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Tightening access to early retirement: who can adapt?

Bernhard Boockmann* Martin Kroczek† Natalie Laub‡

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Abstract: We study heterogeneity in the effects of two pension reforms in Germany that closed pathways into early retirement: the abolition of an old-age pension scheme for women and the abolition of a pension after unemployment or part-time work. We focus on heterogeneity with respect to several occupational characteristics. Both reforms had significant effects on individual employment states, and in both cases the effects differ significantly by occupation. The positive effect on employment is smaller in occupations with higher job strain and, in case of the old-age pension for women, the effect on unemployment is larger. The effects also differ by occupational tasks, PC use and the introduction of new technologies.

Keywords: Pension reforms, effect heterogeneity, occupational demands, occupational tasks
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1 Introduction

In many industrial countries, the employment rate of older workers has increased substantially over the last two decades. In Germany, for instance, employment of 60 to 64 year old individuals increased by almost 42 percentage points between 2000 and 2020 (OECD 2021, 177). In addition, working time has increased among older workers and the incidence of unemployment has declined. These changes are often attributed to a paradigm shift in public pension policy. Over the last 30 years, various legislative acts have raised the regular retirement age and abolished early retirement schemes.

Numerous studies analyse the causal effects of pension reforms on older workers' labour market outcomes (Geyer & Welteke (2021), Lalive et al. (2022), Riphahn & Schrader (2022)). However, the causal relationship between pension rules and labour market status is complex and and it is unlikely that all individuals will respond equally to a particular pension reform. Demographic, socio-structural, cultural, health and economic factors may interact with institutional changes (Coile 2015).

In this paper, the focus is on the role of job strain, tasks and technology in influencing and moderating the impact of pension reforms on employment and retirement transitions of older workers. We consider two reforms of the pension system which closed down favourable pathways into early retirement. We ask to which extent individuals were affected differently by these reforms depending on the characteristics of their jobs.

Using a regression discontinuity desgin (RDD) and rich individual-level data from the German pension insurance, we find substantial heterogenity in the reform effects on labour market status. For both pension reforms analysed, the effect on employment is smaller for those working in highly demanding occupations or performing more non-routine manuals tasks, while the effect on unemployment is higher for those performing more cognitive tasks. Our results also point to a role of new technology in fostering employment and reducing unemployment for workers affected by the abolition of early retirement schemes.

The remainder of the paper is organised as follows. Section 2 briefly summarizes the relevant literature. Section 3 introduces the German pension system and the details of the reforms considered. Our identifcation strategy and the data are described in section 4. Section 5 present our results for the whole sample and for subgroups, while section 6 draws conclusions.

2 Previous literature

Behavioural responses to benefit-cutting reforms of the U.S. Social Security system are substantial, see e. g. Coile & Gruber (2007). Blau & Goodstein (2010), Mastrobuoni (2009), or Behaghel & Blau (2012) for example show that increases in the retirement age lead to increases in labour force participation and retirement age and affect the age at which benefit claiming is most likely. In addition, several studies focus on unintended effects of retirement reforms, such as increased claiming of benefits at distinct ages (Song & Manchester 2007) or the spillover effects to other schemes like disability pensions (Duggan et al. 2007).

Findings for European countries are generally close to those for the US. According to Lalive et al. (2022), an increase in retirement age and reduced retirement benefits in Switzerland substantially delayed claiming pensions. Similar findings are obtained by Staubli & Zweimüller (2013) who also find considerable spillover effects on both unemployment and disability insurance. Results by Engels et al. (2017) suggest that employment rates increased in Germany in response to a reform exclusively affecting women and raising their normal retirement age: The authors do not find an effect on unemployment over the age range they consider, as periods of unemployment are postponed from earlier to later age brackets, i. e. unemployment is used as a bridge into retirement. Analysing an increase in the early retirement age for women, Geyer & Welteke (2021) show that women affected by the reform remain longer in their respective labour market status instead of actively substituting from employment into unemployment or inactivity. Riphahn & Schrader (2022) analyse early retirement reforms and find strong behavioural responses, i. e. postponed retirement, employment later in life, unemployment shifted from before to after age 60 and the use of other pathways into retirement.

There is also some evidence on heterogeneous effects of pension reforms. Staubli & Zweimüller (2013), Geyer et al. (2020) or Oude Hengel et al. (2021) find that reform effects differ with respect to health status and/or income. Hanel & Riphahn (2012) differentiate their analyses with respect to education.

Another area of research paramount to our research question analyses the relationship between working conditions and retirement. Berg et al. (2010) conclude from their literature review that high physical and psychosocial work demand are important factors for early retirement. Blekesaune & Solem (2005) find that low autonomy in job tasks and psychological job stress are associated with early retirement. Robroek et al. (2013) also identify low job control as a risk factor for early retirement.

Besides job demand, other characteristics, such as tasks performed, might favour either prolonged employment or early retirement. Velde (2022) compares results for Germany and the UK and

finds that workers in routine jobs have a significantly higher probability of early retirement in the former but not in the latter country. Radl (2013) uses data from 11 Western European countries and finds workers who retire latest both at the upper and the lower end of the occupational ladder. He attributes late retirement among routine workers to low pension entitlements and limited access to occupational pension plans.

Friedberg (2003) uses the US Health and Retirement Study from 1992 until 1992 and shows that workers who use computers exit from the labour market later than workers who do not use computers. Biagi et al. (2013) use Italian survey data from 2000 until 2004 and find that computer use on the job together with computer literacy significantly reduce the probability to retire. However, the authors do not find significant results for computer literacy or computer use on the job per se. Hudomiet & Willis (2022) find that older workers who were not familiar with the use of computers were significantly more likely to leave the labour force when their jobs were computerized. Technical change at the industry level can have different effects on early retirement. Bartel & Sicherman (1993) and Burlon & Vilalta-Bufí (2016) for example find that in industries with high technical change the probability for later retirement is higher than in industries with low technical change. Ahituv & Zeira (2011) show in a general equilibrium model that aggregate technical change induces individuals to work longer, while sector-specific technical change has the opposite effect.

A small number of studies link the effects of pension reforms with the heterogeneity in retirement behaviour according to job characteristics. Among them, Giesecke (2018) and Ardito (2021) find that the reaction to pension reforms differs by occupational tasks. Geyer et al. (2022) do not find different reactions to pension reforms due to differences in job demands. Carrino et al. (2020) also do not find different employment effects of a pension reform between routine, intermediate and managerial workers. However, their results suggest that prolonged exposure to high-strain jobs characterised by high demands and low control lead to negative health effects of an increasing retirement age.

3 Pension reform in Germany

3.1 Overview over the German pension system

The German public pension insurance belongs to the oldest public pension systems worldwide.[1] It is constructed as a pay-as-you-go system for dependent employees with contributions paid by

[1] A detailed description of the German public pension system can be found in Börsch-Supan et al. (2020).

both individuals and their employers.[2] Benefits are roughly proportional to average lifetime labour market income, adjusted by the number of years of contributing to the system. There are three different types of benefits individuals can claim: old-age pensions (from the age of 60), disability pensions (paid to those younger than 60[3]) and surviving dependants' pensions (paid to widows and orphans). As regards old-age pensions, there are several pension types with different eligibility criteria. Besides the regular old-age pension, which cannot be claimed early, there are specific old-age pension types, e. g. for women, unemployed or disabled persons or for long-term insured persons, which allow for early retirement. In this paper, we will focus on two specific old-age pension types, the old-age pension for women and the old-age pension after unemployment or part-time work.

Throughout its history, the German public pension system has already undergone many far-reaching reforms – not only in the past two decades (see Börsch-Supan et al. 2020). Generous early retirement schemes were available from the 1970s. From the mid-1980s on, the increasing fiscal burden due to an ageing population in combination with early retirement became more and more apparent and contribution rates were projected to skyrocket. This started an era of reforms aiming at securing the long-run sustainability of the pension system. In 1992, decrements for early retirement were introduced and eligibility rules tightened.[4] In 2007, the regular retirement age was legislated to increase from 65 to 67 years. This increase will take place stepwise between 2012 and 2031 and affects cohorts born in 1947 and thereafter.

3.2 Pension reforms analysed

In this paper, we analyse two early retirement schemes abolished by legislation in 1999. The first one is the **old-age pension for women**. Women could retire from the age of 60, but this threshold was increased to 65 for cohorts born in the end of 1944 and later.[5] Early claiming from age 60 remained possible with decreased benefits. Prerequisites for being able to claim this pension type were having paid contributions for at least ten years after the age of 40 and having fulfilled a qualifying period of 15 years.

[2] This does not hold for the majority of self-employed and for civil servants. The former have to save for their retirement themselves and the latter are insured in an entirely separate system.

[3] These pensions are converted to old-age pensions at the regular retirement age.

[4] Having fulfilled a qualifying period of 35 years, retirement is possible from the age of 63. However, for every month an individual retires before the regular retirement age, deductions of 0.3% are due. Earlier retirement is only possible for severely disabled workers and miners. Further provisions for women and unemployed are about to expire and apply only to certain cohorts.

[5] The retirement age was increased in 60 monthly steps for the cohorts born from the beginning of 1940.

The second pension type is the **old-age pension after unemployment or part-time work**. This pension type covers two probably different groups. First, it insures elderly individuals against the risk of unemployment. Second, it covers those who had agreed upon old-age part-time work with their employers. The first group by trend consists of individuals with employment careers interspersed with periods of unemployment. The second group contains more advantaged individuals closely attached to the labour market and being able to bargain favourable arrangements such as old-age part-time work. Originally, the old-age pension after unemployment or part-time work could be claimed from the age of 60. From 1997, the retirement age was increased to age 65,[6] but incentives to retire early remained strong as early retirement with benefits reduced by decrements was still possible from age 60. The threshold for early claiming was finally also increased to age 63.[7] However, this increase contained an important protection of legitimate expectation clause (so called *Vertrauensschutzregelung*).[8] It was legislated that for individuals who had been unemployed on January 1st, 2004 or who had agreed upon old-age part-time work with their employers by that date, early retirement remained possible from the age of 60 on. It was argued that these individuals had planned ahead the end of their career relying on the status-quo of pension legislation and that their reliance upon the pension system had to be protected.[9] To claim this type of pension, individuals had to have fulfilled a qualifying period of at least 15 years and paid contributions for at least eight out of ten years before retirement. Additionally, individuals either had to be unemployed at the time of retirement or have worked part-time for at least two years after the age of 55. Unemployment had to have lasted for at least one year after the age of 58 years and 6 months. It did not matter when unemployment occurred or if several shorter periods of unemployment added up to one year.

We analyse the closing of the pathway to early retirement via both of the pension types described above. From 2015 on, early retirement via the old-age pension for women was not possible any more. Early retirement via the old-age pension after unemployment or part-time work was not possible from 2012 any more. Both reforms affected individuals born after 1951. While the first reform mentioned affected women only, the second reform was directed mainly at male employees; in 2012, 87 percent of claimants to this pension type were male (Deutsche Rentenversicherung Bund 2022, 62). This allows us to implicitly compare the effects of pension reforms between men and women.Table 1 gives an overview over the reforms.

[6]The increment took place in 60 monthly steps from 60 to 65 years for the cohorts born from 1937 until 1941.

[7]The increase began with the cohort born in 1946 and was completed for cohorts born from December 1948 on.

[8]The draft legislation can be found in Deutscher Bundestag (2003, 27) (however only available in German). It lays out the aims of the protection of legitimate expectation clause and contains detailed explanations.

[9]In fact, the results will show that the phasing out of the exemption had a much larger effect than the abolition of the early-retirement option itself.

Abolition of old-age pension for women	
Affected	Reform effective from
Women born after 1951	2012 (early retirement)
	2017 (regular retirement)
Abolition of old-age pension after unemployment or part-time work	
Affected	Reform effective from
Individuals born after 1951	2015 (early retirement)
	2017 (regular retirement)

Table 1 – Pensions Reforms Under Study

4 Methods and data

4.1 Identification and estimation

Our approach to identify and estimate the average effects of early retirement reforms builds up on the regression discontinuity design used by Geyer & Welteke (2021). The basis of identification is that different birth cohorts are either affected or not affected by a particular reform. We limit attention to individuals who are, due to their birth dates, just affected or just not affected by the reforms. In particular, we consider individuals born in 1951 (controls) or 1952 (treated). Our dataset contains all individuals of the respective cohorts who have ever been insured in the German pension system. It is thus large enough for our analysis and we do not have to include adjacent cohorts. We estimate the effect based on the comparison of these cohorts and differentiate the effects by job strain, tasks and technologies.

As outcome variables, we consider employment and unemployment as distinct individual labour market states. These variables capture whether affected individuals continued in employment up to new retirement age or whether they have an unemployment spell (or several of them) as a bridge between employment and retirement. In a part of the analysis, we also consider entry into retirement (in all possible pension types) and disability pensions. The effect on retirement shows the degree of compliance with the pension reform, i.e. the share of individuals directly affected. Disability pensions could be a possible substitute for the types of pension abolished by the reforms (Duggan et al. (2007), Staubli & Zweimüller (2013)).

Since the outcomes may vary with birth cohort, age, or time, we account for these (note that

there is a linear dependence of the three, so we need to account only for two of them). In the basic regression without further differentiations, we estimate a linear model of the form

$$y_{it} = \alpha + \beta D_i + \gamma_0(1 - D_i)f(z_i - c) + \gamma_1 D_i f(z_i - c) + \mathbf{X}'_{it}\delta + \varepsilon_{it}, \tag{1}$$

where y_{it} is a (binary) outcome variable, D_i is a binary treatment indicator, which equals 1 if an individual i is affected by a reform in period t, $\gamma_0(1 - D_i)f(z_i - c)$ and $\gamma_1 D_i f(z_i - c)$ capture possibly different time trends around the reform cut-off c, and the matrix $\mathbf{X}_{it}$ contains individual characteristics as controls. The main parameter of interest is β, which measures the effect of a specific pension reform on outcome y_{it}.

The RDD approach hinges on the assumption that we correctly capture trends in the outcome variable before and after the reform cut-off. If the respective trends are non-linear, the linear model in equation 1 is miss-specified and a non-linear trend may falsely be interpreted as discontinuity. In order to check for such miss-specification, we analyse pre- and post-reform trends graphically by depicting local linear regression estimations of the pre- and post-reform time trends. Figures 3 and 4 show the respective graphs. As pre- and post-treatment trends are reasonably linear and the discontinuities at the cut-off are apparent, we are confident that our RDD approach is valid.

Our objective is to analyse whether reforms of the pension system affected different subgroups of the population heterogeneously. In essence, β measures the average treatment effect and we are interested in how the treatment effect of a pension reform differs along individual-level characteristics W_i, i.e. we want to estimate treatment effects conditional on given characteristics,

$$\beta(w) = \mathbb{E}\left[Y(D = 1) - Y(D = 0)|W_i = w\right]. \tag{2}$$

To assess the overall heterogeneity in $\beta(w)$, we use the sorted effects method of Chernozhukov et al. (2018). The main idea is to estimate the entire set of partial effects sorted in increasing order and to rank them according to effect size, rather than to present one measure for the effect of interest, e.g. the average effect. To that end, we estimate an interactive linear model with an additive error term

$$Y_{ij} = g(Z_{ij}) + u_{ij}, \tag{3}$$

where $g(Z_{ij}) = Z'_{ij}\tau$, with $Z_{ij} = (D_{ij}, Q_{ij})$, where Q contains interactions between D and W to capture the treatment effect heterogeneity with respect to occupation and individual characteristics. The predictive effect (PE) is then given by

$$\beta(q) = (1, q)'\tau - (0, q)'\tau, \tag{4}$$

with q containing specific values of Q. Other than in the case of the standard interactive linear model, effect heterogeneity is now accounted for with respect to a number of different

occupation and individual-level characteristics in the same model. If μ is the distribution of W in the population, aggregation of the PEs over μ yields the average treatment effect. However, Chernozhukov et al. (2018) propose to report the entire set of PEs sorted in increasing order and indexed by ranking $u \in [0, 1]$. The u-th quantile of $\beta(Q)$ is the uth-Sorted Partial Effect (u-SPE). Displaying the SPEs at different (increasing) values of u, i.e. at different quantiles of the estimated effect, yields a one-dimensional representation of the heterogeneity in the PEs.

Empirically, sample analogues of β and μ are employed to obtain estimators of the SPEs. In case of the interactive linear model with additive error, the PE estimator $\widehat{\beta(q)}$ is obtained by replacing τ in equation 4 with its ordinary least squares estimator $\hat{\tau}$.[10]

To assess specific factors that give rise to treatment effect heterogeneity, we interact the binary treatment indicator D_i with indicators for the subgroups as well as continuous measures of individual-level characteristics. Based on hypotheses from the literature, our focus is on effect differences between, first, individuals working in occupations with different levels of overall, physical and psycho-social demands; second, individuals performing different types of tasks in their jobs; and, third, individuals using or not using particular technologies. Job demands and tasks can be measured either continuously or discretely. We build discrete indicators from the underlying continuous information. This simplifies the interpretation of the results and allows us to analyse all differences with a similar approach. We estimate interaction effects and report point estimates for $\beta(w)$ performing tests for equality in the different subgroups.

4.2 Data and construction of the sample

To examine whether and to which extent eligible individuals reacted to the reforms, we use administrative data of the Rehabilitation Statistics Database (RSDLV, Reha Statistik Datenbasis Verlaufserhebung)[11] provided by the German Pension Insurance (Deutsche Rentenversicherung). Our dataset contains information on all insured individuals born in the years 1951 and 1952. Thus, the number of observations is quite large with more than 1.2 million individuals in every cohort. The data contains information on socio-economic variables such as gender, month and year of birth, place of residence (at the state level). Very importantly, the dataset also includes detailed information on the employment status on a monthly basis for the age span between 56

[10] For an extensive description see Chernozhukov et al. (2018).

[11] The official title of the dataset is RSD insurance history survey 2017 and 2018, control group of the 66 year olds, header data, data on pensions and contributions, source: FDZ-RV, abbreviated: SPF.RSDV.2017-2018.1412-KO_RT_BY.

and 66. The different states contain regular employment, marginal employment, unemployment[12] and part-time work in old-age.[13] Furthermore, the dataset indicates whether an individual receives a pension, the type of pension, as well as month and year of retirement if applicable. Thus, the exact age at retirement can be inferred as well as whether an individual retired before or after the enactment of the reforms.

In addition, annual information on the so-called task code (Tätigkeitsschlüssel), a combined measure of occupational classification (according to the occupational classification of the German Statistical Office, KldB) and qualification, is contained in the data. For various reasons, the task code is sometimes missing in the data. To analyse the potential for selectivity, we distinguish between plausibly and implausibly missing task codes. The reason for a plausibly missing task code in a particular year is that an employment state for which no taks code can be collected last for the whole year (e.g. credit periods because of inability to work, unemployment, voluntary contributions, receipt of unemployment benefits or other benefits). If these employment states last for less than a year, but not a single (mandatory) pension contribution was paid during the year, the absence of the task code is also considered to be plausible. We note that in 19.6% of the cases the task code is plausibly missing, while it is implausibly missing in 13.5% of the cases (see table A1 in the appendix). Reasons for implausible missings include the transition from the KldB1988 classification to the KldB2010 in 2011, which is clearly visible from the table since the number of implausbile missings is higher in this year. In addition, the Research Data Centre of the German Pension Insurance identified two other reasons for implausible missings. First, some regional pension agencies did not collect the task code in the years 2015 to 2018; indeed, the share of implauibly missing observations is higher in these years than in all others except 2011. Second, the original task code was sometimes overwritten with a missing value when the individual changed employment status e.g. from employment to unemployment.

To impute missing values of the task code, we replaced missing information with the task code of contiguous periods if available. Even after the imputation, 11.5% of the individuals had no valid information for the task code over the whole observation period (see table A2 in the appendix). To check for possible selectivity due to missing task codes, we ran a series of linear probability models. The dependent variable was defined as 0 if the task code was available and 1 if it was missing implausibly (cases with plausible missings were excluded). The independent variables

[12]As regards unemployment, the data differentiates between short- and long-term unemployment and unemployment with and without benefit receipt. This is important as unemployment with benefit receipt counts as contribution period for the calculation of pension benefits while unemployment without benefit receipt is counted differently.

[13]Actually, part-time work in old-age is merged with other states, but as these states hardly play any role for the population we consider, we can reasonably assume that the vast majority of individuals in this category works part-time in old age. The dataset distinguishes further employment states (e. g. parental leave or military service) which are not important for our analysis.

included socio-demographic characteristics and pension information, such as the size of pension entitlements. The regression results can be found in table A3 in the appendix. They show that foreign nationals have a higher likelihood of missing task codes, which is most likely due to employers having more difficulties assigning a qualification level as compared to the case of German nationals. If the employment state did not last for the whole year, a missing obvervation is more likely for most employment states, corroborating the explanation provided by the German Persion Insurance. All in all, the principal reasons for missing task codes are captured by observed covariates such as nationality or employment state duration, so that sample selection based on unobservables is not a major issue.

Our main focus is on heterogeneity in the effect of pension reforms with respect to job demands, occupational tasks and technology. As the pension data themselves do not contain such information, we merge information on tasks and demands on occupational level from external data sets. To measure occupational demands, we employ three demand measures as calculated by Kroll (2011, 2015). Kroll (2011, 2015) employs data from a representative survey conducted by the German Federal Institute for Vocational Education and Training and the German Federal Institute for Occupational Safety and Health (BIBB/BAuA Employment Survey) to calculate aggregate measures of physical, psycho-social, and overall occupational demand. These provide a measure of the relative position of an occupation in the distribution of physical, psycho-social, or overall demand within a respective ranking of all occupations. We define occupations as highly demanding if they are ranked above the 7^{th} decile of demand distribution and as not highly demanding otherwise.

Concerning occupational tasks, we use a measure of task intensities on occupational level provided by Spitz-Oener (2006), which is also based on BIBB/BAuA Employment Survey data. We employ her proposed method to calculate measures for occupational skill requirements which are defined via reported activities in five task categories: routine manual, non-routine manual, analytic, interactive, and cognitive. We employ the waves 2006, 2012, and 2018 of the BIBB/BAuA Employment Survey to calculate the task sets of the occupations. We differentiate the occupations according to whether tasks from a domain are reported *often* or *rarely*. We define a task domain to occur often if the task share is above the 7^{th} decile of the distribution and as rarely otherwise.

We follow a similar approach to generate indicators for the intensity of computer use and technological development. Employing BIBB/BAuA Employment Survey data for the years 2006, 2012, and 2018, we calculate the share of individuals reporting to use a computer at work and the share reporting to frequently use a computer at work, by occupation. In order to calculate indicators for technological development, we rely on questions in the BIBB/BAuA Employment Survey data, in which individuals were asked to indicate whether certain changes in their work

occurred in the two years previous to the survey. The questions concern the introduction of new techniques or new machines, the use of new products or materials, the provision of new services, or the employment of new computer programmes. As we focus on changes and developments arising previous to the enactment of the reforms, we employ the respective averages over the waves 2006 and 2012 of the BIBB/BAuA Employment Survey. To separate the occupations according to how strongly they are affected by technological change, we again use the 7^{th} decile of the corresponding distribution.

We use the same cutoff point, the 7^{th} decile, for all the indicators. A graphical analysis of the differential effects shows that the corresponding cutoffs, e.g. between high and low job demand, tend to lie in the upper parts of the distributions.[14] Our results are also broadly robust to the use of other break points (6^{th} and 8^{th} deciles).

For the analysis, we first of all exclude individuals who are insured under the pension scheme for miners, as for them more favourable early retirement rules apply. We also exclude individuals receiving an old age pension for disabled, as eligibility to this pension type includes suffering from severe health issues, which impedes comparability to other individuals.

Second, we have to distinguish between individuals who fulfil the eligibility criteria for the two pension types we analyse and individuals who do not fulfil these criteria. Individuals who claim the respective pension types are eligible by definition. Individuals who claim pension types with stricter eligibility criteria are assumed to be eligible to the pension types under consideration as well. Individuals who claim a regular old-age pension (with very low eligibility criteria) are only assumed to be eligible to the pension types under consideration if they have accumulated at least 30 earnings points. We have to apply this rule of thumb as our dataset does not contain information on how long an individual has contributed to the pension system. However, as long as the individual receives a pension, we can approximate the number of earnings points accumulated via the amount of pension benefits received. As the maximum of earnings points which can be accumulated per year of contribution is at two points, a sum of 30 earnings points corresponds to a contribution period of at least 15 years, which is one of the requirements for claiming the pension types under consideration. Finally, we have to exclude individuals who have not yet retired, as we can not approximate whether or not they fulfil the eligibility criteria for the pension types under consideration.

The restricted sample leaves us with almost observations for 560,000 individuals for the analysis of the pension for women. As we do not want effects of different pension reforms to be mixed up, we only consider men when analysing the effects of the reform of the pension after unemployment or part-time work. For this analysis, the restricted sample contains about 215,000 individuals. A

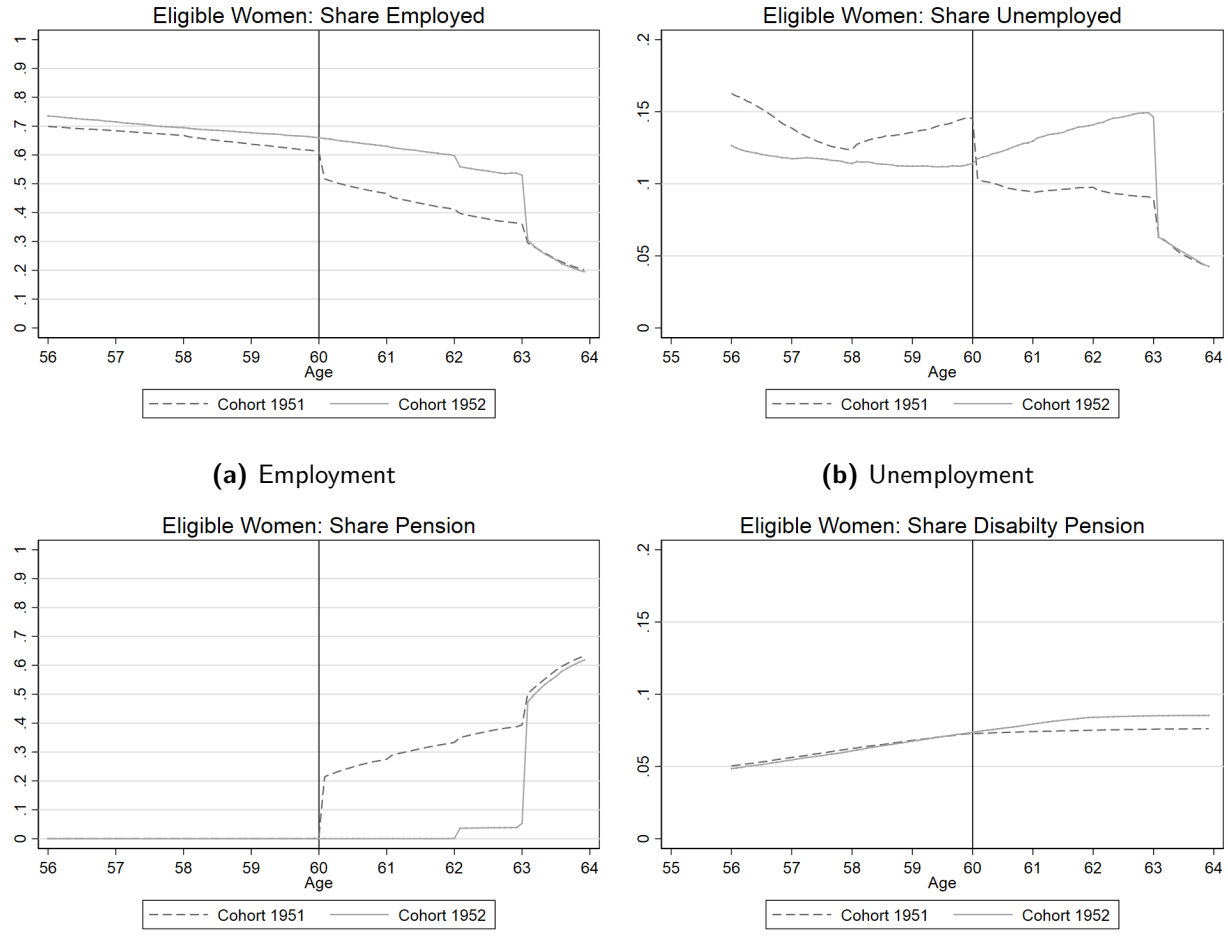
[14] The respective figures can be found in the appendix.

description of the relevant variables in our dataset can be found in table A4.

5 Results

5.1 Results for the whole population

Before we analyse how the reform effects differ with respect to occupational characteristics, we analyse the effects of the reforms on the whole affected population. To that end, we first describe the evolution of employment and pension status close to the onset of the reforms, before presenting estimates of the overall effects of the reforms.



(a) Employment

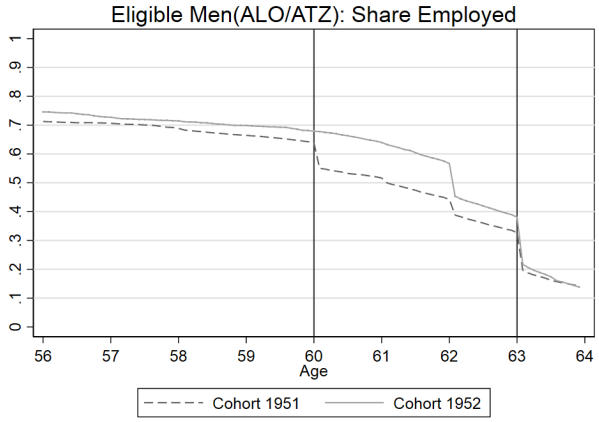
(b) Unemployment

(c) Retirement

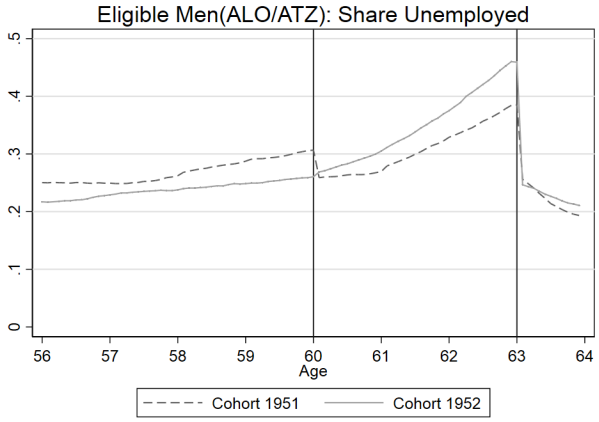
(d) Disability Pension

Figure 1 – Effects of Abolition of Old-Age Pension For Women

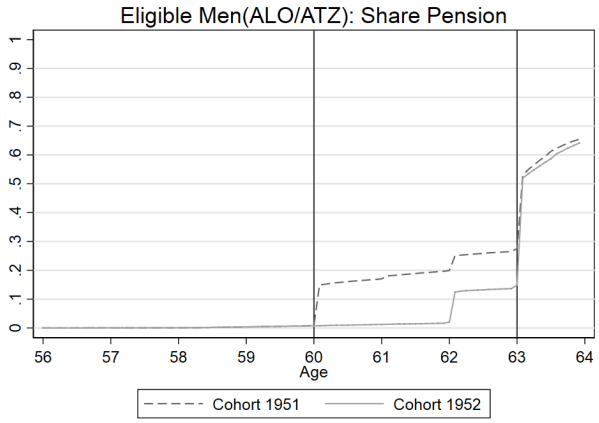
Figure 1 displays the proportion of women born in 1951 or 1952 and meeting the eligibility criteria for the old-age pension for women in different employment states. The figures cover the



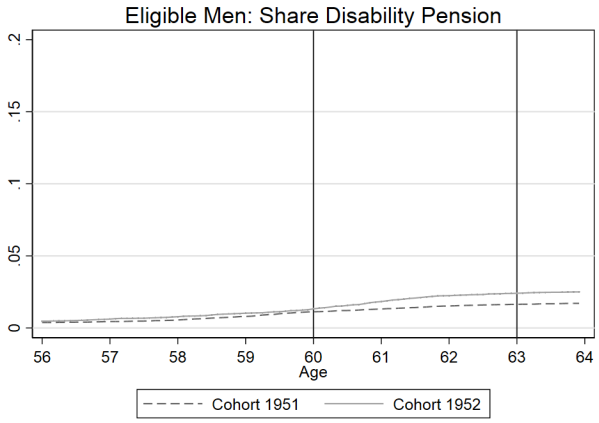
(a) Employment



(b) Unemployment



(c) Retirement



(d) Disability Pension

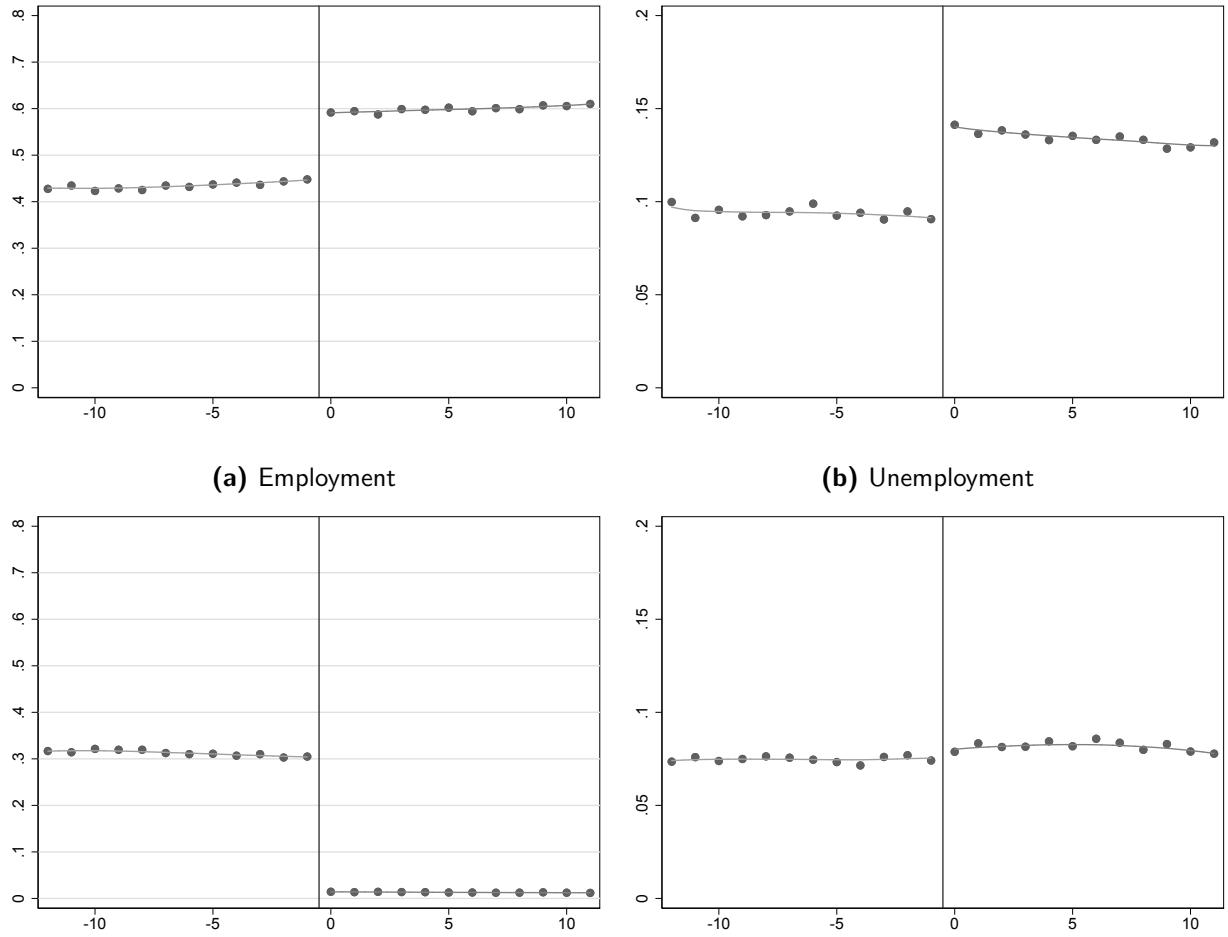
Figure 2 – Effects of Abolition of Old-Age Pension After Unemployment or Part-Time - And an Exception

age bracket from 56 to 64, in which we expect to see reactions to the reforms after age 60. The four panels of figure 1 point to clear differences in the fraction of women in different employment states between the two cohorts. The employment rates of women born in 1951 and 1952 follow a similar trend up to age 60. At age 60, the employment rate drops sharply for women born in 1951 but only decreases slowly for women born in 1952. Similarly, the unemployment rate for cohort 1951 drops sharply after the women reach age 60 but rises smoothly for those in the 1952 cohort. By contrast, the share of women born in 1951 receiving an old age pension exhibits a stark increase at age 60, while this share remains close to zero until age 62 for the 1952 cohort. Regarding the share of individuals receiving a disability pension, there are only small differences between cohorts. Overall, the proportion of women in most of the employment states vary widely between the cohorts affected and not affected by the reform. These results are almost identical to those of Geyer & Welteke (2021) who analysed this pension type only.

The four panels in figure 2 show the share of men eligible for the old-age pension after unemployment or part-time work in different employment states. As in the case for the reform of early retirement for women, we see clear differences between the two cohorts. Before age 60, the two cohorts exhibit comparable patterns. At age 60, eligible men of the 1951 cohort exhibit a drop in employment and unemployment as well as a rise in pension receipt which is not visible among the 1952 birth cohort. For the latter cohort, employment rates fall slowly but steadily until age 62, while pension receipt increases at a similar rate. At age 62, the employment share shows a parallel drop for both cohorts, whereas the share of pensioners increases. Early retirement in the regular old-age pension starts at 63, which may be the reason why the proportions in the different employment states converge to a common level at this age, except for a small difference in the share of individuals having claimed a disability pension. Overall, there are effects on employment, unemployment and pension both at age 60 and 63, which is due to some individuals in the 1951 cohort being protected by the legitimate expectation clause which allowed individuals of the 1951 cohort to take early retirement at age 60 under specific conditions [15].

The panels of figures 3 and 4 display mean values of the outcome variables employment, unemployment, retirement, and disability pension receipt, for individuals born from 12 months before to 12 months after the cut-off for the abolition of the old-age pension for women and the expiration of the protection of legitimate expectation regulation regarding the old-age pension after unemployment or part-time employment in monthly bins, respectively. All outcome variables exhibit a clear discontinuity at the cutoff, though the discontinuity is considerably smaller for the receipt of disability pension payments. To provide further evidence for the discontinuity at the cutoff, the panels of figures 3 and 4 additionally display local linear regression plots with bandwidths of 12 months on both sides of the cutoff. Had we confounded a non-linear relationship between the

[15] For details about the protection of legitimate expectation regulation see section 3.2.



(a) Employment

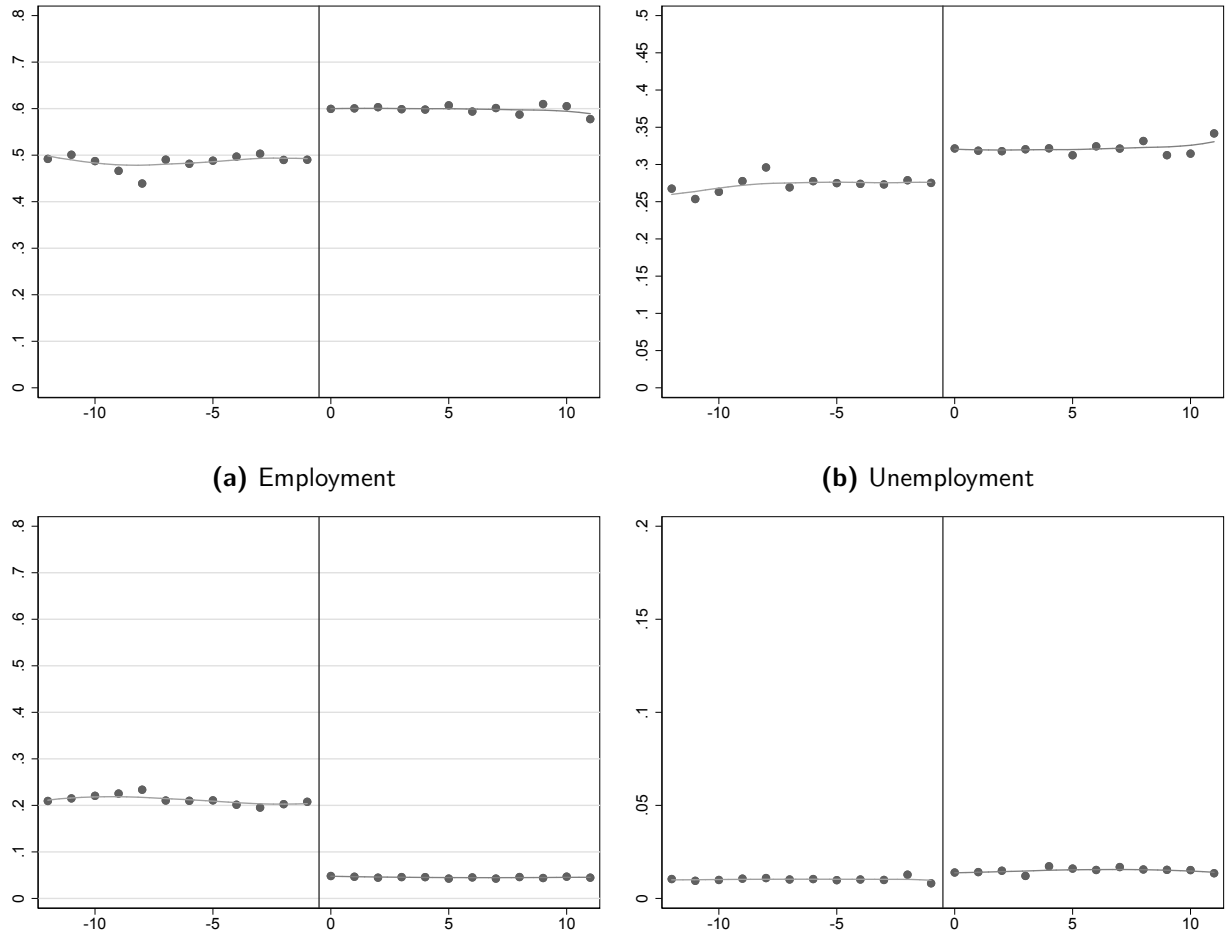
(b) Unemployment

(c) Retirement

(d) Disability Pension

Figure 3 – Local Linear Regression Plots of Abolition of Old-Age Pension For Women Relative to Cutoff

Notes: Scatter plots display mean outcome values using monthly bins. Local linear regression plots are based on triangular kernel functions with a bandwidth of 12 months.



(a) Employment **(b)** Unemployment

(c) Retirement **(d)** Disability Pension

Figure 4 – Local Linear Regression Plots of Abolition of Old-Age Pension After Unemployment or Part-Time Relative to Cutoff

Notes: Scatter plots display mean outcome values using monthly bins. Local linear regression plots are based on triangular kernel functions with a bandwidth of 12 months.

running variable and a dependent variable with the discontinuity, the non-parametric estimation approach should yield evidence for such a relationship. However, the local linear regression plots exhibit clear discontinuities at the cutoff as well. What is more, the local linear regression plots provide further evidence for a roughly linear trend in the dependent variables around the cutoff point. Taken together, we conclude that we can estimate the causal effect of the pension reforms on the displayed outcomes by employing a sharp RDD approach via estimation of a linear model of the form displayed in equation 1.

Early Retirement For Women				
	Employment	Unemployment	Pension	Disability Pension
	0.125***	0.055***	-0.277***	0.002
N	18,980,974			

Old-Age Pension After Unemployment or Part-Time				
	Employment	Unemployment	Pension	Disability Pension
	0.115***	0.030***	-0.149***	0.004***
N	6,347,385			

Table 2 – Main Reform Effects - RDD Results

Notes: Standard errors are clustered by month of birth. ***, **, *: Asterisks indicate significance of coefficients at the conventional significance levels $1\%, 5\%, 10\%$, respectively.

Table 2 shows the estimates of the effects of the retirement reforms on individual employment, unemployment, pension receipt, and receipt of disability pension for the whole population. Tables A5 and A6 in the appendix present the estimated coefficients for all variables in the models except for the fixed effects. Overall the results are in line with the descriptive evidence in figures 1 and 2. Both reforms had significant effects on the proportion of individuals in employment, in unemployment and receiving pension payments. The employment rates increased and the fraction receiving an old age pension decreased, which can be seen as intended reform effects. However, the reforms also led to higher shares of unemployment. The abolition of the old-age pension after unemployment and part-time employment further caused a significant, though quantitatively small, increase in disability pension receipt. The results for the early retirement for women are very close to those obtained by Geyer & Welteke (2021) using a different sample. The effect of the abolition of the old-age pension after unemployment or part-time has not been studied previously.[16] Notably, the effect of this reform on the receipt of old-age pension is lower

[16]While Riphahn & Schrader (2022) analyse both the increase of the early and the regular retirement age of the old-age pension after unemployment or part-time work, they use data on older cohorts. Similar to our results, they find increased employment rates and declined retirement rates due to the reforms.

than the effect of the abolition of the early retirement option for women. This is due to the fact that the eligible women made use of the early retirement option much more frequently than men eligible for pension after unemployment or part-time work (see figure 2). The pension after unemployment or part-time work affects two distinct groups: on the one hand, those who entered retirement from unemployment and, on the other, those who retired after having worked part-time. Table A7 in the appendix shows that the reform indeed had different effects on these two groups: among those entering retirement from unemployment, increases in the employment rate are considerably smaller and increases in the unemployment rate considerably larger than for both groups taken together. Among those having worked part-time, the increase in the employment rate almost exactly mirrors the decrease in old-age pension receipt. Disability pension receipt only increases among the former group. Individuals in part-time employment therefore simply remained (part-time) employed rather than entering old age pension as a reaction to the reform, whereas the unemployed reacted in a multifaceted way: only some moved into employment, while others remained unemployed or claimed disability pensions.

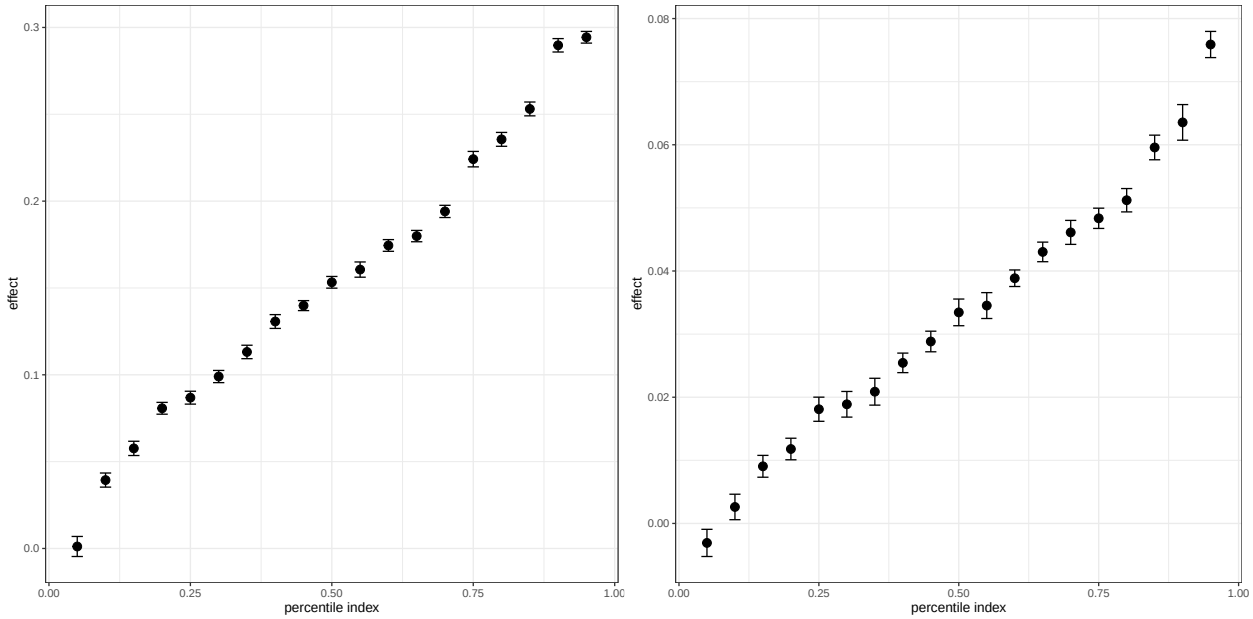
Taken together, both reforms seems to have led to an extension of working life among affected individuals, but also to rising unemployment. By contrast, applying for disability pensions does not seem to have been a widespread option.

5.2 Heterogenity of the effects

Next, we analyse how these reactions differ among affected individuals. To summarise the amount of heterogeneity in the treatment effects, we plot sorted partial effects (SPE) according to Chernozhukov et al. (2018). We account for differences in occupational demands, occupational tasks, and technological change, all measured at the occupation level. We also include a number of individual characteristics: region (East and West Germany), nationality (German or non-German) and cumulative lifetime income (categorised into three groups).

To simplify the exposition, we look at employment and unemployment only, since the effect on retirement is only the mirror image of employment and unemployment and disability pension receipt is an option only for a small share of individuals. Figures 5 and 6 show the sorted partial effects of the two reforms. In estimating the SPE, we do not separately account for every single characteristic, but incorporate all of them simultaneously. The plots show considerable heterogeneity in the treatment effects. However, the range of the predictive effects differs substantially according to employment states and reforms. The estimated SPE for the abolition of the old-age pension for women on employment range from below 0.01 to 0.29. The range of the effect on unemployment is considerably smaller, from just below zero to slightly above 0.07. Regarding the ranges of the effects of the abolition of the old-age pension after unemployment or part-time work, we

find a smaller interval for the SPE for employment but a larger interval for unemployment. The effect on employment ranges from 0.01 to 0.21. The effect on unemployment is almost evenly distributed around zero and ranges from -0.12 to 0.12. Overall, we find a considerable range of heterogeneity in the effects of both reforms.



(a) Employment **(b)** Unemployment

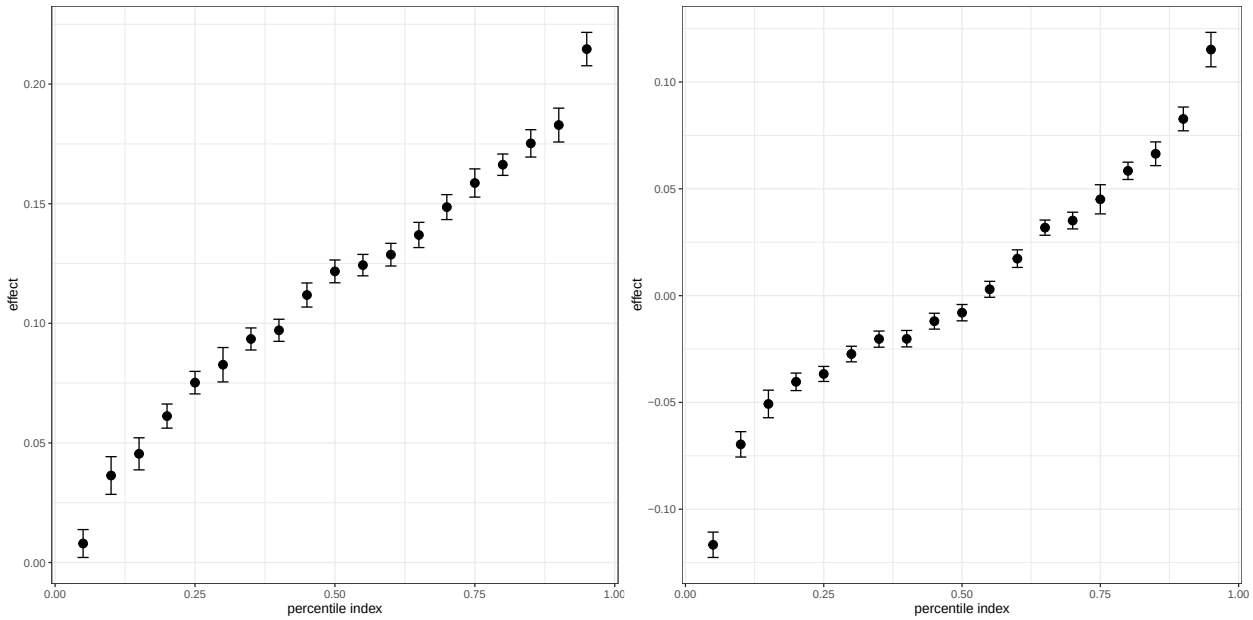
Figure 5 – Sorted Partial Effects of Abolition of Old-Age Pension For Women

5.3 Differences in response by type of work

To study how the effects of the reforms differ with respect to occupational demands, occupational tasks, and technological change, we analyse and compare the effects in the subgroups defined by these characteristics. We look at each occupational characteristic separately. It is important to note that the differences in the treatment effects across subgroups must not be given a causal interpretation. They indicate the effect differences across groups without taking into account the composition of the groups in terms of other observed or unobserved characteristics.

Heterogeneity with respect to job strain

Tables 3 to 6 show the estimated treatment effects of the reforms on employment and unemployment differentiated by occupational demands. The table consist of two parts: the left-hand side refers to the abolition of the early retirement scheme for women, the right-hand side to the



(a) Employment **(b)** Unemployment

Figure 6 – Sorted Partial Effects of Abolition of Old-Age Pension After Unemployment or Part-Time

abolition of the old-age pension after unemployment or part-time work. In all following tables, asterisks point to levels of statistical significance of the predicted effects. If the differences between the estimated effect sizes are statistically different from each other, the respective predictions are printed in bold type.

Table 3 presents the reform effects differentiated with respect to high or low occupational demand. Regarding all types of occupational demands, we find a stronger increase in the employment share for those working in less demanding occupations, possibly because it is harder, or for some individuals even impossible, to keep working within an occupation that is mentally or physically challenging. In the case of the abolition of the old-age pension for women, the employment share increases by around 16 percentage points for those working in less demanding occupations, whereas the share increases by only 12 to 13 percentage points for those working in highly demanding occupations, and all differences are statistically significant. Regarding the reaction to the abolition of the old-age pension after unemployment or part-time work, highly physically and highly overall demanding occupations are associated with a 2 percentage points lower increase in the propensity to become or stay employed after the reform. The estimates for those working under higher and lower psycho-social strain are not statistically distinguishable from each other. Furthermore, table A8 in the appendix reveals that as soon as the both groups covered by this pension type, namely unemployed and those working part-time, are considered separately, differences with respect to high or low occupational demand lose statistical significance.

	Early Retirement Women				After Unemployment or Part-Time			
	Employment		Unemployment		Employment		Unemployment	
Demand Intensity	Low	High	Low	High	Low	High	Low	High
Overall Demand	**0.158*** **	**0.127*** **	**0.032*** **	**0.058*** **	**0.115*** **	**0.090*** **	0.001	0.013
	N = 14,508,448				**N = 4,436,018**			
Physical Demand	**0.158*** **	**0.123*** **	**0.031*** **	**0.067*** **	**0.121*** **	**0.091*** **	-0.001	0.010
	N = 14,622,256				**N = 4,460,760**			
Psycho-Social Demand	**0.161*** **	**0.130*** **	**0.029*** **	**0.057*** **	0.111***	0.098***	0.003	0.009
	N = 14,508,448				**N = 4,436,018**			

Table 3 – Reform Effects Differentiated by Occupational Demand

Notes: Standard errors are clustered by month of birth. ***, **, *: Asterisks indicate significance of coefficients at the conventional significance levels $1\%, 5\%, 10\%$, respectively. Bold coefficients indicate statistical significant difference between effects at low and high levels of occupational demand.

Regarding the reform effects on unemployment, we find statistically significant differences with regard to job strain for the reform of early retirement for women only. Women working under higher job strain are about 3 percentage points more likely to become unemployed as a reaction to the reform. Regarding the abolition of retirement after unemployment or part-time work, differences are small and not statistically significant. A reason why there is no heterogeneity could be that individuals meeting the eligibility criteria for this pension scheme were already unemployed before retirement and therefore either had a similar propensity to (re)enter unemployment or were employed in occupations with a similar prevalence of unemployment. Individuals who could have entered this pension scheme after part-time work almost never become unemployed (see tables A7 and A8 in the appendix) but remain in part-time employment.

Overall, the intended reform effect – prolonging labor force participation – seems to be achieved less effectively for individuals in demanding occupations.

Heterogeneity with respect to occupational tasks

Table 4 presents the reform effects differentiated along the occurrence of occupational tasks. We classify tasks as being performed often if their share of all tasks performed is above the 7^{th} decile of the distribution and rarely otherwise. The table shows statistically significant differences in effect sizes with respect to most tasks. In occupations in which non-routine manual tasks play a bigger role, we find a smaller increase in employment and a larger increase in unemployment for both reforms. In the case of early retirement for women, employment increases by only 13 rather than 16 percentage points if individuals perform non-routine manual tasks often rather

	Early Retirement Women				After Unemployment or Part-Time			
	Employment		Unemployment		Employment		Unemployment	
Occurrence	Rarely	Often	Rarely	Often	Rarely	Often	Rarely	Often
Routine Manual	0.147***	0.141***	0.040***	0.043***	0.110***	0.105***	0.004	0.006
Non-Routine Manual	**0.159*** **	**0.129*** **	**0.034*** **	**0.049*** **	**0.115*** **	**0.082*** **	**-0.003**	**0.031*** **
Analytic	**0.135*** **	**0.170*** **	**0.049*** **	**0.024*** **	0.102***	0.116***	0.010*	-0.000
Interactive	0.143***	0.161***	**0.048*** **	**0.016*** **	**0.112*** **	**0.090*** **	0.007	0.003
Routine Cognitive	0.149***	0.147***	**0.032*** **	**0.049*** **	**0.119*** **	**0.084*** **	**-0.007**	**0.030*** **
	N = 14,753,955				**N = 4,622,860**			

Table 4 – Reform Effects Differentiated by Task Measures

Notes: Standard errors are clustered by month of birth. ***, **, *: Asterisks indicate significance of coefficients at the conventional significance levels $1\%, 5\%, 10\%$, respectively. Bold coefficients indicate statistical significant difference between effects at rare and often occurrence of a respective task.

than rarely, a difference of 3 percentage points. In the case of retirement after unemployment or part-time work, the difference amounts to 4 percentage points, i. e. an increase of 8 compared to 12 percentage points. Conversely, unemployment increases by 5 rather than 3 percentage points after the abolition of the early retirement option for women if individuals work in non-routine manual task intensive occupations and by 3 rather than 0 percentage points after the abolition of retirement after unemployment or part-time work. Similarly to occupations dominated by non-routine manual tasks, work in routine cognitive task intensive occupations is associated with a stronger increase in unemployment as reaction to both reforms and a smaller rise employment; the differences in employment, however, are only significant for the pension after unemployment or part-time work.

Regarding the other task domains, results are more mixed. We do not find statistically significant differences in the reactions with respect to the occurrence of routine manual tasks. With respect to interactive and analytic tasks, the results differ between the two reforms. The results for the abolition of early retirement for women show that occupations with a stronger concentration on analytic tasks are associated with a stronger increase in employment, 17 rather than 14 percentage points, and a lower increase in unemployment, 2 rather than 5 percentage points. There are no such differences in the effects of the other reform. Occupations in which interactive tasks play a larger role are associated with a smaller increase in unemployment after the abolition of the retirement option for women. Hence, the interactive nature of occupational tasks seems to protect against unemployment. By contrast, more interactive tasks are associated with a 2

percentage points smaller increase in employment in case of the abolition of the old-age pension after unemployment or part-time work.

In summary, the reactions to both reforms differ with the frequency of tasks from several task domains. There is a number of possible explanations, among them differences in physical strength requirements between manual and non-manual work, or differences in work satisfaction between routine und non-routine tasks, why individuals are employed or unemployed if they cannot take early retirement (Velde 2022). Remarkably, however, a higher frequency of routine manual tasks does not seem to prevent a longer participation in the labor market. As noted above, these results must not be given a causal interpretation. The differences in the treatment effects may also arise due to the composition of the affected groups. [17]

Heterogeneity with respect to computer use and technological change

	Early Retirement Women				**After Unemployment or Part-Time**			
	Employment		**Unemployment**		**Employment**		**Unemployment**	
Occurrence	Rarely	Often	Rarely	Often	Rarely	Often	Rarely	Often
PC Use At All	0.144***	0.160***	**0.046*** **	**0.016*** **	0.106***	0.106***	0.008*	0.002
PC Use Frequently	**0.135*** **	**0.168*** **	**0.049*** **	**0.025*** **	0.103***	0.114***	0.009*	0.002
	N = 14,753,955				**N = 4,622,860**			

Table 5 – Reform Effects Differentiated by Computer Use

Notes: Standard errors are clustered by month of birth. ***, **, *: Asterisks indicate significance of coefficients at the conventional significance levels $1\%, 5\%, 10\%$, respectively. Bold coefficients indicate statistical significant difference between effects with and without (frequent) computer use.

Last, we analyse differences with respect to computer use and technological change in an individual's occupation. Both categories of occupational characteristics are associated with respective differences. Table 5 gives the reform effects differentiated along the occurrence of computer use in an occupation – either at all or frequently. The effects of the abolition of the early retirement

[17] Furthermore, the two groups affected by the former reform, namely those who enter retirement after unemployment and those who retire after having worked part-time, show different reactions as can be seen from table A9 in the appendix. In some cases (e. g. changes in unemployment regarding occupations in which non-routine tasks occur rarely or often), differences remain significant even if both groups are considered separately. In other cases, significant differences are visible only if the two groups are considered separately. Yet in other cases, the significance vanishes for a separate consideration. This is again a hint that the two groups affected by the reform, namely those who enter retirement after unemployment and those who retire after having worked part-time, are distinct from each other and in consequence react differently to the reform.

	Early Retirement Women				After Unemployment or Part-Time			
	Employment		Unemployment		Employment		Unemployment	
Occurrence	Rarely	Often	Rarely	Often	Rarely	Often	Rarely	Often
New Techniques	**0.146*** **	**0.166*** **	**0.041*** **	**0.026*** **	**0.097*** **	**0.128*** **	**0.012*** **	**-0.006**
New Machines	0.148***	0.142***	0.040***	0.039***	0.109***	0.105***	0.008*	-0.001
New Products or Materials	0.147***	0.150***	0.040***	0.033***	0.100***	0.120***	**0.012*** **	**-0.004**
New Services	**0.140*** **	**0.177*** **	**0.045*** **	**0.021*** **	**0.101*** **	**0.126*** **	0.006	0.001
New PC Programmes	**0.138*** **	**0.173*** **	**0.048*** **	**0.016*** **	**0.096*** **	**0.118*** **	0.013**	-0.001
	N = 14,728,802				**N = 4,609,324**			

Table 6 – Reform Effects Differentiated by Technological Progress Indicators

Notes: Standard errors are clustered by month of birth. ***, **, *: Asterisks indicate significance of coefficients at the conventional significance levels $1\%, 5\%, 10\%$, respectively. Bold coefficients indicate statistical significant difference between effects with and without the presence of a respective technological progress indicator.

option for women differ along the occurrence of PC use in the occupations. A more prevalent use of PCs is associated with a 3 percentage points smaller effect on unemployment, a more frequent use of PCs with an over 3 percentage points larger increase in employment and a more than 2 percentage points smaller increase in unemployment. We find no respective differences in the effects of the abolition of early retirement after unemployment or part-time work.

Table 6 differentiates along the occurrence of new techniques, machines, products and materials, services, and PC programmes.[18] We interpret these as measures of technological change. The effects differ along most of these measures for both reforms. However, the differences are more pronounced in case of the abolition of early retirement for women. The effect on employment is 2 to 4 percentage points larger and the effect on unemployment 2 to 3 percentage points smaller for women who work in occupations in which new techniques, new services, and new PC programmes are introduced more often. The abolition of early retirement after unemployment or part-time work leads to an increase in employment that is 2 to 3 percentage points larger where new techniques, new services, and new PC programmes are reported more often, and to no increases in unemployment in occupations where the prevalence of new techniques or new products or materials is higher (compared to a small increase by 1 percentage point in occupations

[18] Tables A10 and A11 in the appendix separately show the results for those entering retirement from unemployment and those having worked part-time before retirement. Again, the results differ quantitatively. Statistically significant differences point to a stronger increase in employment and weaker increase in unemployment in cases in which technological change is more prevalent.

where new techniques or products or materials are applied rarely). Taken together, these results point to stronger increases in employment and weaker increases in unemployment in occupations in which technological change is more common.

There are different potential explanations for this finding. Work in companies that produce with new technologies may be safer and more satisfying than in other companies, so that workers choose to carry on in employment. Employees in occupations in which new technologies are used intensively may also be more valuable to their employers, while employees not working with new technologies are under a greater risk of losing their jobs.

6 Conclusions

We have studied the treatment effects of abolishing early retirement schemes on employment, unemployment, retirement and disability pension receipt. In line with previous evidence (Geyer & Welteke 2021), we find large and significant effects on employment, retirement and unemployment, but only small effects on disability pensions. Our main contribution, however, is the heterogeneity of estimated treatment effects with respect to occupational characteristics. To this end, we analyse whether individuals were differently affected by the reforms depending on job strain, tasks performed at work and the use of new technologies. Using an SPE analysis, we account for differences in all measures of demand, tasks and technology and find a broad range of treatment effect magnitudes. Looking at occupational characteristics separatley, we find moderately sized and significant differences in treatment effects with respect to different levels of occupational demands, occupational tasks and the use of technologies. For most of these occupational characteristics, the heterogeneity is similar for the two reforms. For both reforms, the effect on employment is smaller for those working in highly demanding occupations, performing more non-routine manual tasks or for whom technological change is less prevalent, while the effect on unemployment is higher for those performing more routine cognitive tasks. For other characteristics, such as analytic tasks or the use of a PC at work, the effects differ between the reforms, which can partly be explained by the different composition of the affected groups with respect to gender or other characteristics.

Our results provide several implications for future research. Based on a proper identification strategy, estimating differentiated treatment effects along occupational characteristics points to circumstances under which the reforms reach the aim of extending working lives or, alternatively, redirect workers into states such as unemployment and disability pension receipt. Although the results of subgroup analysis cannot be interpreted causally, they uncover areas where further analysis of causal mechanisms would be valuable.

Our results further provide implications for suitable policy measures that could accompany future pension reforms as well as labour market policy. In case of both analysed reforms, the political goal of longer working lives has, at least partly, been achieved. However, our results show that it is not equally possible for all employees to adapt to the new circumstances. This highlights the importance of creating jobs which are adequate to the demands of older employees, e.g. with regard to their health status. Furthermore, labour market programmes should also be targeted to the needs of employees in their late careers in order to prevent or shorten unemployment spells in the transition from work to retirement. Additionally, unions and employers should have a joint interest in improving workplace conditions to keep employees in work even in occupations where early exit from work is still frequent.

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