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Early retirement of employees in demanding jobs: Evidence from a German pension reform

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ABSTRACT

Early retirement options are usually targeted at employees at risk of not reaching their regular retirement age in employment. An important at-risk group comprises older employees who have worked in demanding jobs for many years. This group may be particularly negatively affected by the abolition of early retirement options. To measure differences in labor market reactions of employees in low- and high-demand jobs, we exploit the quasi-natural experiment of a cohort-specific pension reform that increased the early retirement age for women from 60 to 63 years. Based on a large administrative dataset, we use a regression-discontinuity approach to estimate the labor market reactions. Surprisingly, we find the same relative employment increase of about 25% for treated women who were exposed to low and to high job demand. For older women in demanding jobs, we also do not find substitution effects into unemployment, partial retirement, disability pension, or inactivity. Eligibility for the abolished early retirement option required high labor market attachment. Thus, we argue that this eligibility rule induced a positive selection of healthy workers into early retirement. We propose alternative policies that protect workers exposed to high job demand better against the negative consequences of being unable to reach their statutory retirement age in employment.

Introduction

Early retirement options offer partial insurance for sub-groups of workers against negative consequences of being unable to continue working until the normal retirement age (NRA)[2] (Börsch-Supan et al., 2022). An important group at risk of exiting employment early is employees exposed to high job demand[3] for an extended time during their working life (Deutscher Bundestag, 2006, 2014; Vermeer et al., 2016; OECD, 2018). To target employees with high job demand, eligibility criteria for early retirement programs include a minimum number of contribution years (i.e., years in employment) or a high labor market attachment in the second half of the career.[4] In addition to a long labor

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[2] The NRA defines the age at which full pension benefits without actuarial deductions can be claimed.

[3] Job demand refers to aspects of the job "that require sustained physical and/or psychological effort" (Bakker and Demerouti, 2007).

[4] Examples are the *Altersrente für langjährig Versicherte* or *Altersrente für besonders langjährig Versicherte* in Germany that require 35 or even 45 years of employment, the *Pensão antecipada por carreiras muito longas* in Portugal that requires at least 46 employment years, or various early retirement options offered by firms in the US for which eligibility depends on long tenure (Modrek and Cullen, 2012). Natali et al. (2016) provide an overview of different policy regimes in Europe that provide special pension regulations for "workers in arduous or hazardous jobs".

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market history, eligibility for some early retirement options is tied to criteria that are related to potential job demand, such as being female[5] or working in a demanding occupation.[6] Finally, there are specific early retirement options for some demanding and hazardous occupations in most countries.[7] For example, in many countries, pilots, flight controllers, police officers, miners, and judicial officers, as well as employees in fire departments or the military services have the option to, or in some instances must, retire earlier without deductions. These regulations are also indirectly tied to specific tenure thresholds because there are maximum age requirements (usually up to age 30) for these occupations.[8] Workers in demanding jobs who are not able to reach the minimum work years for early retirement or have to quit employment earlier than the early retirement age (ERA) have to resort to social support programs. These programs typically have lower requirements with respect to previous work duration but offer lower transfers than early retirement programs. Examples are disability pensions or unemployment benefits, compare for example the international survey of programs for ill and disabled people by the OECD (2010).

Workers in more demanding jobs are more likely to retire early from employment (Blekesaune and Solem, 2005). Therefore, abolishing early retirement options may particularly negatively affect employees who are exposed to high job demand (Vermeer et al., 2016).[9] Instead of extending employment, they may substitute early retirement with social support programs or inactivity that bridges the time until retirement benefits can be drawn (Chirikos and Nestel, 1991). These substitutes for early retirement usually incur large financial disadvantages (Mazzonna and Peracchi, 2017).

In this work, we test empirically whether employees in demanding jobs extend old-age employment less than employees in less demanding jobs when an early retirement option is abolished. We use a pension reform in Germany that abolished an early retirement option for women, the pension for women. This retirement option granted the earliest possible pension access at age 60 for women with at least 15 employment years. Its abolition increased the ERA by 3 years to age 63. We exploit the sharp discontinuity in the ERA between cohorts using a regression discontinuity framework.[10] We select the sub-group of women born 1 year before and after the reform cut off (January 1, 1952) who fulfilled the eligibility requirements for the pension for women. We estimate the causal impact of the pension reform on old-age employment or partial retirement, unemployment, marginal employment, and inactivity. We differentiate the labor market reactions to the pension reform by levels of job demand. We measure physical and psychosocial job demands in occupations using the Job Exposure Matrices (JEM) suggested by Kroll (2011, 2015) matched to the three-digit Classification of Occupations (KldB-2010) in the last job before retirement (see Brussig, 2016; Mazzonna and Peracchi, 2017; Rijs et al., 2014 for similar empirical approaches). Occupation-level indicators of job demand are less likely to be influenced by preferences for work and leisure than subjective information about job demand reported by individual workers (Blekesaune and Solem, 2005).

The reform had the same employment effects for women in occupations with high and low job demand. Employment between 60 and 63 years increased by about 25% in the 1952 treatment birth cohort compared with the 1951 control birth cohort, irrespective of the level of physical or psychosocial job demand. There was no increased program substitution of affected women in both job demand groups. Consequently, there was no stronger effect on unemployment, partial retirement, disability pension, or higher inactivity for women with higher job demand after the reform.

Contrary to its intention, the pension for women did not offer an early retirement option for older workers with high job demand who were unable to work until their NRA. One explanation for this finding is the strong attachment to the labor market required for this early retirement option. As a result, the group of women eligible for early retirement comprised healthy workers who self-selected into jobs with high job demand (Modrek and Cullen, 2012). We present several indicators for our healthy worker hypothesis in the discussion section. One indication is that about double the share of women in less demanding jobs were eligible for the pension for women compared with women in demanding jobs. Many employees in demanding jobs who were not eligible for early retirement had to take the disability pension as a bridge option into retirement (Börsch-Supan et al., 2022).

We contribute to the large and growing literature on the labor market effects of pension reforms that increase the ERA of the affected employee groups (Ardito and d'Errico, 2018; Atalay and Barrett, 2015; Cribb and Emmerson, 2018; Geyer and Welteke, 2021; Geyer et al., 2020; Manoli and Weber, 2016; Oguzoglu et al., 2020; Staubli and Zweimüller, 2013). These studies exploit the quasi-experimental design of reforms, which allows causal effects to be identified using evaluation methods. In general, these studies find that increasing the ERA has large employment effects and small substitution effects into unemployment benefits or other social support systems. Our paper shows that these results also extend to the group of older employees in demanding jobs who were expected to suffer particularly from the abolition of early retirement options.

Our study also contributes to the literature focusing on heterogeneity in retirement entries by occupational characteristics (Blekesaune and Solem, 2005; Chirikos and Nestel, 1991; Giesecke, 2018; Hayward et al., 1998; Hurd and McGarry, 1993; Plomp et al., 2019). Most papers found no or small associations between work demand and retirement behavior (for example, see the literature review in van den Berg et al., 2010).[11] Studies have mainly estimated structural models of the relationship between work demand and retirement. Job demand influences retirement, but it also may itself depend on the planned retirement age. Thus, previous papers must assume that all factors related to job choice and labor market behavior in old age could be controlled for (Henseke, 2011). This paper is one of the first contributions to use quasi-experimental variation for identification. We can control for otherwise unobserved heterogeneity between labor demand groups and the

[5] Examples are the *Opzione Donne* in Italy (at least 35 employment years) and *Rente für Frauen* "pension for women" in Germany (at least 15 employment years).

[6] Examples are the *Schwerarbeiterpension* in Austria with eligibility requiring at least 45 employment years or the *Pensjonstrygden for sjoemenn* in Norway for fishermen with at least 150 months of pensionable seagoing service.

[7] This list of occupations formally recognized as arduous and hazardous varies greatly. Some countries, like Austria, Poland, and France, broadly recognize arduous and hazardous work conditions in statutory rules, and thus are relatively generous in the definition of demanding work; some countries, such as Germany or Norway, have short lists; and some countries, such as Switzerland or the UK, do not recognise demanding jobs at all (Natali et al., 2016).

[8] The OECD (2018, 2019) provide international overviews of early retirement options.

[9] Brussig (2016: 56) notes, for example: "In a time with more generous early retirement, the effect of work strains on early retirement is expected to be weaker than in a time with more restrictions on early retirement, because in an institutional environment of generous early retirement many people retire even when they could work longer". Staubli and Zweimüller (2013: 17) put it as follows: "the less healthy workers in low-paid jobs (with the highest incentive to retire) are hurt while the retirement age is less binding for workers in good health in well-paid jobs".

[10] Previous studies using the same quasi-experimental variation include Geyer and Welteke (2021) with an analysis of the general employment effects of this reform and Geyer et al. (2020) with a focus on the income effects of this reform.

[11] The paper by Giesecke (2018) is a rare exception. They found that manual workers were less responsive to a pension reform than non-manual workers and explained this finding by the increase in take-up of disability pensions after the reform. Presumably, manual workers were in worse health and qualified for disability pensions more often than non-manual workers.

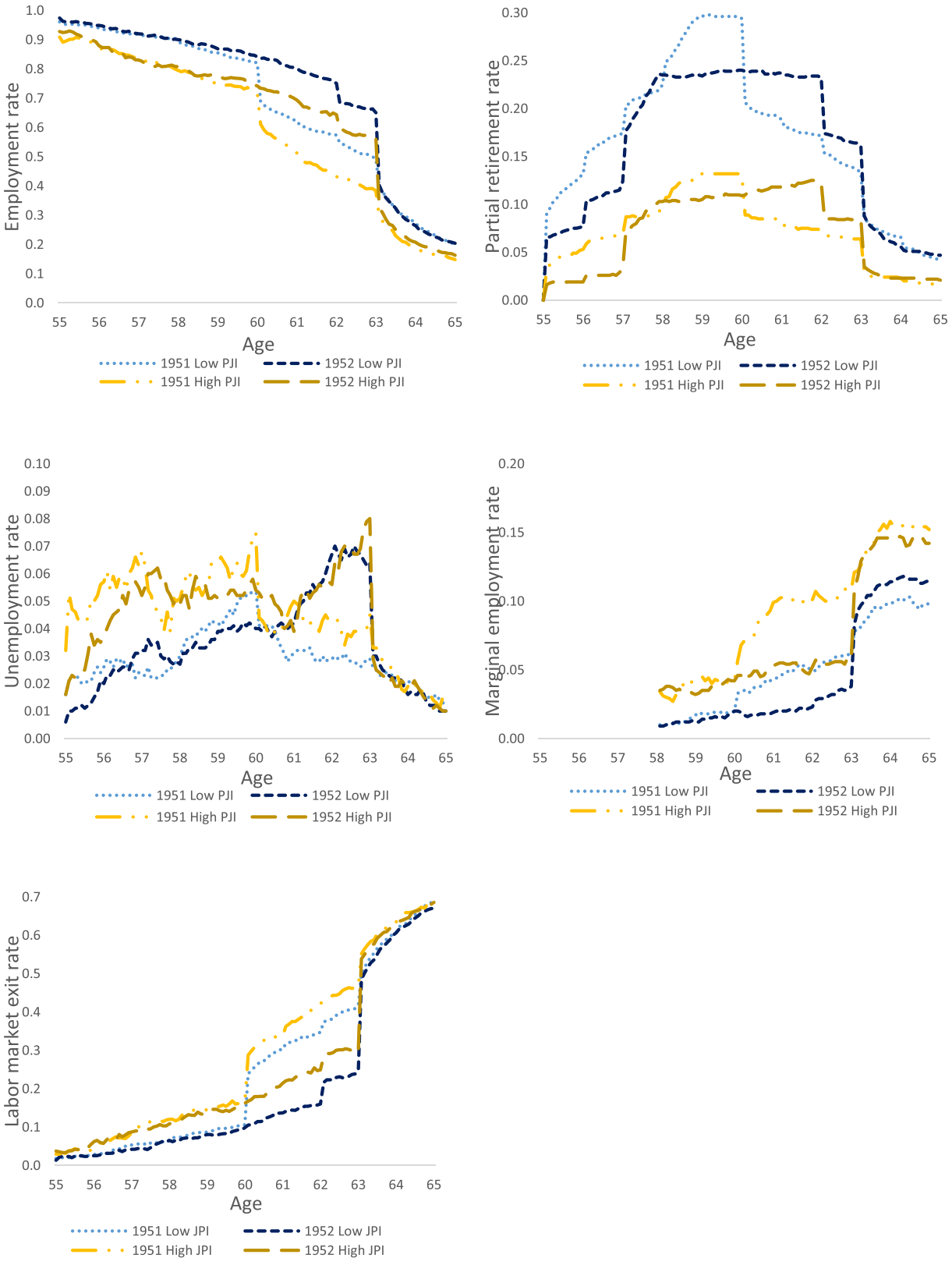


Fig. 1. Labor market effects by cohort and physical job demand Source: SIAB 7517, own calculations.

endogeneity of the choice of labor demand. We also differentiate between retirement via early retirement programs for a selected group of employees and retirement via social support programs that are open to all employees who are unable to work until the NRA.

The paper is organized as follows. Section 2 presents the institutional details and discusses the pension reform. Section 3 describes the data and Section 4 presents our work demand measure. Section 5 discusses the empirical methodology and Section 6 shows the results. Section 7 discusses the results and Section 8 concludes.

Table 1
Retirement benefits and alternative labor market status for birth cohorts 1951 and 1952.

	Birth cohort	
	1951	**1952**
Alternative labor market status		
Retirement benefits	**ERA/NRA**	**ERA/NRA**
Pension for women	60/65	Abolished
Pension for long-term insured	63/65	63/65
Pension after unemployment or partial retirement	63/65	Abolished
Pension for people with severe disabilities	60/63	ERA: 60.08–60.5/ NRA: 63.08–63.5
Old-age pension	65.42 (NRA)	65.5 (NRA)
Employment before retirement		
Regular employment	Not changed between cohorts	
Marginal employment	Not changed between cohorts	
Partial retirement	Not changed between cohorts	
Unemployment before retirement		
Unemployment benefits	Not changed between cohorts	
Out of labor force	Not changed between cohorts	

Notes: The table summarizes whether institutional settings changed for the 1951 and 1952 cohorts.
Source: Own compilation.

Institutional background

Public pensions and the 1999 reform

The 1999 pension reform in Germany abolished the pension for women for those born after 1951. Before the reform, the pension for women was the most important pathway for women to draw pension benefits earlier than the NRA (compare Lorenz et al., 2018 and Fig. 1 in Börsch-Supan et al., 2022)[12]. In this section, we provide a brief overview of the German pay-as-you-go pension system and discuss the options for entering retirement before and after the reform in more detail.

The German public pension system covers about 90% of the German workforce,[13] and it provides old-age pensions, disability pensions, and survivor pensions. Public pensions account for about 66% of gross income in retirement. Pension benefits are based on a system in which workers earn pension points based on their individual earnings for each year of contributions.[14] A pension point (PP_{it}) is the ratio of individual earnings (E_{it}) to average earnings ($\overline{E_t}$) of the German workforce,

$$PP_{it} = \frac{E_{it}}{\overline{E_t}}$$

At retirement, the sum of pension points is multiplied by a pension point value (PV_t) to convert them into a regular pension payment (PB_{it}).[15] The pension formula (Eq. (2)) also includes discount factors for the type of pension (TF)[16] and for retirement before the NRA (actuarial deductions, AD_i), which amount to a 0.3% permanent deduction for every month of retirement before the NRA (3.6% per year).

$$PB_{it} = \left(\sum PP_{it}\right) \times PV_t \times TF \times AD.$$

There are several possible ways to draw retirement benefits. The pension system offers options, each with different eligibility criteria and with the ERA and NRA varying across cohorts and alternatives (Table 1).

First, the statutory pension age was 65 for all cohorts born before 1947. For cohorts born later, it was raised in monthly or bimonthly steps to age 67. The NRA increase will be fully phased in for all cohorts born in 1964 or later. For women born in 1951, the statutory retirement age was 65 and 5 months, for those born in 1952, it was 65 and 6 months. People qualify for this standard old-age pension after 5 years of pension contributions.

Second, there are four types of regular old-age pension benefits that can be claimed by women with actuarial deductions before reaching the NRA: the pension for women, the old-age pension for people with severe disabilities (*Schwerbehindertenrente)*, the pension for the long-term insured, and the pension after unemployment or after partial retirement. The calculation of pension benefits does not differ between alternative pension forms, whereas eligibility requirements and age thresholds do.

The pension for women allowed women born before 1952 to retire when they were 60 years old, and thus provided the earliest retirement option for women besides the disability pension. The NRA of the pension for women was 65. Thus, retiring through the pension for women at age 60 was associated with *AD* of 18%. Women needed at least 15 years employment and at least 10 years employment after age 40 to be eligible for this early retirement option. About 60% of women in the 1951 birth cohort were eligible for the pension for women. The share of women who would have been eligible for the pension for women in the 1952 birth cohort is comparable.

The old-age pension for severely disabled people allowed people born before 1952 with severe disabilities and a long insurance record (35 years) to retire at age 60. The NRA of this pension was 63; that is, *AD* amounted to a maximum of 10.8%. Both age thresholds were minimally increased for people born after 1951.[17] People born between July and December 1952 had an ERA of 60 years and 6 months and an NRA of 63 years and 6 months, accordingly.

The pension for the long-term insured and the pension after unemployment or after partial retirement had an ERA of 63 and an NRA of 65. The pension after unemployment or after partial retirement was also abolished for all cohorts born after 1951 by the pension reform. However, the pension for the long-term insured, which offered the lowest ERA for women without severe disability after the 1999 reform, was unchanged.

Table 1 summarizes the changes in retirement options for birth cohorts 1951 and 1952 and notes that employment and unemployment rules before retirement have not been changed by the pension reform.

Alternative routes to retirement: Unemployment benefits, disability pension, and partial retirement

In addition to the early retirement options mentioned in the last section, there were three main institutional ways to exit the labor force early: by bridging the time to the earliest possible retirement entry by claiming unemployment benefits, by partial retirement, or by claiming a disability pension.

Eligibility and the entitlement period of unemployment benefits depended on the age and the previous working history. The maximum entitlement period for unemployment benefits for those older than 57 years was 24 months during our observation period. Unemployment

[12] About 31% of all women in the 1951 cohort who retired between the ages 54 and 64 used the pension for women (SUFRTZN, 2010–2017).
[13] Civil servants and most of the self-employed are not covered by public pensions.
[14] In addition, people earn pension points during periods of child-rearing, short-term unemployment, and while providing informal long-term care.
[15] The pension component, PV_t, is indexed and linked to, among other factors, average annual wage growth.
[16] The pension type factor is always equal to 1 for old-age pensions. It is < 1 if it is a survivor pension or partial disability pensions, which are defined as a fraction of an old-age pension.
[17] ERA and NRA were increased in monthly steps by month-of-birth for people born in the first half of 1952.

could be used as a bridge into retirement and could be combined with other early retirement options. Thus, all women in our sample could enter unemployment as early as age 58 before claiming the pension for women in the 1951 cohort. Analogously, women in our sample who were born in 1952 could enter unemployment at age 61 before claiming the pension for the long-term insured.

Partial retirement also allowed exit from employment before the NRA and could be combined with other early retirement options. On average, about 90% of older employees chose the block model of partial retirement (Brussig et al., 2009; Wanger, 2010),[18] which is characterized by two periods of equal length: in the first half, the employee works full-time (active period) and in the second half, the employee reduces the number of working hours to zero (Bundesagentur für Arbeit, 2015; Huber et al., 2016; Kirchner and Mittelhamm, 2010). For a standard partial retirement contract of 5 years, a woman in the 1952 cohort could start partial retirement at age 59, reduce her working hours to zero at age 61.5, and enter early retirement for the long-term insured at age 63. A woman in the 1951 cohort could start partial retirement at age 56, stop working at age 58.5, and enter the pension for women at age 60.

People permanently unable to work due to severe health conditions could retire before the age of 60 through the disability pension (*Erwerbsminderungsrente*). Eligibility required a long-term (at least 6 months) inability to perform an activity under normal labor market conditions for at least 6 h (partial disability pension) or at least 3 h (full disability pension) per day. Earnings incapacity had to be assessed by a strict physical examination performed by specialized insurance physicians. About 60% of all applications were rejected after the examination (Aurich-Beerheide et al., 2018). The examination had to be repeated every 3 years, although the work disability was deemed irrevocable. The disability pension was calculated based on the contribution and insurance history and amounted to the pension that would have been paid had the individual continued to work until he or she turned 60. Actuarial deductions also applied to the disability pension, reducing pension claims by 10.8% for all entrants before age 60. At the statutory retirement age[19], the disability pension was converted into an old-age pension, usually at the same level (for example, compare Geyer and Welteke, 2021; Börsch-Supan et al., 2022).

Expected reform effects

The abolition of the pension for women raised the ERA for eligible women without severe disability by 3 years to 63 years. Geyer and Welteke (2021) showed that the reform on average led to a strong increase in employment. However, they did not analyze occupational or job demand heterogeneity and their data did not allow to differentiate between employment, marginal employment, and partial retirement. We assume that the positive employment effect was smaller for women with high job demand because some women were unable to continue to work for another 3 years. Moreover, some women probably did not want to work longer than their old ERA in an unpleasant or difficult job, in contrast to women working in pleasant or easy jobs (Hurd and McGarry, 1993; Kim and Moen, 2002). Therefore, for women in demanding jobs, unemployment or partial retirement, marginal employment, disability pension, or inactivity may have been an attractive alternative to working longer.

The abolition of early retirement at age 60 may have increased the attractiveness of reducing employment to marginal employment before the new ERA, especially for women in demanding jobs.[20] Earnings from marginal employment are income-tax-free and do not require social security contributions, in contrast to labor earnings beyond marginal employment.[21] Marginal employment also usually allows employees to reduce job demand by working few and flexible hours.

The pension reform may also have increased the attractiveness of unemployment as a bridge option, especially for women in demanding jobs. As documented, for example, by Borghans et al. (2014), Engels et al. (2017), and Inderbitzin et al. (2016), take up of unemployment benefits increased when the generosity of early retirement benefits was reduced. In particular, unemployed individuals may have expanded their unemployment spell by exhausting their full entitlement period for unemployment benefits and employed individuals may have shifted their entry into unemployment if they planned to use the full unemployment period or enter unemployment instead of retirement at the previously planned ERA. The design of the institution provided strong incentives for program substitution because the social transfers for unemployment and early retirement were comparable and labor search requirements for unemployed people close to retirement were low.

Exiting employment via partial retirement may have become more attractive for women in demanding jobs. Both versions of the partial retirement options reduced job demand before the ERA. Access to partial retirement required a mutual agreement with the employer; thus, it was mainly large employers that offered this early retirement option because employers had to participate in collective bargaining to offer it (Schmähl, 2003; Wanger, 2010). Therefore, employees working in demanding occupations may have had no access to partial retirement because their employers did not offer the program.

The 1999 pension reform abolished the early retirement option after unemployment and partial retirement at age 63 for the treatment group. However, this legal change hardly affected the retirement options of the group eligible for these bridge options. Almost all people who qualified for early retirement after unemployment and partial retirement were also eligible for the pension for women and for the pension for long-term insured.[22] Consequently, almost all women affected by the pension reform could combine a period of unemployment or an earlier exit from employment via partial retirement with the pension for long-term insured early retirement option.

The abolition of the pension for women may have also increased the attractiveness of the old-age pension for severely disabled employees. The pension deductions for this pension were lower than those for the pension for women at each given retirement age before the NRA. Therefore, for our control cohort, severely disabled women usually preferred the pension for severely disabled people to the pension for women. Therefore, we do not expect a substitution effect into this pension type induced by the reform. According to our hypothesis, the share of those using pension for severely disabled people with retirement entries between the ages of 60 and 64 remained roughly constant for the 1952 cohort (13.6%) compared with the 1951 cohort (14.5%) (Rentenzugangsstatistik 2010–2017; Scientific Use File).

Finally, the pension reform may have prompted more women to claim a disability pension. However, the pension for severely disabled employees was not an easily accessible pathway to a regular old-age pension. Although Germany has a slightly more generous compensation level for disabled people than other developed countries (OECD, 2009; Chapter 4), it was not financially attractive for ill or disabled people to claim the disability pension if they could work until their ERA (Hanel, 2012; Natali et al., 2016; Geyer and Welteke, 2021). Indeed, descriptive studies have not shown a correlation between labor market

[18] The other option was the *continuity model*, in which working hours were reduced during the entire partial retirement period.

[19] In 2012, the NRA of disability pensions was increased from 63 to 65 years.

[20] Marginal employment is defined as dependent employment with a maximum monthly salary of 400 EUR (raised to 450 EUR in 2013).

[21] The employer pays flat rates for taxes and social insurance.

[22] The share of women eligible for the pension for women who qualified for the pension for long-term insured was 93% in the 1951 cohort and 92% in the 1952 cohort (Lorenz et al., 2018; Geyer and Welteke, 2021). Eligibility requirements for the pension for women are so similar to those for partial retirement and the pension for unemployment that eligibility groups almost completely overlap (Lorenz et al., 2018).

indicators and entry into the disability pension (Aurich-Beerheide et al., 2018; OECD, 2010). Geyer and Welteke (2021) also showed descriptively that the 1999 pension reform did not lead to a discontinuous inflow into the disability pension, and in a regression discontinuity design estimation, there was no reform effect on disability pension usage.

In summary, we expect that the abolition of the pension for women led to an increase in employment between the old and the new ERA (the 60th and the 63rd birthdays). The employment expansion in this age bracket is expected to be stronger for employees in jobs with lower demands. Consequently, employees in demanding jobs should show a stronger increase in their unemployment, marginal employment, partial retirement, and inactivity than employees in less demanding jobs. We do not expect changes in the use of the disability pension and the old-age pension for the severely disabled.

Data

Our study is based on a large, high-quality administrative dataset provided by the German Federal Employment Agency (FEA). The data consist of a 2% sample of the population with information from the Integrated Employment Biographies from 1975 to 2017 (SIAB, 1975–2017).[23] The SIAB contains daily information about employment, wages, occupations, and receipt of unemployment benefits, as well as individual characteristics, such as date of birth, gender, and education.

Following Lorenz et al. (2018) and Pfister et al. (2018), we calculate individual pension entitlements. We also identify whether a woman was eligible for the pension for women by calculating the qualifying period for pension entitlement. We select a sample of women born in 1951 and 1952 focusing on the 55–65 age groups. We also exclude women who paid contributions to special miners' or seamen pension schemes, women who did not show any labor market activity before 1999, and women who were registered as unemployed throughout the entire observation period. Most importantly, we restrict the sample to women fulfilling the eligibility criteria for the pension for women and to women who were employed subject to social security contributions at age 55. We exclude all women who were not employed at age 55 because this group could not react to the pension reform: hardly any of the women unemployed at age 55 returned to employment before entering retirement (OECD, 2015; Geyer and Welteke, 2021).[24] Thus, our sample allows us to estimate an average treatment effect on the treated. After introducing the sample restrictions, we are left with 9718 individuals.

Our analysis focuses on the pension reform effect on the labor market status. We observe whether an individual was employed, marginally employed, unemployed, in partial retirement, or exited the labor market.[25] A woman is defined as employed if she had a job subject to social security contributions. If a woman is no longer observable in the SIAB, she is treated as out of the labor market. This status represents all types of non-employment without the involvement of the FEA and employment that was not subject to social security contributions, such as self-employment.

The pension reform was announced in 1999 and came into effect for women turning 60 in 2012. Thus, women had 13 years to adjust their labor market behavior (from age 47). However, it is unclear how they could react to the reform. Seibold (2021) and Geyer and Welteke (2021) did not find bunching on pension contribution years necessary for the pension for women or the pension for long-term insured in the 1952 cohort. They also did not find discontinuities in the fraction of women fulfilling the eligibility criteria for early retirement options and the sum of years worked up to age 60 before and after the reform. Moreover, Geyer and Welteke (2021) did not find any difference in labor market behavior of both cohorts before turning 60. Our descriptive analysis also reveals practically identical labor market behavior of treatment and control groups before the age of 60 (see section 4). Based on this evidence, we assume that there were few affected women who changed their employment behavior before the reform came into effect. The reform only affected women in employment until their 63rd birthday. We do not expect that there were reform effects for women beyond the age of 63, and we show this in our descriptive analysis.

Workers are not randomly assigned to jobs and choose them based on individual characteristics, preferences, and job attributes, like earnings levels. Therefore, we check whether our results are biased by self-selection into job demand related to the pension reform, such as a reduction in job demand after the announcement of the pension reform (Filer and Petri, 1988). Additionally, the quality of the match between an employer and employee may influence job demand, and thus an employee may change employer to increase his or her chances of working longer after the announcement of the pension reform (Henseke, 2011). In a robustness test, we restrict our sample to those older women who did not change employer and job demand after the announcement of the reform.

Job demand index

We measure physical and psychosocial job exposure in occupations using the JEM suggested by Kroll (2011, 2015). We attribute job demand to each employee by matching the JEM to the three-digit Classification of Occupations (KldB-2010) of the last job before retirement. Job exposure is defined by Kroll (2011) as, "conditions with potential physiological and/or psychological effects on the human organism resulting from the characteristics of the activity itself or from its external conditions". The JEM is based on 39 items and distinguishes five dimensions of job demand: ergonomic stress during work execution (EB), stress caused by the working environment (UB), mental (PB) and social stress (SB) in the workplace, and temporal load (ZB). The individual scores of the five dimensions of job demand are summarized separately in a physical job index (PJI) that includes EB and UB, and in a psychosocial index (PSI) that includes PB, SB, and ZB.[26] The values of the indices refer to job demand indicators derived from a representative workforce survey on working conditions for 20,000 employees considering age, tenure, and other individual characteristics, aggregated at the occupational level. According to the recommendations of Kroll (2011), we define high job demand as jobs with index scores of 8–10. Employees exposed to low job demand are analogously defined as those with an index score of 1–3.[27] Occupations with low demand in our sample are mainly in administration, occupations with high demand are mainly in

[23] Data access was provided via on-site use at the Research Data Centre (FDZ) of the FEA at the Institute for Employment Research (IAB) and subsequently via remote data access. A detailed description of the SIAB is available in Antoni et al. (2019).

[24] The restrictions reduce our sample by 35%.

[25] In our main sample, which requires labor market attachment at age 55, the disability pension plays a negligible role because most employees who suffered disability left the labor market well before age 55; the average entry age into disability pension was about 50 years (Rentenzugangsstatistik, 2010–2017, Scientific Use File). For our relevant age group after 60, only 0.9% of the 1951 cohort and 1.6% of the 1952 cohort entered the disability pension (Rentenzugangsstatistik, 2010–2017; Scientific Use File). Therefore, we do not consider the disability pension as an alternative labor market state.

[26] The individual scores of the five dimensions of job demand are summarized in an overall job index (sum of all dimensions).

[27] In robustness tests, we also define a high job demand with index values of 9–10 or 7–10 and vary the definition of low job demand similarly. The results remain constant.

the cleaning and medical sectors.[28]

The JEM is externally and internally validated to depict the occupation-related exposures and health risks at work based on health indicators using German Telephone Health Survey data gathered by the Robert Koch Institute in 2009 (Santi et al., 2013), the German Pension Insurance Scientific Use File 'SUFRSDLV15B', and data from a nationwide survey of 2530 rehabilitation patients (Brünger et al., 2019). Mazzonna and Peracchi (2017) also used the JEM and found a positive effect of retirement on health for people working in physically and psychosocially demanding jobs. In general, the link between individual health and physical as well psychosocial job demand is well established (Argaw et al., 2013; Case and Deaton, 2005; Bödeker and Barthelmes, 2011; Beehr et al., 2000; Ravesteijn et al., 2013; Rijs et al., 2014; Richter et al., 2012). Therefore, we assume that jobs characterized as demanding in the JEM are not fully compensated by higher control, learning opportunities, rewards, or social support. Consequently, these demanding jobs are, on average, positively correlated with health hazards. The JEM is a measure that is not sector-specific and does not differentiate between genders; hence, there may be measurement error because we must assume that each occupation has the same job demand in all economic contexts and for men and women alike (Modrek and Cullen, 2012).

Estimation strategy

In our quasi-experimental design, we analyze how employees with high and low job demand respond to an increase in the ERA. We use the exogenous cohort-specific variation in the ERA to estimate causal effects on whether a woman is employed, in partial retirement, unemployed, in marginal employment, or inactive at any given age measured in months.

Following Geyer and Welteke (2021), we estimate the effect of the reform using a regression discontinuity design. The regression discontinuity design exploits the exogenous variation in ERA by birth month and birth year and it relies on the assumption that women cannot manipulate the treatment assignment variable. Moreover, we assume that any discontinuity in labor market outcomes at the cutoff (January 1952) was solely caused by the 1999 pension reform. We include trends in birth month to allow for continuous changes over time. We also test for discontinuities in covariates to check whether the characteristics of women born close to the cutoff were sufficiently similar.

We analyze potential differences in the reform effect for employees in low- and high-demand jobs by splitting the sample into two groups. The models in equations (3) and (4) estimate the impact of the increase in the ERA on labor market outcomes.

$$y_{it} = \alpha + \beta D_i + \gamma_0 f(z_i - c) + \gamma_1 D_i (z_i - c) + X_{it}^{'}\delta_i + e_{it} \text{ if } i \in \text{low job demand} \tag{3}$$

$$y_{it} = \alpha + \beta D_i + \gamma_0 f(z_i - c) + \gamma_1 D_i (z_i - c) + X_{it}^{'}\delta_i + e_{it} \text{ if } i \in \text{high job demand} \tag{4}$$

Treatment indicator D is 1 if the woman was born on or after January 1, 1952. Variable y denotes employment, partial retirement, unemployment, marginal employment, and labor market exit of individual i at age t measured in months in the baseline specification. Birth month z_i is the running variable defined as the difference from cutoff c (January 1952). We include a linear trend in the running variable accounting for secular time trends in employment outcomes. All specifications include calendar month fixed effects, education, and the sum of pension points at age 58 in vector X.[29] Education, pension eligibility, and pension entitlements are the most important drivers of old-age employment behavior (Blau and Goodstein, 2010; Modrek and Cullen, 2012). We cluster standard errors by birth month.

In addition to controlling for calendar month fixed effects and a linear trend in the running variable, we check whether our observation period, 2011–2014, was characterized by breaks in the German labor market. The number of employees slightly and almost linearly increased from 41.6 million to 42.7 million, the share of employees increased from 72.5% to 73.6% and the unemployment share declined moderately from 7.1% to 6.7%. The general labor market climate during the observation period was favorable, but far from booming or characterized by large macroeconomic shocks.

We conduct several robustness tests for our model specification. We rerun our main regressions and add quadratic trends in the running variables z_i - c. In addition to the linear specification, we relax the functional form assumption and estimate non-parametric local linear regressions (Appendix E). We also test whether estimates are sensitive to variation in bandwidth (Appendices F and H). In addition to specification changes, we vary our sample design. To check whether our results are biased by announcement effects (the reform was announced in 1999 but implement in 2011), we rerun our main regression without women who changed their employer or the level of job demand after the announcement of the pension reform (Appendix C). We also rerun our regressions for women not eligible for the pension for women. This additional regression provides evidence whether, without a change in the retirement incentives, there were differences in labor market outcomes for both birth cohorts (compare Appendix G). Finally, we conduct a placebo regression using the 1951 cohort as the treatment group and the 1950 cohort as the control group (Appendix F).

Descriptive evidence

We present the descriptive evidence of labor market outcomes for women in the 1951 and 1952 birth cohorts between the ages of 55 and 65 separately for low and high PJI (Fig. 1). The age patterns of labor market status for low and high PSI were similar (Appendix D). In general, employment levels differed across groups and decreased monotonically with age. Within each cohort, women with a lower PJI/PSI showed higher employment rates than women with a higher job demand. There was a large decrease in employment rates of the 1951 cohort at age 60 that was not observed for the 1952 cohort. This employment gap appeared because the pension for women was abolished. There was another decrease in employment at age 63 for all groups. This effect was stronger for the 1952 cohort, who did not have the opportunity to retire at age 60. Differences in employment rates between high and low PJI/PSI after age 63 were much smaller. According to our theoretical considerations, the pension reform effect was confined to the age bracket 60–62. There appeared to be no anticipation effects in labor market activity and no employment difference for women who reached age 63 in employment in the treatment and control cohorts. Most importantly, the increase in employment for the treatment group was similar for women in high- and low-demand jobs.

Partial retirement rates increased until the age of 60 (1951 cohort) or

[28] The most widespread high- and low-job-demand occupations are as follows. Low PJI: office clerks and secretaries (714); occupations in public administration (732); and occupations in business administration and strategy (713). High PJI: occupations in cleaning services (541); occupations in nursing, emergency medical services, and obstetrics (813); occupations in warehousing and logistics, in postal and other delivery services, and in cargo handling (513). Low PSI: office clerks and secretaries (714); occupations in public administration (732); and occupations in insurance and financial services (721). High PSI: occupations in cleaning services (541); sales occupations in the retail trade (621); and occupations in nursing, emergency medical services, and obstetrics (813).

[29] Tables 8 – 11 in Appendix A show that average values of covariates hardly differ between treatment and control group. We also present more formal tests on discontinuities in covariates in Table 12. These tests confirm that all treatment and control groups are equal with respect to observable covariates, also compare similar evidence presented by Geyer and Welteke (2021) in Appendix Table D1.

Table 2
Share of individuals in bridge paths by cohort and PJI.

Cohort	Total		Low PJI		High PJI	
	Share (%)	*N*	Share (%)	*N*	Share (%)	*N*
1951						
Unemployment as bridge path	19.71	940	15.86	323	24.76	237
Partial retirement as bridge path	20.95	999	30.44	620	13.58	130
1952						
Unemployment as bridge path	19.76	978	17.46	358	23.94	255
Partial retirement as bridge path	16.95	839	24.34	499	12.49	133

Notes: The table shows shares and number of observations of bridge paths by cohorts and job demand groups. A bridge path is defined as being in unemployment or partial retirement before exiting the labor market.
Source: SIAB 7517, own calculations.

Table 3
Employment exit age by bridge path, cohort, and PJI groups.

	Average employment exit age (years)		**Average employment exit age from partial retirement (years)**		**Average employment exit age from unemployment (years)**	
Cohort	1951	1952	1951	1952	1951	1952
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Low PJI	62.06 (2.61)	62.66 (2.32)	56.79 (1.73)	56.87 (1.63)	59.44 (2.53)	59.74 (2.48)
High PJI	61.40 (2.78)	62.06 (2.74)	56.94 (1.66)	57.69 (1.88)	59.36 (2.56)	59.56 (2.54)

Notes: Number of observations: low PJI: 4087 in total, 1951 (2037), 1952 (2050); high PJI: 2022 in total, 1951 (957), 1952 (1065). SD: standard deviation.
Source: SIAB 7517, own calculations.

62 (1952 cohort). Interestingly, women with low PJI/PSI had higher partial retirement rates (approximately 24%) than women with high PJI/PSI (approximately 11%). There was a steep drop in partial retirement rates at age 60 for the 1951 cohort and at ages 62 and 63 for cohort 1952[30]. On average, exit from partial retirement was more than 1 year later in the 1952 cohort than in the 1951 cohort. According to our theoretical considerations, we found no changes in the use of partial retirement among cohorts after age 63.

Unemployment decreased at age 60 for the 1951 cohort and at age 63 for the 1952 cohort. We assumed that unemployed women switched into early retirement after unemployment at these ages. After age 63, unemployment was low and decreasing because almost all women in our sample were eligible for the pension for the long-term insured, and thus

[30] The drop in partial retirement at age 62 can be explained by an exceptional reduction in the ERA for the pension for long-term insured for a sub-group of women. The 1999 reform included a reduction of the ERA of the pension for long-term insured by 1 year from 63 to 62. Starting in 2010, the ERA was supposed to decrease in monthly steps for every two month-of-birth cohorts. In 2008, this reform was revoked. However, a small share of women born in 1952 benefited from a confidence protection rule: women who already had an agreement with their employer to enter partial retirement could still retire at age 62.

Table 4
Partial retirement: entry age, duration, and exit age by cohort and PJI groups.

	Average entry age for partial retirement entry age (years)		**Average duration of partial retirement (months)**		**Average partial retirement exit age (years)**	
Cohort	1951	1952	1951	1952	1951	1952
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Low PJI	57.11 (2.87)	56.92 (3.64)	65.36 (21.40)	76.60 (22.61)	62.18 (1.86)	63.17 (1.22)
High PJI	57.09 (4.57)	58.10 (1.93)	62.69 (20.47)	66.14 (21.03)	62.07 (1.78)	63.11 (1.11)

Notes: Number of observations: low PJI: 4087 in total, 1951 (2037), 1952 (2050); high PJI: 2022 in total, 1951 (957), 1952 (1065). SD: standard deviation.
Source: SIAB 7517, own calculations.

could choose early retirement without pension deductions. The increase in unemployment rates of women born in 1952 between age 61 and 63 indicated that unemployment was used as a bridge to early retirement. Around 30% of women with high job demand and 40% of women with low job demand used the maximum duration of unemployment benefits of 24 months before exiting the labor market. Accordingly, there was a spike in unemployment for the 1952 cohort at age 61 instead of age 58, as seen for the 1951 cohort.

Women with high PJI/PSI had a significantly higher rate of marginal employment before the reform. The share of women born in 1951 who were marginally employed at the age of 60 was around 12% (9% for low job demand women and 17% for high job demand women). We suggest that women hardly used marginal employment as a substitute for regular employment, and instead they started to work in marginal employment after entering early retirement. [31]The share of women with high job demand who continued to work in marginal employment after retirement was higher than the share of women with low job demand.

The labor market exit rates for both cohorts and job demand groups increased with age. The out-of-labor-force rate confirmed that there were no anticipation effects for the reform. Women with high PJI left the labor market earlier and their jump in labor market exit rate at age 60 was greater than the jump for women with low PJI for the 1951 cohort. After the reform, there was a linear increase in the share of labor market exit shortly before and after age 60 and only a small jump at age 62 due to the confidence expectation rule for women in partial retirement.[32] After age 63, there were no large differences between cohorts and PJI levels for the share of those women out of the labor market. This labor market exit pattern provided additional evidence for our claim that women who reached their 63rd birthday in employment did not change their behavior in reaction to the 1999 pension reform. Hence, we concentrated on the age bracket between the 60th and 63th birthday in our multivariate regressions.

Further descriptive results

We add further descriptive analyses to illustrate the effects of the pension reform on labor market outcomes and their heterogeneity between the job demand groups.[33] Table 2 shows that the share of unemployed remained constant from the 1951 to the 1952 cohort (19.71% vs. 19.76%) and that the share of partially retired fell from the 1951 to

[31] For data protection reasons, all values based on < 20 observations have to be deleted (FDZ, 2017). Therefore, for the age groups 55 to 57, the marginal employment rate cannot be shown.
[32] See last footnote.
[33] The results for PSI are similar, see Appendix D, Table 16.

Table 5
Unemployment: entry age, duration, and exit age by cohort and PJI groups.

	Average entry age for last unemployment (years)		Average duration in unemployment (months)		Average unemployment exit age (years)	
Cohort	1951	1952	1951	1952	1951	1952
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Low PJI	60.05 (2.34)	60.68 (2.18)	19.64 (10.46)	19.90 (13.01)	61.31 (2.30)	61.90 (2.22)
High PJI	59.87 (2.41)	60.24 (2.40)	17.83 (10.83)	18.67 (12.03)	60.81 (2.44)	61.29 (2.37)

Notes: Number of observations: low PJI: 4087 in total, 1951 (2037), 1952 (2050); high PJI: 2022 in total, 1951 (957), 1952 (1065). SD: standard deviation.
Source: SIAB 7517, own calculations.

Table 6
Linear regression results for employees with low and high job demand: physical job demand index PJI (ages 60–62 years).

	Employment		Employment and partial retirement		Partial retirement		Unemployment		Labor market exit		Marginal employment	
	I		II		III		IV		V		VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.072** (0.023)	0.088* (0.033)	0.145** (0.021)	0.114** (0.025)	**0.073**** **(0.024)**	**0.026 (0.021)**	0.019* (0.009)	0.014 (0.013)	**−0.154**** **(0.016)**	**−0.085* (0.035)**	**−0.010 (0.007)**	**−0.043**** **(0.011)**
Pre-reform mean	0.423	0.415	0.604	0.494	0.180	0.079	0.033	0.043	0.317	0.371	0.046	0.092
N	147,132	72,792	147,132	72,792	147,132	72,792	147,132	72,792	147,132	72,792	147,132	72,792
R^2	0.025	0.052	0.069	0.083	0.027	0.052	0.030	0.019	0.054	0.045	0.010	0.023

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

the 1952 cohort (from 21% to 17%). Women with low job demand were more likely to enter partial retirement in old age than women with high job demand in both cohorts.

Before and after the reform, women with low PJI exited employment later than women with high PJI (62.06 vs. 61.40 years) (Table 3). The postponement of employment exit was similar for both labor demand groups and was not associated with a change from full-time to part-time work – the share of part-time workers roughly remained equal for treatment and control group. Women with bridge paths left regular employment before age 60. However, women with low PJI entered partial retirement earlier than before the reform (56.92 years instead of 57.11 years) (Table 4). Analogously to the increase in the partial retirement spell length, the exit from partial retirement shifted from 62.18 to 63.17 years. Partial retirement entry age for women with high PJI was also deferred. The average duration of partial retirement after the reform was 66 months, which was 3.5 months longer than before the reform. Therefore, women with high job demand postponed their withdrawal from partial retirement after the reform from age 62.07 to 63.11 years.

Both groups extended unemployment spells by <1 month and entered unemployment about 6 months later after the reform to reduce the gap to pensionable age (Table 5).

Summing up the descriptive evidence, the pension reform did not lead to active program substitution into bridge options, especially for women with high job demand. Therefore, the pension reform did not increase the share of women who entered unemployment or partial retirement as bridge paths. However, women who chose bridge options increased partial retirement spell lengths after age 60, partly by entering the bridge options later and partly by extending their duration.

Labor market effects for women with high and low job demand

We used multivariate regressions to examine how women with high and low levels of PJI and PSI reacted to the increase in the ERA when they were between 60 and 62 years old. The main variable of interest was the binary treatment indicator. The results of the linear regression discontinuity analysis are shown for the PJI groups in Table 6 and for the PSI groups in Table 7.[34] Significant differences (at the 5% level) between high and low job demand groups are shown in bold.

The employment rate of women aged 60–62 was increased by the reform for women with low and high job demand by between 7.2 and 10.7 percentage points (column I, Tables 6 and 7). The relative employment increase was between 17% and 25% compared with the pre-reform means. There were no significant differences in the employment effects across job demand groups. [35]However, there were strong and significant differences between the effects of the pension reform by employee group with respect to partial retirement (column III, Tables 6 and 7). The partial retirement rate increased between 5.9 (34%) and 7.3 (41%) percentage points for women with low job demand and by just 2.6 percentage points (33% and 38%) for women with high job demand (relative increases in brackets). The reform effect on partial retirement was not significant for the high PJI group. Thus, the differences in the increase in absolute employment rates including partial retirement between the two employee types were mainly driven by women with low job demand prolonging partial retirement (column II, Tables 6 and 7). The relative increases in employment including partial retirement were around 26% for all four groups.[36] Moreover, the fraction of women leaving the labor market before age 63 dropped by 8.5 or

[34] In Appendix E, Fig. 3 and Fig. 4 visualize the different results using local linear regression on both sides of the cutoff, a triangular kernel, and a bandwidth of 12 months for the PJI and PSI. Distance to the cutoff does not seem to be important for the effects.

[35] Estimation results for the pooled sample in Appendix B, Table 1 are similar to those in the high- and low-labour-demand sub-samples.

[36] This figure coincides exactly with the estimate in Geyer and Welteke (2021). However, they could not differentiate between employment and partial retirement.

Table 7
Linear regression results for employees with low and high job demand: psychosocial job demand index PSI (ages 60–62 years).

	Employment		Employment and partial retirement		Partial retirement		Unemployment		Labor market exit		Marginal employment	
	I		II		III		IV		V		VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.088*	0.107*	0.146**	0.133**	**0.059***	**0.026**	0.016	0.018*	−0.148**	−0.109*	−0.015	−0.042**
	(0.032)	(0.039)	(0.027)	(0.040)	**(0.024)**	**(0.014)**	(0.008)	(0.007)	(0.022)	(0.043)	(0.008)	(0.011)
Pre-reform mean	0.398	0.441	0.570	0.508	0.172	0.068	0.035	0.045	0.346	0.358	0.049	0.089
N	120,888	128,160	120,888	128,160	120,888	128,160	120,888	128,160	120,888	128,160	120,888	128,160
R^2	0.030	0.048	0.084	0.087	0.040	0.032	0.043	0.031	0.059	0.042	0.013	0.024

*Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earning points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.*
Source: SIAB 7517, own calculations.

10.9 percentage points for women with high job demand and by 14.8 or 15.4 percentage points for women with low job demand. These figures imply a relative decrease in the labor market exit rate of between 43% and 49% for women with low job demand and between 23% and 30% for women with high job demand.

According to our descriptive findings, the multivariate analysis showed that there was a small, non-significant increase in the unemployment share between age 60 and 63 that was similar in both job demand groups. In addition, the negative effects of the reform on marginal employment supported our hypothesis that marginal employment was mainly used as additional income by those in early retirement before the abolition of the women's pension. The combination of early retirement plus marginal employment was used more frequently by women with high labor demand than by women with low labor demand.

Our robustness checks on the estimation specification confirmed our previous results. Adding a quadratic trend for the running variable increased the employment effects for the women in occupations with high job demand significantly (available upon request). Analogous to Tables 6 and 7, women in occupations with low job demand significantly increased partial retirement more than women in occupations with high job demand. There were no differences in the small unemployment effects, and there was a stronger decrease in marginal employment for women with high job demand. Our local linear estimations also showed the pattern we observed for our parametric models (Appendix E, Figs. 3 and 4). The estimates also remained stable for all labor market outcomes for a bandwidth of 6 months (compare Appendix F, Tables 20 and 21) and for triangular kernel functions with a bandwidth of 12 months (compare Appendix H, Tables 26 and 27). Estimating the reform effects in a difference-in-differences model instead of a regression discontinuity design also gave robust results (available upon request).

The results remained robust when we changed our sample definition. We only included women eligible for the pension for women who did not change their employer and the level of their job demand after the announcement of the pension reform in 1999 (Appendix C, Tables 14 and 15). This sample restriction reduced the number of our observations by about a half. We nevertheless obtained the same reform effects. The employment increase was about 25% compared with the pre-reform means in the reduced sample and it was also the same for women in the high and low PJI and PSI groups. The increase in partial retirement was stronger for women in less demanding jobs. We therefore conclude that there hardly were estimation biases induced by an endogenous choice of employer or job after the reform was announced. There were no differences in labor market outcomes between the 1951 and 1952 birth cohorts for women not eligible for the pension for women (Appendix G, Tables 2 and 25); women not affected by the reform did not change their employment behavior. In a final robustness test, we performed a placebo regression where we imposed the reform cut-off as January 1951 (Appendix F, Tables 22 and 23). As expected, the point estimates were close to zero and the group differences were insignificant.

Discussion

We found that the increase in the ERA of women by 3 years led to a strong employment increase of about 25% compared with pre-reform employment levels in the 60–62 years age bracket. Surprisingly, the employment effect was the same for women with low and high psychosocial and physical job demand. We did not find a substitution effect into the disability pension. Especially for women in demanding jobs, the absence of substitution effects is in contrast to evidence from the literature that shows a correlation between job demand and the inflow into disability pensions (Blekesaune and Solem, 2005; Chirikos and Nestel, 1991)[37] and between job demand and early retirement, including the disability pension option (Krause et al., 1997; Laine et al., 2009).

The first reason for the difference between our findings and those in the literature may be a difference in the estimation method. Almost all papers on the relationship between job demand and the intended or realized employment exit or retirement used structural estimation models. However, a problem with this estimation approach could be that employees self-select into employment contracts because they anticipate early retirement (Filer and Petri, 1988; Modrek and Cullen, 2012). One example of potentially unobserved self-selection is a negative correlation between job demand and socioeconomic status that is itself associated with health-related behavior (Borg et al., 2000; Contoyannis et al., 2004). Another example is the self-selection of high-stamina workers into high-demand jobs because these workers expect to have a high probability of reaching the standard retirement age in good health in these jobs, and thus they have the opportunity to collect higher earnings in these jobs (Filer and Petri, 1988). Other workers may choose a less demanding work environment instead to be able to reach early retirement eligibility, which is usually tied to certain tenure or work experience thresholds (Filer and Petri, 1988). These structural differences among workers contribute to selection bias in labor market status regressions if they are not adequately controlled for. Therefore, it is unclear whether the measured associations between job demand and labor market status in previous papers are causal or a consequence of unobserved associations between job choice and work demand (Blekesaune and Solem, 2005). The regression discontinuity design used in this paper avoids estimation biases incurred by time-invariant unobserved heterogeneity.

The second reason for the difference in our results with those in the literature is that entry into the disability pension was not an attractive option for women eligible for the pension for women in our sample. Studies that do not include disability pensions usually do not find a correlation between retirement age and work demand according to our findings (for example, see the literature reviews in van den Berg et al.,

[37] Hayward et al. (1989) found that physical job demands were positively correlated with early retirement and not correlated with the disability pension after age 55, controlling for health.

2010; Carr et al., 2016).

Our main explanation for the strong positive employment reaction of women in high-demand jobs is that eligibility conditions for the pension for women exclude women who were unable to continue working long before they reached the ERA from obtaining early retirement eligibility.[38] Almost half (44%) of the women in our sample with high physical job demand in their last job before retirement were not eligible for the pension for women compared with only 25% in the group exposed to low physical job demand (the figures were 41% for high PSI and 27% for low PSI). Thus, the strongly positive selection of women in high-demand jobs eligible for early retirement may have induced a so-called healthy worker effect (McMichael, 1976; Sewdas et al., 2018). Positive selection of employees eligible for early retirement may have also caused the small difference in average employment exit age of 6 months between women in low- and high-demand jobs in our sample of women eligible for early retirement[39]. For all women in our dataset, the average difference in employment exit age between low and high labor demand groups was 3.5 years.[40]

Börsch-Supan et al. (2022) also documented a healthy worker effect for individuals eligible for early retirement when they compared the health status of individuals in early retirement after 45 years of employment before entering retirement with that of individuals in early retirement after<45 but more than 35 employment years. They did not find any health differences between both eligibility groups and concluded that stronger pension eligibility requirements with respect to previous work spells increased the positive selection of older employees using early retirement. The usual adverse health effects of longer careers spans with demanding jobs could not be found for the group of employees who were eligible for early retirement programs if long labor market experience was the decisive eligibility criterion.

The first indicator of the healthy workers effect in our sample is that double the share of women in demanding jobs worked in marginal employment after entering the pension for women after age 60 compared with women in less demanding jobs. Even the share of women with high job demand who worked in marginal employment after entering the pension for long-term employed after age 63 of about 13% was also substantial[41]. These observations suggest that after entering early retirement, many women with a high-demand job were able to continue working for a few hours in marginal employment. The share of employed women aged 60–65 with sick-pay periods of more than six weeks also does not differ dramatically between women in demanding and less demanding jobs.[42] These data patterns support our hypothesis that women eligible for early retirement in demanding jobs had an at least similar work capability as women in less demanding jobs beyond age 60. Women in demanding jobs seem to have stronger financial reasons for continued work during early retirement. Their lower pension entitlements render work after retirement attractive (Lorenz and Zwick, 2021); the share of the post-retirement earnings of marginal employment in pension entitlements was around 50% for women with high job demand compared with 40% for women with low job demand in our sample. This difference is mainly driven by the substantially lower pension entitlements women in more demanding jobs collected before retirement, compare Tables 8 and 10 in Appendix A. The low income associated with marginal employment may be a reason why women eligible for early retirement hardly used it as a substitute for ordinary employment and therefore a way to reduce their job demand before entering retirement.

The second indicator of the healthy worker effect in our sample is that women with high job demand hardly used partial retirement as an option to exit employment earlier than ERA or reduce their working hours. Partial retirement would have allowed them to reduce working time between the old and new ERA. A reason for the low substitution into partial retirement may be that women in demanding jobs mainly worked for employers that did not offer partial retirement (Brussig, 2016; Wanger, 2010). Furthermore, before the reform, partial retirement was mainly offered to women with less demanding jobs. In our data, we cannot observe whether employers in general offered partial retirement or not, and thus we cannot assess whether the higher partial retirement incidence for women in low-demand jobs was a consequence of a selective offer by their employers or a consequence of women in high-demand jobs mainly working for employers that did not offer partial retirement. We in addition only observe whether an employee was employed full-time (more than 18 h per week) or part-time (<18 h per week). We do not have an indication that employers reduced working hours within the full-time or part-time hours brackets. Wages increased after age 60 for treated employees with high and for workers with low labor demand, and thus we assume that there was little scope for reductions in hours worked within the full-time and part-time brackets. For employees with low PJI who were born in 1952, daily wages were on average 86 EUR before the age of 60 and 89 EUR thereafter. The wages for employees with high PJI who were born in 1952 were on average 50 EUR before the age of 60 and 55 EUR thereafter.

Our third indicator of the healthy worker effect is that exit from the labor market before age 63 via unemployment as a bridge option was used similarly by women in demanding and women in less demanding jobs. Unemployment before retirement in addition hardly was used as a substitution alternative for early retirement after the introduction of the reform. These patterns may be explained by the social stigma of unemployment and the large financial deductions during unemployment (Engels et al., 2017). In addition, unemployment benefits were only paid for a maximum of 24 months for the cohorts we analyzed. Thus, women did not have the option of bridging the entire difference between the old and new ERA. The average unemployment period of eligible women before the reform was already almost 18 months; therefore, there was little scope for a further increase induced by the pension reform.

Our fourth indicator of the healthy worker effect comes from other research on the 1999 pension reform. Geyer and Welteke (2021; Table 16) showed that women eligible for the pension for women who had been absent from work for more than 6 weeks because they were ill in the age bracket 50–55 showed even stronger increases in their employment after age 60 than women without earlier health conditions. Thus, health conditions in the years before early retirement seemed to have no negative impact on retirement behavior for those eligible for early retirement. However, for all older employees, including those not eligible for early retirement, health conditions at an earlier age are a strong negative predictor of retirement age (Staubli and Zweimüller, 2013).

Health conditions and high job demand lead to an earlier exit from employment on average for all employees, but they did not affect employment in old age of those eligible for early retirement. As a consequence, the early retirement option did not insure employees against the risk of not reaching their NRA in employment. Therefore, we

[38] Work demand reductions for older employees in demanding jobs may be an alternative explanation for the employment extensions of this group of individuals after the pension reform. German employers however hardly used these human resource measures. More specifically, the share of establishments with work demand adaptations for older employees was below five percent during the time period of the introduction of the pension reform (Brussig and Leber, 2019, Fig. 1).

[39] Compare columns 1 and 2 in Table 3.

[40] The average employment exit age for all women with high job demand was 58.34 years for the 1951 cohort and 58.59 years for the 1952 cohort. The average employment exit age was 61.40 years for women with low job demand born in 1951 and 62.06 years for women with low job demand born in 1952 according to our own calculations including women not eligible for the pension for women.

[41] The shares of women in mini jobs in addition to early retirement after age 63 were comparable for those in demanding and less demanding jobs.

[42] The shares were 15% vs. 11% for high vs. low PJI and 14% vs. 12% for high vs. low PSI.

propose two ways to insure older workers in high-demand jobs better against the risk of dropping out of the labor force before their NRA. The first measure may be better health prevention because it increases the chance of avoiding disability and staying in employment longer (OECD, 2009). Another option is a better financial compensation in the disability pension for all who need it (Chirikos and Nestel, 1991; Hanel, 2012). Disability pensions are usually the only alternatives to retire before the NRA for those not eligible for early retirement. Thus, social transfer programs constitute the relevant work disability insurance for a large share of employees in demanding jobs. At least in Germany, about a quarter of those who report being unable to work do not receive disability insurance pay (Börsch-Supan et al., 2022). Therefore, this group of individuals does not seem to be insured at all against the risk of dropping out of the labor market.

Conclusions

Women in jobs with high demand who were eligible for early retirement and managed to work until age 60 increased employment to the same extent as those in low-demand jobs after an increase in their ERA. These women did not use unemployment, partial retirement, marginal employment, disability pension, or inactivity as alternatives for their employment extension after age 60. This surprising result reveals an unintended effect of existing early retirement eligibility rules. Employees are only eligible for early retirement options if they worked between 15 and 46 years before retirement (see overview in the Introduction). This eligibility rule leads to the selection of healthy workers into early retirement. However, a large share of workers in high-demand jobs are not eligible for early retirement and must resort to social transfer programs, such as the disability pension, if they cannot reach their NRA in employment. Social transfer programs for disabled workers are typically less generous than early retirement options. Consequently, the eligibility rules for early retirement work against the intention of insuring hard-working employees against the risk of being unable to reach the NRA.

Our results pertain to women aged between 60 and 62 years. We do not know whether the healthy worker effect also applies for early retirement programs with higher ERAs. The eligibility rule of 15 years in employment for the pension for women was relatively generous. For example, existing early retirement rules in Germany with an ERA of 63 require a minimum of 35 or even 45 years that may induce an even stronger positive selectivity for employees in demanding jobs. We also cannot verify whether the effects measured in this paper can be generalized from women to men, given that the occupation structure differs between genders. Therefore, further studies on the effects of the recent wave of abolitions of early retirement options in several developed countries (Börsch-Supan and Coile, 2018) on labor market outcomes by job demand are required to test the robustness of our findings.

Although many countries have abolished or tightened early retirement programs in recent years, our results are relevant for the future. There seems to be a renaissance of early retirement options in the making (Börsch-Supan et al., 2022). For example, early retirement at age 63 without actuarial deductions for workers with 45 service years was reintroduced in 2014 in Germany ("pension for the especially long-term insured"). The main motivation of its introduction was "to honor the achievement of especially hard-working individuals who have modest earnings, are burned out and often in bad health" (Deutscher Bundestag, 2014). The political reason for this new early retirement option was a cushioning of increases in the NRA for employees in demanding jobs. As in many countries, the NRA is increasing in Germany from age 65 to 67 in the period between 2012 and 2029. Another example is the expansion of beneficiaries of special retirement benefits for employees in arduous and hazardous jobs in Italy that will more than triple the beneficiaries between 2016 and 2023 (compare Natali et al., 2016; Annex 5). Therefore, politicians in many countries may be tempted to reintroduce general early retirement options or pension age exceptions for demanding occupations[43] with long-term employment requirements when they face opposition to increases in the NRA.

CRediT authorship contribution statement

Thomas Zwick: Conceptualization, Methodology, Formal analysis, Supervision, Project administration, Funding acquisition. **Mona Bruns:** Conceptualization, Methodology, Software, Validation, Formal analysis, Data curation, Visualization. **Johannes Geyer:** Conceptualization, Methodology. **Svenja Lorenz:** Conceptualization, Methodology, Software, Validation, Formal analysis, Data curation, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table 8
Sum of pension points at age 58 years by cohort and PJI groups.

Sum of pension points at age 58 years		
Cohort	1951 Mean (SD)	1952 Mean (SD)
Low PJI	29.47 (12.25)	30.70 (13.48)
High PJI	19.89 (9.45)	20.13 (9.28)

Notes: Number of observations: low PJI: 1951 (2037), 1952 (2050); high PSI: 1951 (957), 1952 (1065). SD: standard deviation.
Source: SIAB 7517, own calculations.

[43] See, for example, the description of the Dutch discussion on the differentiation of NRA by occupations in 2009 in Vermeer et al. (2016).

Table 9
Education by cohort and PJI groups.

Education								
Cohort	1951				1952			
	No degree	Vocational training	University degree	Other	No degree	Vocational training	University degree	Other
Low PJI	3.94%	73.78%	18.04%	4.23%	3.29%	70.02%	22.80%	3.89%
High PJI	29.13%	63.98%	3.77%	3.12%	28.26%	66.18%	2.78%	2.78%

Notes: Number of observations: low PJI: 1951 (2037), 1952 (2050); high PSI: 1951 (957), 1952 (1065).
Source: SIAB 7517, own calculations.

Table 10
Sum of pension points at age 58 years by cohort and PSI groups.

Sum of pension points at age 58 years		
Cohort	1951 Mean (SD)	1952 Mean (SD)
Low PSI	28.88 (12.22)	29.90 (12.82)
High PSI	21.62 (10.28)	21.65 (10.00)

Notes: Number of observations: low PSI: 1951 (1711), 1952 (1647); high PSI: 1951 (1756), 1952 (1804). SD: standard deviation.
Source: SIAB 7517, own calculations.

Table 11
Education by cohort and PSI groups.

Education								
Cohort	1951				1952			
	No degree	Vocational training	University degree	Other	No degree	Vocational training	University degree	Other
Low PSI	4.32%	79.43%	12.34%	3.91%	3.73%	76.83%	16.01%	3.43%
High PSI	17.67%	73.01%	6.49%	2.83%	17.57%	74.52%	5.86%	2.05%

Notes: Number of observations: low PSI: 1951 (1711), 1952 (1647); high PSI: 1951 (1756), 1952 (1804).
Source: SIAB 7517, own calculations.

Table 12
Tests for discontinuities in covariates.

	All	High PJI	Low PJI	High PSI	Low PSI
	RDD Coefficients				
Sum of pension points	1.250 (1.159)	0.921 (1.101)	1.126 (1.134)	0.352 (0.484)	1.112 (1.099)
Education: No degree	−0.001 (0.002)	−0.002 (0.003)	−0.000 (0.000)	−0.001 (0.001)	−0.000 (0.000)
Education: Vocational training	−0.008 (0.006)	−0.010 (0.007)	−0.006 (0.006)	−0.009 (0.006)	−0.006 (0.006)
Education: University degree	0.007 (0.005)	0.009 (0.006)	0.006 (0.005)	0.008 (0.006)	0.005 (0.006)
Education: Other	0.002 (0.003)	0.002 (0.003)	0.002 (0.002)	0.001 (0.002)	0.002 (0.003)
Number of observations in each regression	9718	2022	4087	3560	3358

Notes: Covariates are measured at age 60. All regressions include calendar month fixed effects and linear trends of the running variable (month of birth) on both sides of the policy cutoff (January 1952). Standard errors (in parentheses) are clustered by month of birth.
Source: SIAB 7517, own calculations.

Appendix B

Table 13
Linear regression results, pooled sample (ages 60–62 years).

	Employment	Employment and partial retirement	Partial retirement	Unemployment	Labor market exit	Marginal employment
	I	II	III	IV	V	VI
Treatment	0.107**	0.147**	0.040**	0.018**	−0.140**	−0.024**
	(0.023)	(0.020)	(0.012)	(0.005)	(0.017)	(0.005)
Running	0.003	0.001	−0.002	0.0002	−0.0009	0.000003
	(0.002)	(0.001)	(0.002)	(0.0003)	(0.001)	(0.0004)
Running* treatment	0.001	0.002	0.001	−0.001	−0.0001	−0.001
	(0.003)	(0.003)	(0.002)	(0.0007)	(0.002)	(0.0006)
Pre-reform mean	0.441	0.564	0.123	0.038	0.335	0.063
Observations	349,848	349,848	349,848	349,848	349,848	349,848
R^2	0.036	0.078	0.040	0.030	0.051	0.016

Notes: We control for monthly age fixed effects, the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

Appendix C

Table 14
Linear regression results for employees with low and high PJI without changes in employer and PJI since the reform announcement (ages 60–62 years).

	Employment I		Employment and partial retirement II		Partial retirement III		Unemployment IV		Labor market exit V		Marginal employment VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.096**	0.072*	0.152**	0.091	0.056	0.019	0.026*	0.010	−0.169**	−0.072	−0.008	−0.029
	(0.031)	(0.033)	(0.021)	(0.048)	(0.038)	(0.028)	(0.012)	(0.018)	(0.017)	(0.052)	(0.008)	(0.019)
Pre-reform mean	0.416	0.406	0.616	0.503	0.199	0.097	0.034	0.037	0.324	0.405	0.027	0.055
N	75,852	32,724	75,852	32,724	75,852	32,724	75,852	32,724	75,852	32,724	75,852	32,724
R^2	0.031	0.078	0.071	0.093	0.022	0.037	0.037	0.027	0.051	0.056	0.012	0.034

Notes: High is defined as PJI with an index value of 8 to 10. Low is defined as PJI with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that group differences are significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

Table 15
Linear regression results for employees with low and high PSI without changes in employer and PSI since the reform announcement (ages 60–62 years).

	Employment I		Employment and partial retirement II		Partial retirement III		Unemployment IV		Labor market exit V		Marginal employment VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.084**	0.104*	0.133**	0.098	**0.049**	**−0.006**	0.017	0.021*	−0.143**	−0.101	−0.008	−0.018
	(0.036)	(0.039)	(0.032)	(0.052)	**(0.035)**	**(0.022)**	(0.014)	(0.008)	(0.032)	(0.051)	(0.008)	(0.014)
Pre-reform mean	0.400	0.431	0.584	0.517	0.185	0.087	0.037	0.039	0.351	0.394	0.027	0.05
N	62,100	59,076	62,100	59,076	62,100	59,076	62,100	59,076	62,100	59,076	62,100	59,076
R^2	0.031	0.063	0.084	0.098	0.035	0.025	0.053	0.043	0.054	0.050	0.014	0.030

Notes: High is defined as PSI with an index value of 8 to 10. Low is defined as PSI with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earning points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that group differences are significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

Appendix D

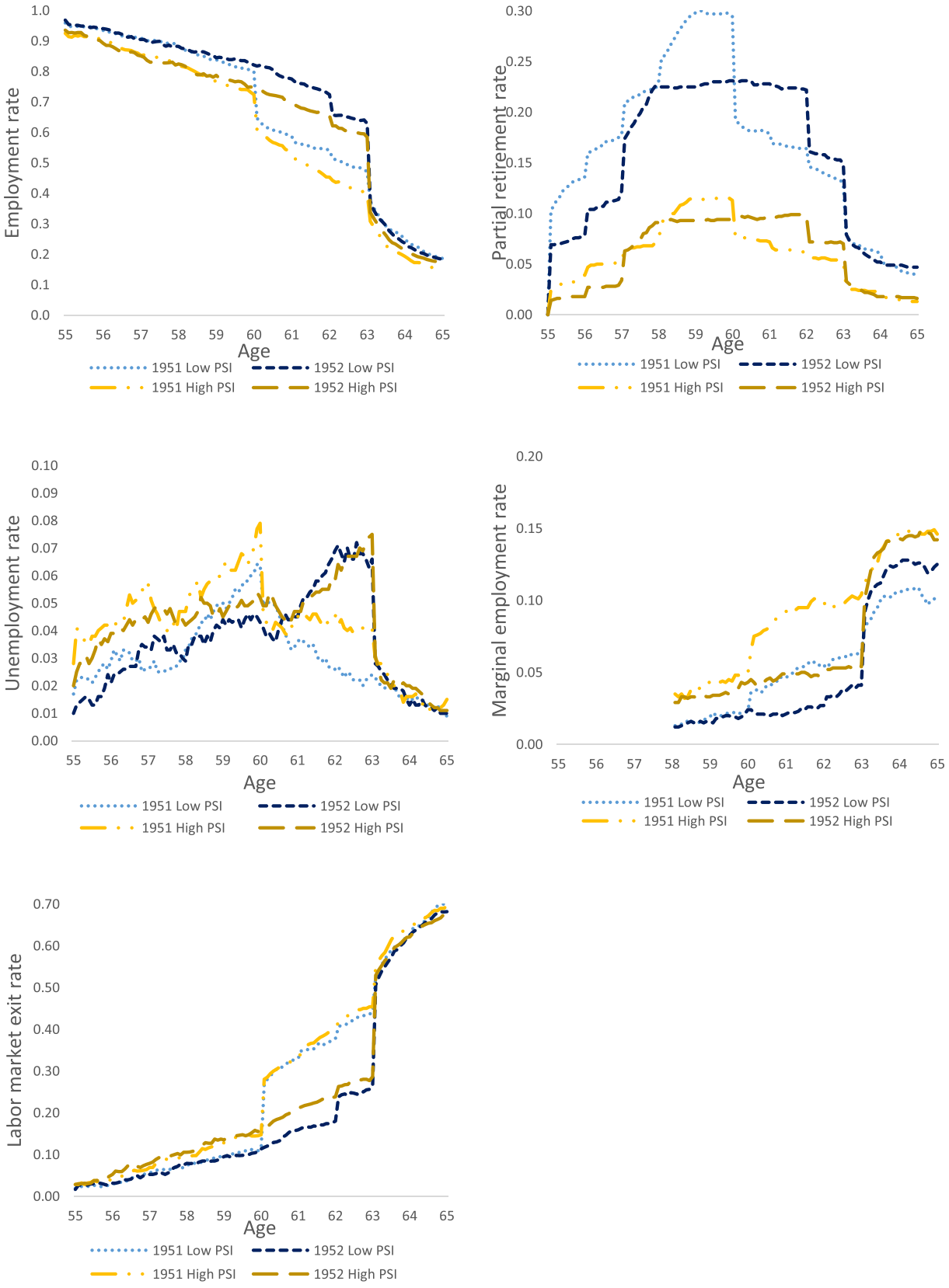


Fig. 2. Labor market status by age, cohort, and PSI Source: SIAB 7517, own calculations.

Table 16
Share of individuals in bridge paths by cohort and PSI group.

	Total		Low PSI		High PSI	
Cohort	Share (%)	*N*	Share (%)	*N*	Share (%)	*N*
1951						
Unemployment as bridge path	19.71	940	16.54	283	24.77	435
Partial retirement as bridge path	20.95	999	30.68	525	11.56	203
1952						
Unemployment as bridge path	19.76	978	18.52	305	23.34	421
Partial retirement as bridge path	16.95	839	23.44	386	10.37	187

Notes: The table shows shares and numbers of observations of bridge paths by cohorts and exposure groups. A bridge path is defined as being in unemployment or partial retirement before exiting the labor market.
Source: SIAB 7517, own calculations.

Table 17
Employment exit age by bridge path, cohort, and PSI group.

	Average employment exit age (years)		Average employment exit age from partial retirement (years)		Average employment exit age from unemployment (years)	
Cohort	1951 Mean (SD)	1952 Mean (SD)	1951 Mean (SD)	1952 Mean (SD)	1951 Mean (SD)	1952 Mean (SD)
Low PSI	61.86	62.46	56.72	56.82	59.13	59.59
	(2.68)	(2.44)	(1.71)	1.61	(2.42)	(2.50)
High PSI	61.53	62.17	57.06	57.46	59.41	59.61
	(2.70)	(2.67)	(1.61)	(1.74)	(2.43)	(2.50)

Notes: Number of observations: low PSI: 3358 in total, 1951 (1711), 1952 (1647); high PSI: 3560 in total, 1951 (1756), 1952 (1804). SD: standard deviation.
Source: SIAB 7517, own calculations.

Table 18
Partial retirement: entry age, duration, and exit age by cohort and PSI group.

	Average entry age in last partial retirement (years)		Average duration in partial retirement (months)		Average partial retirement exit age (years)	
Cohort	1951 Mean (SD)	1952 Mean (SD)	1951 Mean (SD)	1951 Mean (SD)	1952 Mean (SD)	1951 Mean (SD)
Low PJI	57.00	56.84	64.55	76.64	62.05	63.12
	(3.01)	(3.38)	(21.72)	(22.82)	(1.87)	(1.24)
High PJI	57.29	57.59	60.59	68.46	62.05	63.06
	(3.77)	*(3.85)*	*(20.12)*	*(21.37)*	*(1.82)*	*(1.22)*

Notes: Number of observations: low PSI: 3358 in total, 1951 (1711), 1952 (1647); high PSI: 3560 in total, 1951 (1756), 1952 (1804). SD: standard deviation.
Source: SIAB 7517, own calculations.

Table 19
Unemployment: entry age, duration, and exit age by cohort and PSI group.

	Average entry age in last unemployment (years)		Average duration in unemployment (months)		Average unemployment exit age (years)	
Cohort	1951 Mean (SD)	1952 Mean (SD)	1951 Mean (SD)	1952 Mean (SD)	1951 Mean (SD)	1952 Mean (SD)
Low PJI	59.72	60.56	20.04	19.77	61.01	61.72
	(2.22)	(2.22)	(10.62)	(13.11)	(2.18)	(2.29)
High PJI	59.95	60.28	16.94	17.62	60.90	61.28
	(2.24)	(2.37)	(10.53)	(11.50)	(2.30)	(2.40)

Notes: Number of observations: low PSI: 3358 in total, 1951 (1711), 1952 (1647); high PSI: 3560 in total, 1951 (1756), 1952 (1804). SD: standard deviation.
Source: SIAB 7517, own calculations.

Appendix E

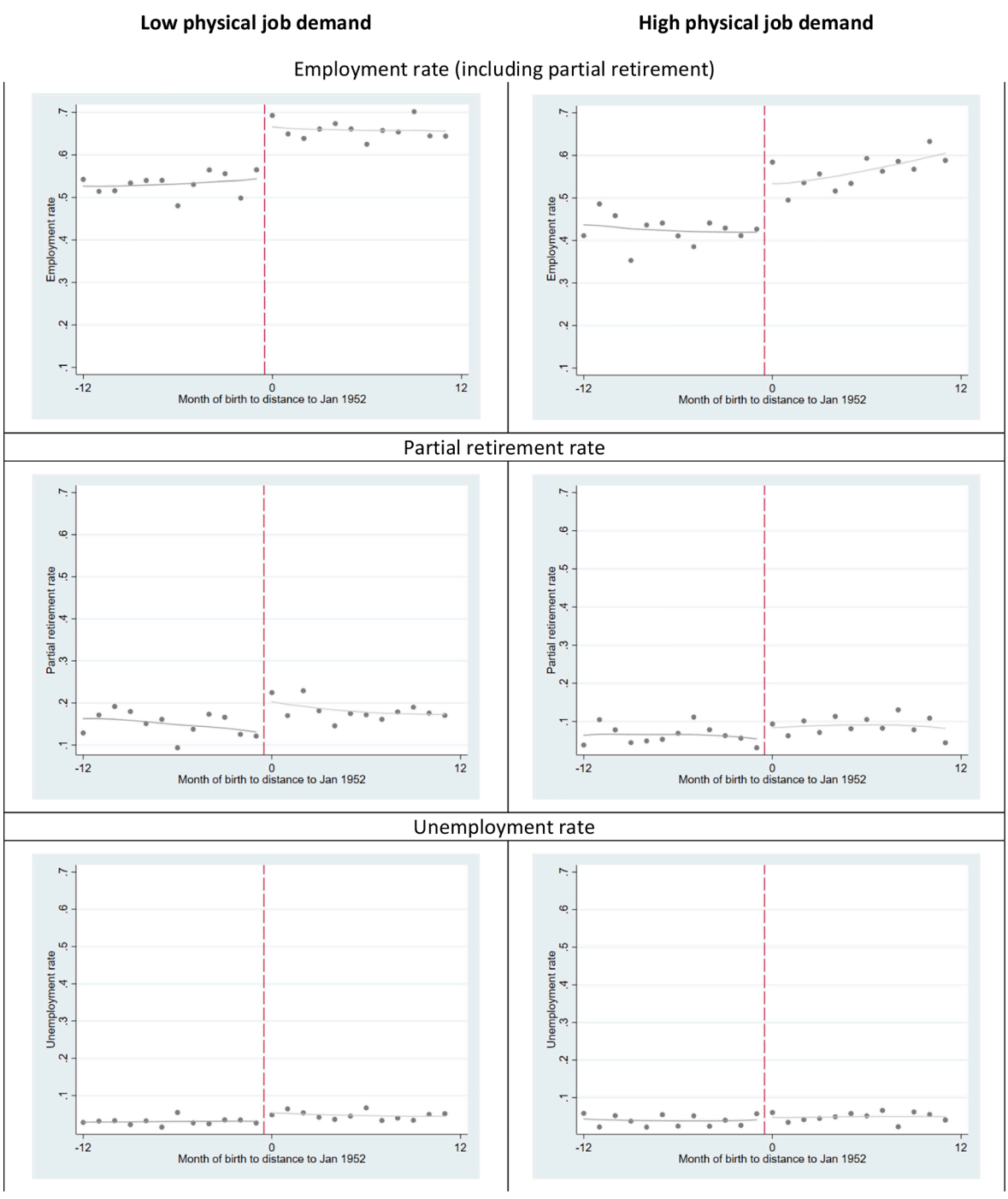
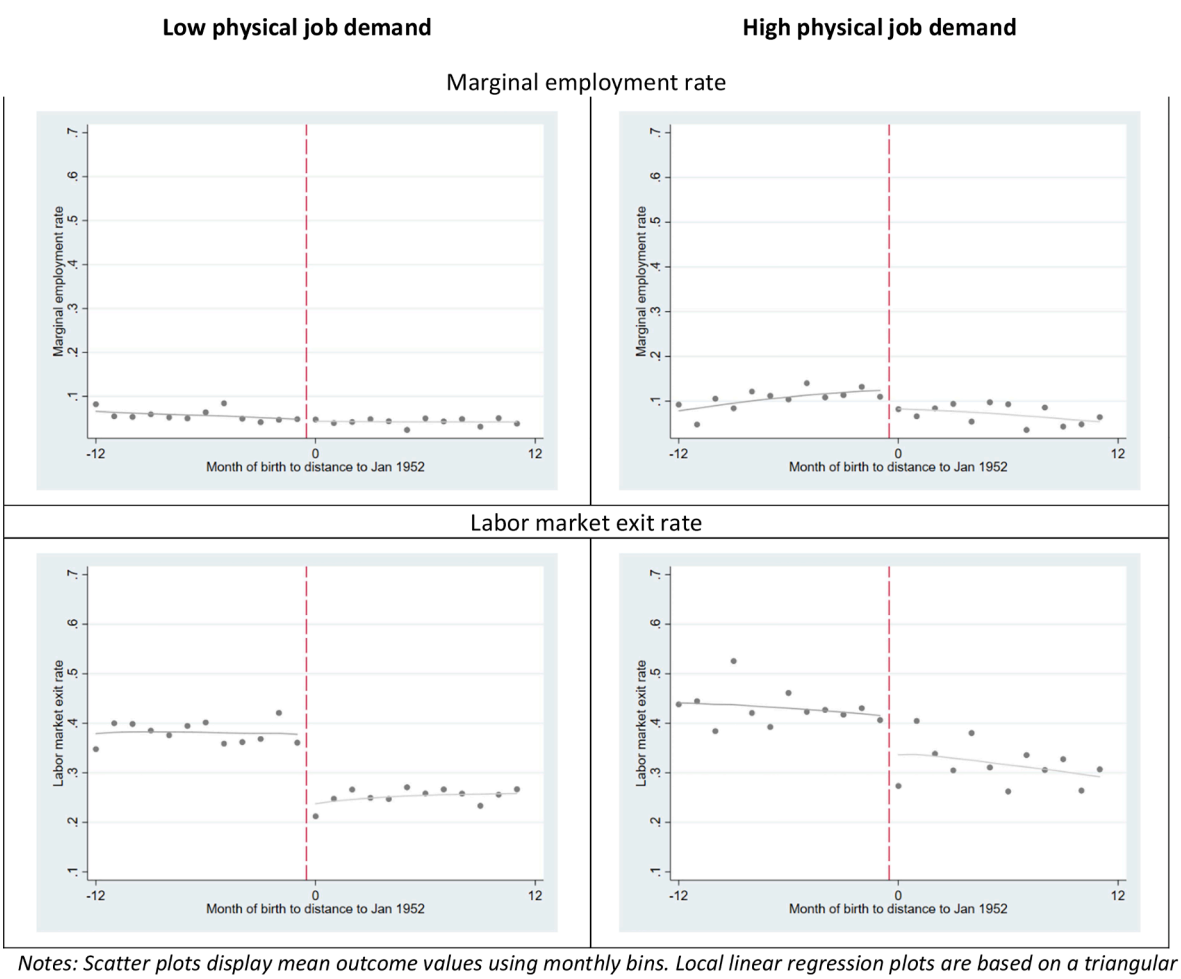


Fig. 3. Local linear regression plots between low and high PJI Notes: Scatter plots display mean outcome values using monthly bins. Local linear regression plots are based on a triangular kernel function with a bandwidth of 12 months. Source: SIAB 7517, own calculations.



Notes: Scatter plots display mean outcome values using monthly bins. Local linear regression plots are based on a triangular kernel function with a bandwidth of 12 months.
Source: SIAB 7517, own calculations.

Fig. 3. (*continued*).

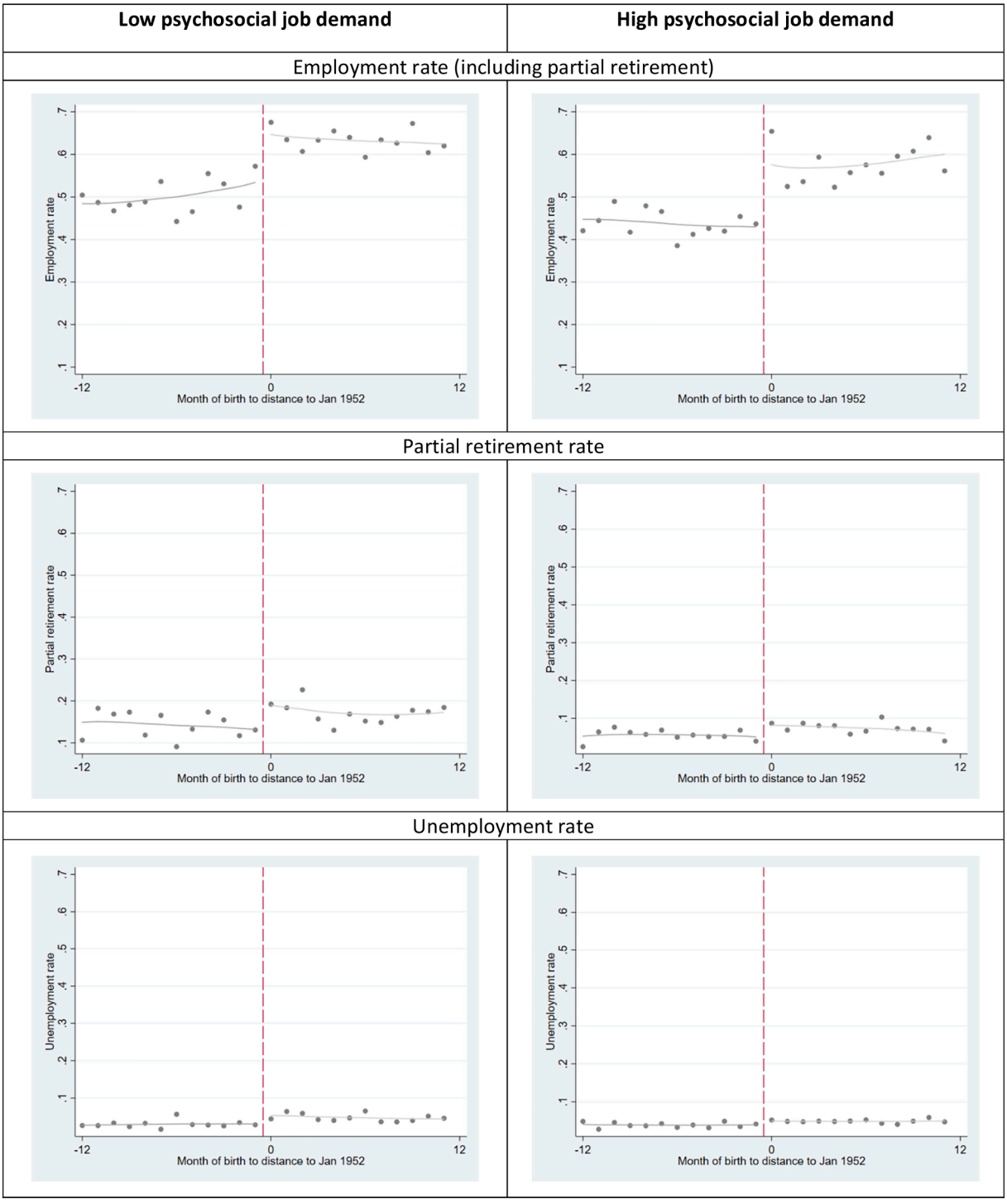
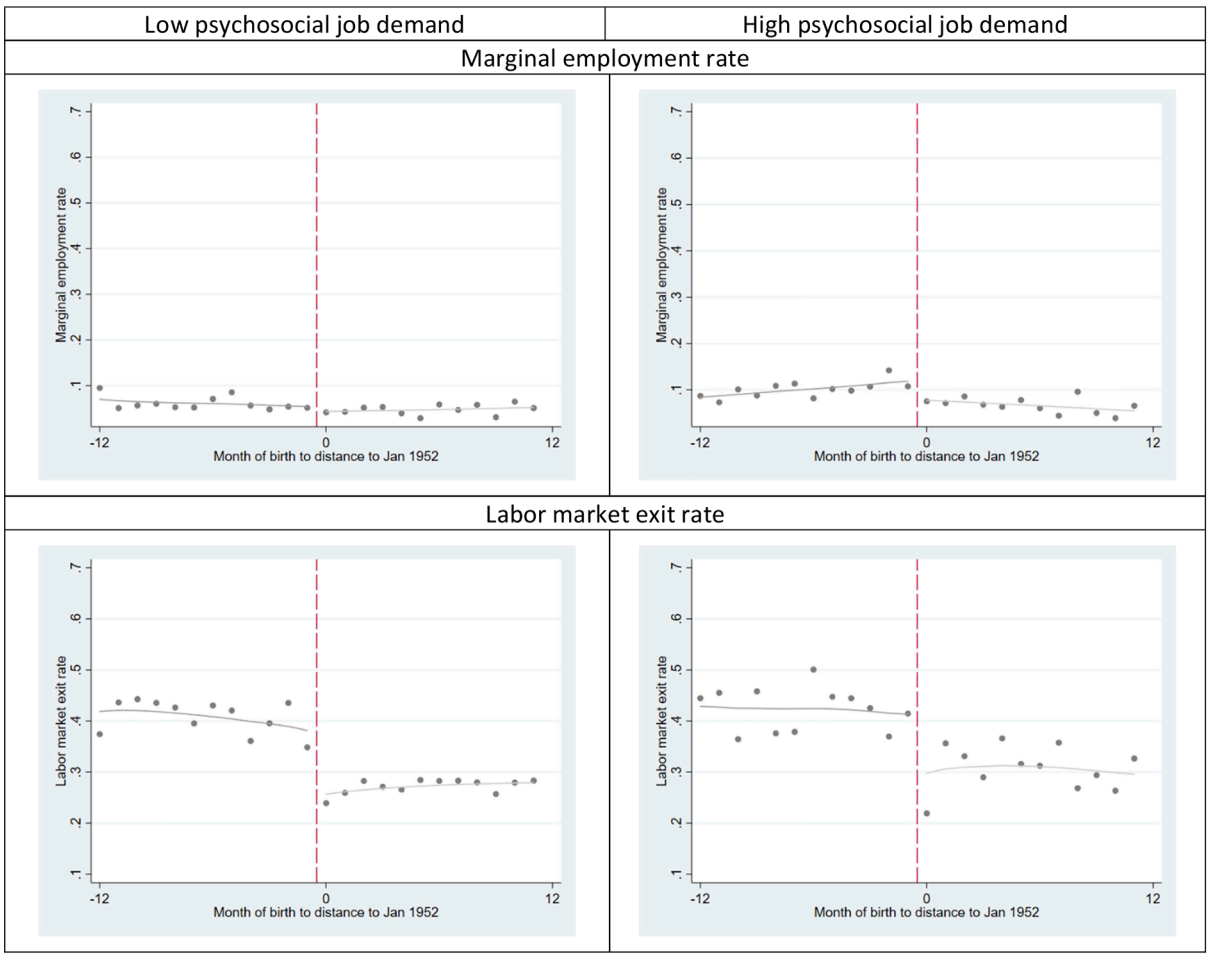


Fig. 4. Local linear regression plots between low and high PSI Notes: Scatter plots display mean outcome values using monthly bins. Local linear regression plots are based on a triangular kernel function with a bandwidth of 12 months. Source: SIAB 7517, own calculations.



Notes: Scatter plots display mean outcome values using monthly bins. Local linear regression plots are based on a triangular kernel function with a bandwidth of 12 months.
Source: SIAB 7517, own calculations.

Fig. 4. (*continued*).

Appendix F

Table 20
Linear regression results with a bandwidth of 6 months for employees by PJI (ages 60–62 years).

	Employment I		Employment and partial retirement II		Partial retirement III		Unemployment IV		Labor market exit V		Marginal employment VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.104**	0.131**	0.153**	0.151**	**0.049**	**0.020**	0.042**	0.008	−0.192**	−0.111	**−0.004**	**−0.048****
	(0.029)	(0.034)	(0.018)	(0.046)	**(0.029)**	**(0.019)**	(0.012)	(0.022)	(0.014)	(0.063)	**(0.006)**	**(0.012)**
Pre-reform mean	0.406	0.420	0.601	0.496	0.195	0.076	0.029	0.044	0.323	0.378	0.047	0.082
N	75,492	38,484	75,492	38,484	75,492	38,484	75,492	38,484	75,492	38,484	75,492	38,484
R^2	0.025	0.035	0.067	0.071	0.021	0.065	0.033	0.018	0.056	0.037	0.013	0.026

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

Table 21
Linear regression results with a bandwidth of 6 months for employees by PSI (ages 60–62 years).

	Employment		Employment and partial retirement		Partial retirement		Unemployment		Labor market exit		Marginal employment	
	I		II		III		IV		V		VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.111*	0.140*	0.159**	0.142*	**0.048**	**0.001**	0.036**	0.016	−0.195**	−0.106	**−0.000007**	**−0.051****
	(0.043)	(0.049)	(0.023)	(0.052)	**(0.028)**	**(0.013)**	(0.012)	(0.009)	(0.021)	(0.052)	**(0.008)**	**(0.006)**
Pre-reform mean	0.381	0.447	0.563	0.518	0.181	0.071	0.030	0.045	0.357	0.351	0.050	0.086
N	62,604	67,968	62,604	67,968	62,604	67,968	62,604	67,968	62,604	67,968	62,604	67,968
R^2	0.031	0.035	0.079	0.075	0.034	0.040	0.046	0.029	0.062	0.039	0.015	0.023

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earning points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01. Source: SIAB 7517, own calculations.

Table 22
Placebo reform with treated cohort for employees by PJI (ages 60–62 years).

	Employment		Employment and partial retirement		Partial retirement		Unemployment		Labor market exit		Marginal employment	
	I		II		III		IV		V		VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.009	0.013	0.0006	0.034	−0.008	0.021	−0.006	0.008	−0.0006	−0.023	0.006	−0.020
	(0.030)	(0.041)	(0.021)	(0.044)	(0.019)	(0.021)	(0.005)	(0.011)	(0.022)	(0.044)	(0.009)	(0.021)
Pre-reform mean	0.375	0.396	0.568	0.480	0.192	0.085	0.034	0.038	0.346	0.397	0.053	0.085
N	143,604	70,200	143,604	70,200	143,604	70,200	143,604	70,200	143,604	70,200	143,604	70,200
R^2	0.014	0.031	0.037	0.045	0.021	0.038	0.028	0.019	0.026	0.026	0.008	0.012

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01. Source: SIAB 7517, own calculations.

Table 23
Placebo reform with treated 1951 cohort for employees by PSI (ages 60–62 years).

	Employment		Employment and partial retirement		Partial retirement		Unemployment		Labor market exit		Marginal employment	
	I		II		III		IV		V		VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	0.014	−0.011	−0.003	−0.007	−0.017	0.004	−0.006	0.002	0.004	0.012	0.005	−0.007
	(0.032)	(0.023)	(0.025)	(0.026)	(0.020)	(0.015)	(0.005)	(0.008)	(0.027)	(0.030)	(0.011)	(0.013)
Pre-reform mean	0.341	0.424	0.523	0.501	0.182	0.077	0.035	0.045	0.383	0.375	0.059	0.078
N	121,932	124,632	121,932	124,632	121,932	124,632	121,932	124,632	121,932	124,632	121,932	124,632
R^2	0.018	0.030	0.048	0.052	0.031	0.024	0.041	0.029	0.030	0.027	0.010	0.014

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earning points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01. Source: SIAB 7517, own calculations.

Appendix G

Table 24
Linear regression results for employees by PJI (sample ineligible for pension for women; ages 60–62 years).

	Employment		Employment and partial retirement		Partial retirement		Unemployment		Labor market exit		Marginal employment	
	I		II		III		IV		V		VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	−0.188	−0.227	−0.176	−0.230	0.012	−0.002	0.057	0.049	0.024	0.224	0.095	−0.044
	(0.114)	(0.140)	(0.106)	(0.140)	(0.040)	(0.003)	(0.028)	(0.035)	(0.095)	(0.167)	(0.068)	(0.064)
Pre-reform mean	0.688	0.533	0.734	0.533	0.050	0	0.046	0.027	0.159	0.320	0.119	0.057
N	6768	7992	6768	7992	6768	7992	6768	7992	6768	7992	6768	7992
R^2	0.030	0.116	0.041	0.123	0.032	0.015	0.026	0.028	0.021	0.070	0.015	0.022

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01. Source: SIAB 7517, own calculations.

Table 25
Linear regression results for employees by PSI (sample ineligible for pension for women; ages 60–62 years).

	Employment I		Employment and partial retirement II		Partial retirement III		Unemployment IV		Labor market exit V		Marginal employment VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Treatment	−0.159	0.0008	−0.140	−0.027	0.019	−0.028	0.027	0.034	−0.019	0.031	**0.132**	**−0.038**
	(0.143)	(0.088)	(0.135)	(0.103)	(0.051)	(0.026)	(0.047)	(0.029)	(0.117)	(0.112)	**(0.080)**	**(0.047)**
Pre-reform mean	0.636	0.517	0.695	0.533	0.059	0.016	0.068	0.029	0.164	0.317	**0.073**	**0.121**
N	5580	12,924	5580	12,924	5580	12,924	5580	12,924	5580	12,924	5580	12,924
R^2	0.051	0.070	0.068	0.077	0.031	0.016	0.069	0.025	0.019	0.053	0.021	0.014

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for monthly age fixed effects, the sum of earning points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. The coefficients in bold mean that the job demand types are at least significantly different at the 5% level. The pre-reform mean is calculated for the 1951 cohort. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

Appendix H

Table 26
Local linear regression results based on triangular kernel functions with a bandwidth of 12 months for employees with low and high job demand: physical job demand index PJI (ages 60–62 years).

Bandwidth	Employment I		Employment and partial retirement II		Partial retirement III		Unemployment IV		Labor market exit V		Marginal employment VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
12 months	0.024	0.069**	0.109**	0.123**	0.120**	0.056**	0.026*	0.009	−0.106**	−0.112*	−0.017**	−0.01
	(0.023)	(0.022)	(0.024)	(0.029)	(0.022)	(0.015)	(0.012)	(0.017)	(0.004)	(0.045)	(0.0008)	(0.01)
N	147,132	72,792	147,132	72,792	147,132	72,792	147,132	72,792	147,132	72,792	147,132	72.792

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for the sum of earnings points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

Table 27
Local linear regression results based on triangular kernel functions with a bandwidth of 12 months for employees with low and high job demand: psychosocial job demand index PSI (ages 60–62 years).

Bandwidth	Employment I		Employment and partial retirement II		Partial retirement III		Unemployment IV		Labor market exit V		Marginal employment VI	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
12 months	0.034	0.121**	0.051*	0.174**	0.066**	0.077**	0.015	0.018**	−0.033**	−0.161**	−0.018**	0.008
	(0.031)	(0.040)	(0.024)	(0.046)	(0.014)	(0.005)	(0.011)	(0.001)	(0.0008)	(0.053)	(0.001)	(0.006)
N	120,888	128,160	120,888	128,160	120,888	128.160	120.888	128.160	120.888	128.160	120.888	128.160

Notes: High is defined as job demand with an index value of 8 to 10. Low is defined as job demand with an index value of 1 to 3. We control for the sum of earning points at the age of 58 years, and education. Robust standard errors in parentheses are clustered by birth month. *p < 0.05, **p < 0.01.
Source: SIAB 7517, own calculations.

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