, 2017). When thinking about the connection between health and work, the same condition matters differently in different jobs (French and Jones, 2017; Sonnega et al., 2018). The granularity of health information also matters. With only two health states, French (2005) over-predicts work among those in bad health, which is suggested to potentially be due to health bins mixing people with different health conditions. However, self-assessed health measures, which implicitly take the demands of one's occupation into account, can be at least as informative about work capacity as objective ones (Blundell et al., 2016; French and Jones, 2017). We find that our self-rated health variable performs similarly to the more direct SF-12 physical component score, which is asked only every two years from 2002; the two have a correlation of 0.77 and predict leaving work equally well.

We generally aggregate occupations into three categories based on one-digit ISCO-88 occupation codes. These are a "strenuous" occupation involving physical activity or strain (ISCO 5–9), a "light" occupation of managerial and professional work (ISCO 1–2), and a "medium" occupation in between (ISCO 3–4). This classification is consistent with one based on physical requirements of the job, for example using Kroll's Job Exposure Matrices (Kroll, 2011a,b) (Appendix Table A.1). For each person, we define the career occupation as the one most held between ages 45 and 59. Education we consider as a binary (any tertiary education or not).

Wealth information, including housing and private pensions, comes from the SOEP's wealth modules, fielded every five years, and all monetary amounts are deflated to 2016 euros.

Table 2: Men born 1935–1953, by career occupation

	Strenuous	Medium	Light	All
Men	1,802	699	747	6,823
Person-years	20,467	8,647	9,086	58,696
Waves observed per man (mean)	10.6	11.7	11.6	9.2
Birth year (mean)	1945.2	1945.6	1946.2	1944.3
born 1935–1941 (%)	28.5	24.2	21.1	37.3
born 1942–1947 (%)	31.1	32.9	30.9	27.2
born 1948–1953 (%)	40.4	42.9	48.0	35.5
Tertiary education (%)	12.7	32.7	70.1	28.9
Current occupation, employed person-years (%)				
strenuous	94.4	6.8	2.9	49.1
medium	3.7	83.3	10.3	25.5
light	1.9	9.9	86.8	25.4
Self-rated health, person-years at 45–64 (%)				
good	32.3	47.2	47.6	36.9
middling	42.1	37.9	36.8	39.5
poor	25.7	14.8	15.6	23.6
Self-rated health at 59, men (%)				
good	26.9	38.8	43.7	31.1
middling	41.2	42.4	37.8	40.1
poor	31.9	18.9	18.5	28.8
Net worth (personal share), person-years at 50–64				
median (euros)	29,151	107,091	152,447	58,788
zero or negative (%)	26.2	10.7	8.3	21.6
Men born 1940–1953 and seen at 55 (%)				
still observed at 65	46.7	53.7	59.7	51.0
no longer observed at 65 (died or left the panel)	53.3	46.3	40.3	49.0
Confirmed exit from work, men born 1940–1953 (%)	52.6	51.9	44.6	37.5

Notes: SOEP men born 1935–1953, observed 1994–2018, excluding men only ever observed as civil servants or self-employed. Columns are career occupation groups, reflecting the occupation held longest at ages 45–59. "All" is every man of these cohorts, including 3,575 with no career occupation (mostly because the panel does not observe them during these ages). All statistics are weighted. Net worth is the individual's share of household net worth, including housing.

We supplement the SOEP with administrative data from the DRV (Deutsche Rentenversicherung) on pension award flows by age, year, and route, including disability pensions (Deutsche Rentenversicherung Bund, 2020). This data also has information on the number of disability pension applications and the share accepted. The SOEP records whether a person draws a statutory pension, but does not directly record which one. We infer a pension to be a disability pension when it is first drawn before the earliest age at which any old-age pension was open to that person, which depends on their birth cohort and on whether they have a recognised severe disability. The SOEP has no information on unsuccessful applications, so the DRV data tell us how strictly applications are assessed as well as precisely how many people receive a disability pension.

2.4 Descriptive facts

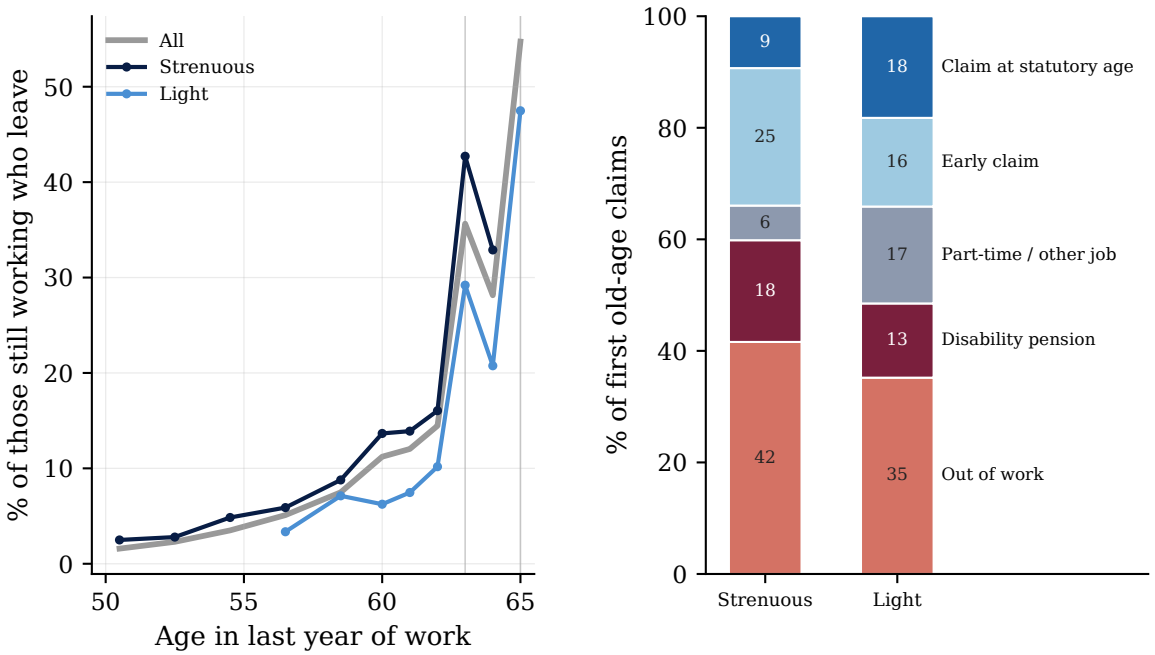
While many workers do retire at the normal retirement age (65 for most of our sample), there are a substantial number of people who retire or exit the labour force earlier through other channels. In particular, there are spikes in retirement flows at eligibility ages for each early pension route. In Figure 1a we see that the rate of permanent exits from work jumps at 63 and again at 65. 79.2% of men (whose exit we observe) have already left the labour force through one route or another before the normal retirement age, and 39.9% before 60. Permanently exiting work and claiming an old-age pension are therefore distinct events. Of those making a first old-age pension claim, 54% were not in work beforehand (Appendix Table A.2).

Workers in different occupations have different career trajectories, including when and how they leave work. Workers in our strenuous occupation tend not to have a tertiary education, and as such begin work earlier than those in the light occupation (at a median age of 20 compared to 23 for the light occupation). They also tend to permanently exit work earlier (median age 59 cf. 63), and more often through disability or not working (Figure 1b). This is partly for institutional reasons (see the especially long-term insured route in Section 2.1). However, this is also partly driven by health issues causing inability to work. Despite the fact that strenuous occupation workers tend to exit earlier, they still tend to spend slightly longer in the labour market than their more educated peers (an average of 38.9 years compared with 38.1 in the light occupation).

Three critical links tie occupation, health, and retirement together. Strenuous work wears down health; poor health pushes people out of work, more strongly in strenuous jobs; and those in poor health do not move to lighter work, but leave through whichever route is open to them.

We observe in our data that those in the strenuous occupation accumulate health deficits more rapidly than those in light careers. While health deficit tends to increase with age itself, this is compounded by working in a strenuous occupation, as can be seen in Figure 2, which shows the rates of poor health status over the lifecycle by career occupation. While part of the gap between these two occupations is already present in the early career (Appendix Table A.3), these groups further diverge over time. In contrast, deficits accumulate at comparable rates in the medium and strenuous occupations.

We also see that workers in poor health have a 2.5 times higher hazard of permanently exiting work at ages 55–64 compared to those in good health (Figure 3). Since health is quite persistent, this means that those in the worst two categories of self-rated health at 59 permanently exit 3 years earlier than those who are in the best two health categories at this age, even conditioning on occupation. This does not appear to happen in a linear manner; it is mostly the poorest health states that drive the exit mechanism (Appendix Table A.4). Further, the effect of health on exit rates depends on occupation, with poor health raising the exit rate by 9.3 percentage points in the strenuous occupation compared to 4.7 points in the light occupation (Appendix Table A.5). The relative risk is similar in the two, so poor health compounds whatever already makes people leave the strenuous occupation sooner.



(a) Hazard of permanent exit from work, by age

(b) Status before first old-age claim

Figure 1: When and how careers end

Notes: SOEP men, weighted; all men and split by strenuous and light career occupations. (a) The share of those still working whose last year of work it is, all cohorts. (b) Men born 1938–1953, by their status in the last observation before the first old-age pension claim, as in Table A.2.

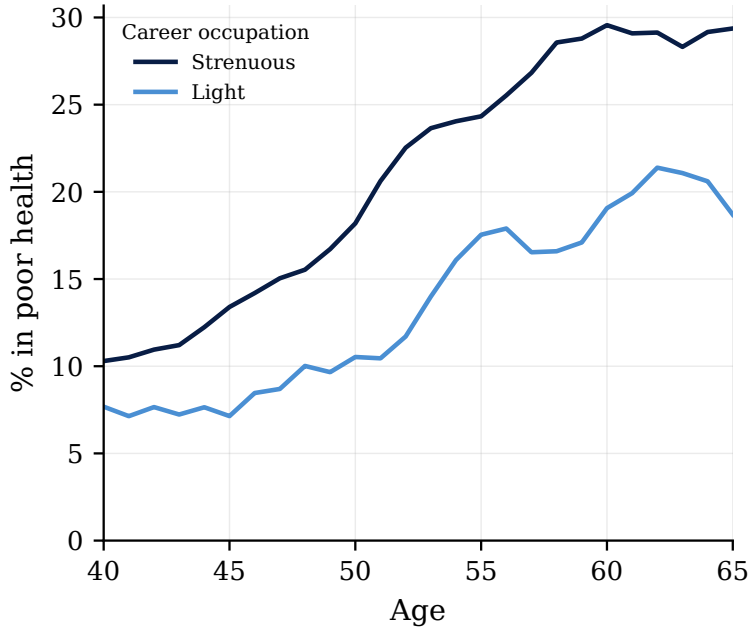


Figure 2: Rates of poor health by age and career occupation

Notes: SOEP men, person-years, weighted. Poor health is the two worst categories of self-rated health. The career occupation is the one held longest between the ages of 45–59.

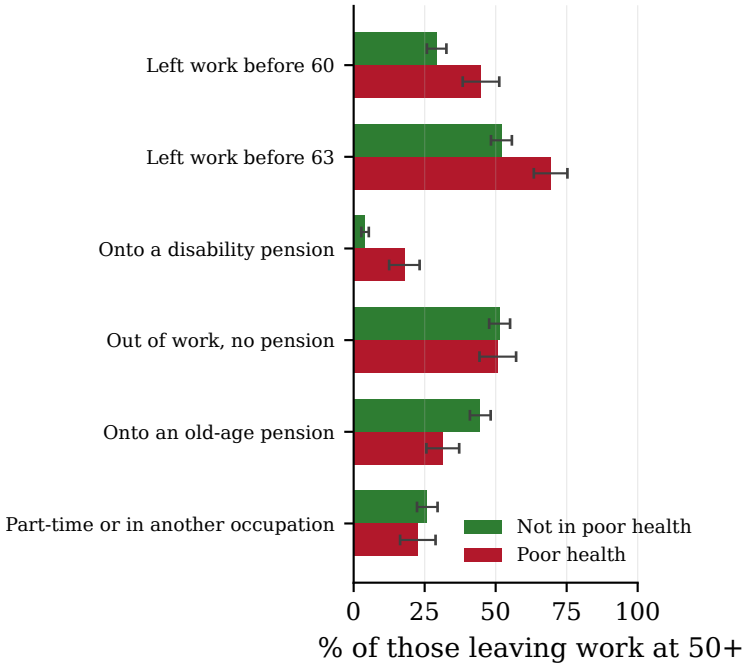


Figure 3: Leaving work, by health

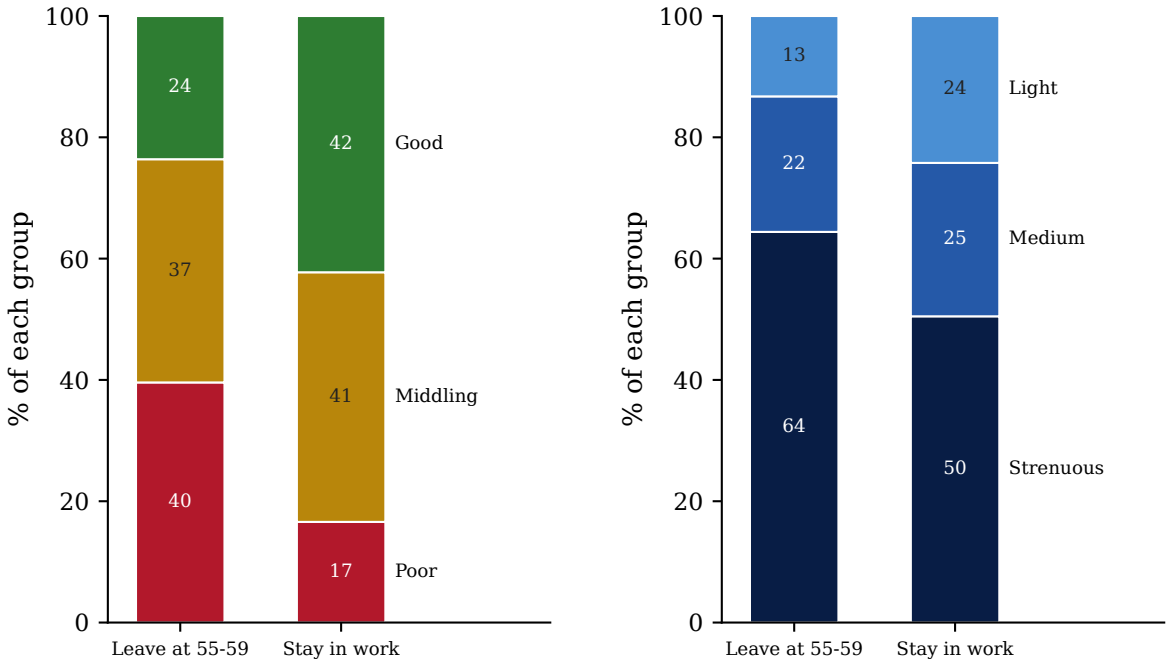
Notes: SOEP men born 1938–1953 who permanently leave work at 50 or later, with the following year observed; weighted, and split by health in the last year of work. Each bar is a share of that group's exits.

Given that poor health is associated with more rapid exit from a strenuous occupation, one might imagine that many of those in poor health would reallocate to a lighter occupation. This does not appear to happen. Indeed, among those who do change occupation, those in poor health are less likely to end up in the light occupation. Of those leaving the medium occupation, 64.1% of those in good health move into the light occupation, against 49.1% of those in poor health; leaving the strenuous occupation, health makes little difference to where people go (Appendix Table A.6). However, those in poor health do adjust their work in another way, moving more often from full-time to part-time work within the same occupation (1.7% a year, against 1.0% of those in good health). Poor health raises the yearly rate of leaving employment from 3.6% to 11.7%, yet only about 22% of those leaving in poor health go onto a disability pension; those who are too unhealthy to work leave by whatever route is open to them. Once out of work, they are also less likely to return, with 14.7% re-entering employment within a year against 23.6% of those in good health. Our data is also consistent with previous work finding that workers with low education leave early through disability pensions and long-term unemployment at higher rates, with low work ability and poor physical health accounting for much of the gap (Rohrbacher and Hasselhorn, 2022).

Not all early leavers are in poor health or from strenuous careers, however. Both groups are over-represented among those who leave work early, but neither accounts for them all (Figure 4). Among those leaving work for good at 55–59, 39.6% are in poor health in their last year of work, against 16.6% of those of the same age who stay in work, so 60% leave in good or middling health. Similarly, 64.4% of early leavers come from strenuous careers, against 50.5% of those who stay, leaving 36% from medium or light careers.

3 Model

Fundamentally, we want to model how people make choices as they move from working life to retirement, including whether and when to claim an old-age pension, a disability pension,



(a) Health while in work

(b) Career occupation

Figure 4: Who leaves work early

Notes: SOEP men, person-years at ages 54–58 still in work; weighted. "Leave at 55–59": the year is the last year of work, so the first year out of work is at 55–59; "stay in work": every other such year. Health is the self-rating in that year (good: the two best; poor: the two worst).

or unemployment support, and, if still working, whether to change occupation or to switch between full-time and part-time work. It must allow for agents to be forward looking so they can anticipate and plan their retirement, and for their retirement options to depend on their previous choices.

Section 2.4 showed that strenuous work wears down health, and that sufficiently poor health tends to push people out of work. Within our model then, health deficits should accumulate with the work a person does, and in turn change the value of working in each occupation. Since it is the work history that damages health, a person choosing an occupation is also choosing, in part, their health and their options later in life. Because people anticipate pension rules, a change to them can affect not only when they claim but also their choices in earlier life.

Our model takes the form of a dynamic discrete choice model of occupation, hours, consumption, and pension claiming, following workers through their careers and into retirement. In this we follow the tradition of French (2005), Haan and Prowse (2014), and Blundell et al. (2023) who model retirement and health, and Jacobs (2023) and Wen (2023) who model occupation, health, and retirement. Our health evolution follows an accumulated deficits model similar to those of Schünemann et al. (2017), Strulik (2022), and Grossmann et al. (2024).

3.1 The choices modelled

We consider individual agents who make choices each period about their labour market status, consumption, and potential pension claims. Concretely, an agent i in period t makes a discrete choice over the following options. They may choose to work in one of three occupations $\text{occ}_{i,t} \in \{1, 2, 3\}$, each of which offers the option of choosing either full-time or part-time work, captured by the variable $\text{emp}_{i,t} \in \{1, 0.5, 0\}$ taking value zero in non-employment, $\frac{1}{2}$ in part-time, and 1 in full-time employment. If choosing not to take work, then an individual with no job may

choose to apply for a disability pension, for which they have some probability of acceptance, to claim any old-age pension for which they are eligible, or to fall on unemployment support. For those eligible they may also claim an old-age pension while working. For convenience, we define indicator variables for the state of claiming an old-age pension and not working $\mathrm{ret}_{i,t}$, for claiming disability pension and not working $\mathrm{disab}_{i,t}$, and for falling into unemployment $\mathrm{unemp}_{i,t}$. Each individual falls into exactly one of these states or has $\mathrm{emp} > 0$.

Each of these choices gives an associated income, and agents may choose how much of that income to consume or save. While they may later dissave if their income drops, there is no borrowing in the model.

Choices made today will affect the future through three channels. Returns to occupational tenure make a job more attractive the longer it is held, health shapes later options and mortality, and pension eligibility and entitlement depend on the work history.

3.2 Agents, their characteristics, and their health

An individual i has permanent observed characteristics education E_i (a binary for any tertiary education), birth cohort B_i, and age at labour market entry A_i^{entry} (which determines eligibility for the especially long-term insured pension route). In addition, they carry (continuous) permanent unobserved productivity I_i.

The time-varying states of the model include calendar year t, health deficit $h_{i,t}$, and assets $\Xi_{i,t}$, as well as some labour-market related states described below. Age, $a_{i,t}$, is of course fixed by calendar year and cohort.

Health is treated as a continuous scalar deficit $h_{i,t} \in [0, 1]$, such that poor health is reflected by a higher value, and evolves as a random walk each period with a drift λ depending on the chosen labour market status and an idiosyncratic permanent shock. We parametrise this as

$$h_{i,t+1} = h_{i,t} + \lambda_{\mathrm{occ}_{i,t}} \cdot \mathrm{emp}_{i,t} + \lambda_R \mathbb{1}_{\mathrm{ret}_{i,t}=1} + \lambda_U \mathbb{1}_{\mathrm{unemp}_{i,t}=1} + \lambda_D \mathbb{1}_{\mathrm{disab}_{i,t}=1} + \psi_{i,t} \tag{1}$$

with $\psi_{i,t} \sim \mathcal{N}(0, \sigma_\psi^2)$ and h confined to the unit interval.

This health evolution equation allows for different occupational choices to have different health consequences that persist in the long term. We will see that the strenuous occupation damages health faster than the light one through $\lambda_1 > \lambda_3$. There is also persistent individual heterogeneity supported by the shocks ψ.

In contrast to e.g. Grossmann et al. (2024), we do not consider health deficits to be self-productive. This largely depends on how health is operationalised, and our data does not support it for the measure we use.

3.3 Labour force status

Our three occupations j are conventionally ordered in decreasing order of physical strenuousness. That is, we consider occupation 1 to be the strenuous occupation and occupation 3 the light occupation.

An individual will make their choices informed in part by their occupational history. Within our model, the states upon which the individual can base their choice include previous occupation held $j_{i,t-1}$, previous hours worked $\mathrm{hours}_{i,t-1}$, and occupational tenure $C_{i,t}$.

Occupational tenure accrues by one each period of full-time employment and by a half each period of part-time employment. It does not reset over non-employment spells but does upon taking up employment in an alternative occupation. That is, an individual does not lose the human capital from their previous trade simply by leaving employment, but only when they start accruing human capital from an alternative trade.

Each occupation j provides a wage offer to individual i parametrised as:

$$\ln w_{i,j,t} = \alpha_j^0 + \alpha_t^T + \alpha^A a_{i,t} + \alpha^{Asq} a_{i,t}^2 + \alpha^C C_{i,t} + \alpha_j^E E_i + \alpha_j^I I_i + \alpha^H h_{i,t} + \alpha^V \varepsilon_{i,j,t} \tag{2}$$

for standard iid normal shocks $\varepsilon_{i,j,t}$. These potential earnings would be halved for part-time employment. Differential returns to productivity I_i and education E_i produce sorting across occupations on these margins, allowing people to be better suited to one occupation or another. Further sorting on career history is produced by the lock-in effects of returns to tenure $C_{i,t}$. Persistence in individual wages conditional on observables is carried by the productivity I_i. Calendar time, age, and health enter the Mincer equation with the same returns to each occupation for parsimony.

As well as a wage, work may offer utility amenities or costs. We measure these amenities in units of leisure. An individual's flow utility is determined by their consumption c and leisure l, into which amenities are absorbed:

$$u_{i,t}(c, l) = \gamma_C \upsilon(c) + \gamma_l l \tag{3}$$

for a CRRA consumption function υ.

The majority of the nontrivial mechanics of the model are captured within the leisure term, which gives utility costs and benefits to various activities or states. The leisure term assumes that there are $L = 8760$ hours in the year, and that full-time work would consume $N = 2000$ of them. Leisure utility is then specified as

$$\begin{aligned} l_{i,t} = L - \left[N + \phi_J(\mathrm{occ}_{i,t}, E_i, I_i, h_{i,t}) + \phi_A(\mathrm{occ}_{i,t}, a_{i,t})\right] \cdot \mathrm{emp}_{i,t} - \phi_{\mathrm{H}} h_{i,t} \\ - \phi_{PT}(a_{i,t})\, \mathbb{1}_{\mathrm{PT}_{i,t}} - \phi_{WC}\, \mathbb{1}_{\mathrm{emp}_{i,t}>0}\, \mathbb{1}_{a_{i,t} \geq A_i^R} \\ - \phi_{SW}(s_{i,t}, s_{i,t-1}, C_{i,t}, h_{i,t}, a_{i,t}) - \phi_{\mathrm{DApp}} \mathbb{1}_{\mathrm{DApp}_{i,t}=1} - \phi_{\mathrm{D}} \mathbb{1}_{\mathrm{disab}_{i,t}} \\ + \phi_{\mathrm{Ret}}\, \mathbb{1}_{\mathrm{pension}_{i,t}} + \phi_{\mathrm{beh}}(a_{i,t})\, \mathbb{1}_{\mathrm{claim}_{i,t}} \end{aligned} \tag{4}$$

where here $\mathrm{PT}_{i,t}$ indicates part-time work, A_i^R is the normal pension age of the individual's cohort, $\mathrm{pension}_{i,t}$ indicates drawing an old-age pension, whether or not also working, and $\mathrm{claim}_{i,t}$ indicates the period in which it is first drawn. The status $s_{i,t}$ collects occupation, hours, and pension status, so that $s_{i,t} \neq s_{i,t-1}$ is any change of status.

The first line of (4) gives leisure L minus the number of hours worked $N \cdot \mathrm{emp}_{i,t}$, together with the amenities of the occupation ϕ_J, which depend on education, productivity, and health, and an age-related disamenity of working ϕ_A. The term ϕ_J captures, for example, that a job requiring training is harder for someone without it, and that poor health makes work more costly. This health dependence is non-linear, reflecting the behaviour described in Section 2.4. Individuals also value health per se through ϕ_H. The second line introduces costs of working either part-time or after the normal pension age.

The third line captures the switching costs associated with changing status ϕ_{SW} (whether it be changing occupation, re-entering employment, or changing from part-time to full-time work). These largely capture the frictions of finding and taking up a suitable job, which is why they differ with the individual's characteristics. ϕ_{DApp} is the cost of applying for a disability pension, whether or not the application succeeds, and ϕ_D the utility value of drawing one. The final line gives the amenity value of drawing an old-age pension, together with behavioural terms influencing the timing of claims. It has been seen that financial incentives alone cannot explain the bunching of claims at statutory ages (Seibold, 2021); we include terms ϕ_{beh} which capture the psychological utility benefits of retiring exactly at the normal retirement age or at the early retirement age reference points[1].

[1] To some extent these may also capture bunching due to work contracts being more likely to expire at these ages.

3.4 Pensions

The choice of when to claim a pension and through which route is critical to our analysis.

The six old-age eligibility routes we model are the regular route, the long-term insured route, the especially long-term insured route, the severely disabled route, the unemployment route, and the part-time route. Each of these paths carries its own ages at which it can be accessed, potential deductions for access at early ages, and additional eligibility criteria as described in Section 2.1. Some approximations are made in the implementation of these eligibility criteria, as is discussed in Appendix C.2.

Several eligibility criteria involve the number of years insured $\mathrm{yi}_{i,t}$. We do not track this directly but instead infer it from the age of entry to the labour force A_i^{entry}, as if coverage were continuous. The especially long-term insured route is modelled as open to those having at least 45 insured years. The 35 year requirement of the long-term insured and severely disabled routes is satisfied by the vast majority of those liable to social security contributions (our sample) and is not imposed. Unemployment and part-time routes are open following a period in unemployment or part-time work, respectively (assuming the cohort and age conditions are met). The severely disabled route is open with a probability depending on health status:

$$p_{i,t}^{\mathrm{sev-dis}} = \left(1 + \exp\left[-b_0^{\mathrm{sev-dis}} - b_H^{\mathrm{sev-dis}} h_{i,t}\right]\right)^{-1} \tag{5}$$

This probability resolves prior to the agent's choice, so they know if the route is available to them when deciding whether to retire that period.

Being eligible to claim a pension does not imply one actually does. There are features of pensions that may cause one not to want to claim immediately when eligible. As discussed in Section 2.1, there are deductions of 3.6% per year for some early claiming routes, and bonuses of 6% per year for delaying claim past the normal retirement age (for up to three years, after which the model requires the pension to be claimed). In addition, within the model one cannot work when claiming the old-age pension early or while claiming a disability pension, though one can continue working while claiming the old-age pension past the normal retirement age. As such, pension claiming is an active choice, not a state inferred by other labour market status variables.

The old-age pension benefit level is computed as the number of accumulated earnings points times the statutory pension value in the year of payment. Instead of directly storing this, which covaries strongly with age, we keep track of the average earnings points per year in the labour force, $\mu_{i,t}$. The total earnings points at a given time are then $\mu_{i,t}\mathrm{yi}_{i,t}$. The running mean $\mu_{i,t}$ evolves while employed as

$$\mu_{i,t+1} = \frac{1}{\mathrm{yi}_{i,t+1}} \left(\mu_{i,t}\, \mathrm{yi}_{i,t} + \mathrm{emp}_{i,t} \frac{w_{i,\mathrm{occ}_{i,t},t}}{\bar{w}_t}\right) \tag{6}$$

where $\bar{w}_t$ is the statutory average earnings figure, so that a year at average earnings earns exactly one point and a part-time year earns half[2]. At the time of claim, the total entitlement is reduced or increased by the appropriate deductions or bonuses.

The disability pension is modelled as open to agents ineligible for any old-age entry routes. An application costs utility ϕ_{DApp} regardless of whether it is successful, and if this application is made then analogous to the severely disabled old-age pension route, the disability pension is available with probability

$$p_{i,t}^{\mathrm{disab}} = \left(1 + \exp\left[-b_0^{\mathrm{disab}} - b_H^{\mathrm{disab}} h_{i,t}\right]\right)^{-1} \tag{7}$$

[2]While drawing unemployment insurance in the first period out of work after a job, an earnings point credit is applied; zero earnings points are accrued while in basic income support.

While claiming the disability pension, the benefit level is computed in the same way as the old-age pension entitlement, except that additional future years of earnings points are imputed at the individual's prior rate (every such award also taking the maximum deduction of 10.8%). These additional years run to a statutory age which varies with the year of award. We do not allow an individual to work while claiming the disability pension. The award is reviewed each year. A recipient keeps the pension with the same probability function (7) but where the intercept is raised by b_D, so that those whose health improves may lose their disability pension. Recipients may also leave voluntarily to return to work.

Apart from the old-age pension and the disability pension, those out of employment receive unemployment support. For the first year of unemployment they receive a benefit equal to the statutory replacement rate (60% of net earnings) applied to the mean wage of the last occupation they held. If remaining in unemployment longer than one year, they receive basic income support, modelled as a consumption floor of €9,000.

3.5 Consumption and savings

Whether in employment, drawing a pension, or receiving unemployment support, each individual has an income stream $Y_{i,t}$ of some kind. We allow savings at interest rate r so agents can build up asset stocks to smooth consumption in retirement, but we do not consider borrowing.

From their asset stocks and income, agents choose consumption $c_{i,t}$. They gain a CRRA utility from this consumption:

$$v(c) = \frac{c^{1-\nu} - 1}{1 - \nu} \tag{8}$$

Assets carried forward, Ξ, is the final state of the model. Once the wage draws and choices have resolved, the asset stock will evolve as

$$\Xi_{i,t} = (1 + r)\,\Xi_{i,t-1} + Y_{i,t}^{\text{net}} - c_{i,t} \tag{9}$$

We take $r = 0.04$; since Ξ includes housing assets a reasonably sized return is appropriate (Appendix C discusses the inclusion of housing in wealth within the model). Here $Y_{i,t}^{\text{net}}$ is income net of taxes and social security contributions.

3.6 Taxes, contributions, and the public budget

Because the policies we study are judged in large part by their fiscal effects, the model keeps a full account of what each person pays to and receives from the state. Income taxes are approximated by a fitted smooth form following Heathcote et al. (2017), described in Appendix C.2. Employee social security contributions are 20% of gross earnings up to the statutory ceiling, and are deductible from taxable income. Pensioners pay contributions of 11% of their pension, 80% of which is taxable, while unemployment insurance is free of both tax and contributions. Revenue from employers' social security contributions is also accounted for, although it does not enter workers' choices, whose wage equation (2) determines gross earnings from which only the employee's share of contributions is deducted.

On the other side of the public budget are the old-age and disability pensions, unemployment insurance, and basic income support that the model pays. When we evaluate a counterfactual policy in Section 5, its net fiscal effect is the change in all of these together. Pension spending withheld by a reform is offset by any extra spending on other benefits, and added to by the income taxes and social security contributions paid on any extra work. We do not consider direct spending on healthcare or long-term care.

3.7 Mortality

Mortality risk varies with health and age, and is taken to have a logistic functional form, giving a survival probability $\varsigma_{i,t}$:

$$\varsigma_{i,t}(h_{i,t}) = 1 - \left[1 + \exp\left(-\kappa_0 - \kappa^H h_{i,t} - \kappa^A a_{i,t}\right)\right]^{-1} \tag{10}$$

Upon death, there is a utility payoff based on a bequest motive:

$$u_{\text{death}} = \gamma_B \left[\upsilon(\Xi_{i,t} + \kappa_B) - \upsilon(\kappa_B)\right] \tag{11}$$

where $\Xi_{i,t}$ are total assets at death and υ is the consumption utility function (8). γ_B is an altruism parameter, while κ_B makes bequests a luxury good more valuable to larger estates.

3.8 The choice model

Agents enter the model at age 25 and are followed until a maximum age of 90, at which point they can be thought of as exogenously dying.

The timing of the model is as follows:

1. Potential wages are drawn for each occupation
2. Labour market, pension claim, and disability application decisions are made
3. Disability acceptance is drawn
4. Consumption is chosen
5. Health shocks are drawn for the following period

Health state is therefore predetermined at entrance to a new period, and fixed while the period's choices are being made. Note that potential wages for each occupation are known by the individual before making any choices. Individuals can move to a job because the wage offer is good, which may offset negative health-related amenities or anticipated health consequences.

In our implementation, the decision frequency is not constant. During early periods of the career, choices are made at a coarser level. Before middle age, the precise details of one's career path will not be so critical for the retirement path. As such, at ages 25 and 35 a choice of occupation and savings is made for the following decade; non-employment, part-time work, and disability are precluded during this period. These choices are made to ensure that occupation is endogenous from entry and to model the health impacts of early occupational choices. From 45, choices are made at an annual frequency and all options are considered.

Together, the state space of the model is

$$\{E_i, B_i, A_i^{\text{entry}}, I_i, a_{i,t}, h_{i,t}, \Xi_{i,t}, j_{i,t-1}, \text{hours}_{i,t-1}, C_{i,t}, \mu_{i,t}, P_{i,t}\}.$$

Here $P_{i,t}$ is the pension drawn in the previous period, none, disability, or old-age. At state s with observed (wage) shocks ε, the agent solves each period the maximisation problem

$$V_{i,t}(s,\varepsilon) = \max_{k,c} \left\{u_{i,t}\left(c, l_{i,t}(k)\right) + \eta_k + \beta \varsigma_{i,t}(h_{i,t})\, \mathbb{E}_\varepsilon V_{i,t+1}\left(s', \varepsilon\right)\right\} \tag{12}$$

for c consumption and the remaining discrete choices k. The agent discounts at β (calibrated to 0.97) and the preference shock η_k is iid extreme value type I distributed.

We do not model directly job offer frictions or involuntary separations. An agent may choose any occupation (or none) in any period, subject only to the utility costs involved. The implicit role of the switching costs ϕ_{SW} is in part to capture the frictions involved in finding a suitable job, which is why they can differ by agent characteristics. Involuntary separations are proxied

by large draws of η_{nonemp} (the preference for non-employment) or very negative draws of the preference shock in the prior job.

3.9 Initial conditions

At entry, agents enter with an exogenous education E_i, birth cohort B_i, contribution entry age A_i^{entry}, initial health $h_{i,0}$, and assets $\Xi_{i,0}$. Intuitively, these are drawn from the empirical distribution of observed initial characteristics. We do make some simplifications. Contribution entry ages A_i^{entry} are drawn from a distribution over the nodes $\{18, 25, 32\}$, which is placed such that the first node satisfies the 45 year service requirements of the especially long-term insured route by age 63, while the second and third do not. The distribution is taken from the binned empirical distribution conditional on education and cohort. Unobserved productivity I_i is sampled independently from a standard normal distribution.

As well as the characteristics described above, individuals also carry their father's occupation F_i which is similarly sampled from the empirical distribution. This will partly determine their initial selection into occupations at the model's initial age of 25, but not further affect choices at later ages.

The initial occupation at age 25 is modelled as a *choice* rather than an exogenous draw. This is important for us to be able to argue that we can measure any effects of changes to the pension system on early career behaviours. An entrant at 25 considers the value function

$$V_{\text{entry}}(j) = \zeta_j + \zeta^F_{j,F_i} + V_{24}(j) + \eta_{i,\text{entry}} \tag{13}$$

where $V_{24}(j)$ is the solved value function (12) for entering age 25 with prior occupation j. Since people may sort into initial occupations based on factors other than their raw future value, individuals' entry choices are also moderated by ζ_j, the general ease or entry desirability of occupation j, and ζ^F_{j,F_i}, which disproportionately pushes people into the same occupation as their father. $\eta_{i,\text{entry}}$ is an EV type-I shock. The agent compares the entry values for each occupation and chooses accordingly.

3.10 Levers and behaviours

Individuals sort between occupations ex ante on their education E_i and individual productivity I_i, which have both wage and amenity differentials across occupations, and ex post on health status $h_{i,t}$ and occupational history through switching costs and returns to occupational tenure $C_{i,t}$.

Strenuous work is damaging to health through the λ parameters in Equation (1), and workers in poor health then sort between occupations and/or non-employment through the disutility of work $\frac{\partial}{\partial h}\phi_J$. Workers in poor health rarely move to less strenuous occupations, even though health appears to drive exit least in those occupations (Section 2.4). The model is able to capture this through switching costs ϕ_{SW} whose health dependence varies between occupations, so that unhealthy workers find it difficult to make this transition.

Pension policy acts on these choices through the eligibility rules and deductions of each route, and also through the utility terms tied to statutory ages. The behavioural claiming bonuses ϕ_{beh} are given to those claiming the old-age pension exactly at their statutory ERA or NRA. When a reform moves these ages, the reference points move with them, meaning that part of a reform's effect on when people claim comes from moving where these rewards fall, not only from changing which choices are available. When the 2014 reform lowered the deduction-free retirement age for the especially long-term insured, the shift in their claims to the new age has been found to be driven both by the financial incentives and by the new eligibility age acting as a revised reference point (Dolls and Krolage, 2023). This matters for welfare. If a pension reform causes people to delay retirement simply because they have revised their reference point then

the welfare costs are likely to be much smaller than if they do so for financial reasons (Blundell et al., 2016)[3].

4 Estimation

In this section we describe how the model is estimated, the moments that identify its parameters, the resulting estimates, and how well the model fits the data.

The functional forms of the amenity and cost terms in the leisure equation (4), and the numerical methods used to solve the model, are set out in Appendix C. The model is solved by backward induction from age 90, with the consumption choice solved by the endogenous grid method (Carroll, 2006), taking the upper envelope across discrete alternatives (Iskhakov et al., 2017). One choice of functional form matters for what follows. Health enters the cost of working only beyond a threshold value $\bar{h} = 0.375$, above which the cost rises convexly.

4.1 Estimation strategy

We estimate the model by indirect inference (Gouriéroux et al., 1993; Smith, 1993). We define a series of auxiliary moments in the form of conditional means and parameters from OLS regressions, and estimate each of these moments in the data to give the vector $\tilde{m}$. Having solved the model we can simulate its behaviour at a given set of parameters θ, which gives us a panel on which we can compute exactly the same set of auxiliary moments, giving estimates $m(\theta)$. The estimator is the solution which most closely matches $\tilde{m}$, formally the solution to

$$\hat{\theta} = \underset{\theta}{\operatorname{argmin}} \ (\tilde{m} - m(\theta))' \ W \ (\tilde{m} - m(\theta)) \tag{14}$$

for a weighting matrix W which defines the relative importance of the moments. This matrix is constructed to be diagonal, whose entries depend on the precision with which a given data moment is measured, as well as factors reflecting the relative economic importance of these moments in determining the model's behaviour.

It is well understood at a technical level that dynamic discrete choice models of the form we have here cannot be completely non-parametrically identified (Magnac and Thesmar, 2002; Rust, 1994). As is standard, we calibrate the discount factor β, here to 0.97. In addition, we calibrate the relative risk aversion $\nu = 1.5$. The remaining 78 parameters are estimated jointly.

4.1.1 Inference

Standard errors for the indirect inference estimator are computed by

$$\mathrm{Var}(\hat{\theta}) = \left(1 + \frac{1}{S}\right) (G'WG)^{-1} G'W\Omega WG \, (G'WG)^{-1} \tag{15}$$

with $G = \frac{\partial m}{\partial \theta'}\big|_{\hat{\theta}}$, Ω the sampling covariance of the data moments $\tilde{m}$, and S the number of simulated agents per individual in the estimation sample. We do not use the econometrically optimal weighting matrix W, and so this formula does not simplify in our case.

[3] Our welfare measures are computed from the model's own lifetime utility and so include these bonuses, so a delay that follows the reference point to its new age is not counted as the loss of a bonus, only as its later receipt. However, including the bonus or not when evaluating welfare makes little difference; it is the changed behaviour it causes that affects welfare, not the evaluation of the utility bonus per se.

4.2 Moments and identification

In total, the 78 parameters of our model are estimated from 373 moments, grouped into blocks as shown in Table 3. Though many of these sets of moments closely mirror the structural equations of the model, it should be emphasised that they are misspecified when run as OLS regressions. Indirect inference matches these misspecified coefficients as produced both by the true data and the model simulations, but does not directly match the parameters of the model with moments from the data.

Formal identification of a model of this size is infeasible; instead, we argue intuitively that each family of parameters moves specific sets of moments that can distinguish their effects. This will be supported numerically with the sensitivity of each parameter to each block, and the verification of the full rank of the Jacobian, in Appendix E.1. Appendix D sets out the moments behind each block in full.

Table 3: Moment blocks and the parameters they target

Family	Moments	Number	Targets
Wages	Mincer regression of log full-time earnings; residual variance; within-person autocovariance	17	α
Occupations	Shares by education and age; switching LPM; switchers' destinations; tenure	67	ϕ_J, ϕ_{SW}
Participation	Employment by age, education, and health; exit and re-entry LPMs; exit hazards to each pension; re-entry wages	74	ϕ_A, ϕ_{SW}
Part-time	Part-time LPM, shares, and persistence	18	ϕ_{PT}
Health	Deficit drift; transition shares at lags; levels	37	λ
Disability	DI receipt LPM; recognised disability	14	ϕ_D, ϕ_{DApp}, b
Retirement	Claiming rates by age and cohort; destinations; occupation	57	ϕ_{Ret}, ϕ_{beh}
Entry	Entry occupation by education and father's occupation	12	ζ
Aggregate	DRV award rates and DI acceptance	37	ϕ_D, ϕ_{DApp}, b
Wealth	Wealth levels and mass	28	γ
Mortality	Mortality by age and its health gradient	12	κ
Total		373	

Each family of parameters is identified mainly by the following moments.

- Wages: The wage equation is identified by wage regressions that follow (2) in their regressors, and the returns to productivity and the variance of the transitory shock by the residual variance and within-person autocovariance of earnings.
- The cost of working: The occupation amenities and the age costs of working are identified by employment and occupation shares by age, education, and health, and by the regressions of leaving employment at 45–58 and 59–64. These regressions carry both a linear health term and a quadratic term beyond the threshold, so they can distinguish a cost of poor health that rises steadily from one that sets in past the threshold.
- The barriers to moving: The switching costs are identified by how often people change occupation and where they go; the mean destination of switchers by origin and health identifies the health gradient of the cost of moving. The re-entry costs are identified by re-entry rates and destinations by age and health.
- The retirement and disability margins: The value of drawing a pension and the claiming bonuses are identified by the claim hazard by age, cohort group, and occupation, whose bunching at the early and full-pension ages the bonuses produce, and by regressions of

claiming and of exit at 59–64. The disability parameters are identified by receipt of a disability pension by health, age, education, and occupation, and by administrative award rates, the stock of recipients, and the share of applications accepted, which pins down the acceptance probability that no survey moment observes.

- Health, mortality, and savings: The drifts of the health process are identified by the regression of the change in health on status, and the variance of the health shock by the persistence of reported health over lags of up to eight years. Mortality is identified by death rates and their dependence on health, and the weights on consumption and leisure by the wealth moments together with labour supply.

- Entry: The entry parameters ζ are identified by the occupation at entry by education and father's occupation.

Beyond the functional forms, two sources of variation aid in the identification of the behavioural parameters. Firstly, over the sample window there are several pension policy changes that are plausibly providing exogenous variation between our cohorts. As discussed in Appendix A.2, some pension routes close during our sample (unemployment and part-time routes), others open (Rente mit 63), and a number of eligibility ages vary. The differences between claiming patterns across cohort groups, captured in the DRV pension award rate moments, will reflect the changing pension routes and incentives available. The model must therefore reproduce not only how many people claim at each age, but how they shift their claiming and substitute between different routes as eligibility rules change.

Secondly, the initial choices at age 25 in our model are driven in part by the father's occupation. To the extent that this is conditionally exogenous from the choices in later life, this acts as an instrument providing exogenous variation in who is pushed into different career paths, and hence provides identification for the parameters that model their later choices.

4.3 Estimates

Here we discuss the economic magnitude of some estimates of particular interest.

Amenities and costs are denominated in hours of leisure a year, so we begin with what those hours are worth. At our estimates, raising consumption by 1% at its mean of €23,749 a year is worth 6 hours of leisure; with $\nu > 1$, consumption utility is bounded above, and no increase in consumption at the mean is worth a large amount. One standard deviation of the preference shock is worth 3,119 hours, more than a full-time year of 2,000 hours, so transient idiosyncratic tastes carry a large part of individual behaviour.

The health process, reported in Table 4, captures the first of the links set out in Section 2.4, that strenuous work wears down health. Health deteriorates four times as fast in the strenuous and medium occupations as in the light, 0.009 a year of the deficit against 0.002, so that ten years of strenuous work adds about 0.07 extra to the deficit relative to light work. Deterioration slows in retirement, to 0.004 a year, and is fastest out of work and on a disability pension, 0.009 and 0.011.

Poor health raises the cost of working, which is the model's counterpart to the second link, that poor health pushes people out of work. Moving from $h = 0$ to $h = 0.5$ adds a modest 80 hours amenity cost, but moving to $h = 1$ adds nearly 2,000, about two-thirds of a preference-shock standard deviation. The utility cost of working rises with age by 140 hours a year from 55 to 60, and faster in the medium and light occupations than in the strenuous one.

Moving between occupations is costly, which bears on the third link, that those in poor health do not move to lighter work. Entering an occupation costs 3,300 hours in the strenuous, 4,600 in the medium, and 5,400 in the light, between one and two preference-shock standard deviations, and a change of trade adds 2,100 more, together with up to 100 hours for each year of tenure

given up. Re-entering employment from non-employment costs 7,800 hours, two and a half standard deviations, the largest friction in the model.

The remaining parameters govern the routes by which people leave work. Drawing an old-age pension is worth 490 hours a year, a sixth of a preference-shock standard deviation. The claiming bonuses are larger and paid once, at 4,500 hours for claiming from work at the earliest eligibility age and 3,700 at the full-pension age (1.4 and 1.2 standard deviations respectively), which is what produces the bunching of claims at those ages. Applying for a disability pension costs 1,100 hours, and drawing one is worth 900 hours a year. Acceptance is a sharp threshold in health. An applicant with $h = 0$ is almost never accepted, one with $h = 0.5$ in 3% of cases, and one with $h = 1$ in 98%.

Table 4: Parameter estimates: the health process

	Estimate ($\times 10^3$)	SE
$\lambda_{\text{occ}}(1)$	8.82	(0.28)
$\lambda_{\text{occ}}(2)$	8.82	(0.28)
$\lambda_{\text{occ}}(3)$	2.16	(0.85)
λ_R	4.02	(0.69)
λ_U	9.01	(0.47)
λ_D	10.80	(0.88)
σ_ψ	14.29	(2.67)

Notes: Annual drifts of the health deficit (on $[0, 1]$) by occupation and status, and the annual standard deviation of its innovation. All values are multiplied by 1,000 for clarity. $\lambda_{\text{occ}}(1)$ and $\lambda_{\text{occ}}(2)$ are found to be comparable and so are assumed equal in our in our preferred specification.

4.4 Fit and model behaviour

Our model is both very overidentified and also misspecified, as must be any model of behaviours as complex as the ones we seek to capture. As such we do not hope for the model to exactly reproduce the whole suite of data moments identically, but to both approximately capture the bulk of these moments and to most precisely capture those which are especially economically relevant. Appendix Figure A.2 plots each target moment against its simulated counterpart; the bulk of them lie close to the 45-degree line. Here we briefly explore some of the gross behaviours of the estimated model that are important for the connections between health, occupation, and retirement, comparing them to the data to assess the reasonableness of the model's predictions.

As seen in Section 2.4, health deteriorates faster in strenuous work. In Table 5, we look at the change in health by occupation from middle age to near retirement age in the model and data. The estimated gap between the health of those in strenuous careers and those in light careers grows from 0.053 at age 45 to 0.117 at age 59, faster than the data at 0.060 to 0.093, but the broad trends are largely reproduced. To understand the sources of this gap, we can decompose it within our model simulations into the parts explained by sorting at labour market entry, by time within the career occupation, by time spent in other occupations or non-employment, and idiosyncratic shocks. Time spent in the career occupation itself overpredicts the overall gap, with time in other jobs reducing this deficit between strenuous and light workers' health.

We see in Section 2.4 that men in strenuous occupations or poor health tend to work less and retire earlier, and those in both even more so. Figure 5 demonstrates that these features

Table 5: Occupation and health, data and model

(a) Mean health deficit, data and model				
	Strenuous	Medium	Light	Strenuous–Light
At 45, by career occupation				
Data	0.398	0.375	0.338	0.060
Model	0.435	0.399	0.382	0.053
At 59, by career occupation				
Data	0.511	0.458	0.418	0.093
Model	0.545	0.513	0.428	0.117

(b) Decomposition of the model health gap at 59	
Strenuous–Light gap at 59	0.117
Deficit at entry	-0.009
Drift from career occupation	0.221
Drift from other jobs	-0.084
Drift from non-employment	-0.007
Residual: shocks and survival	-0.004

Notes: Panel (a): the mean health deficit by career occupation, the occupation held longest while employed between ages 45 and 59. Panel (b): the simulated difference in deficit at age 59 between those with strenuous and light career occupations. This is decomposed into the part explained by selection at entry, the parts explained by the average effects of their choices, and the part explained by idiosyncratic shocks and selection due to differential survival.

are reproduced by our model. The model simulations reproduce well the evolution of employment over the lifecycle for different health groups and the difference between those in light and strenuous occupations, though it does underpredict employment around 60 in the medium occupation. Within the model we can also compute directly how a negative health shock will affect employment. Giving men working at 54 a health shock of one standard deviation and holding all else constant subsequently, the share not working at 60 increases from 37.1% to 51.7%, with a roughly proportional effect across occupations (but in absolute terms loading most on strenuous career workers). We rarely see people transitioning from strenuous to lighter work in their late careers, and as in the data it does not appear to be an exit channel disproportionately used by those in poor health. Only 3.0% of those in medium or strenuous jobs in their 50s switch to a lighter occupation each year, and this does not differ by health status. Nor do we find later-career workers in poor health frequently returning to work after exit. Only 13.1% of those in poor health who stop working in their 50s are working again within two years.

In order to accurately determine the effect of a pension reform on retirement behaviours it is important that we are accurately capturing when people are retiring in the first place and how this is affected by pension eligibility thresholds. We see in Figure 6 the hazard of making an old-age pension claim. The characteristic bunching of claims at the statutory thresholds of 63 and 65 is broadly reproduced, though with some moderate overclaiming between these ages and underclaiming at 66. In the data, claim rates are front-loaded in the more strenuous occupations compared to the light occupation, while in our model those in light occupations overclaim at 63 (these largely driving the aggregate overclaiming at that age).

As well as when people exit work, we need to capture by which route they transition to retirement, in order that we can accurately model the substitution between these routes as pension policy varies. Panel (a) of Figure 7 shows the timing of permanent exit from work, split by health. We capture well how workers exit over the lifecycle and the differences in this timing between those in good and poor health. Panel (b) looks at the destinations of these exits and shows that we also broadly capture these channels. The model mildly underpredicts disability pension take-up, particularly of those in good and middling health, which leads to a corresponding

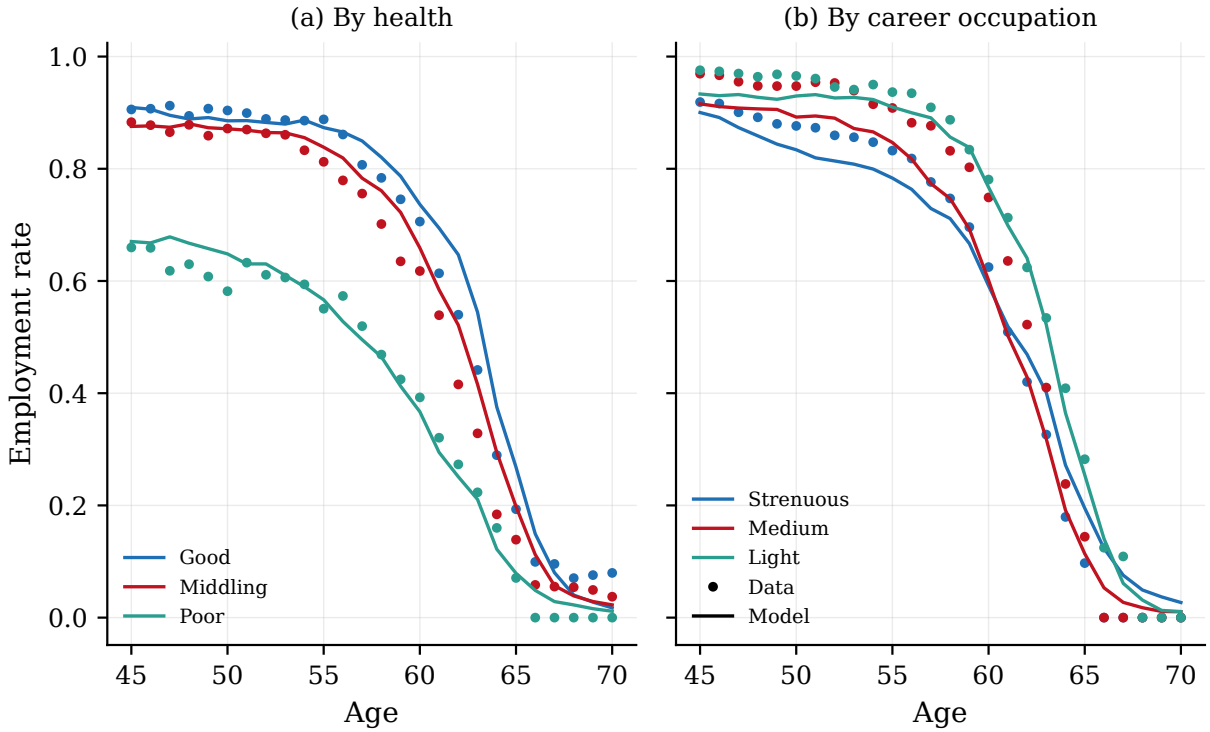


Figure 5: Who is working: employment by age, data and model

Notes: Employment rate by age. (a) By self-rated health (good, middling, poor). (b) By career occupation, the modal occupation over the years employed at 45-59 (strenuous, medium, light). Data is shown as dots and the simulated panel by solid lines.

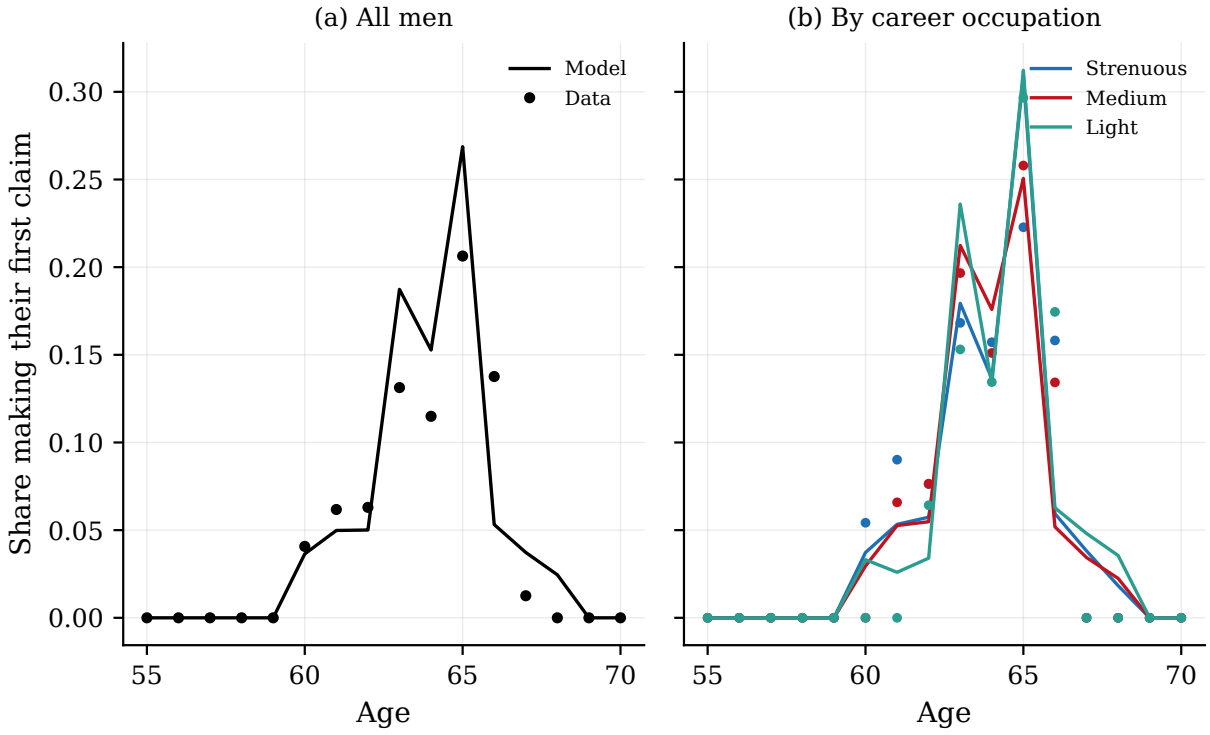
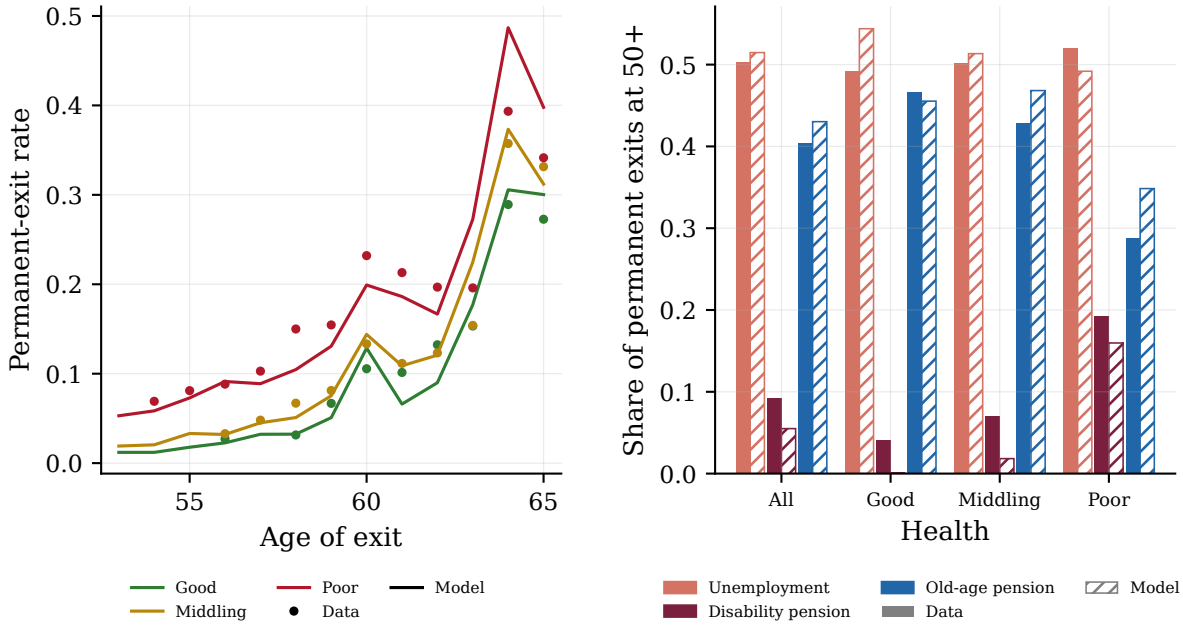


Figure 6: When people claim: first old-age claims by age, data and model

Notes: The share of men at each age who make their first old-age pension claim at that age. (a) All men. (b) By career occupation (modal occupation held during the years 45-59). Data (dots) and model simulations (lines).

overprediction of exit through unemployment for these workers.



(a) Hazard of permanent exit from work

(b) Destination of permanent exits

Figure 7: Exit timing and destinations in the model and data

Notes: (a) Hazard of permanently exiting work split by health category. (b) Each man's destination at final exit from employment (restricted to those permanently exiting after age 50). Shown broken down by health group (good, middling, or poor). Destinations are classified into old-age pension, disability pension, and unemployment. Data is shown in solid bars with model simulations in hatched bars.

5 Policy experiments

One key motivation for our analysis is to evaluate counterfactual scenarios corresponding to potential pension policies. In this section we analyse policy proposals and their effects. The simulations used to estimate the model as described in Sections 3 and 4 involved variable eligibility criteria and pension entry routes for different cohorts in line with the real-world data. Instead here we establish a baseline policy regime where all normal retirement ages are 65, all early retirement ages are 63, the long-term insured and especially long-term insured early claiming routes are open, and the unemployment and part-time entry routes are closed. For details of these routes, consult Section 2.1.

Against this, we consider the impacts of several potential policy changes. Firstly, to establish a reference point, we ask what the labour market impacts and fiscal benefits of a uniform rise in the pension age are, and how its costs are distributed. Secondly, we consider policies that condition the rise in eligibility age on career history or health status. We ask how this changes the labour market, fiscal, and distributional consequences compared to the uniform policy. We consider further policy experiments in Appendix F.

5.1 A uniform increase in the retirement age

If we raise the pension eligibility age for every route uniformly by two years, then on average, people will delay their pension claims by 1.83 years. The remainder of those two years is accounted for by those who previously had not claimed at the earliest opportunity, and so now use

a route they had previously not used. While the claim delay is nearly the full statutory raise, as shown in Figure 8 only around a third of that is spent working (0.64 years). The remainder is mostly spent drawing other benefits of some kind, primarily the disability pension (0.38 years) or basic income support (0.60 years). Fehr and Fröhlich (2024) find the same shift towards disability pensions in a calibrated model of the German system. A small amount of time is, on average, spent drawing no benefits, during which these people live off savings while waiting to claim a pension. An increase in the pension age does move people off the old-age pension, but for the majority of that time it does not drive them into work.

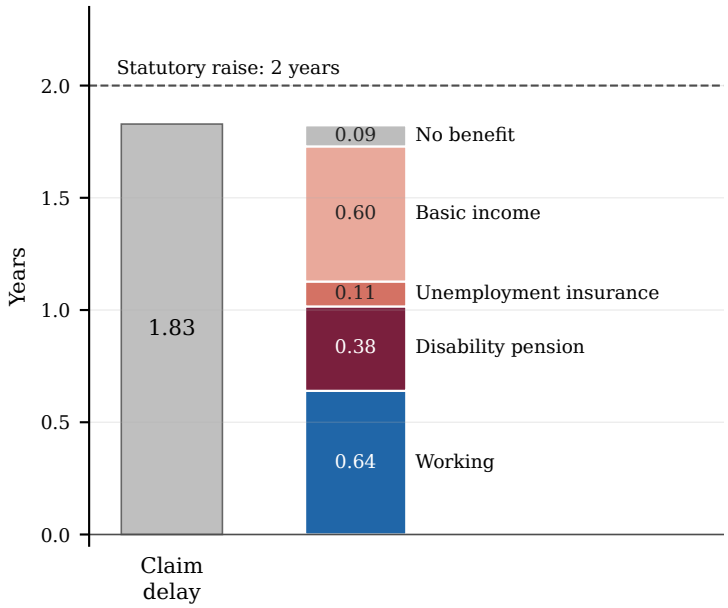


Figure 8: The effect of a uniform pension age raise on behaviours.

Notes: We consider all individuals in the years before age 70, and compare the total time spent in each state under the uniform age increase to the baseline simulation (the cut at age 70 to ignore mortality at later age). On the left is the decrease in the number of years spent drawing an old-age pension, on the right the increase in the years spent in each other state.

Who replaces a withdrawn pension with work largely depends on what people were doing prior to claiming the pension in the first place. In all, 33.0% of people completely lose eligibility for pension years they would have claimed, 1.66 years each on average (note that this undersells the total effect of the reform, since it excludes those who have access to an earlier route but must take a deduction to claim it). Appendix Table A.7 shows that of the withdrawn years, those who were still working until claiming in the baseline spent 68.9% of withdrawn years in work compared to just 12.5% of those who had been out of work prior to claiming their old-age pension, and 2.7% of those who had been drawing a disability pension. This increase in the pension age can keep many working who had already been working until their pension claim, but is not effective at bringing back into work those who had already left early.

How this affects the public finances is illustrated in Figure 9. The naive value of two years' delayed pension spending would have been €26,676 per person. Of course, given that people adjust their behaviour the actual gain to the government is not this amount. The amount paid in old-age pensions decreases only by €20,431, as a result of people not delaying their claims by the full amount. Working in the other direction, those who choose to claim through an early route then receive only a deducted pension for the remainder of their lives, improving the fiscal position of the government. Clawing back some of these savings, the extra time people spend drawing benefits costs a further €9,300. However, additional tax revenues from those working bring €11,790, leading to a net gain of €22,921. Those who remain in work are positively selected higher earners, and so bring in disproportionate tax revenue. Despite the relatively

small increase in working lives, close to half the net benefit of the policy is made up of additional revenue raised from these workers.

In Germany the pension system itself, the old-age and disability pensions financed by pension contributions, is nominally separate from unemployment support and income tax. Costed on the pension system alone, the reform gives a similar net saving, €22,435 per person, but only because two large effects outside it offset each other. One is the additional income tax and other social contributions on the extra work, and the other the additional spending on unemployment support for those who do not work. Which of these dominates depends on how much additional work the reform produces, and a costing confined to the pension budget would miss both.

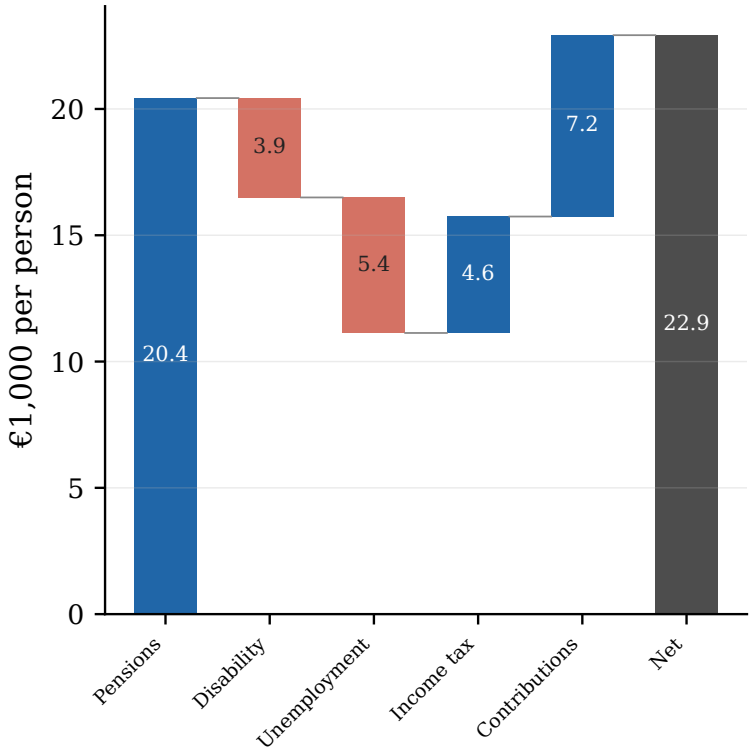


Figure 9: The fiscal impact of a uniform age increase

Notes: The change in government balances under a uniform two year pension eligibility raise compared to the baseline simulation, computed undiscounted over the whole lifetime. "Unemployment" includes both unemployment insurance and basic income support, while "contributions" includes both the employee and employer social security contributions. A positive number is a net gain to the government.

This reform bites differently on different groups. Measured by how many years a person loses eligibility for a pension they would have claimed (and has no earlier pension route to fall back on), the policy imposes more on those with lower education (see Appendix Figure A.3), who tended to claim as early as possible and spent relatively less of these years in work, meaning that on this margin the policy bites hardest where it is least effective. In contrast, those in better health had more years of claimed eligibility withdrawn, since those in poor health were more likely to be on a disability pension than an early old-age pension.

We will come back to the distributional consequences of these policies in Section 5.4, where we will consider the welfare effects of counterfactual pension policies.

5.2 Targeted policies and their limits

The uniform policy raises eligibility ages for everyone, whatever their capacity for work. Since capacity for work is not observed, we consider two scenarios in which pension eligibility is conditioned on either career history or health status as a proxy for ability to continue work.

Framed in this way, with eligibility requirements as proxies for ability to work, we can think of a targeted exemption as trying to solve a classification problem, set out in Table 6, which will be a useful organising principle for our results in this section. The rows of this table reflect the behaviour of an individual when pension eligibility is withdrawn. They may work, else they may not work but have the ability to substitute the old-age pension with other sources of income, such as unemployment insurance or a disability pension, or by drawing down personal savings. The final group are those who will not work when the pension is withdrawn, but have no alternative but to fall to the basic income support consumption floor. These we will call "stranded". The goal of a targeted policy would be to exempt the stranded, who cannot be induced to work and will otherwise be hurt by the pension withdrawal, and to make sure it does not exempt any of those who would work when the pension is withdrawn; keeping these in work being the real aim of the pension reform. The two policy failures are to leave the stranded exposed to an eligibility age increase and to wrongly exempt those who would have worked.

Table 6: Exemptions are a classification problem

	Exempted	**Not exempted**
Would work	wrongly exempted	works longer
Never works, substitutes	spared	substitutes
Never works, stranded	protected	exposed

We can think of the uniform policy without any exemptions as having no wrong exemptions but leaving the maximum number exposed. Any exemption will be a tradeoff between these errors to some extent. We will largely quantify these errors by person-years in each category.

Concretely, the main two policies we will consider in this section are:

Career-based policy: by default, the entitlement age for each pension route is raised by two years, as in the uniform policy. A person is exempted from these increases if they have accumulated at least 8 years of occupational tenure in the strenuous occupation at the time of potential eligibility[4].

Health-based policy: again, by default all entitlement ages are raised by two years. Those in the "poor" health state are exempted from these increases (as evaluated at the time of potential eligibility).

Table 7 compares these two policies with the uniform raise. The career-based policy exempts 41.2% of claimants and the health-based policy 35.7%. The average increase in eligibility ages decreases accordingly from 2 years for the uniform policy to 1.18 and 1.28 for the career-based and health-based policies respectively. Under the career-based policy the number of additional years worked declines accordingly, but the health-based policy keeps more of the uniform policy's effect, with 0.47 additional years of work per claimant against 0.32 for the career-based policy, and a net saving of €17,045 per person against €14,855. The health-based policy, exempting over a third of claimants, gives up only 26% of the fiscal benefit of the uniform policy. Many of those exempted would not have worked anyway. Even the career-based policy gives up only 35% of the uniform policy's fiscal gain despite exempting 41.2% of claimants.

The fiscal impact of each of these policies is broken down in Figure 10. While the health-based policy saves the least on pensions paid, it loses less in other benefits paid and brings in more taxes than the career-based policy. It exempts fewer people who kept working and paying in taxes rather than drawing other benefits.

[4]A tenure requirement is chosen as opposed to something like a current-occupation tag to try and avoid manipulation of eligibility by strategically switching occupations for a short period of time.

Table 7: Comparison of a uniform raise and the two targeted policies

	Uniform	Career-based	Health-based
Claimants exempted (%)	0.0	41.2	35.7
Years per claimant, before age 70			
Delay in eligibility	2.00	1.18	1.28
Delay in claiming	1.83	1.05	1.12
Additional years worked	0.64	0.32	0.47
Share of the claim delay worked (%)	35	30	42
Net fiscal saving (EUR per person)	22,921	14,855	17,045

Notes: Each policy reform compared with the baseline. Claimants exempted are those who claim an old-age pension in the baseline and who the policy's rule would exempt from any eligibility age increase judged at their baseline claim. The fiscal saving is per person, undiscounted over the whole life.

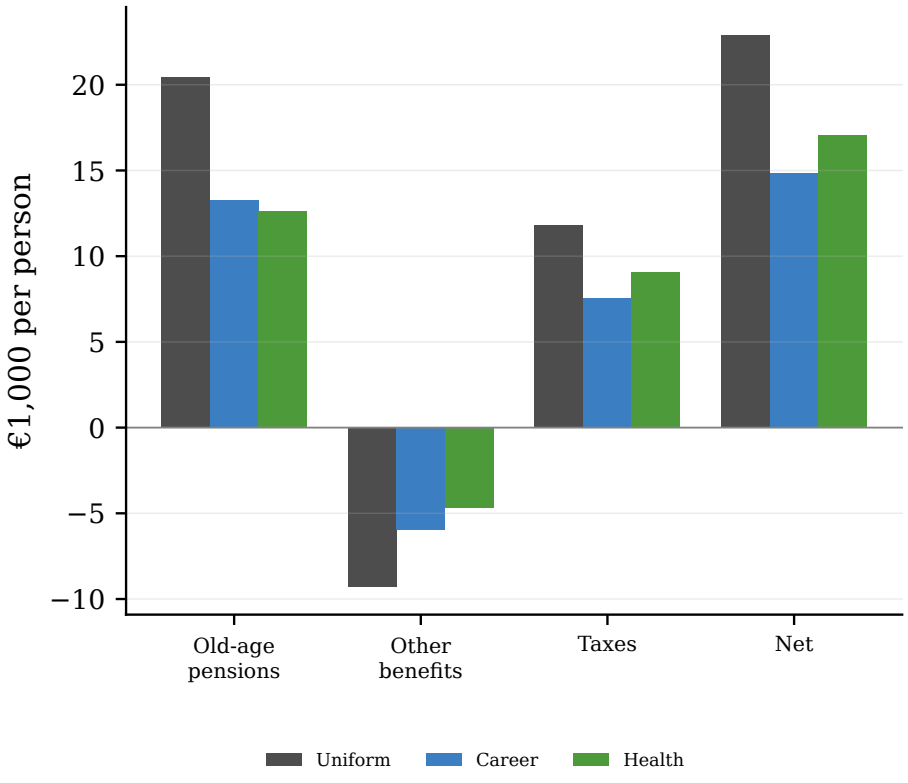


Figure 10: The fiscal effect of each policy

Notes: Change in the government's balance compared to the baseline, measured over the whole life; positive is a gain for the government. "Other benefits" include disability pensions, unemployment insurance, and basic income support. "Taxes" encompass both income taxes and social security contributions (from the employee and employer).

5.2.1 Who is protected, and who is left exposed

Following our classification in Table 6, a successful exemption takes those who would not work and have no other potential sources of income bar basic income support, and protects them from the pension increase. Conversely, those that are left exposed represent a failure of the exemption rule. We see in Table 8 that the career-based policy fails to exempt a similar number of stranded as it wrongly grants exemptions to those who would work (18.0% cf. 17.1%). This is in contrast to the uniform policy which of course only fails to exempt the stranded (28.6%) and never wrongly grants an exemption. The health-based policy sits in between, wrongly exempting fewer but leaving more of the stranded exposed, demonstrating this tradeoff between the two types of classification error. A stricter or looser health test moves along this tradeoff. Protecting more of the stranded means wrongly exempting more of those who would have worked, and giving up more of the fiscal gain (Appendix Figure A.4). In practice health would be assessed with error. Modelling that assessment on the one for the severely disabled route gives a policy with much the same fiscal saving and work response, which sits at another point on the same tradeoff rather than necessarily being strictly worse (Appendix F.2.3).

Table 8: Who is exempted, rightly and wrongly

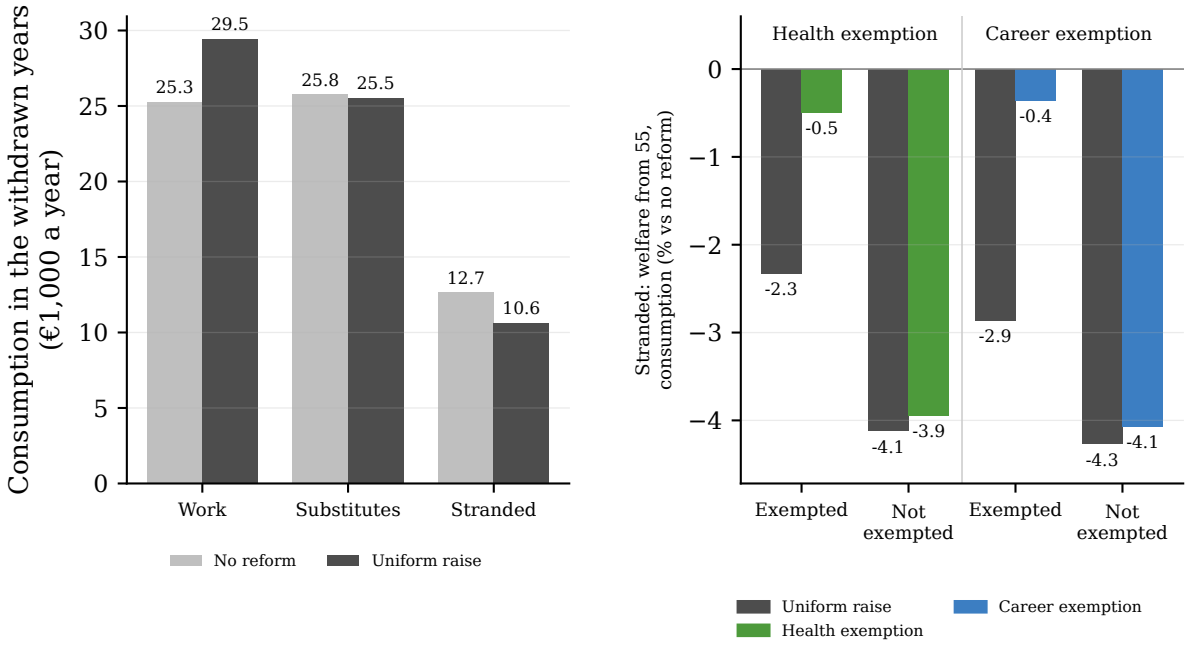
	All	Career-based		Health-based	
		Exempted	Not exempted	Exempted	Not exempted
Works	42.3	18.0	24.3	7.7	34.6
Substitutes	29.2	10.6	18.5	9.8	19.4
Stranded	28.6	11.4	17.1	7.6	20.9

Notes: Of those who would claim an old-age pension in the baseline but be ineligible for that pension for at least one year under the uniform policy (35.9% of claimants), the first column shows how many of those (i) *works*: work in every withdrawn year, (ii) *substitutes*: spend at least one withdrawn year out of work but every such year claiming a disability pension or unemployment insurance, or drawing down savings, and (iii) *stranded*: spend at least one withdrawn year on basic income support. The career-based and health-based columns show how many of these are exempted from the pension eligibility age increase and how many not.

The target of these exemptions is the stranded group. Panel (a) of Figure 11 shows that they are by far the poorest of the three groups (works, substitutes, stranded), even before any reform, having around half the average consumption level of the other two groups during the years the pension would be withdrawn. Not only this, but they are the only group that is seriously harmed by the uniform policy increase, with their consumption dropping by 16%. In contrast, those pushed into work increase their consumption and those who substitute to another income source see it largely unchanged.

When the health-based or career-based exemptions are implemented, as expected we see that for this stranded group the exemptions almost entirely negate the negative effects of the policy for those exempted but have essentially no effect for those not exempted. The policies are effective at neutralising the negative effects of the policies on this at-risk group when they identify them correctly. As was seen in Table 8, these policies only identify a minority of the stranded, 40.0% under the career-based policy and 26.7% under the health-based policy.

Neither policy can effectively target most of those stranded on basic income support when the old-age pension is withdrawn, because it turns out that the stranded are not, for the most part, in especially poor health or from strenuous careers. Figure 12 shows the distribution of career occupation and health among this group compared to the general population at the same ages. While it is true that the stranded group is slightly more likely to be in a strenuous career than the general population, this is not a drastic difference and there are substantial numbers of stranded in medium and light occupations. In terms of health, the stranded are actually less



(a) Consumption during withdrawn years

(b) The stranded: consumption welfare from 55

Figure 11: Consumption when the old-age pension is withdrawn

Notes: (a) Consumption during years the pension is withdrawn under the uniform policy but would have been claimed in the baseline. Groups are as in Table 8, restricted to those whose lives do not change before age 55 in every simulated scenario (since we are considering a subsample of individuals defined by outcomes under the uniform raise, this ensures that differences measured between policies reflect the effect of the policy near retirement rather than chance divergence decades earlier; this restriction retains 97% of each group, and we find similar results if we instead consider the policy change to be suddenly announced at age 55). (b) Of the stranded, their change in consumption welfare (i.e. excluding leisure terms and taste shocks) as consumption-equivalent variation compared to the baseline. Those exempted compared to those not exempted are shown for the health-based and career-based policies, to see the effect of the exemption on the two groups compared to the uniform (no exemption) policy.

likely to be in poor health, since those in poor health are more likely to be able to substitute to a disability pension. 19.3% are even in good health. No exemption based on occupation or health status would be able to protect these people.

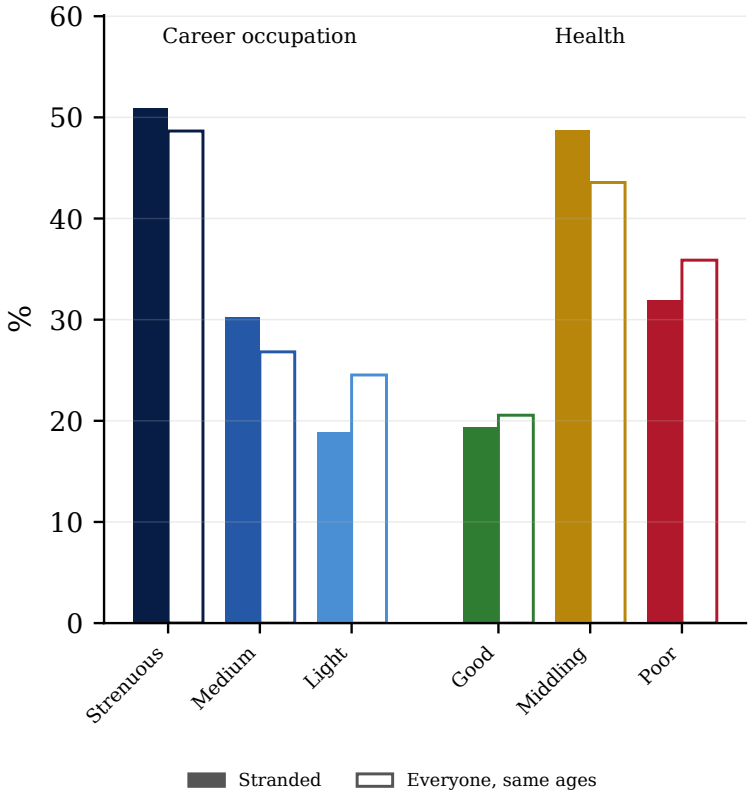


Figure 12: Who are the stranded

Notes: "Stranded" are those who, under the uniform policy, experience a withdrawal of the pension and do not work but instead fall onto basic income support. The career occupation and health of this group are compared against the whole population, age-matched (excluding those with no observed career occupation).

5.2.2 The costs of exemptions

The costs of exemptions given to different types of individual are shown in Figure 13. For the group protected by a given policy's exemption, i.e. those from whom pension eligibility was removed and who would otherwise not have worked and would have fallen into basic income support, the costs are quite minor. Someone protected by the career-based exemption only costs around €1,171, while someone protected by the health-based exemption costs €4,139. This is because these are stranded people, who have low pension entitlements in the first place and would otherwise need to be paid benefits of some other kind which mostly counteract the savings from pensions not paid. On the other hand, the cost of wrongly exempting people is substantially higher. A wrongly exempted person under the career-based policy costs €71,718, while under the health-based policy such a person costs €83,335. These are people who would have worked because they are positively selected, and hence there is a large loss in revenue from tax and social security contributions when they no longer do. This lost tax is large compared to the savings from pensions not needing to be paid (this gain is also smaller than might be expected since keeping them out of work does reduce the future pension entitlement paid for the rest of their life). A wrongly exempted person costs the government 4.5 times the pension they are paid under the career-based policy, and 3.4 times under the health-based policy. The bulk of the cost is the income tax and contributions they no longer pay. While it is relatively inexpensive to

correctly protect those who the policy sets out to protect, the cost of a mistaken exemption is dramatically larger.

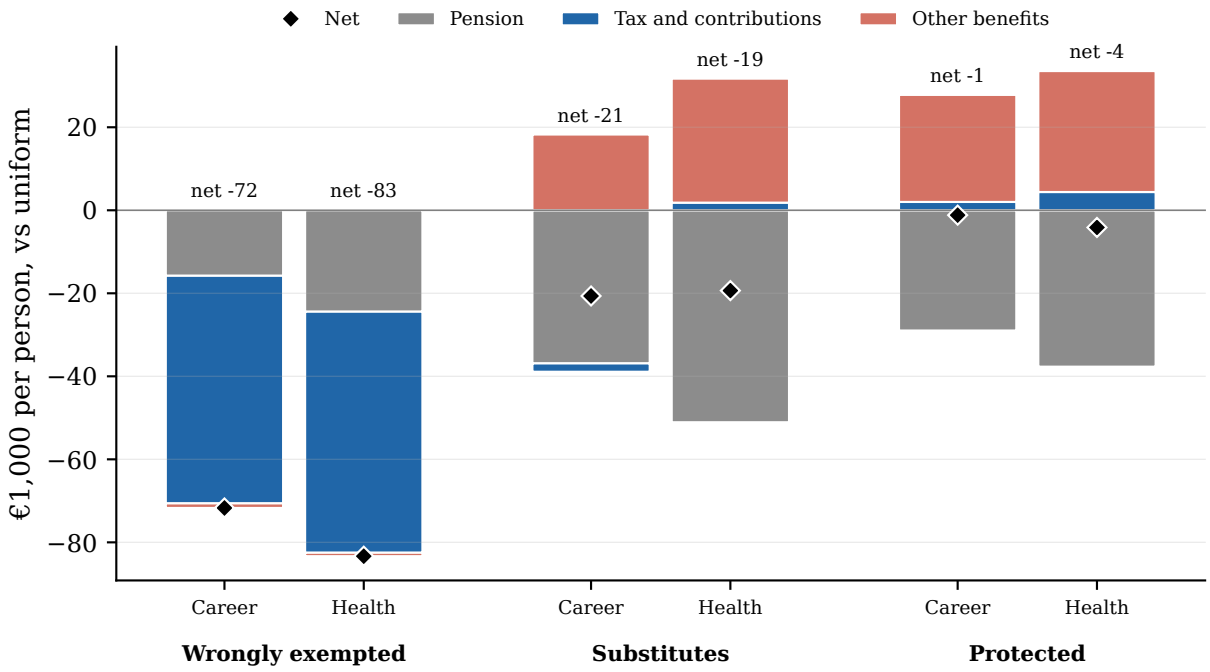


Figure 13: The fiscal costs of exemptions by who they reach

Notes: Per person exempted, the cost of this exemption to the government compared to the uniform policy (undiscounted over the whole life). Positive represents a gain to the government. Change in old-age pensions paid shown in grey, in other benefits (disability pension, unemployment support) in red, and in income taxes and social security contributions received in blue. Restricted to individuals whose lives are identical prior to age 55 in each simulation. Wrongly exempted: those who would have worked under the uniform policy; Substitutes: those who would not have worked but would have been able to find an alternative source of income; Protected: those who would not have worked and would have fallen onto basic income support.

5.2.3 Occupational distortion

Although the career-based and health-based policies may be more precisely targeted, a risk of implementing a policy with differential impacts across groups is that it may affect individuals' behaviours in ways apart from their claiming. Allowing those in the strenuous occupation to retire early makes this a more attractive option when work has a large disutility. Appendix Figure A.5 shows the behavioural consequences of these policies in terms of labour market distortion.

In practice, we find that these distortions are small. By age 60 the career-based policy shifts people to have worked in the strenuous occupation as their most recent job 0.55 percentage points more often. This shift, drawn mostly from the medium occupation, begins earlier in the career, already being 0.33 points by age 50, but there is essentially no re-sorting at labour market entry. Retiring early does not appear to be a sufficient draw for people to forgo the higher wages and better amenities of the other occupations for their whole careers. All policies appear to make the light occupation relatively more attractive by age 60 and the medium one less so. This arises from our estimated disutility of working in the medium occupation increasing most in old age, but again all these effects are relatively modest, having little effect on the aggregate occupational distribution.

5.3 Financing the exemptions

The policy proposals we have discussed thus far are not directly comparable in terms of their average effects on pension take-up, labour market impact, or fiscal impact. In order to give a fairer way to judge these policies against one another as we move forward, we consider adapted versions of the targeted policies in which we equalise their fiscal impacts.

There are a number of ways in which this could be done. The main mechanism we consider is an increase in the social security contribution rates paid by employees, either pay-as-you-go (PAYG), with each year's exemptions paid from that year's contributions, or funded, with each cohort's contributions saved, earning returns, to pay for its own exemptions later. The latter will of course require lower contributions than the former, as we see in Table 9, in which we show the level of contributions required to fully fund the exemptions to the eligibility age rise in the health-based and career-based policies.

Table 9: Alternative funding mechanisms for the targeted exemptions

	Contrib. rise funded (pp)	Contrib. rise PAYG (pp)	Old-age pension cut (%)	Contrib. rise, pension budget (pp)	Occupational contribution (pp)
Career-based	0.45	1.21	4.76	0.69	2.57
Health-based	0.31	0.90	3.45	0.50	–

Notes: Each rate finances the targeted policy to the same level of net fiscal savings as the uniform policy. Funded contribution rise: additional contributions are paid into a fund earning returns, from which the policy's costs are drawn when they fall due. PAYG (pay-as-you-go) contribution rise: contributions paid by the young finance pensions paid to the old in the same year. Pension cut: a proportional cut to every old-age pension. Pension budget: the pay-as-you-go contribution rise that matches the uniform policy's saving on the statutory pension insurance's own budget alone, excluding effects on income tax, unemployment support, etc. Occupational contribution: the career-based policy financed by a pay-as-you-go contribution increase on earnings in the strenuous occupation.

The cost of financing these exemptions in a pay-as-you-go system is relatively large, around 1 percentage point, while financing them in a funded system would be much less costly to workers, around a third of that. As a point of comparison, the table also shows the PAYG contribution rises that would be needed to fund the exemptions if the goal were only to equalise the impact on the pension system rather than the government as a whole (i.e. excluding income taxes, non-pension social security contributions, and unemployment support). This is noticeably smaller than the PAYG contribution rise needed when considering the government as a whole, mostly because contributions are deductible from income tax and so the increase itself is partly offset when considering it in conjunction with the tax system.

As an alternative to increasing contributions paid during the working life, the exemptions could be financed by reducing old-age pensions for everybody. The burden of this financing mechanism would obviously fall very differently, reducing income in old age rather than during the working life. Each of the options mentioned so far would act as a transfer from the population at large to those who would later benefit from the exemptions. A final option we consider for funding the career-based policy would be to raise contributions only for those working in the exempted occupation. Broadly speaking, this would be making those who are eligible for an early pension fund it themselves; similar funding schemes exist in Austria (Österreichische Gesundheitskasse, 2026), Czechia (OECD, 2025), and Spain (Gobierno de España, 2026, art. 206.4).

As we move forward, the financing method we will generally assume is a funded contribution rise. In the German context, contribution increases are more natural than a change in the pension benefit rate, since this benefit level is directly anchored in law, and the funded version is the most flattering method by which to consider funding the exemptions, so what we see will generally be an upper bound in terms of their appeal.

5.4 Welfare consequences

In addition to measuring the positive effects of the various policy counterfactuals, we are also interested in their welfare consequences, both in the aggregate and in determining who benefits and who bears the cost.

We measure welfare by the consumption-equivalent variation (CEV), but we are interested in welfare evaluated in two ways. First, measured at labour market entry behind the veil of ignorance (apart from initial characteristics), and second, evaluated at a given age later in life. The latter differs from the former in two important ways. For one thing, health, wage, and preference shocks have been revealed up to that point in time, but more importantly this also allows us to ask how a given individual values an (until then) unexpected change in the future pension system at different points in their life.

When comparing policies we generally use the versions funded by contribution rises to give equal fiscal benefits to the government as described above. Without equalising the fiscal impact this would be an unfair comparison, since exemptions would benefit some people without any corresponding cost to others.

5.4.1 Ex ante welfare

The CEV of a policy is here the proportion by which an individual's consumption would need to be scaled in every period under the baseline policy, to give the present value of expected utility equal to that under a given counterfactual. Measured this way, the uniform policy is slightly welfare-improving on average and for many subgroups (0.09% ex ante; Appendix Figure A.6a). This may be surprising, since the policy withdraws two years of pension eligibility from everybody. The utility gains are a result of the claiming bonuses ϕ_{beh} (see Section 3) moving with the statutory eligibility ages. These terms model the contractual incentives and behavioural reasons to retire at the statutory ages, allowing the model to reproduce the bunching of claims at the statutory ages that financial incentives alone cannot explain (Dolls and Krolage, 2023; Seibold, 2021). In the baseline, these bonuses incentivise some people to claim at 63 or 65 when they would perhaps otherwise have worked longer and enjoyed higher consumption; raising the eligibility age allows them to do so and still collect the same bonus at the later date[5].

We will generally judge the utility of the targeted policies by comparison with the uniform policy. Measured ex ante, relative to the uniform policy, we find that the career-based policy is less preferred across the board, by 0.45 percentage points of consumption on average (Appendix Figure A.6b; see also the age 25 point of Figure 14), while the health-based policy is broadly comparable in utility to the uniform policy, within 0.03 points of it. Those in middling health at labour market entry prefer the health-based policy, which insures them against health declining late in the career, while those already in poor health, who are likely to end up on a disability pension, do not. Overall though, by ex ante welfare people do not seem to value this insurance mechanism too highly. The career-based policy does not really provide much insurance against unanticipated shocks, since people can largely make choices about whether to become eligible for it or not. The health-based policy does provide some insurance, but at age 25 this is quite far in the future and too uncertain to give a clear benefit on average.

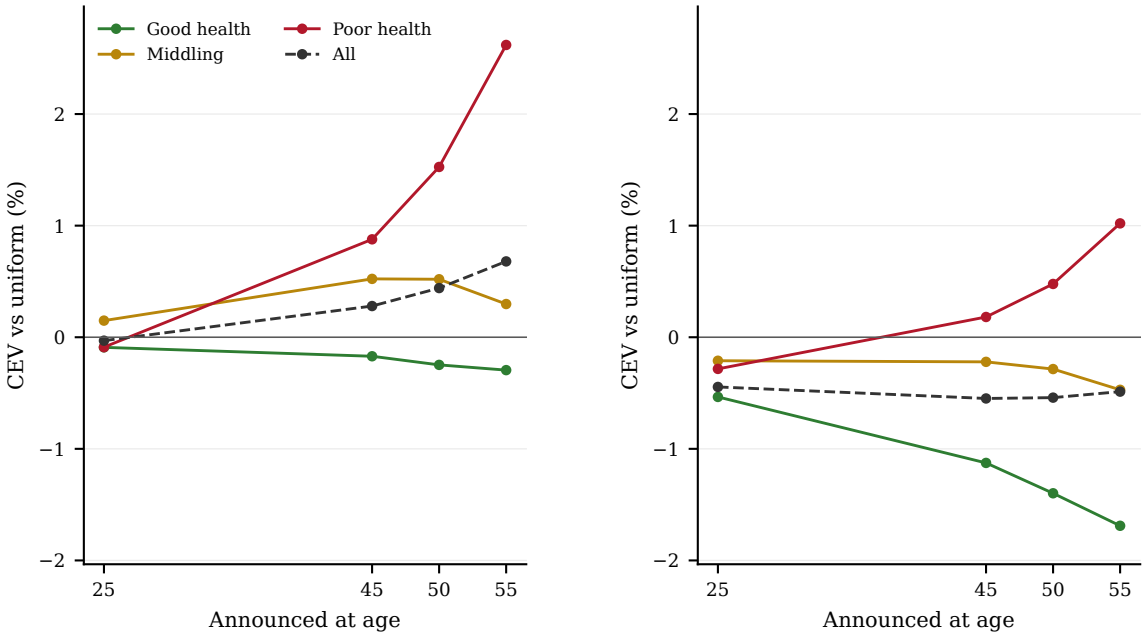
5.4.2 Welfare under unanticipated policy shock

In contrast to those at labour market entry, workers late in the career will have a much better idea of their health and career history, and may even already have begun making choices with

[5]This gain is not an artefact of counting the bonus in welfare. If welfare is instead evaluated without these bonuses, treating them as a norm that shapes behaviour but carries no true utility, the uniform policy remains preferred over the baseline regime.

an eye to their transition out of work. They will have a clearer idea of which policies might be beneficial to them and these benefits will be much less distant.

We consider now individuals who have lived until a particular age expecting the baseline policy, and then are faced with the announcement of a new policy regime[6]. If a policy is announced and implemented in the short term, then people who are in the middle of their careers and have limited ability to adjust will view the consequences of the policy differently than those who are younger and have a longer horizon before retirement. We ask what the welfare effects of the announcement of different policies would be at different ages in Figure 14.



(a) Health exemption

(b) Career exemption

Figure 14: Welfare of each targeted policy against the uniform policy, by the age at which it is announced

Notes: Consumption-equivalent variation of each exemption compared to baseline, less that of the uniform policy. All policies are announced unexpectedly at the age shown. Positive values indicate that the exemption is preferred. The career-based and health-based policies are financed by funded contribution increases such that their fiscal benefit matches the uniform policy.

While the health-based policy may have been slightly disfavoured compared to the uniform policy at labour market entry, this reverses at older ages. By middle age the benefits of the health-based policy are nearer and some part of the cost paid for these exemptions (in increased contributions) is behind you. As might be expected, the welfare benefit of this policy for those in poor health rises rapidly with age. By age 55 one might be more confident about their health state moving into retirement and whether this is likely to provide them with any benefit. In contrast, people in middling health originally value the insurance provided by the health-based policy, but as old age approaches those that are still in middling health realise they are less likely to transition into poor health by the time pension eligibility is decided, and the attractiveness of the policy declines. Similar phenomena are seen in the career-based policy, but it just appears less attractive in general, requiring slightly larger contributions and providing less insurance against uncontrollable shocks.

[6]This is also done to simplify comparisons so that all individuals have made the same choices under each counterfactual until the age at which their utility is judged.

The relative attractiveness of the different policy options does depend on how they are financed, however (Appendix Figure A.7). Financed by a contribution rise, the exemptions become more attractive as retirement approaches, since part of their cost has already been paid; financed by a cut to old-age pensions, they become less attractive, since that cost is approaching. Even so, the health-based policy becomes more attractive with age among those in poor health, the approaching lowered pension outweighed by the growing certainty of being exempted. The career-based policy, by contrast, is on average less attractive than the uniform policy even to those in strenuous careers, about half of whom would have kept working anyway, a reflection of how many it wrongly exempts.

Announcement of a policy change also affects choices (Appendix Figure A.8). Around 6% of individuals change their behaviour at some point in response to the uniform and career-based policies, while only 3% do so for the health-based policy, eligibility for which is harder to influence. Those under the career-based policy are much more likely to have changed occupation, while those under the uniform policy are simply more likely to have changed their employment status. The level of behavioural adjustment drops off sharply with age at announcement; the shift into strenuous work that the career-based policy induces (Section 5.2) is muted only if it is announced at 50 or later.

An inequality-averse planner with Kolm–Pollak preferences (Appendix F) finds the health-based policy mildly preferable to the uniform policy at moderate inequality aversion ex ante, and clearly so at age 55, but extreme inequality aversion favours the uniform policy, since the worst-off are among those the exemptions miss.

6 A pension reform referendum

The previous section discussed what a number of potential policy reforms actually do and how they might be judged by a social planner. Now we ask who would prefer each policy and what political coalitions would be involved in any votes choosing a new policy to implement. We compare the three budget-matched policies of Section 5.3: the uniform two year increase in pension ages, a career-based exemption, and a health-based exemption; the relaxed eligibility policies of the latter two financed by a funded increase in social security contribution rates such that each policy leaves the government in the same fiscal position. The choice between these options is then about their distributional consequences, which we look at here through a political economy lens[7].

Which pension rules a population would vote for has its own literature (Galasso and Profeta, 2002). Majority voting sustains a system larger than a voter would choose at the start of their working life, because the decisive middle-aged voter weighs only remaining contributions against the pension to come (Browning, 1975). Support can come from coalitions spanning retirees and particular groups of workers (Casamatta et al., 2000; Tabellini, 2000). Beyond its size, the system's design is also a political outcome, both in how redistributive it is (Conde-Ruiz and Profeta, 2007) and in whether it offers early retirement, which can be sustained by older and low-ability workers who expect to use it (Conde-Ruiz and Galasso, 2003). The same logic will lead older voters in our setting to favour exemptions that younger voters reject.

6.1 Within-cohort coalitions

Suppose a potential policy reform affecting their cohort is announced just prior to an individual turning age A, and that this policy was entirely unanticipated prior to that point (every individual previously expecting the baseline policy to continue indefinitely). We evaluate the individual's

[7] In so doing we do not address the additional intergenerational inequality argument that arises from funding any pension shortfall with deficit spending, but even without this there are interesting intergenerational considerations that we discuss.

expected lifetime utility from that point forwards under the three potential policy changes (uniform, career-based, health-based; each matched to deliver the same net fiscal benefit to the government). A given individual will prefer one policy to another whenever it delivers the higher continuation value. Aggregating the preferences of each person we can understand which policy would be preferred by the cohort as a whole, and which demographic coalitions drive this preference.

Figure 15 shows these preferences for cohorts who are various ages at the policy announcement. Note that these results only apply to cohorts whom the policies will affect; if the policy only affects cohorts younger than, e.g. 55, then older cohorts will be indifferent between the policies (assuming they are not to be affected by any contribution increases as well as pension eligibility changes).

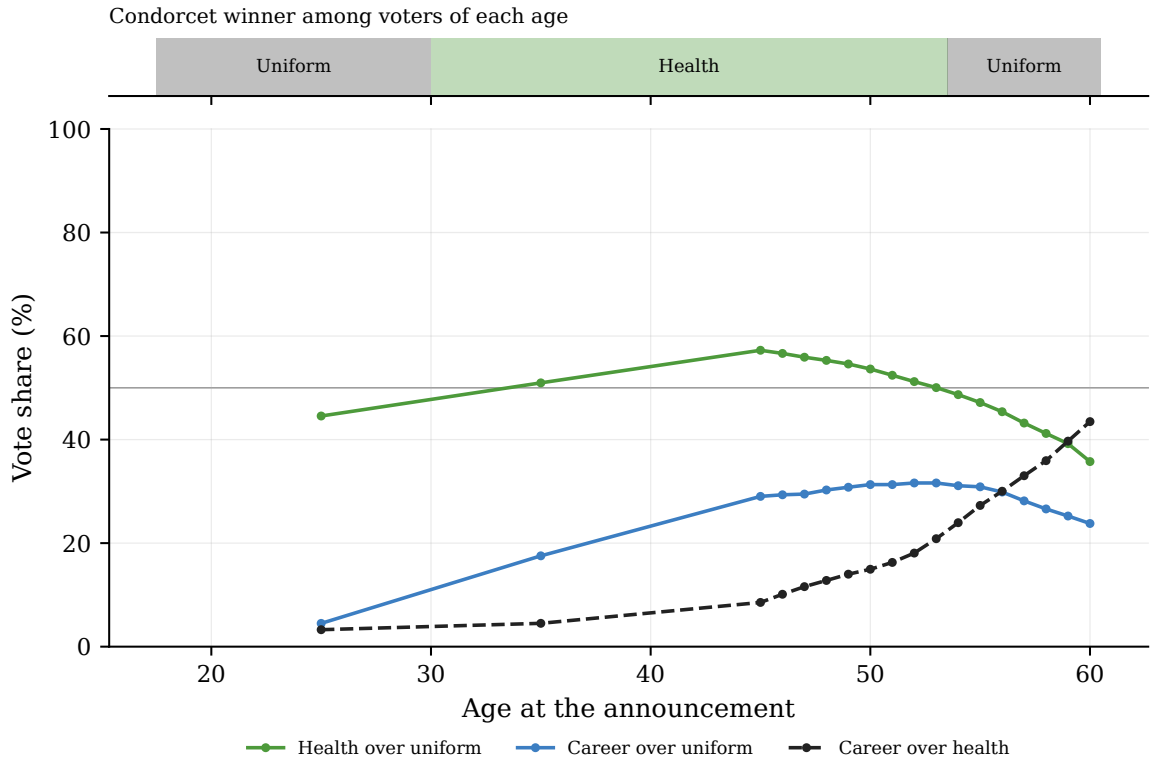


Figure 15: Pairwise preferences between policies, by age at announcement

Notes: Shares who would prefer each policy in pairwise comparisons, by age at the announcement of a policy reform. The strip above marks the policy that wins both of its pairwise votes.

As we saw in Section 5.4, the career-based policy does not generally produce good outcomes, while the health-based and uniform policies produce relatively similar welfare on average at young ages, with the uniform policy being slightly preferred by that measure, and the health-based policy becoming more attractive with age. This is reflected in voting patterns of Figure 15, with the career-based policy having little support but the health-based and uniform policies being competitive in a vote. Young people slightly prefer the uniform policy, which makes it a Condorcet winner at the youngest ages, before the health-based policy becomes the winner at intermediate ages. People above the age of 53 at the time of policy announcement prefer the uniform policy again, even despite the fact that the health-based policy produces higher total welfare for these age groups.

An individual who is older when the policy is announced differs from a younger person in several important ways. Firstly, they have made choices up to age A expecting a different pension system when they retire and have more limited ability to adapt to the policy change. Secondly, they know the wage, preference, and health shocks that have been realised in their life to date,

and have less uncertainty about what their state will be as they enter retirement. Finally, they have fewer remaining years subject to any increases in the social security contribution rate[8]. This final channel means that the relative attractiveness of the uniform policy (requiring no additional contributions) decreases with age.

Now, since individuals do not perfectly know what their state will be by the time the pension eligibility question is live, there will also be a risk-hedging motive which will bite more strongly earlier in life. Intuitively, this motive would tend to prefer the health-based policy, as health shocks are those that agents are least able to ameliorate. In practice this motive is strong enough for the health-based policy to win from the early thirties to the early fifties. Above this age people are more confident about whether they will benefit from the policy or not, and no longer get much insurance value from it; it does not offer an exemption to the majority so it cannot command majority support near retirement age.

Table 10: Majority ranking of the reforms at 55, by occupation and health

	Good health	Middling health	Poor health
Strenuous	U > H > C	U > H > C	H > C > U
	(10.0)	(17.4)	(9.1)
Medium	U > H > C	H > U > C	H > C > U
	(7.6)	(9.7)	(3.7)
Light	U > C > H	U > H > C	H > U > C
	(8.6)	(10.4)	(3.7)
Not working	U > H > C	H > U > C	H > C > U
	(3.3)	(6.0)	(10.3)

Notes: U denotes uniform, C career-based, and H the health-based policy. Each cell ranks the reforms by pairwise majority vote at age 55 when the reforms are announced. The occupation and health status are those held as the agent reaches age 55. Numbers in parentheses represent the share of people in a given cell at that age.

To see the effect of knowing one's state approaching retirement, we break down the rankings of the reform at age 55 by health and occupation in Table 10. Those to whom the career-based and health-based policies would not give any eligibility exemptions (i.e. those in the light occupation and in good health) prefer the uniform policy over either of the targeted policies. Those in poor health prefer the health-based policy, though even those in strenuous work do not prefer the career-based policy if they are also not in poor health. Those in strenuous careers but with reasonable health would prefer to continue working longer and are not prepared to pay any additional contributions for an exemption to the age increase[9].

6.2 The people's vote

A real electorate does not consist of only single cohorts at a time, so we now compute the result of voting across the whole population at once. We assume that those above a critical implementation age $A^{\max}$ will not be subject to the new policy, and so will be indifferent between each reform (assuming that not only will they not be subject to the changed pension eligibility rules, but also to any associated increases in the social security contribution rate). As such, we need

[8] As mentioned in Section 5.3, we could alternatively have equalised the fiscal impact of these policies by changing pension payment rates rather than social security contribution rates. Had we done this, this final channel of age-dependence in preferences would work in reverse.

[9] As discussed in Section 5.4, this is also in part due to the fact that for behavioural or contractual reasons, modelled by the parameters $\phi_{\text{beh}*}$, some of these workers would retire earlier than they would otherwise like simply because that is the statutory retirement age, so they actually would prefer deferred pension eligibility per se.

only compute the preferences of individuals below this age. However, the result of such a vote may well depend on exactly which implementation age is chosen. Since young cohorts are more likely to prefer the uniform policy and middle-aged cohorts the health-based policy, the more cohorts that are unaffected by and hence indifferent to the policy change (i.e. the younger the implementation age cutoff), the more likely the uniform policy will win out. As Figure 16 shows, between the uniform and health-based policies the vote is competitive and the overall winner depends on the implementation age chosen. If only those 48 or younger are affected then the uniform policy wins, but if the implementation age is above this (within the range we consider) then the health-based policy will win the vote. This figure shows the aggregated voting shares over all cohorts assuming perfect turnout.

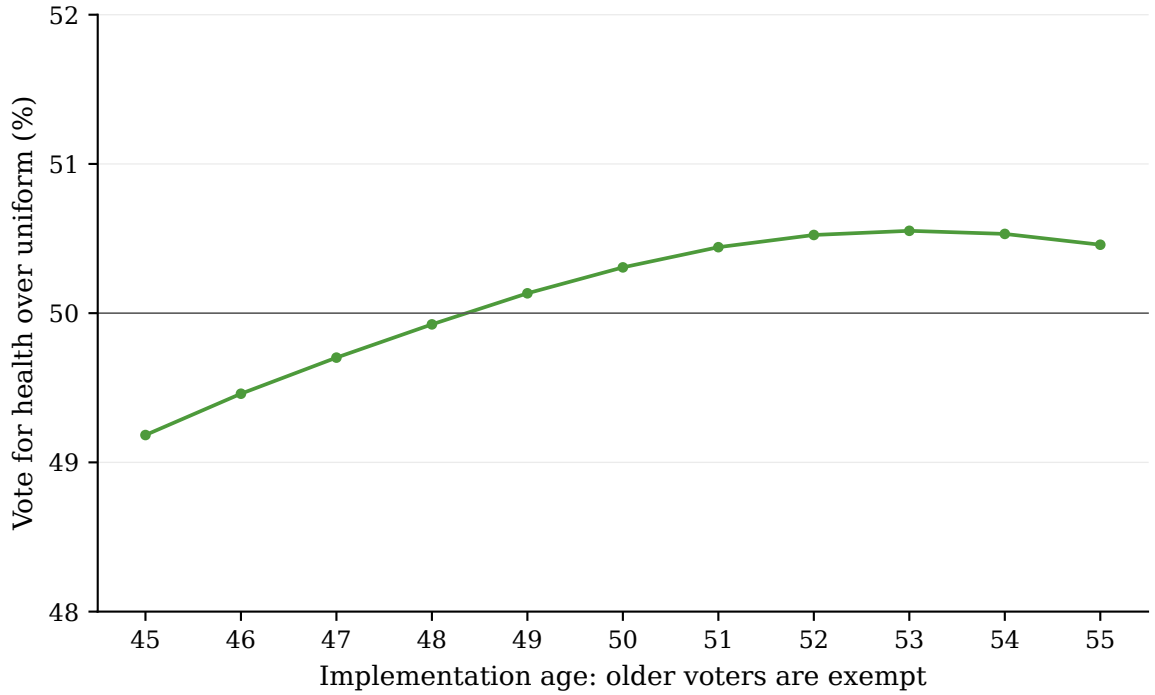


Figure 16: The population vote, by implementation age

Notes: The pairwise choices between policies aggregated over the whole electorate up to the implementation age $A^{\max}$. This plot assumes perfect turnout of German citizens aged 18 and over. Only the vote between the health-based and uniform policies is shown: the career-based policy loses both of its votes at every implementation age (at least 80.8% prefer the uniform policy to it, and at most 8.3% prefer it to the health-based policy).

So the political economy of this set of reforms does not simply lead to the ex ante preferred policy (uniform) being chosen. Once people are mid-career, a majority prefer a targeted health-based policy which provides them with some insurance, and a reform that applies to cohorts already at these ages may well pass. The career-based exemption has no constituency at any age.

Note that the voting results in Figure 16 assume perfect turnout. With older people typically having higher turnout, this would tend to further favour the health-based policy under the votes depicted in Figure 16. In addition, one could imagine that in a more realistic vote where many issues are on the table at once, salience of pension system reform could also be much higher for older people than young people, who might vote instead based on other issues. This would also work in favour of the health-based policy broadly preferred by the older cohorts within the range of implementation ages we consider.

The targeted policies therefore face a political tradeoff as well as an economic one. The career-based exemption is both the more expensive to finance and the less valued. It does not command a majority at any age, even among those to whom it would give exemptions. The

health-based exemption is valued by voters in mid-career as insurance against future poor health, and whether it or the uniform policy would win a vote depends on the details of which cohorts the reform affects. If a reform were proposed to be implemented with long notice, such that it only affects those currently young, then voters would favour the uniform increase. If instead it were proposed to also affect those already mid-career, then targeted health exemptions could be the vote winner.

7 Discussion: tradeoffs in pension policy design

We discuss our results in light of three goals for pension policy. The first two, usually set for pension systems, are that they be fiscally sustainable in the long run and that reforms not overly penalise those already disadvantaged (European Commission, 2012). Finally, we add the concerns that pension reforms which treat certain groups preferentially may affect behaviours of workers in potentially undesirable ways, moving them away from an efficient allocation in the labour market. These goals are of course not independent. The burdens of a policy whose goal is to improve sustainability may not fall equally on all groups. Tailoring policies designed to reduce inequality potentially introduces distortionary effects.

7.1 Sustainability

A higher pension age only partly keeps people in work. We find that the uniform rise delays pension claims by almost the full two years, but lengthens working lives by only around a third of that (1.83 and 0.64 years per baseline claimant before age 70). The remainder of the delay is spent drawing on a disability pension, unemployment insurance, basic income support, or savings. The reform improves the public finances by €22,921 per person over the whole lifecycle, a large part of that gain being not withheld pensions but the income tax and contributions paid on the additional years of work, coming disproportionately from higher earners. Lower old-age pension spending saves €20,431, and additional income tax and social security contributions on the extra years of work bring in €11,790, offset by €9,300 of additional spending on other benefits.

The fiscal case for a pension reform must be made on the whole social insurance system. Many of those that are moved out of an old-age pension will substitute to other benefits, in our case either the disability pension or some kind of unemployment support. A costing confined to only the pension system would show a similar saving from the uniform rise, but only by coincidence, because the extra taxes and contributions from those who work longer happen to roughly offset the extra benefits paid to those who do not (Section 5.1). A reform that induced more or less additional work, or which had different distributional impacts, would not generally balance in this way.

How much a higher pension age hurts those who cannot work depends on the rest of the safety net, and this cuts both ways. Part of the reason the uniform policy is not more undesirable in our context is that the German safety net still catches most of those the reform pushes out of the old-age pension. The disability pension is available for those whose health has failed; for others, unemployment insurance is generous at first, before being replaced with basic income support. Even after people fall into this least generous benefit, many have the ability to dissave and self-finance their consumption in anticipation that the old-age pension will provide sufficient income once they become eligible. By paying benefits in place of the pension, the same safety net also returns part of the reform's fiscal gain. Under a social insurance system in which these other channels do not exist or are less generous, those who cannot work would be much worse off when the pension age increases, and the insurance value of a targeted policy would be higher.

We considered alternative policy proposals that condition pension eligibility on health status or career history, with the goal of preferentially exempting those groups with less capacity for

continued work. However, this comes at a substantial cost in forgone fiscal benefits. Without changing the contribution rates to compensate, the career-based and health-based policies retain only 65% and 74% of the uniform policy's fiscal gain. Matching it requires raising contribution rates by 1.21 and 0.90 percentage points respectively if the additional contributions are paid out as they come in, or 0.45 and 0.31 if they are invested. These are the costs of attempting to decrease the burdens on those who can no longer work.

The saving a reform delivers also depends on when it is announced, because people who learn of it early in their careers adjust their behaviour. Announced at 25, 5.8% of people change their jobs, hours, or saving at some point in response to the uniform rise; announced at 55, only 3.6% do, and the net saving per person in this cohort rises from €22,921 to €24,905. The health-based exemption is less affected, since health cannot be directly chosen. A reform that binds cohorts close to retirement therefore yields more in the short run than the long-run saving delivered by cohorts that can plan around it.

7.2 Inequality

The negative impacts of the uniform eligibility age increase are concentrated on individuals who lose pension years and do not work more, 19.1% of all people. For them the reform is simply a benefit cut, and how they adjust to this loss of the old-age pension matters. 26.9% of their withdrawn years of eligibility are spent without any state benefits (because their assets disqualify them from basic income support); most of the remainder is spent on basic income support or unemployment insurance. The uniform increase in pension eligibility age results in an average of €7,418 worth of pension benefits withheld from people for whom the policy change elicited no additional work (this is before any substitution to alternative benefit payments). Those affected in this way are disproportionately less educated, and the poorest of them, who neither work nor have any income source except basic income support when the pension is withdrawn (who we call stranded), are the only group whose consumption falls substantially (Figure 11).

However, protecting those who cannot work from a higher pension age is cheap, if they can be identified. Many pension systems already offer such protection, often as early retirement for arduous jobs (OECD, 2023, ch. 2), and Germany's pension commission has proposed a hardship route based on health (Alterssicherungskommission, 2026). Our targeted policies are versions of this idea, and they do in part achieve the intended goal. Conditioning the eligibility increase on career history or on health status reduces the share of men who lose years of pension eligibility without working more, to 11.7% and 13.3% respectively. When an exemption rule identifies and protects a stranded person from the age rise, this is a cheap intervention, since these people have relatively low pension entitlements and their old-age pensions are partly offset by the other benefits they would draw in lieu. Overall, a stranded person protected by the career-based exemption costs €1,171, and by the health-based exemption €4,139.

In contrast, the cost of mistakenly exempting somebody who would otherwise have worked is very large. Each of these mistakes costs €71,718 under the career-based policy and €83,335 under the health-based policy, mostly in lost income tax and contributions; under the health-based policy this is 3.4 times the additional pension paid to them. This asymmetry has important implications for pension design. As an exemption is loosened, each additional stranded person it protects comes with additional people wrongly exempted who would otherwise have worked. There is a clear tradeoff between these two margins (e.g. see Appendix Figure A.4), and the wrong exemptions account for most of the cost of the policy, far more than the people it successfully protects. A rule should be judged by how many workers it exempts for each person it protects.

We also see that health and career history are poor proxies for becoming stranded at the consumption floor by a pension reform. The health-based exemption reaches 26.7% of the stranded and the career-based exemption 40.0%. Many of the stranded are neither in poor health nor

from strenuous careers, so cannot be identified by these tests. Instead of having occupation or health status in common, what the stranded share is a lack of human capital (productivity and tenure) and financial resources. It may be possible to more reliably identify them with asset tests, but any policy designed along these lines is likely to substantially distort people's savings choices.

How much people value a targeted policy depends on when in life they are asked. The benefits of a targeted exemption only appear late in life, so having to frontload the payments for it over the whole life tends to be undesirable, particularly when people don't even know yet whether they are likely to qualify for any of the eligibility exemptions by the time they reach retirement age. Ex ante, a career-based exemption is not desirable at all and a health-based exemption is only valuable to some kinds of people. In contrast, considering people from age 55 onwards reveals the real benefit of the targeted reforms. Announced at 55, the health-based policy is worth 0.68 percentage points of consumption more than the uniform policy, the costs having already been largely paid earlier in life (Figure 14). The targeted policies act as insurance, with the gains especially concentrated among those in poor health. They move resources towards the states of the world, late in life and in poor health, in which the uniform policy costs the most, and the premium is paid by everyone over the working life.

The same pattern shapes the politics of these reforms. Considering votes between the policies by those at a given age, no majority at any age prefers the career-based policy. Between the uniform policy and the health-based policy the youngest ages prefer the uniform policy, but voters from their thirties to their early fifties prefer the health-based exemption. We find that a vote across the whole electorate would be close, with the uniform policy winning if the reform covers only those 48 or younger, and the health-based policy winning if it also covers those somewhat older.

How an exemption is financed decides who pays for it, and in a reform that binds cohorts already in work, that is an intergenerational choice. A pay-as-you-go contribution rise is paid by those in work when the exemptions are used, a funded rise by each cohort over its own working life, and a cut to old-age pensions by those already retired or close to it. The funded rise is the cheapest of the three for workers, but it requires the contributions to be invested rather than spent, which pay-as-you-go systems such as Germany's do not currently do. Whether a targeted reform is politically feasible therefore depends on how it is paid for as well as on whom it targets.

7.3 Distortion

The distortions these policies cause to the labour market appear to be nontrivial but modest. Introducing a targeted policy not only changes who is eligible for the pension, but the exemption rules will also affect the incentives to make certain choices over the lifecycle to potentially gain earlier eligibility. A status which provides early pension eligibility and that can be acquired by choice will be more attractive. Under the career-based policy we consider, the share of men whose last occupation is the strenuous one (for which the eligibility rules are most generous) rises by 0.55 percentage points by age 60, almost entirely through moves later in the career. We observe no measurable re-sorting at labour market entry, which is consistent with the welfare results comparing the uniform and career-based policies, since young people just don't value utility that won't come until retirement several decades later. We have chosen in our main specification an eight year tenure requirement. A longer requirement makes this status more costly to acquire and hence reduces the main distortionary incentives, but also potentially excludes some individuals that it would ideally have captured.

In contrast to the career-based policy, in which one can directly decide to make the choices required for eligibility, one cannot easily control the health status that determines eligibility under the health-based policy. Instead, potential distortions are introduced by the fact that health status is difficult to accurately observe, and hence must be measured through a noisy assessment

which may allow through some individuals who are not truly in poor health. Since health itself is already being used as a noisy proxy for ability to work, this compounds the difficulty in designing an effective policy. Of course, the practical concern is not just that a noisy measurement will lead to poorer identification of those with the ability to work, but also that imperfect observation of the individual's state leads to the opportunity for people to "game" the assessment process and actively misrepresent their true state.

7.4 Conclusion

With pension systems' sustainability under pressure as lives lengthen, raising the pension age is the first policy lever that many governments reach for. Such a rise would be intended to extend working lives, but will bind most tightly on people whose capacity for work has already been exhausted, disproportionately those in poor health and whose careers were spent in physically demanding work. Several countries now tie the pension age to life expectancy (OECD, 2025), as the European Commission has long advised, while recognising that a higher pension age affects people differently according to their ability to find and perform work and their health (European Commission, 2012), both of which differ by occupation.

In this paper we have asked who is capable of continuing work when the pension age rises, what happens to those who cannot, and whether targeted pension eligibility rules can protect the second group without giving up the revenue that the reform is intended to produce. To answer these questions we estimated a dynamic lifecycle model of occupational choice, health, and retirement choices on the German Socio-Economic Panel, in which strenuous work deteriorates health, poor health reduces the capacity for work, and exits from work can run through the old-age pension, the disability pension, or the unemployment support system. The policy proposals we focused on are (i) a uniform two year rise in the pension eligibility age, (ii) an age rise that preferentially exempts those with careers in strenuous occupations, and (iii) an age rise preferentially exempting those in poor health.

In brief, we find that a uniform rise in the pension age mostly delays pension claims rather than lengthening working lives, yet close to half of its fiscal gain comes from the additional work it does induce; for those who do not work longer it is a benefit cut, felt most by the poorest. Eligibility exemptions for people in poor health or from strenuous careers can protect some of those who would otherwise be stranded at the consumption floor, and cheaply, but each worker exempted by mistake costs much more, mostly in lost taxes and contributions, and neither of the tests we consider is able to reach most of those who need help. The cost of an exemption is therefore set less by whom it protects than by whom it lets through by mistake.

Our analysis has focused on men, and it would of course be interesting to consider whether women would value pension reforms differently from men. Women have different career paths and labour force attachment, as well as different health trajectories and life expectancies. Indeed, the role of household decision-making is also an important determinant of retirement choices that we have not considered here. We leave this to future work. Also of interest to extend this model is the possibility of policies that affect rehabilitation or investment in health directly. Rehabilitation is already a focus of the German disability pension system (Alterssicherungskommission, 2026), and our model captures it only in reduced form, through the effect of drawing a disability pension on health. A broader analysis might also include a treatment of costs to the healthcare system of the potential policy options.

Our comparisons of the welfare effects of these pension reforms suggest that there are real tradeoffs in designing a policy to improve the fiscal sustainability of the system. Exempting those who would be most hurt by the policy improves their welfare but the difficulty in precisely targeting the exemptions leads to substantial fiscal losses. The interactions of these reforms with the disability pension and the unemployment insurance system are also critical as people substitute between these channels when the old-age pension is withdrawn. If the burden of

higher pension ages on those who cannot work is to be reduced, policies which keep workers healthy and able to work, rather than attempting to provide targeted exemptions to pension eligibility rules, may be the more promising levers.

References

Abeliansky, Ana Lucia and Holger Strulik (2023). "Health and Aging Before and After Retirement". In: *Journal of Population Economics* 36.4, pp. 2825–2855. DOI: 10.1007/s00148-023-00951-3.

Akerlof, George A. (1978). "The Economics of "Tagging" as Applied to the Optimal Income Tax, Welfare Programs, and Manpower Planning". In: *American Economic Review* 68.1, pp. 8–19. URL: http://www.jstor.org/stable/1809683.

Alterssicherungskommission (2026). *Empfehlungen der Alterssicherungskommission*. Kommissionsbericht. Bundesministerium für Arbeit und Soziales (BMAS). URL: https://www.bundesregierung.de/resource/blob/2196306/2444780/0fcbf810775351c64007ee6cb2c7cad9/2026-06-24-bericht-alterssicherungskommission-data.pdf.

Andersen, Hanfried H. et al. (2007). "Computation of Standard Values for Physical and Mental Health Scale Scores Using the SOEP Version of SF-12v2". In: *Schmollers Jahrbuch* 127.1, pp. 171–182. DOI: 10.3790/schm.127.1.171.

Andrews, Isaiah, Matthew Gentzkow and Jesse M. Shapiro (2017). "Measuring the Sensitivity of Parameter Estimates to Estimation Moments". In: *The Quarterly Journal of Economics* 132.4, pp. 1553–1592. DOI: 10.1093/qje/qjx023.

Ayuso, Mercedes, Jorge Miguel Bravo and Robert Holzmann (2017). "Addressing Longevity Heterogeneity in Pension Scheme Design". In: *Journal of Finance and Economics* 6.1, pp. 1–21. DOI: 10.12735/jfe.v6n1p1.

Badarin, Kathryn et al. (2022). "Does a Change to an Occupation with a Lower Physical Workload Reduce the Risk of Disability Pension? A Cohort Study of Employed Men and Women in Sweden". In: *Scandinavian Journal of Work, Environment & Health* 48.8, pp. 662–671. DOI: 10.5271/sjweh.4053.

— (2023). "Combined Exposure to Heavy Physical Workload and Low Job Control and the Risk of Disability Pension: A Cohort Study of Employed Men and Women in Sweden". In: *International Archives of Occupational and Environmental Health* 96.7, pp. 973–984. DOI: 10.1007/s00420-023-01983-8.

Barschkett, Mara et al. (2022). "The Effects of an Increase in the Retirement Age on Health—Evidence from Administrative Data". In: *The Journal of the Economics of Ageing* 23, p. 100403. DOI: 10.1016/j.jeoa.2022.100403.

Baurin, Arno (2021). "The Limited Power of Socioeconomic Status to Predict Lifespan: Implications for Pension Policy". In: *The Journal of the Economics of Ageing* 20, p. 100339. DOI: 10.1016/j.jeoa.2021.100339.

Blundell, Richard, Eric French and Gemma Tetlow (2016). "Retirement Incentives and Labor Supply". In: *Handbook of the Economics of Population Aging*. Ed. by John Piggott and Alan Woodland. Vol. 1. Amsterdam: Elsevier. Chap. 8, pp. 457–566. DOI: 10.1016/bs.hespa.2016.10.001.

Blundell, Richard et al. (2023). "The Impact of Health on Labor Supply Near Retirement". In: *Journal of Human Resources* 58.1, pp. 282–334. DOI: 10.3368/jhr.58.3.1217-9240R4.

Börsch-Supan, Axel, Michela Coppola and Johannes Rausch (2015). "Die „Rente mit 63": Wer sind die Begünstigten? Was sind die Auswirkungen auf die Gesetzliche Rentenversicherung?" In: *Perspektiven der Wirtschaftspolitik* 16.3, pp. 264–288. DOI: 10.1515/pwp-2015-0020.

Börsch-Supan, Axel, Johannes Rausch and Nicolas Goll (2021). "Social Security Reforms and the Changing Retirement Behavior in Germany". In: *Social Security Programs and Retirement around the World: Reforms and Retirement Incentives*. Ed. by Axel Börsch-Supan and Courtney

Coile. Chicago: University of Chicago Press, pp. 175–226. URL: https://www.nber.org/chapters/c14195.

Browning, Edgar K. (1975). "Why the Social Insurance Budget Is Too Large in a Democracy". In: *Economic Inquiry* 13.3, pp. 373–388. DOI: 10.1111/j.1465-7295.1975.tb00255.x.

Bundesregierung (2018). *Dritter Bericht der Bundesregierung zur Anhebung der Regelaltersgrenze auf 67 Jahre*. Drucksache 19/6239. Deutscher Bundestag. URL: https://dserver.bundestag.de/btd/19/062/1906239.pdf.

— (2020). *Ergänzender Bericht der Bundesregierung zum Rentenversicherungsbericht 2020 (Alterssicherungsbericht 2020)*. Drucksache 19/24926. Deutscher Bundestag. URL: https://dserver.bundestag.de/btd/19/249/1924926.pdf.

Capatina, Elena (2015). "Life-Cycle Effects of Health Risk". In: *Journal of Monetary Economics* 74, pp. 67–88. DOI: 10.1016/j.jmoneco.2015.06.002.

Carroll, Christopher D. (2006). "The Method of Endogenous Gridpoints for Solving Dynamic Stochastic Optimization Problems". In: *Economics Letters* 91.3, pp. 312–320. DOI: 10.1016/j.econlet.2005.09.013.

Casamatta, Georges, Helmuth Cremer and Pierre Pestieau (2000). "The Political Economy of Social Security". In: *The Scandinavian Journal of Economics* 102.3, pp. 503–522. DOI: 10.1111/1467-9442.00212.

Case, Anne and Angus Deaton (2005). "Broken Down by Work and Sex: How Our Health Declines". In: *Analyses in the Economics of Aging*. Ed. by David A. Wise. Chicago: University of Chicago Press, pp. 185–212. URL: https://www.nber.org/chapters/c10361.

Coile, Courtney, Kevin Milligan and David A. Wise (2017). "Health Capacity to Work at Older Ages: Evidence from the United States". In: *Social Security Programs and Retirement around the World: The Capacity to Work at Older Ages*. Ed. by David A. Wise. Chicago: University of Chicago Press, pp. 359–394. URL: https://www.nber.org/chapters/c13749.

Conde-Ruiz, J. Ignacio and Vincenzo Galasso (2003). "Early Retirement". In: *Review of Economic Dynamics* 6.1, pp. 12–36. DOI: 10.1016/S1094-2025(02)00018-2.

Conde-Ruiz, J. Ignacio and Paola Profeta (2007). "The Redistributive Design of Social Security Systems". In: *The Economic Journal* 117.520, pp. 686–712. DOI: 10.1111/j.1468-0297.2007.02046.x.

Cremer, Helmuth, Jean-Marie Lozachmeur and Pierre Pestieau (2004a). "Optimal Retirement and Disability Benefits with Audit". In: *FinanzArchiv* 60.3, pp. 278–295. DOI: 10.1628/0015221042396131.

— (2004b). "Social Security, Retirement Age and Optimal Income Taxation". In: *Journal of Public Economics* 88.11, pp. 2259–2281. DOI: 10.1016/j.jpubeco.2003.10.003.

— (2007). "Disability Testing and Retirement". In: *The B.E. Journal of Economic Analysis & Policy* 7.1. Article 10. DOI: 10.2202/1935-1682.1608.

De Nardi, Mariacristina, Svetlana Pashchenko and Ponpoje Porapakkarm (2025). "The Lifetime Costs of Bad Health". In: *The Review of Economic Studies* 92.3, pp. 1987–2026. DOI: 10.1093/restud/rdae080.

Deutsche Rentenversicherung Bund (2020). *Statistik der Deutschen Rentenversicherung: Rentenzugang, Rentenbestand, Versicherte, Antragsstatistik*. Reporting years 2005–2018. Berlin: Deutsche Rentenversicherung Bund. URL: https://www.statistik-rente.de.

Diamond, Peter and Eytan Sheshinski (1995). "Economic Aspects of Optimal Disability Benefits". In: *Journal of Public Economics* 57.1, pp. 1–23. DOI: 10.1016/0047-2727(94)01435-Q.

Dolls, Mathias and Carla Krolage (2023). "'Earned, Not Given'? The Effect of Lowering the Full Retirement Age on Retirement Decisions". In: *Journal of Public Economics* 223, p. 104909. DOI: 10.1016/j.jpubeco.2023.104909.

Dustmann, Christian, Johannes Ludsteck and Uta Schönberg (2009). "Revisiting the German Wage Structure". In: *The Quarterly Journal of Economics* 124.2, pp. 843–881. DOI: 10.1162/qjec.2009.124.2.843.

Eibich, Peter (2015). "Understanding the Effect of Retirement on Health: Mechanisms and Heterogeneity". In: *Journal of Health Economics* 43, pp. 1–12. DOI: 10.1016/j.jhealeco.2015.05.001.

Etgeton, Stefan (2018). "The Effect of Pension Reforms on Old-Age Income Inequality". In: *Labour Economics* 53, pp. 146–161. DOI: 10.1016/j.labeco.2018.05.006.

European Commission (2012). *White Paper: An Agenda for Adequate, Safe and Sustainable Pensions*. Tech. rep. COM(2012) 55 final. Brussels: European Commission. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012DC0055.

Fehr, Hans and Adrian Fröhlich (2024). "Optimal Retirement with Disability Pensions". In: *Journal of Pension Economics and Finance* 23.3, pp. 335–364. DOI: 10.1017/S1474747223000227.

Fehr, Hans, Manuel Kallweit and Fabian Kindermann (2013). "Should Pensions Be Progressive?" In: *European Economic Review* 63, pp. 94–116. DOI: 10.1016/j.euroecorev.2013.07.004.

Fitzenberger, Bernd, Reinhold Schnabel and Gaby Wunderlich (2004). "The Gender Gap in Labor Market Participation and Employment: A Cohort Analysis for West Germany". In: *Journal of Population Economics* 17.1, pp. 83–116. DOI: 10.1007/s00148-003-0141-6.

French, Eric (2005). "The Effects of Health, Wealth, and Wages on Labour Supply and Retirement Behaviour". In: *The Review of Economic Studies* 72.2, pp. 395–427. DOI: 10.1111/j.1467-937X.2005.00337.x.

French, Eric and John Bailey Jones (2011). "The Effects of Health Insurance and Self-Insurance on Retirement Behavior". In: *Econometrica* 79.3, pp. 693–732. DOI: 10.3982/ECTA7560.

— (2017). "Health, Health Insurance, and Retirement: A Survey". In: *Annual Review of Economics* 9, pp. 383–409. DOI: 10.1146/annurev-economics-063016-103616.

Galama, Titus et al. (2013). "A Health Production Model with Endogenous Retirement". In: *Health Economics* 22.8, pp. 883–902. DOI: 10.1002/hec.2865.

Galasso, Vincenzo and Paola Profeta (2002). "The Political Economy of Social Security: A Survey". In: *European Journal of Political Economy* 18.1, pp. 1–29. DOI: 10.1016/S0176-2680(01)00066-0.

Geyer, Johannes and Clara Welteke (2021). "Closing Routes to Retirement for Women: How Do They Respond?" In: *Journal of Human Resources* 56.1, pp. 311–341. DOI: 10.3368/jhr.56.1.0717-8947R2.

Geyer, Johannes et al. (2020). "Labor Market and Distributional Effects of an Increase in the Retirement Age". In: *Labour Economics* 65, p. 101817. DOI: 10.1016/j.labeco.2020.101817.

Giesecke, Matthias and Michael Kind (2013). *Bridge Unemployment in Germany: Response in Labour Supply to an Increased Early Retirement Age*. Ruhr Economic Papers 410. Essen: RWI – Leibniz-Institut für Wirtschaftsforschung. DOI: 10.4419/86788465.

Giraldo Páez, Daniel (2023). *The Changing Nature of Work, Old-Age Labor Supply, and Social Security*. Working paper. URL: https://wdanielgiraldop.github.io/mywebsite/Giraldo_Paez_JMP.pdf.

Gobierno de España (2026). *Real Decreto Legislativo 8/2015, de 30 de octubre, por el que se aprueba el texto refundido de la Ley General de la Seguridad Social, art. 206: Jubilación anticipada por razón de la actividad*. Boletín Oficial del Estado, BOE-A-2015-11724, consolidated version as of 2026; art. 206 last amended by Ley 21/2021. Accessed 31 October 2026. URL: https://www.boe.es/eli/es/rdlg/2015/10/30/8/con.

Goebel, Jan et al. (2019). "The German Socio-Economic Panel (SOEP)". In: *Jahrbücher für Nationalökonomie und Statistik* 239.2, pp. 345–360. DOI: 10.1515/jbnst-2018-0022.

Golosov, Mikhail and Aleh Tsyvinski (2006). "Designing Optimal Disability Insurance: A Case for Asset Testing". In: *Journal of Political Economy* 114.2, pp. 257–279. DOI: 10.1086/500549.

Gouriéroux, Christian, Alain Monfort and Eric Renault (1993). "Indirect Inference". In: *Journal of Applied Econometrics* 8.S1, S85–S118. DOI: 10.1002/jae.3950080507.

Grossmann, Volker, Johannes Schünemann and Holger Strulik (2024). "Fair Pension Policies with Occupation-Specific Ageing". In: *The Economic Journal* 134.663, pp. 2835–2875. DOI: 10.1093/ej/ueae038.

Haan, Peter, Daniel Kemptner and Holger Lüthen (2020). "The Rising Longevity Gap by Lifetime Earnings: Distributional Implications for the Pension System". In: *The Journal of the Economics of Ageing* 17, p. 100199. DOI: 10.1016/j.jeoa.2019.100199.

Haan, Peter and Victoria Prowse (2014). "Longevity, Life-Cycle Behavior and Pension Reform". In: *Journal of Econometrics* 178.3, pp. 582–601. DOI: 10.1016/j.jeconom.2013.08.038.

Haan, Peter and Maximilian Schaller (2021). *Heterogene Lebenserwartung: Forschungsprojekt im Auftrag des Sozialverbands VdK Deutschland*. DIW Berlin Politikberatung kompakt 171. DIW Berlin. URL: https://www.diw.de/documents/publikationen/73/diw_01.c.822952.de/diwkompakt_2021-171.pdf.

Haan, Peter and Songül Tolan (2019). "Labor Supply and Fiscal Effects of Partial Retirement – The Role of Entry Age and the Timing of Pension Benefits". In: *The Journal of the Economics of Ageing* 14, p. 100187. DOI: 10.1016/j.jeoa.2019.01.001.

Heathcote, Jonathan, Kjetil Storesletten and Giovanni L. Violante (2017). "Optimal Tax Progressivity: An Analytical Framework". In: *The Quarterly Journal of Economics* 132.4, pp. 1693–1754. DOI: 10.1093/qje/qjx018.

Iskhakov, Fedor (2010). "Structural Dynamic Model of Retirement with Latent Health Indicator". In: *The Econometrics Journal* 13.3, S126–S161. DOI: 10.1111/j.1368-423X.2010.00318.x.

Iskhakov, Fedor et al. (2017). "The Endogenous Grid Method for Discrete-Continuous Dynamic Choice Models with (or without) Taste Shocks". In: *Quantitative Economics* 8.2, pp. 317–365. DOI: 10.3982/QE643.

Jacobs, Lindsay (2023). "Occupations, Retirement, and the Value of Disability Insurance". In: *Journal of Public Economics* 225, p. 104976. DOI: 10.1016/j.jpubeco.2023.104976.

— (2025). *Social Security Reform: Work and Welfare Responses Across Occupations*. Working paper. URL: https://lindsayjacobs.github.io/papers/Impacts-of-Social-Security-Reform-Occupations.pdf.

Jacobs, Lindsay and Suphanit Piyapromdee (2025). *Labor Force Transitions at Older Ages: Burnout, Recovery, and Reverse Retirement*. CEPR Discussion Paper 20616. Centre for Economic Policy Research. URL: https://cepr.org/publications/dp20616.

Jones, John Bailey and Yue Li (2023). "Social Security Reform with Heterogeneous Mortality". In: *Review of Economic Dynamics* 48, pp. 320–344. DOI: 10.1016/j.red.2022.06.003.

Jürges, Hendrik, Lars Thiel and Axel Börsch-Supan (2017). "Healthy, Happy, and Idle: Estimating the Health Capacity to Work at Older Ages in Germany". In: *Social Security Programs and Retirement around the World: The Capacity to Work at Older Ages*. Ed. by David A. Wise. Chicago: University of Chicago Press, pp. 149–180. URL: https://www.nber.org/chapters/c13742.

Keane, Michael P. and Kenneth I. Wolpin (1997). "The Career Decisions of Young Men". In: *Journal of Political Economy* 105.3, pp. 473–522. DOI: 10.1086/262080.

Kroll, Lars Eric (2011a). *Job Exposure Matrices (JEM) for ISCO and KldB*. Data set, GESIS Data Archive, Cologne. Version 1.0.0. DOI: 10.7802/1097.

— (2011b). "Konstruktion und Validierung eines allgemeinen Index für die Arbeitsbelastung in beruflichen Tätigkeiten auf Basis von ISCO-88 und KldB-92". In: *Methoden, Daten, Analysen (mda)* 5.1, pp. 63–90. ISSN: 2190-4936.

Kuhn, Andreas et al. (2020). "Fatal Attraction? Extended Unemployment Benefits, Labor Force Exits, and Mortality". In: *Journal of Public Economics* 191, p. 104087. DOI: 10.1016/j.jpubeco.2019.104087.

Lopez Garcia, Italo, Nicole Maestas and Kathleen J. Mullen (2025). "Aging and Work Capacity". In: *The Journal of the Economics of Ageing* 31, p. 100576. DOI: 10.1016/j.jeoa.2025.100576.

Lopez Garcia, Italo, Kathleen J. Mullen and Jeffrey Wenger (2021). *The Role of Physical Job Demands and the Physical Work Environment in Retirement Outcomes*. Working Paper MRDRC WP 2021-437. University of Michigan Retirement and Disability Research Center. DOI: 10.7302/22358.

Low, Hamish and Luigi Pistaferri (2015). "Disability Insurance and the Dynamics of the Incentive Insurance Trade-Off". In: *American Economic Review* 105.10, pp. 2986–3029. DOI: 10.1257/aer.20110108.

Magnac, Thierry and David Thesmar (2002). "Identifying Dynamic Discrete Decision Processes". In: *Econometrica* 70.2, pp. 801–816. DOI: 10.1111/1468-0262.00306.

Mazzonna, Fabrizio and Franco Peracchi (2017). "Unhealthy Retirement?" In: *Journal of Human Resources* 52.1, pp. 128–151. DOI: 10.3368/jhr.52.1.0914-6627R1.

Michaud, Amanda and David Wiczer (2018). "Occupational Hazards and Social Disability Insurance". In: *Journal of Monetary Economics* 96, pp. 77–92. DOI: 10.1016/j.jmoneco.2018.04.002.

Mittlaender, Sergio (2023). "Special Pension Schemes for Workers in Arduous and Hazardous Jobs: Functions and Conditions to Ensure Equal Treatment". In: *International Social Security Review* 76.1, pp. 109–126. DOI: 10.1111/issr.12318.

OECD (2023). *Pensions at a Glance 2023: OECD and G20 Indicators*. The special chapter surveys pension provisions for hazardous or arduous work across the OECD. Paris: OECD Publishing. DOI: 10.1787/678055dd-en.

— (2025). *Pensions at a Glance 2025: OECD and G20 Indicators*. Paris: OECD Publishing. DOI: 10.1787/e40274c1-en.

Oh, Yun Taek (2023). "Three Essays on Bridge Jobs of American Midlife Workers". PhD dissertation, Applied Economics. University of Minnesota. URL: https://conservancy.umn.edu/items/a579d5a9-a3a6-412d-b6c1-e994202a6337.

Österreichische Gesundheitskasse (2026). *Nachtschwerarbeits-Beitrag*. Stand: 01.01.2026. URL: https://www.oegk.at/cdscontent/?contentid=10007.905130&portal=oegkdgportal.

Parsons, Donald O. (1996). "Imperfect 'Tagging' in Social Insurance Programs". In: *Journal of Public Economics* 62.1–2, pp. 183–207. DOI: 10.1016/0047-2727(96)01578-2.

Pestieau, Pierre and Maria Racionero (2016a). "Harsh Occupations, Health Status and Social Security". In: *Journal of Economics* 117.3, pp. 239–257. DOI: 10.1007/s00712-015-0449-1.

— (2016b). "Harsh Occupations, Life Expectancy and Social Security". In: *Economic Modelling* 58, pp. 194–202. DOI: 10.1016/j.econmod.2016.05.030.

Ravesteijn, Bastian, Hans van Kippersluis and Eddy van Doorslaer (2018). "The Wear and Tear on Health: What Is the Role of Occupation?" In: *Health Economics* 27.2, e69–e86. DOI: 10.1002/hec.3563.

Republik Österreich (2026). *Allgemeines Pensionsgesetz (APG), § 4 Abs. 3: Schwerarbeitspension*. BGBl. I Nr. 142/2004, last amended by BGBl. I Nr. 25/2025. Accessed 31 October 2026. URL: https://www.ris.bka.gv.at/eli/bgbl/i/2004/142/P4/NOR40269794.

Riphahn, Regina T. and Rebecca Schrader (2023). "Reforms of an Early Retirement Pathway in Germany and Their Labor Market Effects". In: *Journal of Pension Economics and Finance* 22.3, pp. 304–330. DOI: 10.1017/S1474747221000421.

Rohrbacher, Max and Hans Martin Hasselhorn (2022). "Social Inequalities in Early Exit from Employment in Germany: A Causal Mediation Analysis on the Role of Work, Health, and Work Ability". In: *Scandinavian Journal of Work, Environment & Health* 48.7, pp. 569–578. DOI: 10.5271/sjweh.4043.

Rust, John (1994). "Structural Estimation of Markov Decision Processes". In: *Handbook of Econometrics*. Ed. by Robert F. Engle and Daniel L. McFadden. Vol. 4. Amsterdam: Elsevier. Chap. 51, pp. 3081–3143. DOI: 10.1016/S1573-4412(05)80020-0.

Sánchez-Romero, Miguel, Ronald D. Lee and Alexia Prskawetz (2020). "Redistributive Effects of Different Pension Systems When Longevity Varies by Socioeconomic Status". In: *The Journal of the Economics of Ageing* 17, p. 100259. DOI: 10.1016/j.jeoa.2020.100259.

Sánchez-Romero, Miguel and Alexia Prskawetz (2017). "Redistributive Effects of the US Pension System among Individuals with Different Life Expectancy". In: *The Journal of the Economics of Ageing* 10, pp. 51–74. DOI: 10.1016/j.jeoa.2017.10.002.

Schünemann, Johannes, Holger Strulik and Timo Trimborn (2017). "Going from Bad to Worse: Adaptation to Poor Health, Health Spending, Longevity, and the Value of Life". In: *Journal of Economic Behavior & Organization* 140, pp. 130–146. DOI: 10.1016/j.jebo.2017.02.018.

Seibold, Arthur (2021). "Reference Points for Retirement Behavior: Evidence from German Pension Discontinuities". In: *American Economic Review* 111.4, pp. 1126–1165. DOI: 10.1257/aer.20191136.

Smith Jr., Anthony A. (1993). "Estimating Nonlinear Time-Series Models Using Simulated Vector Autoregressions". In: *Journal of Applied Econometrics* 8.S1, S63–S84. DOI: 10.1002/jae.3950080506.

Socio-Economic Panel (SOEP) (2021). *Data for Years 1984–2019, SOEP-Core v36, EU Edition*. DOI: 10.5684/soep.core.v36eu.

Sonnega, Amanda et al. (2018). "A Comparison of Subjective and Objective Job Demands and Fit With Personal Resources as Predictors of Retirement Timing in a National U.S. Sample". In: *Work, Aging and Retirement* 4.1, pp. 37–51. DOI: 10.1093/workar/wax016.

Strulik, Holger (2022). "A Health Economic Theory of Occupational Choice, Aging, and Longevity". In: *Journal of Health Economics* 82, p. 102599. DOI: 10.1016/j.jhealeco.2022.102599.

Tabellini, Guido (2000). "A Positive Theory of Social Security". In: *The Scandinavian Journal of Economics* 102.3, pp. 523–545. DOI: 10.1111/1467-9442.00213.

Vandenberghe, Vincent (2021a). "Differentiating Retirement Age to Compensate for Health Differences". In: *IZA Journal of Labor Policy* 11.1, pp. 1–34. DOI: 10.2478/izajolp-2021-0002.

— (2021b). "Health, Cognition and Work Capacity beyond the Age of 50: International Evidence on the Extensive and Intensive Margins of Work". In: *International Labour Review* 160.2, pp. 271–310. DOI: 10.1111/ilr.12174.

— (2026). "Career Arduousness and [Healthy] Life Expectancy in Europe". In: *Journal of Pension Economics and Finance* 25.3, pp. 257–287. DOI: 10.1017/S1474747225100061.

Vermeer, Niels, Mauro Mastrogiacomo and Arthur Van Soest (2016). "Demanding Occupations and the Retirement Age". In: *Labour Economics* 43, pp. 159–170. DOI: 10.1016/j.labeco.2016.05.020.

von Gaudecker, Hans-Martin and Rembrandt D. Scholz (2007). "Differential Mortality by Lifetime Earnings in Germany". In: *Demographic Research* 17.4, pp. 83–108. DOI: 10.4054/DemRes.2007.17.4.

Wen, Jiayi (2023). *Occupational Retirement and Pension Reform: The Roles of Physical and Cognitive Health*. Preprint 2308.13153. arXiv. DOI: 10.48550/arXiv.2308.13153.

Zaidi, Asghar and Edward Whitehouse (2009). *Should Pension Systems Recognise "Hazardous and Arduous Work"?* OECD Social, Employment and Migration Working Papers 91. Paris: OECD Publishing. DOI: 10.1787/221835736557.

Zwick, Thomas et al. (2022). "Early Retirement of Employees in Demanding Jobs: Evidence from a German Pension Reform". In: *The Journal of the Economics of Ageing* 22, p. 100387. DOI: 10.1016/j.jeoa.2022.100387.

Appendix

A German pension policy

This appendix adds detail to the description of the German pension system in Section 2.1, and then sets out the reforms that changed it across the cohorts we observe (Section A.2).

Both the old-age and the disability pension are paid out of entitlements that a person builds up as earnings points over their career. Most points come from contributions on earnings, but points are also awarded while caring for children or family members, during illness, or during the initial phases of unemployment support, so that these interruptions to work reduce the eventual pension less than other time out of work does. A pension is the number of points multiplied by the euro value of a point, and that value is adjusted annually depending on average earnings and pension contributions. The contributions that build up points also pay for the pensions currently being drawn: the (old-age and disability) pension system is funded mainly by contributions shared between employers and employees, supplemented by a federal subsidy, while unemployment support is separately funded from the pension system. Private pensions also exist in Germany, including occupational pensions and state-subsidised *Riester* plans, but although covering many employees, they remain a small part of retirement income. For those aged 65 and over occupational pensions provide only 8% and private provision (including private pensions and other investments) 7% of gross income (Bundesregierung, 2020).

The disability pension level is computed from the same earnings points. Because it is drawn before a career is complete, the points are topped up for the years the person can no longer work. It may either be full or partial, and pays at a rate determined by the earnings points you have accumulated during your healthy working years, imputed until a statutory age increasing from 60 in 2014 to 67 in 2031.

Unemployment support has two tiers, which matter differently for someone approaching retirement. The first, the unemployment benefit (ALG I), is insurance: it pays 60% of previous average net pay (or slightly higher if you support dependent children), capped at a maximum value, normally for 12 months (but up to 32 months for those aged 57 and over before 2006, 18 months for those aged 55 and over in 2006 and 2007, and up to 24 months for those aged 58 and over since 2008). If you have less than two years in your contribution history then this period is reduced, while for older workers it is extended (Section 2.1), and pension points continue to accrue while it is paid. The second tier, basic income support (ALG II), is means-tested, so it can bridge the years before a pension only for those without significant savings. Prior to 2005 a different means-tested assistance programme played the role of ALG II.

The means tests for basic income support have an allowance that varies by cohort and year, and it excludes owner-occupied housing of reasonable size and many private pension assets. For working-age people on unemployment assistance prior to 2002, this allowance was 8,000 DM (around €4,100). In 2002 it was €520×age; after 2002 for those born prior to 1948 it remained at this level and for younger cohorts it was €200×age 2003–2006 and €150×age thereafter. People on a pension (disability or old-age) also receive basic income support if their pension entitlements are below the consumption floor. For these groups the allowance during most of our sample period is €2,600 (a little less prior to 2005 and more from 2017 onwards).

A.1 East Germany

Our sample includes those who lived in the GDR before reunification, and those who live in the East German states afterwards. From 1992, former GDR pension rights were brought into the West German system, but under transitional rules: East German earnings, including those in the

GDR years, were scaled up before points were computed by the ratio of average earnings in the West to those in the East, and the resulting points were paid at a separate, lower pension value. Both rules have since been phased out. Basic income support also paid a slightly lower standard rate in the East until mid-2006. Our model applies the West German rules to everyone, and so understates the pensions of East German men, most of all for earnings in the early 1990s, when the gap between East and West wages was largest. In addition, East German workers who left employment between 1990 and 1992 at 55 or over could draw a transitional early-retirement benefit (*Altersübergangsgeld*) until they could claim a pension; this concerns the East German men in our oldest cohorts, born 1935 to 1937, and is not modelled.

A.2 Recent German pension reforms

Over the period we study, reforms first tightened the routes into early retirement, both by putting a price on claiming early and by closing routes altogether, and then in 2014 opened a new route for those with long careers. During our sample period, deductions for early claiming are finishing their phase-in. A 1992 reform set the deduction at 0.3% per month, and laws passed in the 1990s raised the age at which the early routes paid a full pension, while leaving the earliest claiming age in place. As a result, for almost all of our sample the unemployment and long-term insured routes paid a full pension only from 65, so that claiming the unemployment route at 60 cost up to 18% and the long-term insured route at 63 up to 7.2%. The exception is the severely disabled route, whose full-pension age rose from 60 to 63 for those born 1941–1943, so that within our sample this route became more expensive cohort by cohort. The earliest ages at which some routes could be claimed also rose. On the unemployment route the earliest age rose from 60 to 63 for those born 1946–1948, and on the severely disabled route it begins to rise from 60 with the 1952 cohort, reaching 60 and 7 months for those born in 1953.

Several routes to early pensions were phased out entirely. The 1999 reforms closed the unemployment and part-time routes to everyone born after 1951, so some parts of our sample will be eligible for these routes and others not. The same reform closed the early pension route for women born after 1951, which our male sample never had access to. When early retirement for women was abolished, more than half of those affected continued working (Geyer and Welteke, 2021), with transfers cushioning the loss of income for those who did not (Geyer et al., 2020). The later retirement age also increased the prevalence of some health outcomes (Barschkett et al., 2022). Women in more demanding jobs responded no differently from others, which Zwick et al. (2022) attribute to eligibility rules that had already selected healthier workers into the route.

The closure or tightening of pathways to early retirement has led many people to work longer, but not all. Raising the early retirement age for the unemployment route was seen to increase reemployment among older unemployed men (Giesecke and Kind, 2013). When the unemployment pathway for men was tightened, it was those with low pension wealth who delayed their retirement most, and the first of these reforms also saw people substitute the withdrawn route with disability pensions and the severely disabled route to the old-age pension (Riphahn and Schrader, 2023).

The disability pension was tightened over the same period. From 2001, a full disability pension required that a worker could not work in any occupation, rather than only in their own, but a partial pension on the old own-occupation grounds remained available to everyone born before 2 January 1961, which includes all of our sample. The reform also introduced a deduction of 0.3 percent per month for disability pensions claimed before 63 (rising for younger cohorts), up to a maximum of 10.8 percent, which was in force by 2004. The benefits paid in disability pension have also changed over time, as the maximum age used to impute earnings points increased from 60 to 62 in 2014.

Perhaps the most well-known reform was the introduction of the *Rente mit 63* in 2014. Sold

as relief for workers in hard jobs who had worn out their health, it allowed people with 45 years of contributions to claim the old-age pension from age 63 without deduction. Although it was taken up widely (Section 2.1), evidence suggests that it was not successful at targeting those in poor health (Börsch-Supan et al., 2015; Dolls and Krolage, 2023). Like the career-based policy we study (Section 5), it conditions early retirement on career history rather than on health.

As a result, different cohorts in our sample face both different sets of available routes and different prices for claiming their pension early.

B Additional descriptive facts

This appendix adds detail to the description of our data in Section 2.3 and to the descriptive facts in Section 2.4.

B.1 Data

Our primary sample follows its men back to 1984, but we observe information about their health only from 1994 onwards. In addition to this primary sample, we use observations of men born until 1978 to reconstruct behaviours earlier in life, which the men in our main cohorts had already passed through before the SOEP began. The restriction to men covered by the social security system is applied through their employment histories: our sample excludes individuals who were never observed in a job which would require pension insurance contributions (equivalently social security contributions).

Alternative health measures we have for validation are the SF-12 physical component scores (PCS) and mental component scores (MCS). These are constructed largely from questions about how physical or mental health limits activities so are more direct measures of health-related limitations (Andersen et al., 2007). However these are asked only every two years from 2002 onwards, so we prefer SRH for its larger sample size. Throughout, we use a scale such that higher health index represents worse health, i.e. our health variable should be thought of as representing *health deficits*, as in the model (Section 3).

Our three occupational groups are built from one-digit ISCO-88 codes as follows. Our "strenuous" occupation consists of work involving physical activity or strain (concretely, this is ISCO codes 5-9: service and sales workers, skilled agricultural workers, craft and trades workers, plant and machine operators, and elementary workers). The "light" occupation consists of managerial and professional work typically involving little physical exertion (ISCO codes 1 and 2: officials and managers, and professionals), while the "medium" occupation sits in between (ISCO codes 3 and 4: technicians and associate professionals, clerks). Table A.1 shows that this ordering matches the physical demands of the jobs as measured by Kroll's occupational physical index (Kroll, 2011a,b).

Our measure of wealth includes housing assets and private pensions, as these are substantial channels for investment over the lifecycle that will pay dividends in later life. We abstract from the illiquidity of these assets. Around 21.6% of respondents are recorded as holding non-positive net worth at any given time. Monetary amounts are deflated to 2016 euros by the consumer price index.

In addition to information about demographics, occupational history, and health, we also observe information about pension claiming behaviour. As we are especially interested in the ways in which an individual moves out of work and into the old-age pension, we classify each person by the last status they held before their first old-age pension claim, as one of

1. Full-time in the career occupation, claiming at the statutory age
2. Full-time in the career occupation, claiming early
3. Part-time or in another occupation

Table A.1: The three occupations: ISCO groups and physical exposure

ISCO-88 major group	Occupation	Share (%)	OPI	OJI
1 Managers	Light	8.0	3.73	4.57
2 Professionals	Light	16.4	2.34	2.96
3 Technicians and associate prof.	Medium	18.0	3.64	3.65
4 Clerks	Medium	7.4	3.83	3.11
5 Service and sales workers	Strenuous	3.9	6.77	7.28
6 Skilled agricultural workers	Strenuous	1.1	8.63	7.98
7 Craft and related trades	Strenuous	25.7	9.07	8.52
8 Plant and machine operators	Strenuous	13.2	7.65	7.60
9 Elementary occupations	Strenuous	6.4	7.90	7.18
Strenuous (ISCO 5–9)		50.3	8.36	8.00
Medium (ISCO 3–4)		25.4	3.70	3.49
Light (ISCO 1–2)		24.4	2.80	3.49

Notes: SOEP men, employed person-years, weighted. OPI is Kroll's overall physical exposure index and OJI his overall job exposure index (physical and psychosocial), each at the finest ISCO level available for the job.

4. Drawing a disability pension
5. Out of work

Table A.2 reports the shares of exits via each of these routes by career occupation.

Table A.2: Status at last observation prior to first old-age pension claim, by career occupation (%)

	Strenuous	Medium	Light	All
Full-time in the career occupation, claim at the normal pension age	9.3	7.8	18.2	10.9
Full-time in the career occupation, early claim	24.6	26.0	15.9	23.0
Part-time or in another occupation	6.2	18.3	17.4	11.7
Disability pension	18.2	12.1	13.3	15.6
Out of work	41.6	35.9	35.2	38.8

Notes: SOEP men born 1938–1953 with a career occupation whose first old-age pension claim is observed, together with an earlier observation; weighted. Each individual is classified by their status in the last observation before the claim.

As well as the SOEP variables, we make use of administrative data on pension awards as described in Section 2.3, since the SOEP's information on pension claims is not exact while the administrative data cover the full insured population. These are published by the DRV as counts, and we convert them to flows from the population of insured people not yet drawing a pension, also found from DRV administrative data, in the insured-persons (*Versicherte*) statistics series.

B.1.1 East Germany

Our sample covers all of Germany, and 19.5% of the men in it lived in the GDR in 1989. We keep them in the sample for two reasons. First, the counterfactual policies we study are reforms of the German pension system today, and their effects depend on the whole population to which they would apply; a sample restricted to the West would describe a different population from the one the reforms would reach. Second, the ways in which East German men differ from West German men over our period, with lower wages and wealth and more time out of work, are differences the model already generates through its heterogeneity in productivity, education, health, and preferences, rather than ones that would need a separate structure. The main approximation lies in their pension rules: the model applies West German pension parameters to everyone, and

so understates the pensions of East German men, most so for earnings points accrued in the early 1990s (Appendix A.1).

Exclusion of East German men does change some of the data moments. The moments describing claiming and retirement move little, so the pooled retirement moments are close to those of West German men alone. Those describing wages, wealth, employment and exit before 59, re-entry, and occupation shares move substantially more, as expected, since the East German economy differs from the West most on these dimensions.

B.2 Descriptive facts

This subsection expands on Section 2.4, and provides additional tables.

Part of the health gap between occupations is already present when men start work. Table A.3 describes the later cohorts which we observe at labour market entry (men born from the late 1960s), in their first employed year at ages 22–29. Those entering the light occupation report a mean health deficit of 0.231, against 0.282 for those entering the strenuous one, and controlling for education and a birth-year trend leaves the gap at 0.055, so it does not simply reflect differences in other fixed characteristics. After entry the occupations diverge further (Figure 2). The rates at which deficits accumulate in each occupation and labour market status are estimated as part of the health process, and are reported in Table 4.

Table A.3: Health at labour-market entry, by entry occupation

	Strenuous	Medium	Light	All
Health deficit, mean	0.282	0.267	0.231	0.271
Good health (%)	73.7	77.0	81.4	75.6
Tertiary education (%)	14.2	31.1	82.8	27.6

Notes: SOEP men at their first employed year aged 22–29 with a self-rating (2,313 men, born from the late 1960s), weighted, one observation per man. The deficit is the self-rating scaled to $[0, 1]$; good health is the two best ratings.

Table A.4 illustrates how exit rates vary nonlinearly with health. It shows the results of a linear probability regression of not being employed the following year, among employed men aged 45–58, with a separate indicator for each level of self-rated health. Relative to the best rating, the second raises the rate of leaving employment hardly at all, the middle rating raises it a little, and the two worst ratings raise it sharply, the worst by far the most. This is why we group the ratings into good, middling, and poor health. Holding health fixed, men in the medium and light occupations leave employment at lower rates than those in the strenuous one.

Table A.5 breaks down the rate of leaving work for good by career occupation and health. At 55–60, poor health raises the exit rate by 9.3 percentage points in the strenuous occupation, against 4.7 points in the medium occupation and 4.7 in the light one, while the ratio of the exit rates in poor and good health is similar in all three, between 2.49 and 3.38. At 61–64, when most men can claim an old-age pension, the pattern is less regular.

Strenuous occupation workers spend slightly longer in the labour market than those in the light occupation (Section 2.4), and so contribute to the pension insurance system for more time. As was considered by Grossmann et al. (2024), this in conjunction with the fact that they tend to have a shorter life expectancy at retirement (Haan and Schaller, 2021) means that they tend to see a lower return on their contributions.

Table A.6 describes how workers' year-to-year transitions vary with their health. Moves to a lighter occupation are, if anything, less common among employed men in poor health (3.5% a year, against 4.4% of those in good health), and among those who change occupation, men

Table A.4: Rates of leaving employment, by self-rated health

SRH 2	0.004
	(0.006)
SRH 3	0.013**
	(0.006)
SRH 4	0.058***
	(0.009)
SRH 5	0.205***
	(0.028)
Medium occupation	-0.030***
	(0.004)
Light occupation	-0.038***
	(0.005)
Age 55+	0.057***
	(0.005)
Observations	38,489
Persons	7,638

Notes: SOEP men employed at ages 45–58 from cohorts born 1935–1973; weighted linear probability model of not being employed a year later. SRH: self-rated health, running from 1 (best) to 5 (worst); the omitted SRH group is rating 1, and the omitted occupation is the strenuous one. Also controls for occupational tenure and tertiary education. Standard errors clustered by person in parentheses. *, **, ***: significant at 10%, 5% and 1%.

Table A.5: Leaving work for good, in poor and in good health

	Good health (%)	Poor health (%)	Difference (pp)	Ratio
Exit at ages 55–60				
Strenuous	3.9	13.2	9.3	3.38
	(0.5)	(1.4)	(1.5)	(0.55)
Medium	3.2	7.9	4.7	2.49
	(0.7)	(1.9)	(2.0)	(0.78)
Light	2.6	7.4	4.7	2.81
	(0.6)	(2.0)	(2.1)	(0.98)
All men	3.4	10.7	7.3	3.18
	(0.3)	(1.0)	(1.0)	(0.42)

Notes: SOEP men by career occupation, weighted. The rate is the share of employed men in a year for whom it is their last year of work before a permanent exit, by the age of that exit; health is the self-rating that year, good being the two best and poor the two worst. Standard errors in parentheses, clustered by person; the ratio's by the delta method.

in poor health are less likely to end up in the light one, most clearly when leaving the medium occupation. Lighter jobs are in most dimensions "better", so they can likely be more selective about their candidates. Poor health shows up instead in moves to part-time work, in leaving employment, and in not returning to it.

Table A.6: Rates of year-on-year transitions, by health

	Good	Middling	Poor
Employed: moves to a lighter occupation	4.4	3.8	3.5
	(0.2)	(0.2)	(0.3)
Full-time: goes part-time	1.0	0.9	1.7
	(0.1)	(0.1)	(0.3)
Employed, 45–58: leaves employment	3.6	4.9	11.7
	(0.2)	(0.3)	(0.7)
onto a disability pension	0.0	0.5	2.6
		(0.1)	(0.4)
Not employed, 45–58: re-enters employment	23.6	22.7	14.7
	(1.6)	(1.6)	(1.4)
Switchers out of strenuous: into light	38.9	38.6	35.7
	(3.6)	(4.2)	(5.7)
Switchers out of medium: into light	64.1	58.3	49.1
	(2.9)	(3.2)	(5.9)

Notes: SOEP men, one-year transitions between consecutive years, weighted; by health group in the first year. Each row is the share (%) of the group named before the colon, in the first year, that makes the move by the second: employed in both years for moves to a lighter occupation (strenuous to medium or light, medium to light); full-time in the first year and employed in the second for part-time; not employed and drawing no pension for re-entry; employed in both years with a change of occupation for switchers. Ages 45–64 where not stated. A value of 0.0 without a standard error is too thin to publish and shown at its boundary. Standard errors clustered by person in parentheses.

C Model specification details

C.1 Assets within the model

While we abstract from households, we take the asset stock to include housing assets which would be shared among household members. Capital income is folded into the return rate r. Housing expenses (real rents or imputed for householders) are taken to be part of the consumption good c. As such, assuming mortgage interest rates of r, renting and buying are equivalent; in the latter case part of one's income Y goes to the interest payments, but the housing asset produces an identical consumption flow of imputed rents that are the opportunity cost of living in the asset.

C.2 Approximations of the institutional setting

The old-age pension early-claim routes' eligibility criteria necessarily have simplifying assumptions in their model representations. For some cohorts, eligibility ages are a year and some number of months; we round these to the nearest year to fit with our timing scheme.

For computing eligibility for early pension routes, the model simplifies by counting every year since entry to the labour force towards the 45 years of the especially long-term insured route (Section 3). In reality these years include employment, care, and unemployment insurance other than in the two years before the claim, but not time in education or basic income support.

Similarly, in reality, the unemployment route requires 52 weeks of unemployment, which our requirement of a year out of work immediately before the claim matches. On the other hand, the part-time route requires two years of partial retirement under an agreement possible from age 55, among other conditions. It would be a substantial increase in model complexity to capture this precisely, while this pathway accounts for at most around a tenth of men's old-age pension awards in our sample period. We simplify it by allowing eligibility after one year of part-time work.

Turning to support for those out of work, unemployment insurance in the model is computed on the mean wage of the previous occupation, adjusted for part-time work, rather than on the individual's own prior earnings as would be the case in the real world. In reality the maximum duration of these benefits is usually 12 months but it depends on contribution history and age, rising to as much as 32 months for some older workers; we fix it at exactly one year. The €9,000 floor of basic income support is an approximation to the real situation where it is made up of a flat component and a housing component that varies, but the total is usually around this level.

Basic income support is also means-tested on both income and assets. In the model the floor tops up a man's resources, his income plus the assets he carries into the period, to €9,000, so every euro of savings counts against it and a man must run his assets down before he receives any support. In reality each regime protects some assets from the test, by the amounts given in Appendix A. The true means test also exempts an owner-occupied home of reasonable size, which the model cannot capture, since its single asset includes housing wealth. Our floor therefore overstates the means test for men with modest savings, and makes leaving work less attractive for them than it was. Finally, the means test is applied to the household rather than to the man alone. A partner's income and assets count against basic income support, as a spouse's income counted against unemployment assistance, while the model, which abstracts from households, tests each man on his own resources. For men whose partners work or draw a pension, this overstates their access to the floor.

The support described so far is the structure in place from 2005, and before then it was different. When unemployment insurance ran out, a man who had received it could claim unemployment assistance (*Arbeitslosenhilfe*), paid at 53 percent of his prior net earnings, means-tested, and renewable a year at a time without limit, while a man without such a claim fell back on social assistance (*Sozialhilfe*). In 2005 both were replaced by basic income support for job seekers. The model applies the post-2005 structure in every year, so a man out of work for more than a year receives the floor of basic income support, whether in reality he would have received unemployment assistance or social assistance. This understates the income of men who left work with long insurance records before 2005, among them the older men who bridged to the unemployment route of the old-age pension, and since unemployment assistance also earned pension points, it understates their pensions as well.

Pension earnings points are approximated in the same spirit as the eligibility requirement for the especially long-term insured route. All years since entry are counted as insured years. When in unemployment support, points are earned only during the year of unemployment insurance, at the rate its contributions imply. In reality, some periods of unemployment earned points beyond this: the longer entitlements of older workers, unemployment assistance before 2005, and, at a much lower rate, basic income support until 2010.

Turning to work alongside a pension, in our model we only allow working while claiming the old-age pension after the normal retirement age. Early claimers are prohibited from working. In reality there is an earnings test rather than a ban on working, but the threshold amounts (at most €450 a month until June 2017, and €6,300 a year from July 2017, above which the pension was partially withdrawn) are low enough that it is much closer to no work than the part-time work earnings in our model.

Likewise, while in reality the disability pension may be awarded either as full or partial, we only model full disability, and as such do not allow those on disability pension to continue

working.

Finally, the model's tax and contribution rules are set out in Section 3. It is important to explicitly model income tax, not only because we are interested in the government's fiscal position. Many pension concepts apply to net wages, and tax works differently on pension income and labour income. Further, some of the potential policy proposals in discussion are about changing the taxes for working while earning a pension. The contribution ceiling is approximated as twice average earnings and held constant in real terms, against a statutory ceiling of 1.85 times average earnings in 1995, 2.14 in 2005, and 2.05 in 2019. We also approximate the income tax system. Instead of modelling exactly the various rates and brackets over the time period we consider, we approximate the system with a smooth function following Heathcote et al. (2017), with functional form

$$Y^{\text{net}} = aY^{(1-\tau)} \tag{A.1}$$

where Y is taxable income measured relative to average earnings. This function is fitted to the single-filer tax schedule over our period to give values of $a = 0.795$ and $\tau = 0.170$, reproducing net incomes generally within a few percent of the exact schedules. This functional form implies negative tax at sufficiently low incomes, and these are floored to zero; in practice this occurs close to the basic income support level. We do not find that the fit of this function changes substantially as minor income tax policy changes take place during our sample period, and so we assume it constant over time.

Choosing a smooth form is computationally convenient since we use the endogenous grid method to solve the consumption problem, in which tax kinks can make the consumption policy poorly behaved.

C.3 Parametric specification

The leisure term of equation (4) groups a number of amenities and costs faced by the agent. In practice, we make a number of parametric restrictions on how these functions evolve. The amenity of holding a job is split into several components:

$$\phi_J(j, E_i, I_i, h_{i,t}) = \phi_{\text{occ}}(j) + \phi_E(j)E_i + \phi_I(j)I_i + \phi_{JH}(j)\tilde{h}_{i,t} + \phi_{JH2}(j)\tilde{h}^2_{i,t} \tag{A.2}$$

where $\tilde{h}_{i,t} = \max(h_{i,t} - \bar{h}, 0)$ for a threshold health level of $\bar{h} = 0.375$, in order to best capture the non-linear effects of health. Going forward, it will be convenient to denote $[x]^+ = \max(x, 0)$ so that $\tilde{h}_{i,t} = [h_{i,t} - \bar{h}]^+$. In (A.2), poor education can cause an amenity cost to being in the light occupation, for example, and people with different productivity or health status can prefer different types of occupation.

The cost of working increases with age after 55, with a kink at 60, being specified as

$$\phi_A(j, a) = \phi_{NA}\,[\min(a, 60) - 55]^+ + \phi_{NAJ}(j)[a - 55]^+, \tag{A.3}$$

and part-time work carries a cost that also rises from 55, $\phi_{PT}(a) = \phi_{PT} + \phi_{PTA}[a - 55]^+$. Non-employment is normalised to zero amenity per se, so every term of ϕ_J and ϕ_A is a difference relative to not working.

The switching costs in the model depend on the move being made. We denote by j the chosen occupation and j_- the last held occupation (this also being remembered through unemployment

spells). Denoting non-employment by u, we specify the switching costs as

$$\phi_{SW} = \begin{cases} \phi_{SWJ}(j) + \phi_{SWO} + \phi_{SWC}(j_-)C_{i,t} + \phi_{SWH}(j)\tilde{h}_{i,t} & j_- \to j,\ j \neq j_- \\ \phi_{SWJ}(j) + \phi_{REJ} + \phi_{REG}\tilde{h}_{i,t} + \phi_{REA}(a_{i,t} - 55)^+ & u \to j,\ j = j_- \\ \phi_{SWJ}(j) + \phi_{REJ} + \phi_{REG}\tilde{h}_{i,t} + \phi_{REA}(a_{i,t} - 55)^+ & \\ \qquad +\phi_{SWO} + \phi_{SWC}(j_-)C_{i,t} + \phi_{SWH}(j)\tilde{h}_{i,t} & u \to j,\ j \neq j_- \\ 0 & \text{otherwise} \end{cases}$$
$$+ \phi_{PTX}\,\mathbb{1}_{\mathrm{PT}\to\mathrm{FT}} + \phi_{DX}\,\mathbb{1}_{\text{exit DI}} \tag{A.4}$$

Moving into occupation j costs $\phi_{SWJ}(j)$ however it is reached. A change of occupation, whether directly or through unemployment, adds a cost ϕ_{SWO}, as well as a tenure cost ϕ_{SWC}, and a health cost $\phi_{SWH}(j)$. Re-entering employment from non-employment adds health- and age-dependent costs ϕ_{RE*}. Finally, there are amenity costs associated with switching from part-time to full-time work, and to exiting the disability pension.

The last component of the leisure amenity is the behavioural claiming bonuses, specified as $\phi_{\text{beh}} = \phi_{\text{behE}}\mathbb{1}_{\text{ER}} + \phi_{\text{behF}}\mathbb{1}_{\text{FR}}$, where $\mathbb{1}_{\text{ER}}$ marks a claim from work in the year an individual first reaches their earliest eligibility age, and $\mathbb{1}_{\text{FR}}$ a claim in the year they first reach the age at which their route pays a full pension.

C.4 Solution method

The backbone of the model's solution method is backwards induction. We assume a finite horizon at age 90, after which agents no longer make choices. We iteratively solve the model's value functions and optimal choice probabilities for each point on the state space grid backwards in time until the entry age of 25.

The model has six continuous states: birth cohort; productivity; occupational tenure; average earnings points; the health deficit; and assets. Each of these is solved on a grid and interpolated between its nodes. The large state space of this model makes the solution computationally intensive.

To reduce the computational burden, the consumption choice is solved by the endogenous grid method (Carroll, 2006). Here the grid is over assets carried forward rather than cash on hand. Instead of requiring a numerical root finding of the Euler equation at each gridpoint, this allows one to simply invert the Euler equation at the value of the assets carried forward and thence infer the cash on hand that implies it[10]. Discrete choices complicate this slightly, as the continuation value embeds next period's choice and is therefore not guaranteed to be concave, meaning the Euler equation may have several solutions for the same value of cash on hand. Following Iskhakov et al. (2017), we solve consumption using this method separately for each discrete alternative, taking the upper envelope over the resulting solutions of the Euler equation.

Wage shocks are integrated by quadrature over the space of three-dimensional potential wage draws. Similarly the health transition probabilities on the grid are found by evaluating quadrature nodes of the health innovation and interpolating the resulting values back onto the health grid. The preference shocks over the discrete alternatives are extreme value type I, so the choice probabilities at each state have the logit form and the expected value over the shocks is the log-sum over alternatives.

[10] This method breaks down when the borrowing constraint binds, but in this situation the agent simply consumes their full cash on hand.

D Moments

D.1 Identification by moment block

This subsection sets out the identification argument of Section 4.2 in more detail, one family of parameters at a time.

The wage parameters are identified by wage regressions in the data that follow the structural wage equation (2) in their regressors, which are occupation, age and its square, tenure, education interacted with occupation, and health. The returns to productivity, α_j^I, and the variance of the transitory shock, α^V, are identified by the residual variance and the autocovariance of earnings within person, overall and by occupation and education. The wage on re-entry, by length of the spell out of work, disciplines the earnings of those who return.

Among the parameters of the cost of working, the occupation shares by education identify ϕ_E, and the education gaps in employment the rest of education's effect. The age profile of employment, and the exit rates and exit regressions at 45–58 and 59–64, identify the age costs ϕ_A, the occupation-specific part coming from employment and exit by occupation. The health terms of ϕ_J are identified by the health gradients in employment and in exit. The part-time costs are identified by the part-time share by age and occupation, by a regression of part-time work on health, age, occupation, and education among the employed, and by the persistence of part-time work.

Among the costs of moving, switching rates by education, age, and origin, and a regression of switching on health, tenure, age, and education, identify the levels ϕ_{SWJ} and ϕ_{SWO} and the tenure loss ϕ_{SWC}, and tenure by occupation helps separate the last from the returns to tenure in wages. The mean destination of switchers by origin and health also identifies how the cost of moving varies by destination. The re-entry costs are identified by re-entry rates by age, a regression of re-entry on health, the destinations of re-entrants by health, and the share returning to their previous occupation.

For the value of drawing a pension and the claiming bonuses, the destinations of those leaving work at 59–64 add to the claim hazards and regressions, disciplining the value of drawing a pension against remaining in work or out of work without one. The administrative award rates of old-age pensions at single ages from 60 to 66 discipline the claim rate in the population as a whole. They are pooled over windows of years whose edges are pension reforms (2005–07, 2008–11, 2012–13, and 2015–16, with 2017–18 at some ages), so they also show how claiming shifted as routes closed and opened.

The disability parameters are also disciplined by the receipt and exit rates of the disability pension and by exits from employment onto it. Recognised severe disability by health at 60–62 and the administrative award rates of the severely disabled route identify that route's acceptance probability.

The drifts of the health process are identified by the regression of the change in health on status, together with the health level by age and last occupation held, and the variance of the health shock by the shares whose rating changes, worsens, or moves by two categories or more over gaps of one to eight years. Mortality is identified by death rates by age from the life tables, and by the ratio of the death rate in poor health to that in good health in the SOEP. The utility weights on consumption and leisure are identified by the wealth moments, which are the median and the means of the lower and upper thirds of net worth by age and the share with little or no wealth, together with the labour supply moments above.

E Model estimates

E.1 Local identification

To expand on the identification arguments in Section 4.2, we here provide the sensitivity matrix at the estimated parameter value. It is $\Lambda = (G'WG)^{-1}G'W$, following Andrews et al. (2017), the derivative of each estimated parameter with respect to each data moment, with G and W as in Section 4.1.1. Figure A.1 illustrates this, aggregated to the level of blocks of moments and aggregating the elements of vector parameters together, normalised by both parameter and block so that it shows, for each parameter, which blocks move it more than is typical.

This figure only depicts which blocks drive each parameter, which (especially without disaggregating the moment blocks) does not directly speak to the joint identification of the parameter set. To illustrate that, at least in the vicinity of the estimate, the parameters are jointly locally identified, we may assess the column rank of G, the derivative of the simulated moments with respect to the parameters (see Section 4.1.1). Full rank indicates joint identification, as then no direction in parameter space leaves every moment unchanged to first order.

We report this as the singular values of $W^{1/2}GD$, where W is the weighting matrix used in estimation and D rescales each column by the corresponding parameter estimate, such that entries are interpreted as relative changes rather than absolute for comparability. The ratio of the largest to the smallest singular value is 893, and the spectrum declines smoothly, without the gap that would indicate a rank deficiency.

E.2 Fit

Figure A.2 plots each data moment against its estimated model counterpart, on axes that are logarithmic away from zero. All points lying on the 45-degree line would denote perfect agreement. Overall the model approximates its target moments well. An orthogonal regression of this plot, weighting each moment by its size relative to its standard error, has a slope of 1.03 and an R^2 of 0.93.

F Additional policy experiment results

F.1 Additional details of the uniform policy

F.1.1 Destinations

Table A.7 shows how the person-years of withdrawn pension eligibility are spent under the uniform rise, overall and by what the man was doing just before his baseline claim. Section 5.1 reports the shares spent in work, and the table also shows where the remaining years go. Those who were working before they would have claimed most often draw unemployment insurance when they stop. Those who were already out of work spend most of the withdrawn years on basic income support or without any benefit, and those who were on a disability pension mostly fall onto basic income support or remain on the disability pension.

F.1.2 Fiscal effects by behaviour

The costs or benefits for the government depend on these behaviours. In Table A.8, we decompose the total fiscal effect by behaviour in the baseline and under the reform. In each cell of this table we see the combined net fiscal effect of people making particular choices. The diagonal cells represent person-years in which an individual made the same choice in the baseline as in the counterfactual. Off-diagonal cells represent changed behaviours[11].

[11] In this table we exclude those person-years where the mortality outcome changes, which are few.

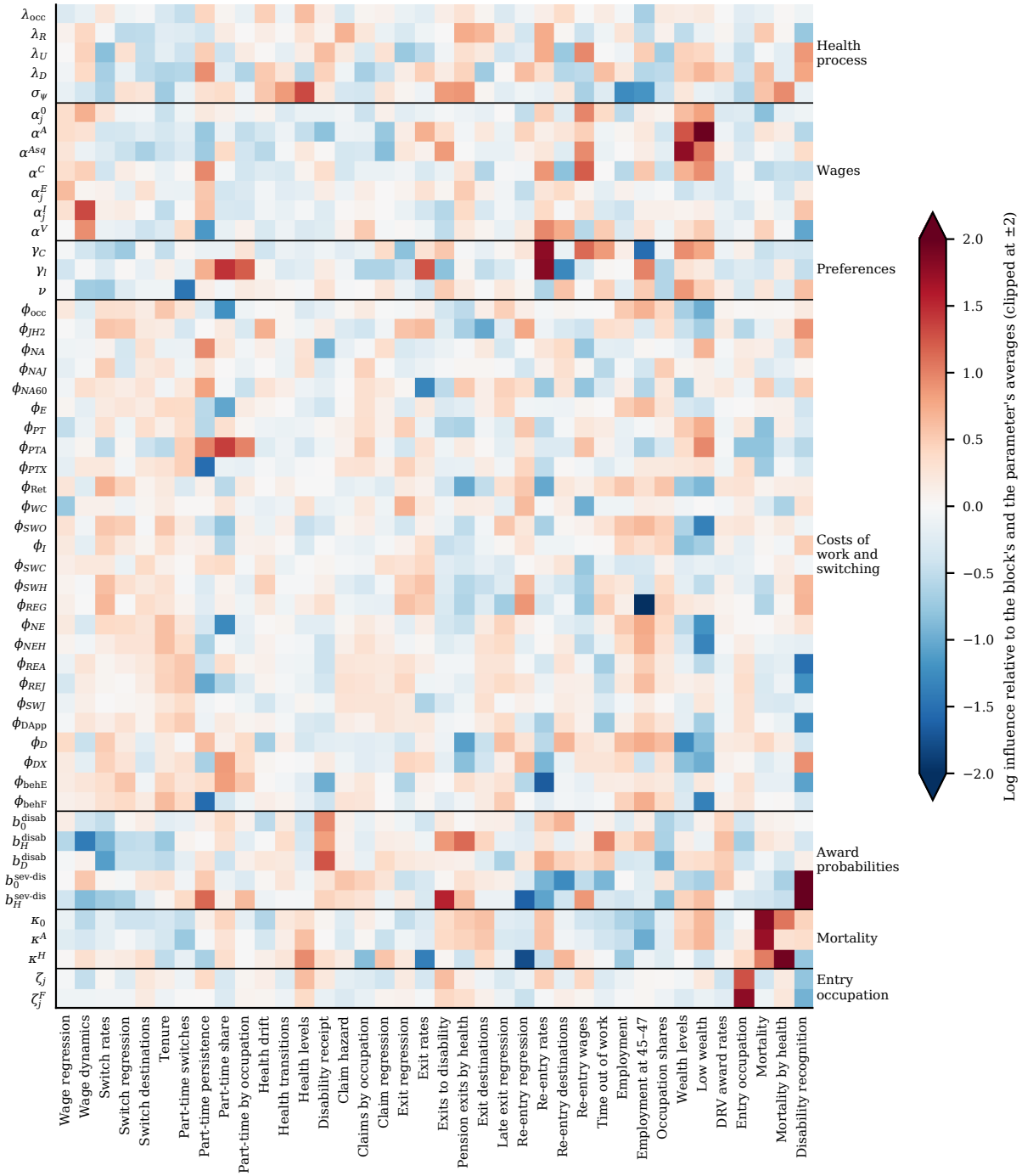


Figure A.1: Sensitivity of each parameter to each block of moments

Notes: Each cell shows how strongly a block of moments moves a parameter, relative to how much that block moves parameters in general and how much that parameter responds to moments in general. Based on the sensitivity matrix of Andrews et al. (2017) at the estimate, with each moment scaled by its standard error. Parameters with several elements are shown as one row, the geometric mean of their elements' sensitivities.

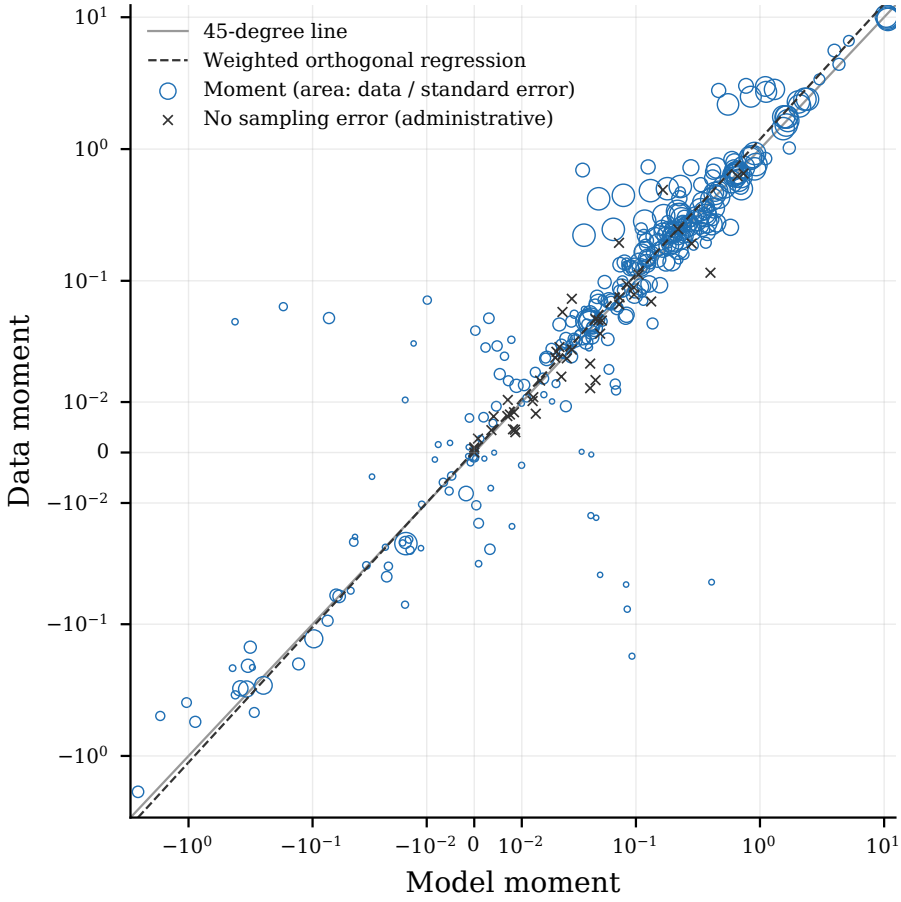


Figure A.2: Comparison of data and model moments

Notes: To reflect the variety of moments and scales their values take, each of the 368 moments are plotted on inverse hyperbolic sine axes, $x \mapsto 0.01\,\mathrm{asinh}(x/0.01)$, which are linear near zero and logarithmic beyond about ± 0.01. Circle areas are proportional to the data moment's size relative to its standard error, capped at 30. Crosses denote the 46 administrative moments, which have no sampling error. 5 moments giving rates of health moves by more than one category are omitted since they are identically zero in the present model specification. The dashed line is a weighted orthogonal regression on the plotted scale, weighting each moment by its size relative to its standard error, squared and capped as for the circles (slope 1.03, R^2 0.93).

Table A.7: How people spend withdrawn pension years (%)

		State before the baseline claim		
	All	Working	Out of work	Disability pension
Working	43.4	68.9	12.5	2.7
Disability pension	5.8	2.0	9.9	32.4
Unemployment insurance	7.6	12.7	1.5	0.0
Basic income support	28.0	6.7	54.0	48.6
No benefits	15.2	9.6	22.1	16.2

Notes: Changes in behaviour of those for whom pension eligibility is withdrawn under a uniform eligibility age increase. Rows denote the choice under the counterfactual policy, measured in the fraction of person-years. Columns 2–4 split these by the state held in the period before the pension claim in the baseline.

Table A.8: Fiscal effect of the uniform policy by behaviour (euros per person)

	Under the counterfactual policy			
In the baseline	Old-age pension	Disability pension	Out of work	Working
Old-age pension	-2,669	10	4,184	23,132
	(25.8)	*(0.5)*	*(1.5)*	*(1.2)*
Disability pension	0	4	23	137
	(0.0)	*(2.3)*	*(0.0)*	*(0.0)*
Out of work, no pension	-187	-204	-1,094	4,783
	(0.0)	*(0.1)*	*(6.2)*	*(0.3)*
Working	-373	-1,070	-5,361	339
	(0.0)	*(0.1)*	*(0.3)*	*(61.7)*

Notes: Person-years classified by state in the baseline (rows) and under the uniform policy (columns). Each cell reflects the net fiscal change for the government (in euros per person). The bracketed number underneath shows the percent of person-years represented by that cell. Person-years in which the individual is alive under one policy regime and dead in the other are excluded.

As might be expected, the bulk of the improvement in the government's fiscal position comes from those who in the baseline were claiming the old-age pension and under the counterfactual worked instead. Perhaps surprisingly on first sight, there is a loss associated with those person-years where the old-age pension was claimed under both policy regimes. This is because additional time employed leads to increased pension benefit levels, and so savings during the delay itself are somewhat offset by increased subsequent payments. Increased disability insurance spending from direct substitution of old-age pension to disability pension causes essentially no change to the government's position in this table, since the entitlement levels under the two pensions are quite commensurate. The losses due to the disability pension are opportunity losses that are not shown in this table of net effects, from people being able to remain on a pension even after the old-age eligibility has been withdrawn.

F.1.3 Distributional consequences

Figure A.3 shows the average number of years a person becomes entirely ineligible for a pension they would otherwise have claimed, by education, baseline career occupation, and baseline health at age 59, as well as how they spend these years. This is a measure of *forced* compliance: these are years where the individual is necessarily required to find a replacement for the old-age pension, rather than simply being able to move to an earlier entry route that they previously did not take advantage of[12].

Section 5.1 describes how the years lost differ by education and by health, and the figure also shows how they are spent. As one would expect, those in poor health were much more likely to spend any withdrawn eligibility period drawing a disability pension.

F.2 Additional details of the targeted policies

F.2.1 Strictness

The health-based policy we base most of our presented results on is one point in a family of health tests that differ in how strict their eligibility criterion is. Figure A.4 illustrates the tradeoff that must be made between reducing the number of stranded left exposed and increasing those who have been wrongly exempted. It is possible to protect more of those who would be left exposed,

[12]The policy also bites in a different way for others who are able to move to an early claim route: they may need to take a deduction to their pension entitlement to do so.

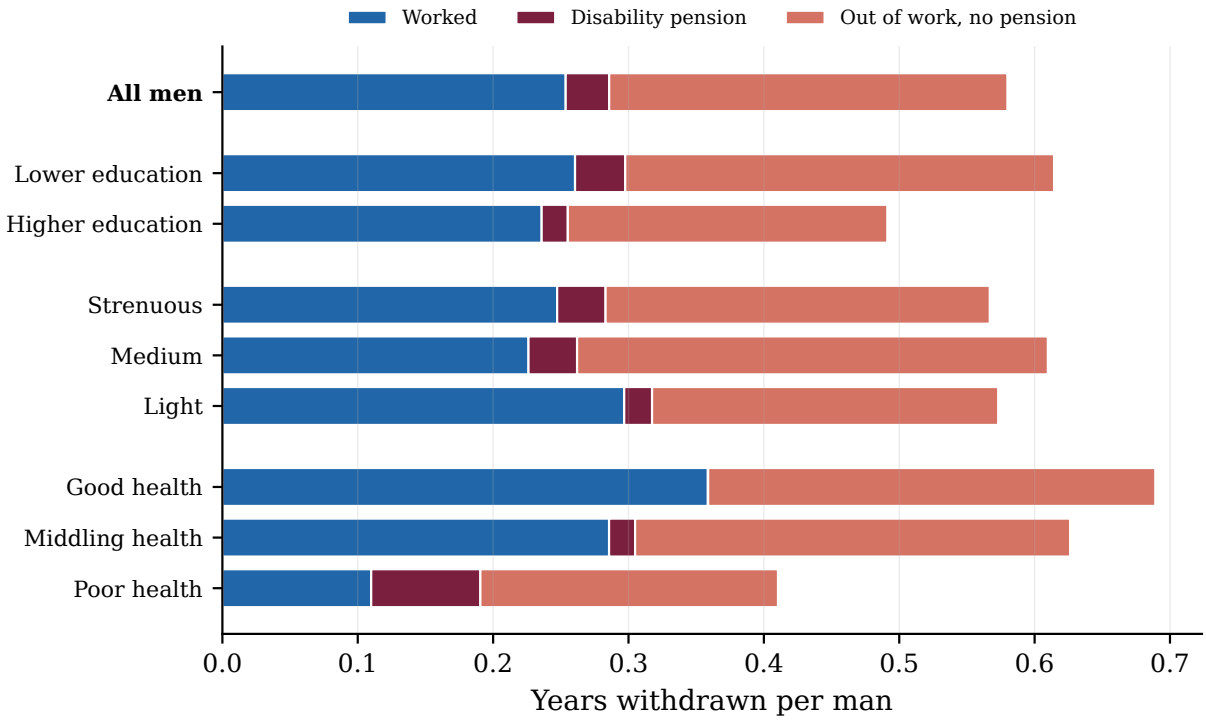
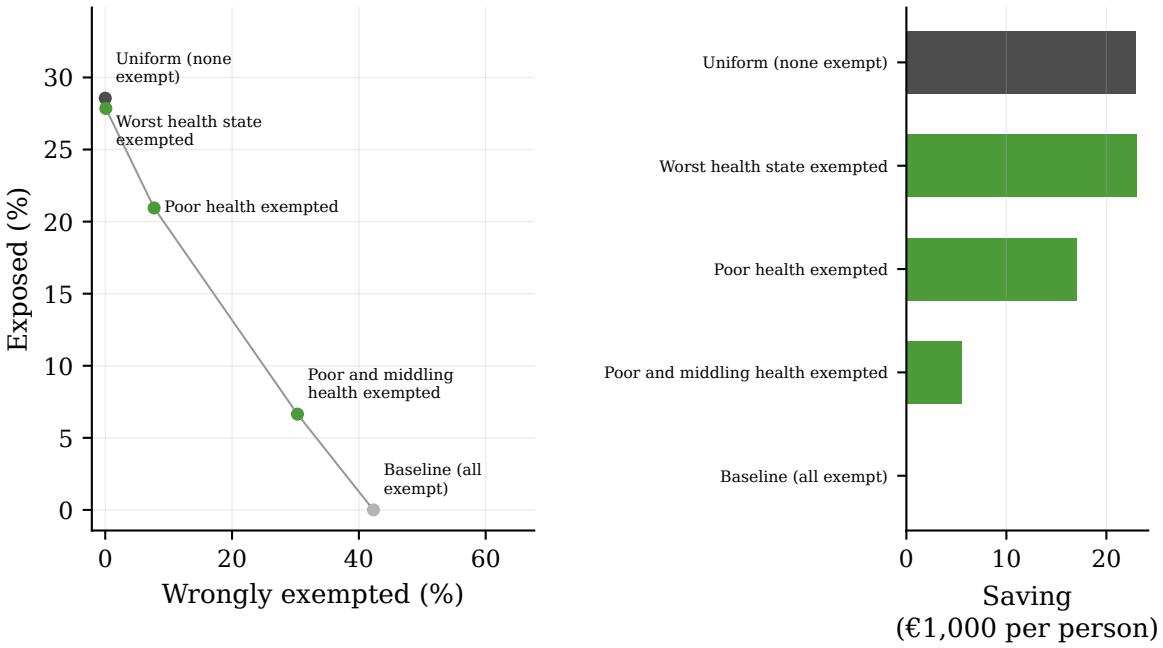


Figure A.3: Pension years the uniform raise withdraws, and how they are spent

Notes: The number of years that a pension which would have been claimed at baseline was entirely withdrawn, meaning there were no alternative early pension eligibility routes available. While the statutory increase was two years, many would previously not claim at the earliest possible date, and hence are not counted as bitten in this strict sense since they would be able to substitute to the earlier route (potentially with deduction) when the eligibility ages increase. Strenuous/Medium/Light are career occupation, i.e. the most common occupation held between 45 and 59 (in the baseline simulation), and Good/Middling/Poor health are measured at age 59 (in baseline). "Out of work, no pension" includes unemployment insurance, basic income support, and those not drawing any benefits.

but at the cost of increasing the number wrongly exempted and reducing the fiscal gains of the policy[13].



(a) The stranded left exposed against those wrongly exempted

(b) Fiscal impact

Figure A.4: Targeting errors as the strictness of the health exemption is varied

Notes: (a) Each point represents a variant of the health-based policy in which people with particular health states are exempted from a pension eligibility age increase. The uniform policy and baseline policy represent the maximally strict and minimally strict endpoints of this tradeoff frontier curve, with exemptions catching different levels of health falling in-between. The population from which the shares are taken is those who face at least one year of withdrawn pension under the uniform policy. "Exposed" represents those who would not work and would fall onto basic income support, and are not exempted by a given policy. "Wrongly exempted" are those who are given an exemption but would otherwise have worked. (b) The corresponding fiscal gains of these policies compared to the baseline, including old-age pension payments, disability pensions and unemployment support, income taxes and social security contributions.

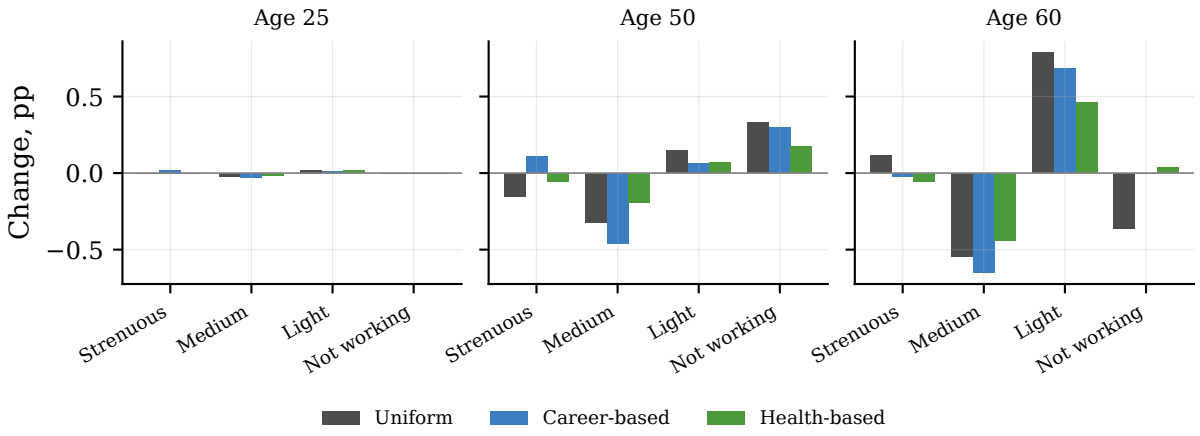
F.2.2 Distortions

Figure A.5 shows how each policy changes the occupational distribution by age, against the baseline, both in what men are currently doing (panel a) and in their current or last occupation (panel b).

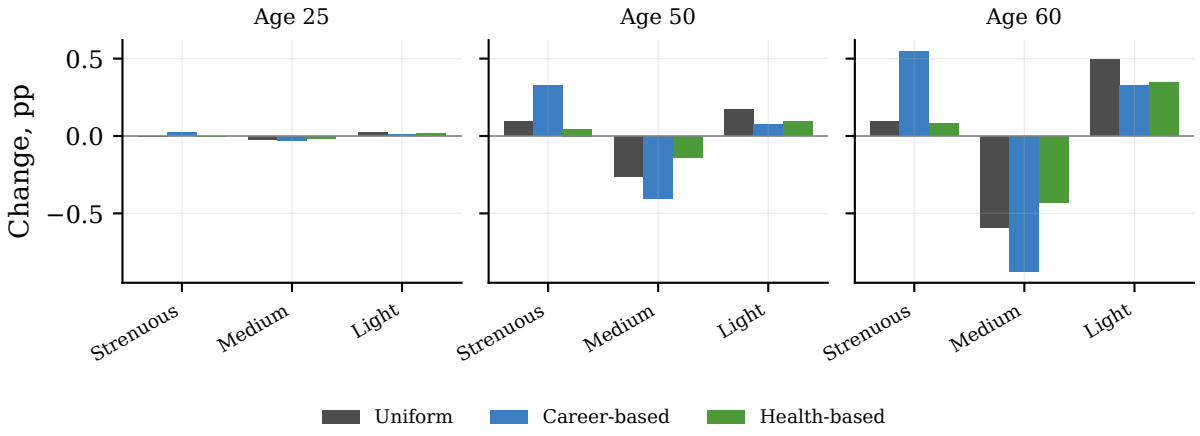
F.2.3 Imperfect observation of health status

We saw above in Section 5.2.1 that the health-based policy is somewhat effective at targeting those who do not have the ability to continue working. However, in contrast to the occupational information used for the career-based policy's eligibility test, the government will of course not directly observe health status. Some noisy assessment must take place to determine eligibility in any real-world implementation. To give some idea of the effect this might have, we model the assessment as similar to that for the severe disability entry route to the old-age pension. In

[13]While our setup does not lend itself to similar experiments varying the strictness of the occupational exemption, one could imagine doing so in principle.



(a) Current activity



(b) Current or last occupation

Figure A.5: The occupational distribution under each policy, against the baseline

Notes: Change from the baseline policy, in percentage points, among men alive at each age. (a) Activity at a given age (b) The last occupation worked (or current occupation if currently working)

this assessed-health counterfactual policy, those who fail the assessment have pension eligibility delayed by two years, and those who pass the assessment may claim their old age pension at the baseline age.

With an imperfect observation of health status, the policy performs broadly comparably to that with perfectly observed health on average, both bringing a government saving of €17k and incentivising a little over a third of a year in additional work (Table A.9). However, as might be expected the assessed policy forces those in poor health to delay by much longer even though they are very unlikely to work, and exempts some of those in better health, leading to weaker employment responses.

Table A.9: A policy where health is assessed rather than observed

	Health, observed			Health, assessed		
	Claim delay	Additional work	Fiscal impact	Claim delay	Additional work	Fiscal impact
By baseline group						
All	1.11	0.38	17,045	1.41	0.35	17,155
Career occupation						
Strenuous (53%)	1.00	0.30	9,951	1.40	0.31	10,720
Medium (26%)	1.13	0.31	14,112	1.34	0.18	11,144
Light (21%)	1.37	0.66	38,344	1.53	0.65	40,519
Health at 59						
Good (25%)	1.77	0.75	33,001	1.67	0.66	30,488
Middling (44%)	1.46	0.48	21,705	1.41	0.40	19,433
Poor (31%)	0.02	-0.02	-405	1.17	0.08	5,302

Notes: Per person in each baseline group, over the whole life cycle: the change in the age of first claim, in years worked, and in the net fiscal balance (in euros). Figures are therefore not identical to Table 7, which counts years before age 70 per baseline claimant.

We can also directly compare how often this policy misclassifies people compared to our headline perfect information policy, shown in Table A.10. The noisy assessment policy mistakenly gives early pension access to 15.2% of those in good health, and denies early pension access to 28.7% of those who are in poor health. This leads to more wrong exemptions and a lower share exposed than our headline perfect-information health-based policy. In practice then, this assessment mechanism produces another potential point on the strictness tradeoff diagram (Figure A.4a), rather than being strictly worse. Of course, this is just one example of a family of noisy assessments that could be considered, but the general point is that health is already a noisy measurement of ability to work, so adding a little more noise in the assessment of health does not fundamentally change the behaviour of the policy.

Table A.10: Misclassification by the health assessment

	Health, assessed	Health, observed
Good health, given early access (%)	15.2	0.0
Middling health, given early access (%)	40.2	0.0
Poor health, denied early access (%)	28.7	0.0
Share wrongly exempted	11.4	7.7
Share stranded & exposed	15.5	20.9

Notes: The fraction of people classified wrongly by the assessed-health policy. Wrongly exempted and exposed groups are as defined in Table 6.

F.2.4 Ex ante welfare

Figure A.6 gives the ex ante welfare of each policy at labour market entry, for all men and by education, the occupation chosen at entry, and health at entry. Panel (a) compares each policy with the baseline, and panel (b) compares each targeted policy with the uniform one. Table A.11 checks that the ranking of the policies does not rest on the claiming bonuses in the value function, which reward claiming at the statutory ages and so move when a reform moves those ages. Its panel (a) is the model's value, while panel (b) removes the utility that the claiming bonuses added along each man's simulated choices. Under funded financing the three policies are ranked the same way under the two measures, both at labour market entry, where the uniform policy is preferred, and when the reform is announced at 55, where the health-based policy is, although the levels differ.

Table A.11: Welfare of each policy with and without claiming utility bonuses (CEV, percent, all men)

	Uniform	Career	Health
(a) Value function, as in Figures A.6 and 14			
Ex ante	0.09	−0.36	0.06
Announced at 25	0.09	−0.36	0.06
Announced at 45	0.23	−0.32	0.51
Announced at 50	0.20	−0.34	0.65
Announced at 55	0.08	−0.41	0.76
(b) Less what the claiming bonuses added			
Ex ante	0.69	0.06	0.62
Announced at 25	0.69	0.06	0.62
Announced at 45	1.78	0.75	1.96
Announced at 50	2.15	1.01	2.48
Announced at 55	2.57	1.30	3.12

Notes: The proportional rise in baseline consumption from the stated age on that is worth as much as the policy; positive is a gain. (a) the model's value. (b) the same, less the utility the claiming bonuses ϕ_{behE}, ϕ_{behF} added along each man's simulated choices, discounted as the value is. These are paid at the policy's own statutory ages, so moving the ages moves them. The career-based and health-based policies are financed by a funded rise in contributions.

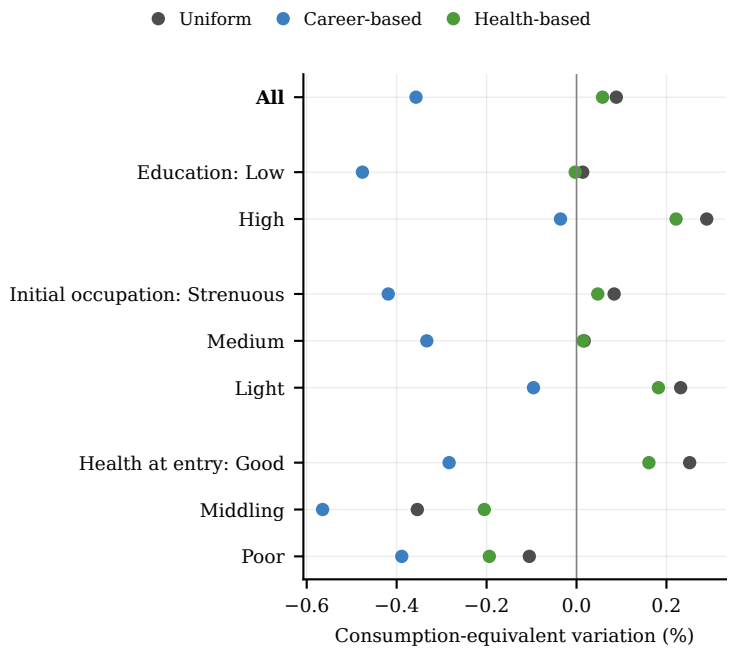
F.2.5 Welfare under unanticipated policy shock

Figure A.7 compares each targeted policy with the uniform one under each way of financing it, by age at announcement. The four ways of financing the exemptions through higher contributions give qualitatively similar results, and Section 5.4 discusses how these differ from financing them through a cut to old-age pensions.

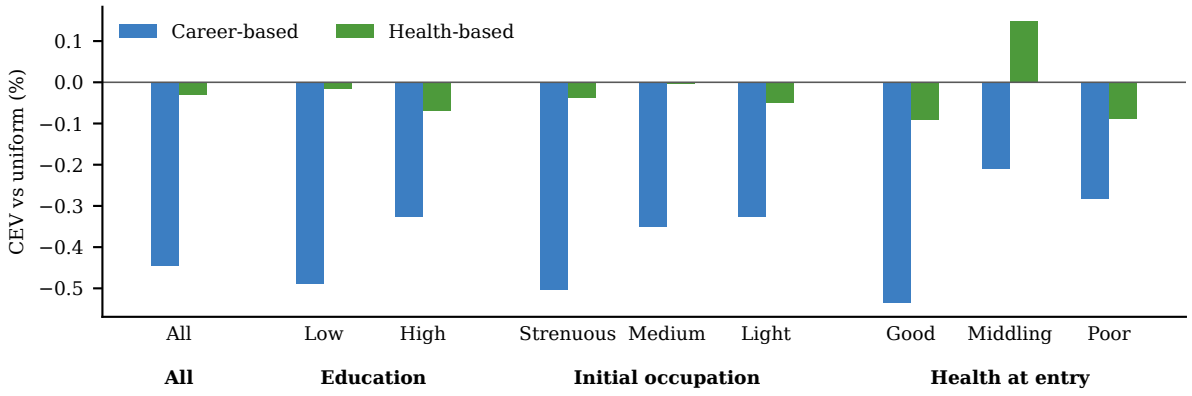
We can also consider to what extent choices adjust as the policy announcement is made at different ages. Figure A.8 shows how many individuals adjust their career choices prior to 60, by the timing of the announcement.

Section 5.4 reports how many people change their behaviour under each policy, and how the adjustment falls with the age at announcement.

Under the career-based policy it is simple to understand exactly how one's choices affect future retirement eligibility. This leads people to choose the early pension-eligible occupations



(a) Utility change compared to the baseline



(b) Utility change compared to the uniform policy

Figure A.6: Ex ante welfare of each policy, by group

Notes: The consumption-equivalent variation of each policy change. Groups are as measured in the baseline. The career-based and health-based policies are financed by contribution increases such that their fiscal benefit matches the uniform policy. Panel (b) is the difference between each targeted policy's CEV and that of the uniform policy, both measured against the baseline.

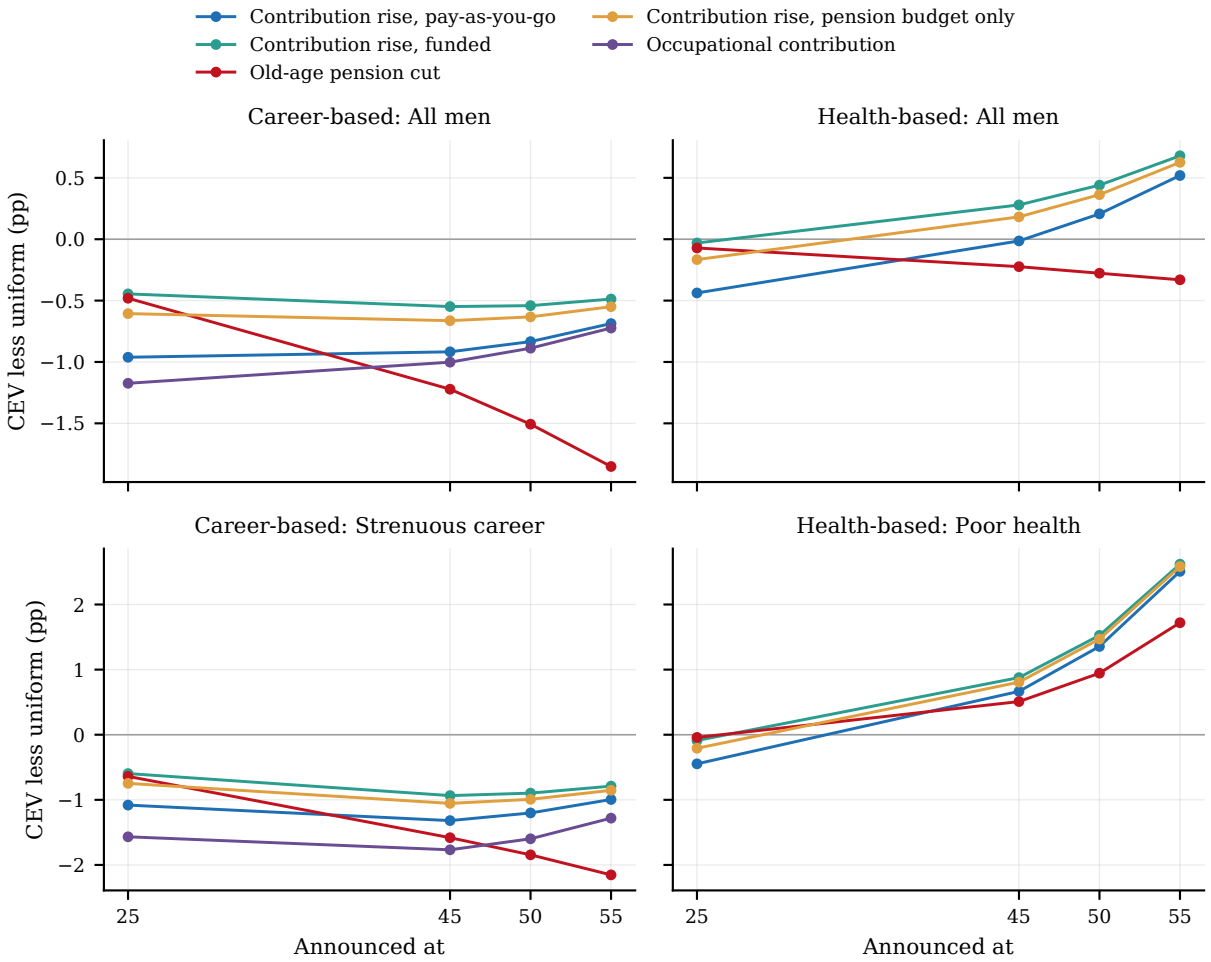


Figure A.7: Welfare of targeted policies relative to the uniform policy by financing method

Notes: Consumption-equivalent variation of each targeted policy over that of the uniform policy, when both are announced unexpectedly prior to the age given; at 25 the announcement precedes all choices, so the value is ex ante. Positive values reflect a preference for the targeted policy over the uniform one. Each targeted policy is financed to the uniform policy's net fiscal gain by different methods: a contribution rise under a pay-as-you-go or funded system, a pay-as-you-go rise matching the pension budget alone, an occupation-specific contribution rise, or a cut to old-age pensions (Table 9). Top row: all individuals alive at the announcement. Bottom row: for the career-based policy, those whose career occupation is the strenuous one; for the health-based policy, those in poor health at the announcement.

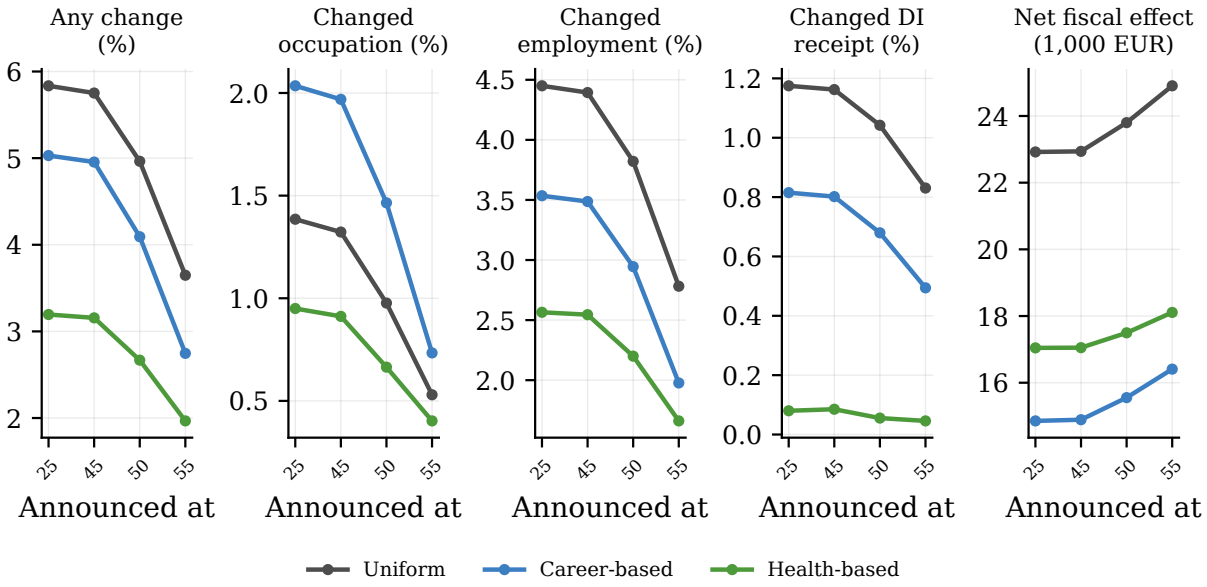


Figure A.8: Behavioural responses to policy change by age at announcement

Notes: The fraction of people who change their behaviour at some point before age 60 in response to the policy, by age at announcement.

more frequently, especially in the lead-up to retirement. If occupation were fixed throughout the lifecycle then one might expect this to strongly influence the initial choice of occupation. In our model there is enough occupational mobility and young people are sufficiently myopic that their initial choices are not strongly affected. By age 50 however, we saw in Figure A.5 that there is a small mass of individuals who would switch to the strenuous occupation in anticipation of gaining an early retirement. As such, there is little difference whether this policy is announced prior to age 25 or at age 45, but if it is announced at age 50 or later then this does have an impact on the policy's behavioural effects, muting the occupational shift response it induces.

The fiscal gain of the targeted policies also changes with the age at announcement, as the Discussion reports for the uniform rise. Announced at 55 rather than at 25, the net saving per person rises from €14,855 to €16,408 under the career-based policy, and from €17,045 to €18,108 under the health-based one. The change is smaller for the health-based policy because its eligibility depends on health, which people can influence only indirectly through their work, so there is less behaviour to adjust in anticipation of it.

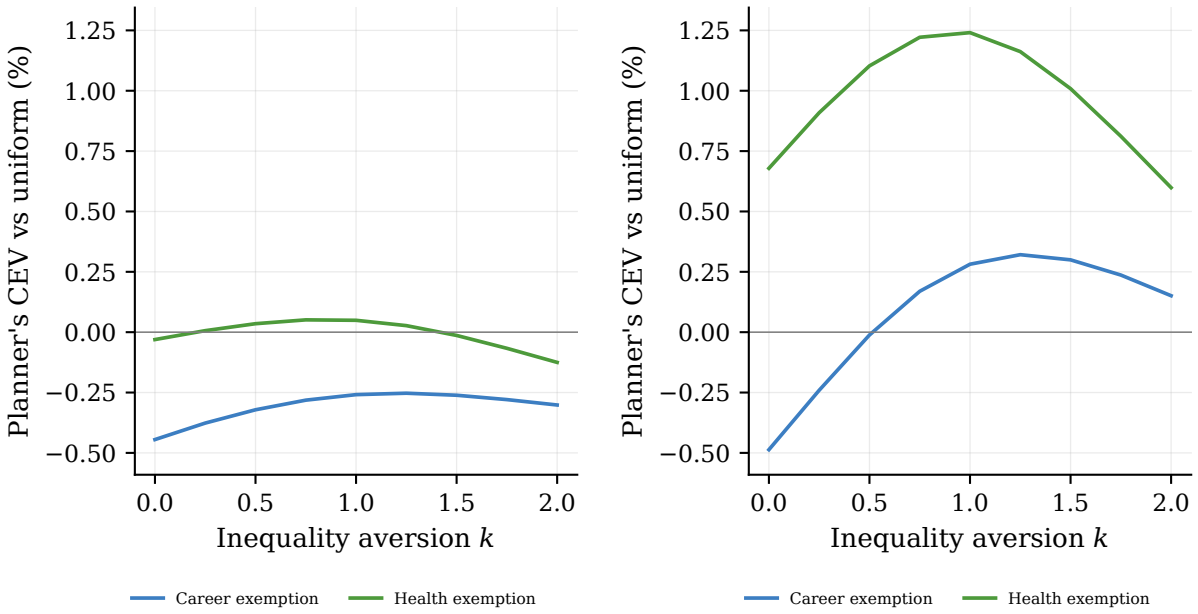
F.2.6 An inequality-averse planner

The average welfare considered thus far weights each individual equally. While individuals' concave consumption utility does give some sense of inequality aversion, we can directly introduce an inequality averse planner's welfare function. Figure A.9 applies a Kolm–Pollak social welfare function, with inequality aversion k measured in units of the spread of values under the uniform raise. This welfare function weights individuals by an exponential penalty on their expected lifetime value V_i^P under policy P:

$$W^P(k) = -\frac{1}{\theta}\log\left(\frac{1}{N}\sum_{i=1}^{N} e^{-\theta V_i^P}\right), \qquad \theta = \frac{k}{\sigma_U}, \tag{A.5}$$

where σ_U is the standard deviation of values under the uniform raise. At $k = 0$ this welfare function reduces to the mean value, reproducing the utilitarian planner implicit in the previous figures. As k rises, those with low utility are given more weight in the social welfare function.

The figure converts the difference between the targeted policies and the uniform policy's welfare to a consumption equivalent variation.



(a) Judged at labour market entry

(b) Judged at 55

Figure A.9: An inequality-averse planner's preference

Notes: A Kolm–Pollak planner over each individual's expected lifetime value, judged at 25 (before the first choice of occupation) and at 55. Inequality aversion k is in units of the standard deviation of values under the uniform raise at that age; $k = 0$ is the utilitarian planner. The figure plots each exemption's equally distributed equivalent less the uniform raise's, as a consumption-equivalent variation; above zero the planner prefers the exemption. The targeted policies are financed by a funded contribution rise to the same level as the uniform policy.

Both targeted policies become more attractive as inequality aversion increases, though this peaks at some point: since these policies do fail to protect some people in need, the worst-off person in the economy will typically be better off under the uniform policy with no contribution rises, and so the limit of large inequality aversion will actually tend to prefer the uniform policy. Judged ex ante, the health policy is mildly preferred at moderate inequality aversion, while this preference is much clearer when judged at age 55, when part of the cost of the exemptions (increased contributions) has already been paid, and the benefits of the policy are becoming more certain to those who it will benefit.