Statutory Ages as Reference Points for Retirement: Evidence from Germany

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Abstract

This paper presents evidence that statutory age thresholds such as the Early and the Normal Retirement Age serve as reference points for workers retirement decisions, using novel administrative data covering the universe of German retirees. The analysis begins by documenting the very large bunching mass and observed elasticities at kinks in the lifetime budget constraint linked to statutory ages, while bunching at other budget constraint discontinuities is much more modest. Reduced-form estimation suggests an average retirement age elasticity between 0.1 and 0.3, and large and significant "statutory age effects" that occur independently of financial incentives. Further evidence on mechanisms indicates that the reduced-form findings cannot be explained by firm responses or informational issues. Finally, a model of retirement with reference-dependent preferences is employed to rationalize the observed patterns. Structural estimation of the model attributes between 50% and 80% of statutory age retirements to reference point effects.

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1 Introduction

In the light of rising expenditure of public pension programs across the developed world,[1] the timing of retirement is an important dimension of labor supply and it is crucial to understand how it responds to features of the pension system. In most public pension systems, retirement incentives are framed around statutory age thresholds such as an Early Retirement Age (ERA) or a Normal Retirement Age (NRA). These thresholds usually define a retirement age from which a certain type of pension can be claimed, or ages based on which some financial adjustment of pensions is calculated. In standard models of retirement where workers maximize utility subject to a lifetime budget constraint, there is no role for such statutory thresholds beyond their implicit effect through the budget constraint. However, the presence of large spikes in benefit claiming and job exits at statutory age thresholds is a well-documented empirical pattern that this view fails to explain (Lumsdaine et al. 1996; Mastrobuoni 2009; Behaghel and Blau 2012; Cribb et al. 2016). Figure 1 shows the distribution of job exit ages of German workers born between 1932 and 1949, confirming this observation. There are large spikes in job exits at the ages 60, 63 and 65 that coincide with the main statutory ages faced by these workers.[2] This translates into a large fraction of 29% of workers exiting their jobs at age 55 and above who bunch at a statutory age.

This paper presents evidence that retirement bunching at statutory ages cannot be explained by responses to financial incentives, and argues that these thresholds serve as reference point for workers' retirement decisions. There is a growing body of work casting doubt on the assumptions of standard retirement models, including survey evidence on the effect of framing on reported retirement plans (Brown et al. 2013; Merkle et al. 2016), but existing evidence on the determinants of retirement decisions is somewhat inconclusive. In particular, the results from this paper may be able to reconcile the results from studies that find modest responses of retirement to financial incentives (Brown 2013; Manoli and Weber 2014) with those finding large and sharp responses to statutory age reforms (Mastrobuoni 2009; Manoli and Weber 2016; Staubli and Zweimüller 2013; Lalive and Staubli 2015).

To estimate the impact of statutory age thresholds, I adopt a bunching approach and propose methods to estimate additional parameters in a setting with many bunching observations. The main result are large differences in bunching between thresholds framed as statutory ages and those framed as "pure" incentives. This highlights the need for caution in interpreting bunching at a single threshold as indicative of "structural" elasticities pointed out in the recent bunching literature (Kleven 2016). However, most existing studies focus on frictions as a source of attenuation (Kleven and Waseem 2013, Gelber et al. 2015). This paper, in contrast, argues that bunching can overstate responses to incentives when reference point effects are taken into account.

The empirical analysis is situated in the context of the German public pension system. Germany

[1] OECD countries spend just below 8% of GDP on public pensions on average (2011). In Germany, pensions are already the single largest item of public spending at €239 billion annually (2014), representing 8% of GDP and 19% of total public expenditure.

[2] Note that different statutory ages apply to workers in Germany depending on their birth cohort and characteristics such as gender and contribution histories.

has a Bismarckian, pay-as-you-go system with defined benefits. There are three types of statutory ages, the Early Retirement Age (ERA), Normal Retirement Age (NRA), and the Regular Retirement Age (RRA). The empirical setting has several advantages. First, it is a large-scale public system covering all employees in Germany. Second, incentives are relatively unconfounded since public pensions are the main source of income for most retirees. Third, few pensioners work while receiving a pension, making retirement an absorbing state for most. Fourth, the setting provides ample cross-sectional and cohort-series variation in statutory ages. Throughout the sample, there are six pathways into retirement that differ in statutory ages. In addition, a number of gradually phased in pension reforms changed ERAs and NRAs for different birth cohorts in different pathways. Statutory ages play several important roles in the pension system. First, benefit eligibility depends directly on statutory ages, where a full pension level is defined at the NRA and pensions are adjusted around this level depending on a worker's retirement age. Second, there is an important role of statutory ages in the framing of pensions. There is gain-loss framing of pensions relative to statutory ages, and they are linked to notions such as "normal" retirement. Moreover, pathways and reforms are generally framed as variation in statutory ages rather than variation in pension levels. Finally, statutory ages can play a role in the termination of labor supply contracts. Contracts can be designed to end at the RRA which may offer firms an opportunity to circumvent employment protection through mandatory retirement.

Pensions are roughly proportional to workers' lifetime earnings, but due to a discontinuous benefit adjustment schedule, workers face kinks in the lifetime budget constraint at statutory ages. Moreover, a key advantage of the German setting is the presence of other discontinuities in the lifetime budget constraint. These arise from two sources. First, contribution requirements of different pathways create notches, i.e. jumps in pension wealth at these thresholds. Second, the invalidity pathway into retirement does not feature statutory ages, but benefits are also discontinuously adjusted implying kinks in the budget constraint.

The analysis is based on a novel set of administrative data from the German State Pension Fund covering the universe of workers who retired between 1992 and 2014. The data includes a rich set of worker characteristics related to earnings careers and pension eligibility, based on which monthly job exits and individual lifetime budget constraints are calculated. Focusing on cohorts 1932 to 1949, the main sample contains more than ten million individuals. Workers are then assigned to 375 groups facing distinct sets of statutory ages and budget constraints, yielding 644 discontinuities where bunching can be estimated.

The first step of the empirical methodology is to estimate excess retirements at each budget constraint discontinuity via the bunching method. To illustrate the variation, the reduced-form analysis begins by presenting some cases of bunching at specific thresholds. In particular, I focus on two comparisons. First, the same group of workers in the women's pathway is shown to respond much more to a statutory age kink than to a discontinuity in pure financial incentives. Second, workers in two similar pathways respond much more at a statutory age than at a similar budget constraint kink not linked to a statutory age. The same patterns emerge when comparing bunching across all available discontinuities. At all types of statutory ages, bunching occurs somewhat irrespectively of the size of the budget constraint kink. Large excess mass is even observed at non-convex kinks linked to a statutory age. The average observed retirement age elasticity across the 387 statutory age kinks is 1.64, which is two orders of magnitude above estimates from previous studies. Across all 258 non-statutory age discontinuities in the data, the average observed elasticity is only 0.15, less than a tenth of the estimate at statutory age kinks. Moreover, the pattern of much larger responses at statutory age discontinuities holds across all retirement pathways, birth cohorts, and retirement ages. Subsequently, I investigate whether the large differences in bunching between statutory ages and other discontinuities can be explained by other observable factors. First, differences in financial incentives have large explanatory power among non-statutory age discontinuities, but do not seem to explain the observed patterns at statutory ages where there is large bunching at statutory ages irrespectively of underlying incentives. Second, while differences in group-level observables can rationalize some heterogeneity in bunching, large additional bunching persists in each quintile of worker and occupation-level characteristics. A regression of observed elasticities on these characteristics and fixed effects as well as statutory age indicators shows that most of the dispersion in elasticities is indeed explained by the presence of statutory ages rather than observable or unobservable differences across workers.

The second step of the empirical methodology is to estimate additional parameters by combining bunching observations, which requires an assumption that bunching is driven by the same underlying parameters. Specifically, the analysis aims first at estimating a reduced-form "statutory age effect", which structural estimation relates to reference dependence later in the analysis. Hence, I propose a reduced-form estimation strategy to assess the quantitative importance of statutory age effects. Intuitively, the method identifies the elasticity from differences in excess mass across budget set kinks of different size, while regression intercepts allow for additional bunching at statutory ages irrespective of the size of the discontinuity. The implied average elasticity is between 0.1 and 0.3 and statutory age effects are large and significant. Results are shown to be robust to controlling for a range of observables and fixed effects. Furthermore, when relaxing the assumption of homogeneous elasticities in a specification with heterogeneous coefficients along different dimensions, results remain very similar.

Next, I investigate mechanisms underlying the reduced-form statutory age effect. To begin with, firm responses are addressed as the main alternative to worker behavior. I show that there is large bunching at statutory ages among two groups of workers where firm responses should not play a role, namely self-employed and employees in very small firms where employment protection does not apply. Furthermore, the main results are shown to hold when excluding all statutory ages where firm-induced mandatory retirement potentially plays a role. Finally, statutory age retirements are only weakly associated with a number of variables proxying for firm incentives including firm size, unionization, and labor market tightness. Three pieces of evidence indicate that statutory ages may serve as reference points for workers. First, most workers exiting their jobs at statutory ages claim benefits immediately, indicating that they wish to retire at those ages. There are even claiming spikes at statutory ages among workers exiting their job at other ages. Second, the fraction bunching at statutory ages decreases substantially during reform transition periods which is consistent with a notion of less intensive reference points, but inconsistent with firm incentives. Third, ERA and NRA retirements are associated with worker characteristics very similar to those at other reference points, namely round ages. In particular, ERA/NRA bunchers as well as round number bunchers are less educated than other workers retiring in the same age range. Finally, I argue that the observed patterns cannot be explained by a number of alternative channels, including salience and information, default options, liquidity constraints, and health insurance.

Having ruled out the main alternative channels, the last part of the paper turns to a more structural interpretation of the reduced-form effects in terms of reference points. To do so, I set up a simple model of retirement decisions that predicts bunching at discontinuities in the implicit marginal net-of-tax rate analogous to a standard labor supply model. I then incorporate two simple versions of reference dependence into the model. In the first version, marginal utility from lifetime consumption changes discontinuously at a reference point given by the consumption level at a retirement age threshold. In the second version, marginal disutility from continuing work changes at the threshold. Both of these types of reference dependence are consistent with the loss aversion property from prospect theory, where loss aversion occurs either in the domain of consumption or labor supply/leisure. The model predicts that both types lead to bunching at the threshold, where the amount of bunching can be related to the utility parameters governing the strength of loss aversion. Since statutory ages are typically linked to a change in pension benefits, bunching responses to a combination of a budget set discontinuity and a reference point are analyzed next. At such a combined threshold, work/leisure reference points are shown to exacerbate bunching from the right, while consumption reference points lead to additional bunching from the left.

Finally, I estimate the bunching relationships implied by the theoretical framework. This structural estimation produces large and significant upper bounds on the utility parameters related to reference dependence in consumption and leisure. Moreover, structural elasticity estimates are similar to the reduced form results at around 0.15. In order to obtain point estimates of the parameters of interest, I further exploit the relative density on both sides of statutory age thresholds. Results indicate that bunching at the ERA occurs from the left and is mainly driven by consumption reference points, RRA bunching is driven by work/leisure reference points and occurs from the right, and NRA bunching seems to be driven by a mix both types. The estimates are then used to simulate bunching at statutory ages under a counterfactual scenario where workers only respond to financial incentives. Across a range of assumptions, only 5% to 16% of all job exits are predicted to occur at statutory ages, implying that 50% to 80% of actual statutory age retirements in the data are attributed to reference points.

This paper relates to several literatures. First, it contributes to the recent empirical literature on retirement. Brown (2013) and Manoli and Weber (2014) investigate the responsiveness of retirement decisions to pure financial incentives and find very small elasticities. Those two papers come closest to this study in terms of the bunching methods used. There are several studies of statutory age reforms (Mastrobuoni 2009; Manoli and Weber 2016; Staubli and Zweimüller 2013; Lalive and Staubli 2015; Cribb et al. 2016) that find large effects on retirement behavior. Other recent evidence from the U.S. includes Goda et al. (2015) and Fetter and Lockwood (2016). Moreover, some studies consider non-standard retirement decisions. In particular, the conjecture by Behaghel and Blau (2012) that workers are loss averse relative to the Full Retirement Age in the U.S. is closely related to the arguments presented in this paper, and Brown et al. (2013) and Merkle et al. (2016) find survey evidence of framing effects and loss aversion around statutory ages. Mastrobuoni (2011) suggests information issues as a potential explanation for benefit claiming spikes at statutory ages. A considerable literature has also found inaccurate perceptions of pension provisions (e.g. Liebman and Luttmer 2012; Liebman and Luttmer 2015; Brown et al. 2016). Brown and Laschever (2012) and Chalmers et al. (2008) investigate the role of peer effects for retirement.

Second, this paper contributes to the bunching literature (Saez 2010; Chetty et al. 2011; Kleven 2016). Initially, bunching was used to estimate an elasticity at a budget set discontinuity, but recent studies have moved towards using additional bunching moments to estimate additional parameters. For instance, Kleven and Waseem (2013) estimate elasticities and the share of individuals subject to frictions at notches. Gelber et al. (2015) develop a difference-in-bunching approach to estimate an elasticity and an adjustment cost parameter. The methods used in this paper build on these approaches and extend them to a case where many discontinuities are available. Furthermore, I incorporate reference dependence in a bunching model and, in contrast to previous work, I use bunching methods to estimate parameters that exacerbate bunching.

Third, the paper contributes to the literature on the role of reference points in field settings. Despite its prominence in behavioral models such as prospect theory (Kahneman and Tversky 1979), there are relatively few studies on the impact of reference dependence in large-scale field settings (Barberis 2013). Rees-Jones (2014) and DellaVigna et al. (2016) demonstrate loss aversion among tax filers and job seekers, respectively, and Allen et al. (2016) show that round numbers serve as reference points for marathon runners. This paper adds a new important context by measuring reference point effects in retirement decisions. Moreover, while existing studies focus on reference points not linked to any incentives such as the status quo and round numbers, the results of this paper suggest that statutory thresholds set by policy as part of an incentive scheme can serve as reference points.

The remainder of this paper is organized as follows. Section 2 outlines the empirical context and the data, section 3 describes the empirical strategy, section 4 presents reduced-form evidence, section 5 investigates mechanisms behind the statutory age effect, section 6 develops the conceptual framework, section 7 presents the structural estimation, and finally, section 8 concludes.

2 Context and Data

2.1 The German Public Pension System

In Germany, the public pension system[3] covers the vast majority of workers in the country (86% of the labor force in 2014). Enrolment is mandatory for private-sector employees, but most self-employed workers and civil servants are exempt. Contributions are levied as a payroll tax on gross earnings.[4] Benefits are defined according to a pension formula based on lifetime contributions. Specifically, one point is credited to a worker for contributing at the average earnings for a year, and points are then summed across the individual's entire contribution history.[5] Hence, pensions are roughly proportional to lifetime income and the system is characterized by relatively little redistribution. The average replacement rate is 50% (OECD 2015).

Public pensions are the main source of income for most recipients. In 2003, 11% of retirees reported to receive any income from employer pension schemes and only 1% had a private pension, and the average income from those sources is small relative to public pensions.[6] There is a relatively strict earnings test for pension recipients where earnings above €450 per month lead to reductions in benefit payments. Only 2.5% of workers have any income from employment while receiving a pension, making retirement an absorbing state for most.[7]

The system features three types of statutory age thresholds. First, the *Early Retirement Age (ERA)* is the earliest age from which any pension can be claimed. Second, the *Normal Retirement Age (NRA)* is the earliest age from which workers can claim their *full pension*. Third, the *Regular Retirement Age (RRA)* is the age from which workers can get more than their full pension. There is a large amount of variation in the location of statutory ages across workers as they differ across retirement pathways and birth cohorts.

There are six pathways into retirement[8], differing in their ERA and NRA, and workers need to meet specific requirements to be eligible. In order to enter a more generous pathway in terms of earlier ERA or NRA, workers must have contributed for longer and/or satisfy other requirements such as disability. Pathways are summarized in table 1 and appendix B provides additional details. The basic pathway is the regular pension that requires only 5 years of contributions. However, early retirement is not possible in the regular pathway and the full pension can only be claimed at the RRA. Workers with at least 35 years of contributions are eligible for the long-term insured pathway that has an ERA of 63. Women with at least 15 years of contributions can retire in the women's

[3]see Börsch-Supan and Schnabel (1999) and Börsch-Supan and Wilke (2004) for a more comprehensive overview

[4]Workers in so-called mini jobs with earnings less than €450 are exempt from contributions. Besides, contributions have to be paid for some non-work periods such as receiving certain types of unemployment benefits.

[5]See Appendix B for additional details of the institutional setting, including benefit calculation.

[6]See Heien et al. (2005). Among retirees with any employer pension income, the employer pension amounts to 34% of their public pension on average. The corresponding figure for private pensions is 23%. The numbers seem to increase somewhat for younger cohorts, but remain small throughout the sample period.

[7]Figure from own sample. Note that this does not include income from self-employment which is not subject to contributions.

[8]In 2012, the pension for very long-term insured was introduced as the seventh pathway, but is not used in this paper.

pathway with an ERA of 60. Workers with at least 15 years of contributions who were unemployed or in old-age part-time work for some time after age 58 are also eligible for special pathway where the ERA is 63. If workers with at least 35 years of contributions additionally have an attested disability of a certain degree, they can enter the disabled pathway with ERA 60 and NRA 63. Finally, there is the invalidity pathway for workers with a relatively low contribution requirement of only 5 years, but a stricter disability requirement. Invalidity pensions can be claimed at any age, and no ERA and NRA are defined for this pathway.[9]

In addition, a series of pension reforms have been enacted since the early 1990s. Panels A and B of figure 3 show the evolution of ERAs and NRAs, respectively, for birth cohorts 1932 to 1949. ERAs differ substantially across pathways, but the only notable reform was an increase from 60 to 63 in the unemployed/part-time pathway for cohorts 1946 to 1948.[10] This was done gradually: the ERA increases by one month for each month of birth in the reform cohort window. NRAs, on the other hand, were changed considerably. The NRA was gradually increased from 63 to 65 for cohorts 1937 to 1938 in the long-term insured pathway, in the women's pathway from 60 to 65 for cohorts 1940 to 1944, in the unemployed/part-time pathway from 60 to 65 for cohorts 1937 to 1941, and in the disabled pathway from 60 to 63 for cohorts 1941 to 1943.

2.2 The Role of Statutory Age Thresholds

Link to Pension Benefits. Benefit eligibility directly depends on statutory ages in all pathways except invalidity pensions. A full pension level is defined at the NRA, and there are permanent reductions in benefits for workers claiming before the NRA as well as permanent increases in benefits for claiming after the RRA. The adjustment function follows a kinked schedule, with a penalty of 0.3% for each month of retirement before the NRA, no adjustment between the NRA and the RRA, and a reward of 0.5% for each month of retirement after the RRA. Section 2.3 explains how this translates into budget constraint discontinuities.

Framing of Benefits and Retirement. Moreover, statutory age thresholds play an important role for how benefits and retirement are presented to workers. Varying the framing of benefits and retirement has been shown to affect reported retirement plans in lab settings (e.g. Brown et al. 2013, Merkle et al. 2016). In the German context, pensions are arguably framed in terms of statutory ages in several ways. First, pension adjustment for early retirement is framed as a loss relative to a "full pension" linked to the NRA, while adjustment for late retirement is framed as a gain. Second, linking statutory ages to notions such as "normal" and "regular" retirement may contribute to expectations regarding levels of consumption as well as lifetime leisure at statutory ages. Third, while different pathways effectively entail different benefit levels for any given retirement age, it was chosen to frame the distinction between pathways via different statutory ages

[9] Moreover, contribution points are credited to invalidity pensioners as if they had continued working until age 60, making benefits less dependent on their contribution history.

[10] Besides, the ERA for cohorts 1948 onwards in the regular pathway increases slowly since it coincides with the RRA.

rather than directly in terms of benefit levels. This logic originates from German Social Law[11], where each pathway is defined in terms of its statutory ages, and pension adjustment based on statutory ages is defined in a separate section. Fourth, major pension reforms are equally framed as changes to statutory ages rather than the changes to benefit levels that they effectively entail.

Labor Supply Contracts. Private-sector contracts do not end automatically at any statutory age. However, mandatory retirement clauses linked to workers' RRA can be specified in the collective industry agreement or in individual contracts. This is often cited as a way for firms to avoid high costs of firing of older workers.[12] Importantly, there is no possibility for mandatory retirement clauses linked to the ERA or NRA. Individual agreements between the worker and the firm to terminate a contract at the ERA/NRA can be added to the contract no earlier than three years before the desired time of job exit, but similar agreements can also be made in reference to other dates.

2.3 Lifetime Budget Constraint Discontinuities

In order to see how the pension system affects incentives for the timing of retirement, a lifetime budget constraint can be written as

$$C_i = \sum_{t=0}^{R_i-1} \delta^t w_{it}(1-\tau^p_{it}) + \sum_{t=\max(R_i,ERA)}^{T_i} \delta^t B_i(R_i) \tag{1}$$

Worker i's lifetime consumption possibilities C depend on lifetime earnings and pension wealth. The worker earns a gross wage w subject to payroll tax τ^p from starting age 0 to the period before her retirement (job exit) age R[13]. Pension benefits $B(R)$ can be claimed from the age at job exit if the worker has already reached her ERA (and from the ERA otherwise) and are paid until time of death T. Finally, all payments are discounted at factor δ.

The slope of the lifetime budget constraint, i.e. the marginal gain in lifetime consumption from delaying retirement by one period, is given by the *implicit net wage* $w^{net} = \frac{dC}{dR}$. Expressing the consumption gain as a fraction of gross earnings, the *implicit net-of-tax rate* can be calculated as $1 - t = \frac{w^{net}}{w}$. In general, delaying retirement affects consumption in three ways. First, the worker gains an additional period of wage earnings. Second, she sees a permanent change in her benefit eligibility $B'(R)$. In the German case $B'_i(R_i)$ is always strictly positive, since later retirement implies both more favorable pension adjustment and a larger sum of contribution points. Third, if she retires at the ERA or later (i.e. she is already eligible to claim benefits), there is an opportunity

[11]See appendix B for details of pensions, pathways and statutory ages in the law.

[12]In the German labor market, most older workers are in labor supply contracts without a term limit which can be costly to terminate. Up to 7 months notice is required, the firm has to state a reason for the layoff and lengthy legal proceedings may follow that often conclude in a substantial severance payment. Mandatory retirement clauses are commonly recommended to employers by industry associations and legal advisors, and European courts have (controversially) ruled in several cases that it does not constitute old-age discrimination.

[13]Throughout this paper, retirement refers to workers' last job exits rather than benefit claims.

cost of work in terms of foregoing one period of benefits.

Kinks linked to statutory ages. Figure 2 shows a stylized version of the lifetime budget constraint. There are *convex kinks*, i.e. decreases in the marginal net-of-tax rate, at the ERA and the NRA. Moreover, there is a *non-convex kink*, i.e. an increase in the marginal return to work, at the RRA.[14] The kinks at the NRA and RRA arise as a direct consequence of the discontinuous pension adjustment described in the previous section, where annual adjustment falls from 3.6% to 0 at the NRA and jumps from 0 to 5% at the RRA. The convex kink at the ERA arises due to a combination of pension adjustment and an additional opportunity cost of working, since workers start foregoing benefits once they reach the ERA.[15]

Contribution notches. The contribution requirement thresholds of different pathways create further budget set discontinuities in the form of *notches*, i.e. jumps in *average* return to work. In figure 2, for instance, the worker reaches 35 years of contributions when working until age 58, where he becomes eligible for the long-term insured pathway and now faces both a lower ERA and a lower NRA. Thus, he can receive a pension earlier (i.e. for more years) and his pension is higher at any given age due to more favorable adjustment, which implies a discontinuous increase in pension wealth and lifetime consumption possibilities. Similarly, workers face notches when they become eligible for regular or invalidity pensions at 5 years of contributions, and for the women's or unemployed/part-time pathways at 15 years.[16] Note that the precise location of these notches is worker-specific since it depends on the individual career starting age.

Kinks in the invalidity pathway. Pensions are also discontinuously adjusted in the invalidity pathway. Specifically, pensions are increased by 3.6% p.a. for retiring between 60 and 63, with no further adjustment when claiming before 60 and after 63. These kinks in the benefit schedule imply budget constraint kinks similar to those around statutory ages. However, the key difference to other pathways is that there are no statutory ages in the invalidity pathway.[17]

2.4 Data

The analysis is based on a novel set of administrative data on the universe of retirees who claimed a public pension between 1992 and 2014. The main data set is assembled from 23 single-year cross

[14] An exception is the regular pathway where the ERA coincides with the RRA. In this case, there is a convex kink at the ERA/RRA.

[15] The ERA kink could be smoothed out by actuarially fair adjustment of pensions. However, the actual adjustment of 3.6% annually is not sufficient (see Börsch-Supan and Wilke 2004).

[16] The notches at 5 years of contributions are not used in this paper since the data on workers with less than 5 years of contributions is incomplete.

[17] Adjustment of invalidity pensions was introduced in 2001, presumably to mirror existing adjustment in the other pathways in order to avoid incentives for switching to invalidity pensions. Notice that the invalidity adjustment function is equivalent to adjustment based on an ERA of 60 and an NRA of 63, and thus coincides precisely with the benefit schedule in the *disability pathway* which may be seen as the closest substitute.

sections provided by the German State Pension Fund.[18] The sample is limited to workers in the six main pathways who claimed a pension for the first time between 50 and 67, have at least 5 earned points from at least 5 years of contributions and do not continue work after retirement. Moreover, individuals part of whose earnings careers have been abroad and members of a special scheme for miners are excluded. Finally, East Germans retiring in 1995 and earlier are excluded since their pension was calculated under a particular set of post-reunification rules. In order to have sufficient parts of each cohort's retirement age distribution available, the analysis focuses on workers born between 1932 and 1949. After applying those restrictions, the *individual sample* consists of around 10.4 million observations.

The data contains all variables necessary for the pension fund to determine a worker's pension eligibility as well as a number of socioeconomic characteristics. Monthly benefit claims and last contributions can be directly observed. The month of job exit can be inferred from the time of the last contribution for most of the sample. For those workers where the last contribution does not coincide with employment, the time of job exit is imputed using additional information on the insurance status in the last three years before retirement.[19] Lifetime earnings and average annual earnings are backed out using information on contribution periods and contribution points,[20] and a pension benefit simulator is built to calculate individual benefit eligibility across possible retirement ages. Lifetime budget constraints are simulated as a version of equation (1) with a 3% discount rate and heterogeneous life expectancies by gender and year of birth. In order to account for the fact that observed take-up of pathways reflect worker's choice to some extent, pathways are assigned in terms of eligibility as far as possible. This may be particularly important for cohorts where reforms could induce some "switching" between pathways, which may change group composition over time.[21]

Since policy varies at the pathway-birth cohort level, the individual sample is split into groups by pathway and year of birth for the bunching estimation. Workers born during the reform periods where policy varies at the monthly level are grouped by pathway and month of birth instead. When analyzing contribution notches, groups by pathway and year of birth are further divided into those retiring at ages 55 to 60 and 60 to 65 in order to capture variation of notch sizes with retirement age. The sample split yields 375 groups each of whom faces a distinct set of statutory ages and lifetime budget constraint discontinuities. In total, bunching is estimated at 644 discontinuities.[22] For the analysis across discontinuities, bunching observations are collected in the *bunching sample*, where each observation represents a discontinuity faced by a particular group of workers.

In addition, survey data from the German Socioeconomic Panel (SOEP) is used for some auxil-

[18] Data citation: *Versichertenrentenzugang 1992-2014, source: FDZ-RV*

[19] see appendix C for details of key variables and group definitions

[20] Earned points are generally proportional to gross earnings. The only caveat is top-coding of earnings above the contributions cap.

[21] For instance, after the NRA in the women's pathway is increased to 65, the number of women retiring at 65 and above claiming a regular pension increases sharply since the regular and women's pathways now entail exactly the same benefits. In this example, all women who satisfy the contribution requirement are classified as eligible for the women's pathway.

[22] See appendix D.2 for the a complete list of all discontinuities used for bunching.

iary analysis.[23] SOEP is an unbalanced panel of around 1.4 million individual-year observations spanning the period 1984 to 2013. It contains a wide range of socioeconomic variables including labor market outcomes. Variables of interest are collapsed at the three-digit occupation level and merged with the main data where occupation can be observed from 2000 onwards.[24] This sample is referred to as the *occupation-matched sample*.

Table 2 shows summary statistics for the individual sample in column (1), for the occupation-matched sample in column (2) and for the discontinuity sample in column (3). In spite of the varying sample restrictions, the table suggests that observables are relatively stable across the different sub-samples. In addition, appendix table A1 shows summary statistics from the individual sample by pathway. Workers differ somewhat across pathways in terms of observables, which seems to be driven by the different entry requirements.

Table 3 summarizes the budget constraint discontinuities in the bunching sample. Across all statutory age kinks, the average kink size is 0.08, that is the net-of-tax rate decreases by 8 pp. at the threshold. However, this average masks a combination of convex kinks at ERAs and NRAs with average size between 0.3 and 0.4 and RRA which feature on average non-convex kinks of size -0.35. At non-statutory age kinks, the average size of the discontinuity is around 0.5, and the contribution notches feature an approximate kink size of 0.9 on average. As indicated by the standard deviations, there is substantial variation in kink sizes across discontinuities within each type.[25]

3 Empirical Methodology

3.1 Basic Bunching Method

The first step of the empirical analysis is to measure retirement responses at the thresholds described in the previous section. The bunching method developed by Saez (2010) and Chetty et al. (2011), which can be applied to the retirement age distribution,[26] provides a way of detecting such responses. A bunching strategy is perfectly suited to the present context, since excess retirements measure both responses to kinks in the budget constraint and any other impact of certain thresholds on retirement. An additional advantage of the method is that it allows for the identification of responses within groups where all individuals face the same incentives.

The bunching mass B at an age threshold $\hat{R}$ can be measured as the observed local spike in the density of retirement ages above a counterfactual density $h_0(\hat{R})$. The standard approach to estimate the $h_0(\hat{R})$ is to fit a flexible polynomial to the observed density excluding the threshold.[27] The

[23]Data citation: *Socio-Economic Panel (SOEP), data for years 1984-2013, version 30i, SOEP, 2015*

[24]Occupations in the administrative data and the survey data are defined according to two slightly different versions of the German occupation classification (*KldB 1988* and *KldB 1992*, respectively.) A mapping between the versions is created manually in order to merge the main data with SOEP.

[25]Note that although each group faces the same "statutory" budget set discontinuities, there is some within-group variation in the effective size of discontinuities due to different individual earnings histories.

[26]See for instance Brown (2013) and Manoli and Weber (2014) for previous work on retirement bunching.

[27]see appendix D.1 for details of the empirical implementation

excess mass $b = B/h_0(\hat{R})$ is computed as the bunching mass relative to the counterfactual. While B measures the absolute number of excess retirements at $\hat{R}$, b expresses bunching in multiples of the counterfactual height of the density and can thus be compared across thresholds.

Assuming that the density would have been smooth in the absence of the threshold, bunching can be interpreted in terms of a local retirement response. A standard bunching approach focused on pure price changes then computes an elasticity by relating the excess mass to the "kink size", that is the local percentage change in the implicit net-of-tax rate $\frac{\Delta t}{1-t}$. Specifically, the elasticity of the retirement age with respect to the net-of-tax rate can be calculated as

$$\hat{\epsilon} = \frac{b/\hat{R}}{\Delta t/(1-t)} \tag{2}$$

The formula exploits the key insight by Saez (2010) that the excess mass is directly related to the labor supply response of the marginal bunching individual, i.e. $b \approx \Delta R$.[28] Elasticities computed according to (2) are referred to as *observed elasticities* for the remainder of the paper.

3.2 Estimation Using Multiple Bunching Observations

$\hat{\epsilon}$ corresponds to a structural labor supply elasticity in a frictionless model without any responses to non-price factors. In such a model, bunching is only a function of the elasticity and a vector of observable variables $\mathbf{x}$ related to the threshold, including the counterfactual density and the kink size. Following the notation of Kleven (2016), $B = B(\epsilon, \mathbf{x})$, and ϵ can be estimated using a single bunching observation as above. However, the recent literature has cast doubt on the structural interpretation of observed elasticities, and moved towards estimating additional parameters to explain differences in bunching across kinks. Writing bunching at threshold i as $B_i = B(\epsilon, \boldsymbol{\omega}, \mathbf{x}_i)$, where $\boldsymbol{\omega}$ is a vector of k additional parameters, identification necessitates observing $n \geq k$ bunching moments. If $n = k$, the implied system of n equations has an exact solution given the set of observed bunching quantities B_i. If $n > k$, parameters can be estimated across "bunching observations" B_i. Existing studies focus mostly on optimization frictions (e.g. Chetty et al. 2011,Kleven and Waseem 2013, Gelber et al. 2015), where $\boldsymbol{\omega}$ contains parameters such as a fraction of workers unable to adjust or a fixed cost of adjustment. This paper, in contrast, is interested in estimating the effect of statutory ages on bunching, which is later interpreted as a reference point effect. Denoting D_i^s an indicator for the presence of a statutory age at bunching threshold i,

$$B_i = B(\epsilon, \boldsymbol{\omega}(D_i^s), \mathbf{x}_i) \tag{3}$$

Hence, some bunching occurs as a "statutory age effect", for instance due to reference dependence. $\boldsymbol{\omega}$ can be identified when bunching is observed at sufficiently many thresholds that vary in D_i^s and x_i under the following assumption:

ASSUMPTION A. *ϵ does not vary systematically with D_i^s. That is, structural elasticities are*

[28] This approximate equality holds if $h_0(R)$ is constant on the bunching interval.

the same across statutory age thresholds and non-statutory age discontinuities on average.

Intuitively, the assumption rules out that stronger responses to financial incentives are falsely interpreted as statutory age effects. Note that the assumption is concerned with underlying structural elasticities, which differ from observed elasticities estimated according to (2) in the presence of statutory age effects. In fact, equations (2) and (3) imply $\hat{\epsilon} = f(\epsilon, \omega(D_i^s))$, such that differences in observed elasticities are a corollary of the equations. In particular, an observed elasticity overestimates the true elasticity if some of the bunching occurs due to non-financial factors such as reference dependence.[29] It is also important to note that the bunching approach generally allows for heterogeneity in underlying elasticities (and other parameters). In this case, bunching identifies an average retirement response, and local average parameter values at the threshold.[30]

Within-group estimation. For part of the analysis, parameters can be estimated within groups indexed by g:

$$B_{ig} = B(\epsilon_g, \omega_g(D_{ig}^s), \mathbf{x}_{ig}) \tag{4}$$

This requires observing bunching both at statutory ages and non-statutory age discontinuities for the same group of workers g. Restricting the analysis to groups of workers facing both types of discontinuities allows for identification under a weaker assumption.

ASSUMPTION B. ϵ_g *does not vary systematically with* D_{ig}^s. *That is, a given group of workers g exhibits the same structural elasticity at statutory age thresholds and non-statutory age discontinuities.*

Hence, elasticities can vary across groups in unrestricted ways, but a given group of workers are required to respond to all financial incentives in the same manner.

Optimization frictions. Evidence from previous work indicates that optimization frictions seem to play a relatively minor role for the timing of retirement (e.g. Manoli and Weber 2016). More generally, extensive margin responses are less subject to frictions than intensive margin responses (Chetty 2012). These findings are also mirrored by the sharp retirement responses documented in this paper. However, it is not necessary to assume that there are no frictions for the purpose of the analysis laid out above. Denoting a vector of friction parameters by ϕ, if $B_i = B(\epsilon, \omega(D_i^s), \phi, \mathbf{x}_i)$, the additional assumption necessary to identify a statutory age effect is that frictions do not vary systematically with D_i^s. In other words, if frictions attenuate responses to different thresholds in the same way, the relative magnitude of the effects of interest can still be identified.[31]

[29] This contrasts to a situation with optimization frictions, where the observed elasticity underestimates the true elasticity.

[30] See Kleven (2016). Also see section 6.4 for a more formal discussion of the conceptual framework with parameter heterogeneity.

[31] For instance, this would be given if there was a constant share of non-optimizers, leading to a proportional attenuation of bunching as in Kleven and Waseem (2013).

4 Reduced-Form Evidence

4.1 Basic Bunching Analysis

4.1.1 Bunching at Specific Thresholds: Some Cases

I first present some cases of bunching at specific group-level thresholds in order to illustrate the variation used. In particular, this section focuses on cases that lend themselves to two types of comparisons across statutory ages and non-statutory age discontinuities.

Statutory Age vs. Contribution Notch Within Group. First, panels A1 and B1 of figure 4 compare the response of the same group of workers to a discontinuity linked to a statutory age and one without a statutory age. Panel A1 shows women born in 1945 and 1946 around their ERA of 60. The average kink size is only 0.08[32], but there is a large excess mass of 12.3 implying an observed elasticity of 4.45. Panel B1 shows the distribution of years of contributions of eligible women in the same birth cohorts around the threshold of 15 years that is necessary for access to the women's pathway. At 14 years and 11 months of contributions, women face a notch of size 1.0069, i.e. they gain 0.69% of lifetime wealth on average from working an additional month. Following Kleven and Waseem (2013), the notch can be approximated as a kink for the marginal buncher. Here, the notch corresponds approximately to a kink of size 0.38. Indeed, there is sharp bunching at 15 years and some missing mass to the left of the notch. However, the excess mass of 1.32 is significantly less than that in panel A1 where workers face the ERA and a much smaller kink. Hence, two very different observed elasticities of 4.45 and 0.12 are estimated for the same group at the ERA kink and the notch, respectively.

Kinks in Disability vs. Invalidity Pathways. For the second comparison, panels A2 and B2 show bunching at two very similar kinks, with and without the presence of a statutory age. Panel A2 shows bunching around the NRA at 63 for cohorts 1945 and 1946 in the disability pathway. The kink size is 0.51 and the excess mass is estimated at 10.5, which implies an observed elasticity of 0.67. Panel B2 shows the distribution of job exit ages for workers born between 1938 and 1946 in the invalidity pathway. The adjustment factor is 100% at age 63 for the birth cohorts in the figure, which coincides precisely with adjustment in the disability pathway with its NRA at 63. Consequently, workers in panels A1 and B1 face very similar kinks at age 63, but in LEP the threshold is not framed as the NRA in the invalidity pathway.[33] Indeed, bunching around 63 differs dramatically across the two groups. In contrast to the large excess mass at the NRA, bunching is hardly visible and the excess mass is only 0.083 at the invalidity kink. Consequently, the observed elasticity of 0.007 is two orders of magnitude below the estimate at the NRA.

[32] see appendix figure A1 for lifetime budget constraints of the groups shown in figure 4

[33] The fact that the kink size differs slightly in figure 4 is due to different average earnings histories of workers in the two pathways.

4.1.2 Bunching Across all Thresholds

Figure 5 and table 4 summarize bunching across the 645 discontinuities in the data. The black dots in the figure and columns (1) to (4) of the table summarize bunching across the 387 available budget set kinks linked to statutory ages. The average excess mass of 21.8 is very large, and it is driven by large responses at all three types of statutory ages. Across convex kinks, attributing all bunching to the discontinuity in the implicit net-of-tax rate implies an average observed job exit age elasticity of 1.64. This observed elasticity is two orders of magnitude above previous estimates of around 0.01 to 0.04 by Brown (2013) and Manoli and Weber (2014) from pure financial incentives. Moreover, an indication that bunching seems to occur somewhat irrespectively of the financial incentive is given by the large excess mass at the non-convex RRA kinks. Note that non-convex RRA kinks are not included in the elasticity estimation since bunching in response to those would imply a negative elasticity.

Next, the red triangles in figure 5 and columns (5) to (7) of table 4 summarize bunching at the 258 non-statutory age discontinuities in the same setting. The average excess mass is 2.99. The average observed elasticity is around 0.01 at non-statutory age kinks, and 0.22 at non-statutory age notches.[34] Averaging across all non-statutory age discontinuities yields an elasticity of 0.15, compared to 1.64 at statutory age kinks in column (1). This implies that, conditional on kink size, bunching at statutory ages is more than ten times larger than at other kinks.

Heterogeneity. The preceding analysis averages bunching across discontinuities at different retirement ages faced by different groups of workers defined by pathway and year of birth. Figure 6 explores heterogeneity along these dimensions, sorting discontinuities by pathway (panel A), by year of birth (panel B) and the retirement age at the discontinuity (panel C). Again, the black dots refer to statutory ages and the red triangles show bunching at non-statutory age discontinuities. There is some heterogeneity in excess mass (left panels) and observed elasticities (right panels) across retirement pathways, while bunching is more homogenous across birth cohorts and retirement ages. However, the main pattern described above holds across all groups: There is more bunching at statutory ages than at non-statutory age discontinuities, which translates into substantially larger observed elasticities.

4.2 Determinants of Bunching

A great advantage of the setting is that the large number of available bunching observations allows for a further investigation into the determinants of bunching across groups. In particular, this

[34] This difference could be driven by three factors. First, kinks apply to the LEP pathway where workers may display a lower true elasticity than in other pathways. Second, observed elasticities measured at notches represent an upper bound: Kleven and Waseem (2013) point out that the approximation of the notch as a kink for the marginal buncher in order to compute a reduced-form elasticity undestimates the size of the discontinuity since everyone between the marginal buncher and the notch faces a larger change in the marginal tax rate. Third, additional months of contributions could come from some non-work periods such that workers may have additional margins of adjustment to bunch at contribution notches.

section investigates whether the large differences in responses between statutory ages and other discontinuities can be explained by other observable factors.

Financial Incentives. Maybe most immediately, differences in bunching could be explained by different financial incentives. Figure 7 shows binned scatterplots of the excess mass at a threshold against kink size. Panel A shows a positive, virtually linear relationship between bunching at discontinuities not linked to a statutory age and the underlying financial incentive to retire across a wide range of kink sizes. Extrapolating the fitted line towards a zero kink size suggests that no bunching is predicted in the absence of a financial incentive. Moreover, the estimated slope corresponds to a precisely estimated difference-in-bunching elasticity of 0.18. Panel B repeats the exercise across statutory ages. The estimated slope is positive but insignificant and there is large bunching across all kink sizes, including even negative ones. This indicates a strong response at statutory ages regardless of the incentive to retire.[35] Thus, while workers respond to financial incentives to some extent, bunching at statutory ages seems to be driven by factors independent of incentives.

Group Characteristics. Besides, differences in bunching between statutory ages and other discontinuities could be driven by differences in group-level characteristics. Figure 8 shows average observed bunching elasticities[36] at statutory ages and other discontinuities by quintiles of selected observables. Panels A to C focus on worker characteristics, namely lifetime wealth (panel A), years of schooling (panel B), and health status proxied by sick leave periods (panel C). Groups with higher lifetime wealth and higher education seem to respond less strongly at statutory ages, but more strongly at other discontinuities. In particular, workers in the highest schooling quintile seem to respond more to pure financial incentives. Groups in worse health, on the other hand, are less responsive to both statutory ages and other discontinuities. Panel D to F sort bunching observations by some occupation-level characteristics, in particular firm size (panel D), unionization rate (panel E) and tenure in the firm (panel F). Again, the gap between bunching at statutory ages and other discontinuities differs somewhat across groups. However, observed bunching elasticities are higher at statutory ages by at least a factor of two in each quintile of each variable. Appendix table A2 provides a more formal test of whether differences in bunching can be explained by group characteristics, regressing observed elasticities on dummies for the presence of statutory ages and group-level controls. Column (1) shows a regression on statutory age dummies only, returning large and strongly significant coefficients. Columns (2) adds the characteristics from above plus additional controls, and column (3) adds pathway and year-of-birth fixed effects. The statutory age coefficients remain large and significant in both specifications. Moreover, the R-squared in column (1) of 0.47 suggests that statutory age explain a large share of the dispersion in observed elasticities, compared to 0.27 in the regression with control variables only in column (4).

[35] Appendix figure A2 shows plots separately by statutory age types, suggesting that the flat slope is driven by a combination of positive slopes at ERAs and NRAs and a negative slope at RRAs.

[36] see appendix figure A3 for analogous graphs with excess mass

4.3 Reduced-Form Estimation

The evidence presented above suggests that there is large amount of additional bunching at discontinuities linked to statutory ages. In order to gauge the quantitative importance of these statutory age effects, the following regression specification is employed:

$$\frac{b_i}{\hat{R}_i} = \epsilon \frac{\Delta t_i}{1 - t_i} + \sum_s \beta^s D_i^s + Z_i'\gamma + \nu_i \tag{5}$$

where an observation indexed by i corresponds to one of the group-specific discontinuities in the bunching sample. D_i^s is an indicator for a statutory age of type $s \in (ERA, NRA, RRA)$ attached to discontinuity i, and the coefficients β^s measure the additional bunching due to the respective statutory age type. Finally, Z_i is a vector of control variables, and ν_i is an error term.

While equation (5) may be a natural way to detect statutory age effects in a reduced-form specification, it can be also be interpreted as a simple, linear version of the bunching equation (3), where the parameter vector ω consists of a set of dummies for the presence of statutory ages. Note that the empirical setting provides many more bunching observations than parameters to be estimated, which has two major advantages. First, additional regressors can be included, allowing to control for a number of group-level characteristics and fixed effects in a flexible way. Second, rather than finding a solution to an exactly identified system of bunching equations, the equation can be estimated via OLS, thus combining the information provided by all available bunching moments. In terms of estimation, the specification fits a regression to the discontinuity-level data, where the slope is interpreted as the elasticity and additional regression intercepts for statutory age kinks are interpreted as the direct effect of statutory age thresholds. Hence, statutory age effects are identified from the difference in bunching *between* statutory age kinks and non-statutory age discontinuities while the elasticity is identified from bunching at kinks of different sizes *within* each type of discontinuity. Standard errors are obtained via bootstrap by re-sampling bunching observations.[37]

The key identification assumption can be phrased in terms of this regression. ν_i needs to be uncorrelated with the regressors across discontinuities, which crucially requires assumption A. To see this, consider a case where true elasticities vary across discontinuities with $D_i = 0$ and $D_i = 1$. Then $E(\nu_i|D_i) \neq 0$, since ν_i contains some residual bunching not captured by the average elasticity ϵ, and this would introduce bias into the estimation since. Note that in practice, the inclusion of control variables and fixed effects somewhat weakens the required assumption, such that elasticities should be independent of D_i conditional on these controls. Some support for assumption A is provided by the results from figure 7, where the implied difference-in-bunching elasticities at statutory ages and other discontinuities are relatively similar.

Table 5 reports results from the regressions based on equation (5). To begin with, column (1) shows results from a basic specification without controls. This yields an elasticity of 0.11 and large and

[37]This corresponds to a block bootstrap procedure on the individual-level data, where blocks are defined by the groups of workers facing the same discontinuity.

significant statutory age effects. Next, column (2) adds interactions between different statutory age types in order to account for the fact that more than one type is present at some discontinuities. Columns (3) adds a set of worker controls, as well as pathway and year of birth fixed effects accounting for the dimensions along which groups are defined. Column (4) adds the maximum set of group fixed effects, controlling for pathway times year of birth fixed effects. Finally, column (5) controls for occupation-level characteristics including firm size and unionization rates. In spite of the varying set of controls and fixed effects, the estimated statutory age effects are remarkably stable and remain highly significant, while elasticities vary within a narrow range between 0.05 and 0.09.

Heterogeneous Coefficients. As discussed above, a particular concern for identification arises if parameters are heterogeneous across workers facing different types of discontinuities. Adding group fixed effects partly addresses this by allowing for group-specific bunching intercepts. However, a more direct way to address the concern is to allow for heterogeneous parameters in the following specification:

$$\frac{b_{ig}}{\hat{R}_{ig}} = \epsilon_g \frac{\Delta t_{ig}}{1 - t_{ig}} + \sum_s \beta_g^s D_{ig}^s + \nu_{ig} \tag{6}$$

where g indexes groups. Since the main concern with the previous specification is heterogeneity correlated with kink sizes and statutory ages, a natural solution is to allow for heterogeneous parameters at the level where these variables are determined, namely pathway and year of birth.

The identification assumption for this specification is weaker than before. Assumption B requires that the same group of workers exhibits the same elasticity at different types of discontinuities, while true elasticities can vary arbitrarily across groups. Also note that if underlying parameters are heterogeneous, even if its idenfitication assumption is satisfied, equation (5) identifies weighted averages where the parameter of each group is weighted by the conditional variance of the corresponding regressor within the group.[38] These weighted averages are not necessarily equal to "true" population averages. However, the coefficients identified in equation (6) can be used to calculate population averages by weighting estimates by group size.

Table 6 reports results from the specification with heterogeneous coefficients. Column (1) reproduces the basic specification with homogenous parameters without controls from column (2) of table 5. Columns (2) to (4) show results from estimating equation (6) with varying group definitions.[39] Note that for the specifications with heterogeneous coefficients, table 6 reports weighted averages, while pathway- and cohort-specific estimates are shown in appendix table A3. Column (2) estimates a specification with pathway-specific coefficients, and column (3) repeats the exercise with groups defined by birth cohorts. In both specifications, the elasticity estimate increases somewhat compared to column (1), but statutory age effects remain strongly significant and increase slightly in magnitude. Column (4) reports estimates with groups defined by pathway and birth

[38] see Angrist (1998)

[39] Groups with no variation in the presence of statutory ages at discontinuities have to be dropped from the within-group estimation in columns (2) to (4).

cohort. In the spirit of the comparison presented in figure 4, this specification estimates elasticities and statutory age effects within narrowly defined groups such as women born in 1945.[40] Again, the estimates in column (4) are similar to the previous columns. Appendix table A3 suggests some parameter heterogeneity across pathways, and little heterogeneity across birth cohorts, which is in line with the evidence from figure 6. However, the fact that average parameters in table 5 change little when allowing for more heterogeneity indicates that there is little bias in the basic specification with homogeneous coefficients. Overall, the results suggest large and significant estimated statutory age effects, and the elasticity estimates between 0.09 and 0.29 are modest.

5 What is Behind the Statutory Age Effect?

The evidence presented in the previous section suggests that the large number of excess retirements at statutory ages that cannot be explained by financial incentives faced by workers. This section discusses the potential mechanisms behind this "statutory age effect". In particular, I first argue that the observed patterns cannot be explained by firm responses in section 5.1. Then, I present some pieces of evidence that results are indeed driven by worker behavior. In the absence of more direct evidence on perceptions or intentions, it remains outside the scope of this paper to offer fully conclusive proof of the exact behavioral channel. However, I argue that reference point effects are the most likely mechanism for three reasons. First, as laid out in section 2.2, the institutional framing of pension benefits and retirement is likely to facilitate the formation of goals or expectations, which are typically interpreted as reference points. Second, section 5.2 shows that there are other reference points in the same setting which seem to attract similar workers. Third, section 5.3 presents evidence against some other potential channels of worker behavior.

5.1 The Role of Firms

Self-employed and very small firms. First, I focus on subgroups where firm incentives play a small role or no role at all. Two such groups are available in the present context. First, very small firms with less than 10 employees are exempt from employment protection, which implies that there is no need for employers to use statutory ages to lay off older workers. Second, although very limited, there is a number of self-employed individuals enrolled in the public pension system.[41] Figure 9 shows job exit age distributions among all workers in the full occupation-matched sample (panel A), the 20 occupations most frequently in very small firms, including medical receptionists, hairdressers, pharmacists, florists, and dental technicians (panel B), the 20 occupations least frequently in small firms, including bankers, executives, machine operators, miners and train drivers

[40] Similarly, the estimates in column (4) of table 5 use within-group variation due to the inclusion of fixed effects, but coefficients are restricted to be homogenous.

[41] Self-employed individuals can be enrolled in the public pension system for two reasons. First, there may be part of a small set of occupations where enrollment is mandatory. This includes mainly craftspersons, workmen, self-employed teachers and educators, nurses and artists. Second, self-employed workers can voluntarily enrol in the public scheme.

(panel C), and self-employed workers enrolled in the public pension system (panel D). There are large and sharp job exit age spikes at the main statutory ages among workers most frequently in small firms, although the vast majority of contracts falls below the threshold for employment protection. However, the spikes appear somewhat larger among those least frequently in small firms. In addition, there is substantial bunching at statutory ages among the self-employed. Hence, even workers where firm incentives play a small role or no role at all seem bunch at statutory ages, which seems to rule out that statutory age effects are driven purely by firm responses.

Mandatory retirement. The most direct way for firms to induce workers to retire at statutory ages is through mandatory retirement clauses linked to the RRA. A direct way of checking whether the previous results are driven by this is to exclude all statutory ages from the analysis where this firm-induced mandatory retirement is possible. Appendix table A4 shows results from regressions analogous to table 6, but excluding all discontinuities linked to a RRA. Results are virtually unchanged, with elasticity estimates ranging from 0.14 to 0.26, and highly significant statutory age effects at the ERA and NRA similar in magnitude to those in table 6. Thus, even if all RRA job exits were driven by mandatory retirement (which seems unlikely, given bunching by the self-employed), there remains a large portion of unexplained statutory ages retirements.

Proxying for firm incentives. To shed light on the role of firms more generally, statutory age retirements can be related to a number of variables proxying for firm incentives. First, firing costs are higher for larger firms since employment protection becomes more severe in line with certain size thresholds. Small firms could also have less standardized contracts for other reasons. Indeed, there is anecdotal evidence that some large firms may have "policies" of retiring workers at statutory ages. Second, firing costs are likely to be higher when workers are more unionized. Third, firing costs are higher for workers with longer tenure since employment protection increases as a function of tenure thresholds. Fourth, job exits at statutory ages are not necessary at all as a tool for firms when workers have contracts that end automatically after a term limit. Since firm- or contract-specific variables are not available in the main data, the analysis is based on matching the individual data with SOEP data at the 3-digit occupation level. Finally, in a tighter labor market it may be more valuable to firms to keep older workers beyond statutory age thresholds. Labor market tightness is constructed from annual vacancy and unemployment data at the state level.

Panels A to D of figure 10 show binned scatterplots of the fraction of workers in an occupation exiting their jobs at statutory ages against the four occupation-level variables. The fraction bunching at statutory ages is large in all bins of the explanatory variables and the estimated slopes are relatively flat. While there seems to be no effect of unionization, the fraction exiting is indeed increasing in firm size, average tenure and the fraction of workers in unlimited contracts. Panel E repeats the exercise with labor market tightness. Again, the fraction bunching at statutory ages is large for all values of labor market tightness, and somewhat surprisingly, there seem to be more statutory age job exits in tighter labor markets.

Columns (1) and (2) of table 7 show results from corresponding individual-level regressions of a dummy for statutory age job exits on all these variables, including individual controls as well as pathway and year-of-birth fixed effects.[42] Due to the potentially distinct role of the RRA, results are reported separately for the ERA/NRA and the RRA itself. The positive relationship of statutory age retirements with firm size and tenure remains, while the effect of the remaining variables becomes more ambiguous. The positive association with labor market tightness seems to be driven entirely by the RRA, which may be surprising given that the RRA is the most direct way for firms to lay off older workers. Of course, these correlations do not prove the role of firms themselves. For instance, the effect of firm size may stem from stronger peer effects or social norms in larger firms, enhancing reference point effects of statutory ages. Hence, the results should be interpreted in the sense that even if there was some role of firms for statutory age retirements, its magnitude seems to be limited.

5.2 Worker Behavior and Reference Points

Benefit claiming at statutory ages. First, I exploit the distinction between job exits and benefit claiming to argue that statutory age job exits seem to be desired by workers. In particular, if statutory job exits were somehow induced by firms but workers did not want to retire yet, one might expect that some affected workers delay benefit claiming in order to search for another job. Panel A of figure 11 shows a histogram of the gap between job exit and benefit claiming among workers who exit at a statutory age (white bars) and workers who exit at other ages, but are already eligible to claim (red bars). Around half of workers exiting at other ages claim immediately, while a substantial shares seem to wait up to around 12 months to claim. For statutory age job exits, however, the fraction claiming immediately is around 95%. In addition, panel B shows the job exit age and claiming age distribution of workers not exiting at statutory ages, but are eligible to claim immediately. There are sharp spikes in claiming at the main statutory age thresholds, in particular at age 65, which suggests that many workers seem to wait until a statutory age to claim even if the job exit occurred at other ages. Since the time of benefit claiming is determined by workers themselves, this can be seen as indicative that statutory age retirements are desired by workers.

Reform periods. As a second piece of evidence, figure 12 shows the fraction exiting their job at statutory ages by cohort for a group subject to one of the gravest statutory age reforms. In the women's pathway, the NRA was gradually increased from 60 to 65 by one month for each month of birth born between 1940 and 1945. Prior to the reform, between 40% and 50% of eligible women retire at statutory ages, including a large fraction of around 20% retiring at the NRA. During the reform window, the fraction at statutory ages shrinks dramatically, with most of the decrease driven by a lower fraction of women at the NRA. The decrease is partly offset by an increase in the

[42] Appendix table A6 shows full results from the regressions of bunching probabilities on worker and occupation-level characteristics.

fraction of retirements at the RRA. After the reform is fully phased in, the fraction at the NRA rises slightly, but remains far below the pre-reform level. Importantly, firm incentives should unaffected by the reform: Since the ERA and RRA remain unchanged at 60 and 65, respectively, firms should have the same scope for inducing workers to retire through mandatory retirement or other means. In turn, this suggests that statutory age retirements are driven by workers' choices. In particular, it may take some time for a statutory ages to become an established reference point, and effects are weaker during a transition period where the statutory age changes every month.[43] Appendix table A5 generalizes the analysis, replicating the decomposition from table **??** with reform effects. Columns (1) and (2) show that estimated reference point during the reform in the women's pathway are indeed weaker during the reform period. Columns (3) and (4) show that results remain the same when using the ERA and NRA reforms in all pathways.

Worker characteristics. Third, it may be interesting to ask which workers are most likely to bunch at statutory ages. Since it may be a priori unclear which workers are more likely to respond to reference points[44], the analysis focuses on comparing statutory ages to a type of "natural" reference points in the empirical setting. Figures 1 and 4 indicate clear bunching at round ages not linked to statutory ages.[45] Round ages arguably represent pure reference points since they do not entail any financial incentive to retire. Table 8 shows regression of dummies for bunching at statutory ages on a number worker characteristics. Columns (1) and (2) show that workers retiring at the ERA/NRA are less educated, more likely to be female, less likely to be married, and have higher lifetime income and higher annual earnings before retirement. Workers bunching at the RRA are also more less likely to be married and with higher last earnings than other workers, but they are more educated, less likely to be female, and have lower lifetime earnings. In column (3), workers retiring at round ages display very similar characteristics to those retiring at the ERA/NRA, particularly lower education. This may be suggestive that these statutory ages serve as reference points as well. Finally, in order to contrast this against responses to pure financial incentives without a reference point, column (3) repeats the exercise with non-statutory age thresholds. In particular, retiring at notches is strongly associated with *higher education*: an additional year of schooling is estimated to increase the probability of retiring at a notch by around 10%. Moreover, column (4) of table 7 shows that, just like bunching at the ERA and NRA, bunching at other round ages is also positively related to firm size, and negatively related to labor market tightness. Column (4) shows that bunching at non-statutory age discontinuities is negatively related to firm size. Hence, there may be an interaction with firms: In larger firms, workers are less likely to respond to financial incentives, but more likely to bunch at reference points.

[43] The pattern is unlikely to be driven by workers having less time to plan their retirement date, since the reform was announced in 1992 which is 8 years before the first affected worker reaches any statutory age.

[44] For instance, the evidence on whether individuals with lower cognitive ability are more susceptible to framing is mixed (e.g. Stanovich and West 1998, Stanovich and West 2006, Benjamin et al. 2013).

[45] Round-number bunching has been observed in a number of contexts and has been attributed to reference point effects (see Kleven 2016).

5.3 Other Worker-Related Mechanisms

Salience and Information. Another alternative mechanism could be that statutory ages make underlying financial incentives more salient rather than serving as reference points. In other words, there could be more bunching at statutory ages than at other discontinuities because workers are more aware of the budget set kink. This mechanism would imply that the difference in bunching across kink sizes is larger among statutory age kinks than among other discontinuities since workers respond more strongly to financial incentives linked to statutory ages. A priori evidence against this hypothesis is provided by the results from figure 7, where large bunching at statutory ages occurs at all kink sizes, including non-convex kinks, which entail no financial incentive to bunch. If statutory ages made incentives more salient, one could expect a different pattern, where bunching is more steeply increasing in kink size than at pure financial incentives. Appendix table A7 provides a further test, repeating the analysis of table 6 with additional interactions of kink size with statutory age dummies. If statutory ages make the financial incentive more salient, one would expect the coefficient on these interactions to be positive, implying a larger elasticity. However, interaction effects are insignificant or even negative, implying that workers do not respond more to financial incentives at statutory ages.

More generally, the relationship between information and retirement decisions has been discussed in the literature. For instance, Mastrobuoni (2011) tests the impact of information provision on retirement patterns, including benefit claims at statutory ages. He finds no effect of letters by the social security administration informing workers about pension provisions. A similar reform has been implemented in Germany in the early 2000s, where the pension fund started sending out more regular and more detailed information letters to workers. Before June 2002, a detailed letter was sent on workers' 55th birthdays.[46] Under the new regime phased in between June 2002 and December 2003, a basic letter is sent to every worker every year, and detailed letters are sent every 3 years from age 55. Appendix figure A4 shows that the additional information does not seem to cause a decrease in the fraction of statutory age retirements around this reform. If anything, the fraction at statutory ages as well as other round ages seems to increase throughout the reform. Hence, the specific information provided by these letters could even have the perverse effect of reinforcing the framing of pensions around statutory ages.

Finally, a number of other channels have been discussed in the literature, but are unlikely to play a role in the present context.

- **Default options.** In the German context, statutory age thresholds do not constitute a default option for retirement, since benefit claiming requires an active choice in the form of an application.

- **Liquidity constraints.** Liquidity constraints may be a potential explanation for job exits at the ERA. Since pension benefits are only paid from the ERA onwards, workers who exit their

[46] see appendix ... for more information on the content of information letters

jobs before the ERA have to use savings or may have to borrow against their future pension in order to smooth lifetime consumption throughout the gap between the time of retirement at the ERA. With credit constraints, borrowing and smoothing may not be possible to the desired extent. However, recent evidence by Goda et al. (2015) suggests that liquidity constraints are not the main driver of ERA retirements in the U.S. In addition, table 8 shows no indication that workers retiring precisely at the ERA suffer from more severe liquidity constraints than other workers retiring at similar ages. Workers retiring at the ERA/NRA have both higher lifetime incomes and higher last incomes before retirement. Moreover, ERA/NRA retirees are more likely to be married, increasing within-household smoothing opportunities.

- **Health insurance.** Finally, health insurance availability has been suggested in the U.S. context as a potential driver of retirements at the NRA. Since most workers have employer-provided health insurance in the and Medicare is also available from 65, they would have to purchase private health insurance to cover any gap between the time of retirement and 65. However, in Germany there is universally mandated public health insurance that covers workers as well as pensioners. Hence, the availability of health insurance does not depend on age and is unlikely to be a driver of retirements at any particular age.

6 Bunching and Reference Dependence in a Simple Model

As argued in the previous section, reference point effects can be viewed as the most likely explanation for large bunching at statutory ages. The remainder of this paper is devised under this hypothesis. This section incorporates reference dependence into a bunching model and derives equations describing retirement bunching at reference points and incentive thresholds. The next section then uses these equations to estimate key parameters from the model.

6.1 Basic Setup and Bunching at a Budget Constraint Kink

Consider a simple static model[47] of retirement decisions where workers maximize lifetime utility

$$U = u(C) - v(R, n)$$

C is lifetime consumption, R is the worker's retirement (job exit)[48] age relative to a career starting age normalized to 0, and n is a parameter capturing earnings ability at old age. Utility is increasing and concave in consumption and disutility from lifetime labor supply is convex such that $u'(C) > 0$, $u''(C) < 0$, $v_R > 0$, and $v_{RR} > 0$. Moreover, low ability increases disutility from postponing retirement such that $v_{Rn} < 0$. A stylized lifetime budget constraint can be written as a simplified

[47] The static model considered in this section corresponds to the "lifetime budget constraint" model of retirement suggested by Burtless (1986). It can be viewed as a reduced form of a full dynamic model abstracting from dynamic uncertainty and liquidity constraints. Similar static models are used in recent retirement bunching applications such as Brown (2013) and Manoli and Weber (2016).

[48] Throughout this paper, retirement refers to workers' last job exits rather than benefit claims.

version of equation (1):

$$C = w(1-\tau^p)R + B(R)(T-R) \tag{7}$$

where the implicit net-of-tax $1-t$ rate is again defined by

$$\frac{dC}{dR} = w^{net} = w(1-t)$$

Consider first the case of a linear budget constraint $C = w(1-t)R$, and a utility function that is quasi-linear in consumption and iso-elastic in labor supply such that

$$U = w(1-t)R - \frac{n}{1+\frac{1}{\epsilon}}\left(\frac{R}{n}\right)^{1+\frac{1}{\epsilon}}$$

where ϵ is the elasticity of the retirement age with respect to the implicit net-of-tax rate. Workers' utility maximization yields

$$R = n\left[w(1-t)\right]^{\epsilon}$$

If the distribution of ability $F(n)$ is smooth, this implies a smooth distribution of retirement ages with density $h_0(R)$.

Bunching at a Budget Set Kink. Suppose now that there is a kink in the lifetime budget constraint such that the marginal implicit net-of-tax rate increases by Δt at some age threshold $\hat{R}$. Figure 13 illustrates the effect of the budget set kink in a budget set diagram and density diagram following Saez (2010) and Kleven (2016). In the absence of of the kink, individuals locate along the budget line according to their abilities. Whilst an individual with ability $\hat{n}$ initially retires at $\hat{R}$, there is a marginal buncher with ability n^* whose indifference curve is tangent to the initial budget set at R^* and to the upper part of the new budget set at $\hat{R}$. All workers initially located between $\hat{R}$ and R^* bunch at the kink, while all individuals initially to the left of the kink leave their retirement age unchanged and all individuals initially to the right of R^* stay above the kink. Total bunching is

$$B = \int_{\hat{R}}^{R^*} h_0(R)dR \approx h_0(\hat{R})(R^* - \hat{R})$$

where $h_0(R)$ is the pre-kink density and the approximate equality holds if $h_0(R)$ is constant on $[\hat{R}, R^*]$. Assuming quasi-linear utility, the two tangency conditions for the marginal buncher imply $R^* = n^*[w(1-t)]^{\epsilon}$ and $\hat{R} = n^*[w(1-t-\Delta t)]^{\epsilon}$ and thus

$$\frac{R^*}{\hat{R}} = \left(\frac{1-t}{1-t-\Delta t}\right)^{\epsilon} \tag{8}$$

Now define $\Delta R^* = R^* - \hat{R}$ such that bunching is $B = h_0(\hat{R})\Delta R^*$. Assume Δt is small and hence ΔR^* is small, such that $\log(R^*/\hat{R}) \approx \Delta R^*/\hat{R}$, and $\log(1-t-\Delta t)/(1-t)) \approx -\Delta t/(1-t)$. Then equation (8) implies

$$\frac{b}{\hat{R}} \approx \epsilon \frac{\Delta t}{1-t} \tag{9}$$

where $b = B/h_0(\hat{R})$ is the excess mass. This corresponds to the standard bunching formula derived by Saez (2010) applied to the context of retirement.

6.2 Bunching at a Reference Point

In addition to the preferences described above, workers may evaluate outcomes relative a threshold retirement age $\hat{R}$ such as a statutory age threshold. Previous work on the retirement context has pointed out that such reference dependence be present in both utility from consumption and disutility from work (e.g. Behaghel and Blau 2012, Merkle et al. 2016). This section models both types of reference dependence as a discontinuity in the respective marginal utility, i.e. a kink in the utility function. This corresponds to the loss aversion property from prospect theory, where the choice set is divided into two domains, gains and losses.[49] Although either type leads to sharp bunching at the reference point, it is important to consider loss aversion in both domains since they imply different sources of bunching: Workers are predicted to delay retirement in response to a consumption reference point, while they move the retirement forward in response to a work/leisure reference point.

6.2.1 Reference-Dependent Utility from Consumption

Consider first a change in utility from consumption at the reference point:

$$U = u(C) - v(R, n) - \mathbb{1}(C \leq \hat{C}) \cdot \lambda_c(\hat{C} - C) \tag{10}$$

The last term in equation (10) introduces a discrete jump in the marginal utility from consumption at $\hat{C} = C(\hat{R})$ where the parameter $\lambda_c > 0$ captures the size of this utility kink. Thus, workers' marginal utility gain from approaching the reference point from the left is larger than their marginal utility gain from increasing consumption beyond the level at the reference point. Such loss aversion in consumption may arise due to gain-loss framing of pension adjustments around age thresholds or expectations set by benefit or consumption levels linked to "normal" or "regular" retirement ages. Direct empirical support for this type of reference dependence is lent by Merkle et al. (2016) who show that gain/loss framing of pensions around statutory ages induces loss averse behavior in survey respondents.

The left panel of figure 14 illustrates bunching responses to the consumption reference point. Initially, indifference curves are smooth and an individual with ability $\hat{n}$ is initially located at $\hat{R}$, while n^* is located at R^*. When the reference point is introduced, indifference curves rotate clockwise

[49] The "loss aversion" functional form of reference dependence is used by most field studies on the topic (e.g. Rees-Jones 2014 and DellaVigna et al. 2016). Instead, reference dependence could also be modeled as a discontinuity in utility (i.e. a utility notch) or a discontinuity in the second derivative (diminishing sensitivity). Allen et al. (2016) show that all these types lead to bunching at the reference point.

below $C(\hat{R})$ and now exhibit a convex kink at $C(\hat{R})$. The individual whose indifference curve was initially tangent to the budget line at R^* is now tangent at $\hat{R}$. This individual is the marginal buncher: All workers initially located between R^* and $\hat{R}$ now bunch at the reference point, while all individuals initially to the right of the reference point leave their retirement age unchanged and all individuals initially to the left of R^* stay below the reference point. Like a kink in the budget constraint, a kink in utility does not produce a hole in the density of retirement ages, since workers initially below R^* also retire later, causing a rightward shift in the density below $\hat{R}$ that fills the hole.

Bunching at the reference point is

$$B = \int_{R^*}^{\hat{R}} h_0(R)dR \approx h_0(\hat{R})(\hat{R} - R^*)$$

With quasi-linear utility, the two tangency conditions for the marginal buncher imply $R^* = n^*[w(1-t)]^\epsilon$ and $\hat{R} = n^*[(1+\lambda_c)w(1-t)]^\epsilon$. Hence

$$\frac{R^*}{\hat{R}} = \left(\frac{1}{1+\lambda_c}\right)^\epsilon \tag{11}$$

Equation (11) shows that bunching in response to a kink in utility from consumption is independent of the slope of the budget line and depends only on the parameters λ_c and ϵ. The elasticity enters the equation since it determines by how much workers below the reference point are willing to delay retirement in response to the higher-valued marginal gain in consumption.

6.2.2 Reference-Dependent Disutility from Work

The second type of reference dependence is captured by

$$U = u(C) - v(R,n) - \mathbb{1}(R \geq \hat{R}) \cdot \widetilde{\lambda}_l(R - \hat{R}) \tag{12}$$

where marginal disutility from labor supply jumps by $\widetilde{\lambda}_l > 0$ at $\hat{R}$. Higher disutility from continuing work after the threshold is consistent with an interpretation where workers perceive continuing work after the threshold as a loss in lifetime leisure relative to expectations set by "normal" or "regular" retirement ages.

In the right panel of figure 14, an individual with ability $\hat{n}$ is initially located at $\hat{R}$ and n^* is located at R^*. When the reference point is introduced, the marginal buncher whose indifference curve was initially tangent to the budget line at R^* sees a counter-clockwise rotation of their indifference curves to the right of the reference point, and the new point of tangency is at $\hat{R}$. All workers initially located between $\hat{R}$ and R^* now bunch at the reference point, while all individuals initially to the left of the reference point leave their retirement age unchanged and all individuals initially to the right of R^* stay above the reference point. Again, the kink in utility does not produce a hole in the density of retirement ages, since workers initially above R^* also retire earlier, causing a leftward shift in the density above $\hat{R}$.

Bunching at the reference point is

$$B = \int_{\hat{R}}^{R^*} h_0(\hat{R})dR \approx h_0(R)(R^* - \hat{R})$$

The two tangency conditions for the marginal buncher imply $R^* = n^*[w(1-t)]^\epsilon$ and $\hat{R} = n^*[w(1-t-\lambda_l)]^\epsilon$. Hence

$$\frac{R^*}{\hat{R}} = \left(\frac{1-t}{1-t-\lambda_l}\right)^\epsilon \tag{13}$$

where $\lambda_l = \widetilde{\lambda}_l/w$ is the parameter normalized by the wage. Equation (13) implies that a kink in disutility from work has the same bunching effect as a kink in the budget set. Indeed, a local change in the implicit net-of-rax rate $\Delta t = \lambda_l$ would produce exactly the same bunching response.

6.3 Multiple Sources of Bunching: Combining Incentives and Reference Points

Some reference points may be unrelated to financial incentives, such as in the case of round numbers or loss aversion with respect to a status quo. However, at statutory age thresholds, a potential reference point coincides with a change in incentives. Such a situation is analyzed in the following, where there is both a budget constraint kink and a reference point attached to a threshold $\hat{R}$.

In order to compute total bunching, an initial situation without any discontinuity needs to be compared to a situation with both reference dependence and the budget set kink. Appendix figure A5 illustrates this joint effect. There is an individual whose initial indifference curve is tangent at R^*_- and her new, kinked indifference curve is tangent to the lower part of the kinked budget set at $\hat{R}$. This worker is the *lower marginal buncher* who bunches due to the consumption reference point. In addition, individuals bunch from the right due to the combination of the budget set kink and reference dependence in disutility from work. There is an *upper marginal buncher* whose original indifference curve is tangent to the original budget set at R^*_+ and whose kinked indifference curve is tangent to the upper part of the kinked budget set at $\hat{R}$. Hence, all individuals initially located between R^*_- and R^*_+ bunch, and there is no hole in the density because workers to the left of R^*_- also delay retirement due to their flatter indifference curves, and workers to the right of R^*_+ retire earlier due to the flatter budget line and the steeper indifference curves.

Bunching at the threshold is

$$B = \int_{\hat{R}}^{R^*} h_0(R)dR \approx h_0(\hat{R})(R^*_+ - R^*_-)$$

The lower marginal buncher is determined analogously to equation (11)

$$\frac{R^*_-}{\hat{R}} = \left(\frac{1}{1+\lambda_c}\right)^\epsilon$$

The two tangency conditions for the upper marginal buncher imply $R^*_+ = n^*_+[w(1-t)]^\epsilon$ and $\hat{R} = n^*_+[w(1-t-\Delta t-\lambda_l)]^\epsilon$. Hence

$$\frac{R^*_+}{\hat{R}} = \left(\frac{1-t}{1-t-\Delta t-\lambda_l}\right)^\epsilon$$

Total bunching at the combined threshold can be expressed as

$$\frac{b}{\hat{R}} = \left[\left(\frac{1-t}{1-t-\Delta t-\lambda_l}\right)^\epsilon - 1\right] + \left[1 - \left(\frac{1}{1+\lambda_c}\right)^\epsilon\right] \tag{14}$$

Hence, bunching is additive in two components. The first term in equation (14) captures bunching from the right due to the combination of the budget set kink and reference-dependent disutility from work. The second term in the equation captures bunching from the left due to reference-dependent utility from consumption.

6.4 Extensions

This section considers a number of extensions to the simple model above, and discusses how they can be incorporated into the analysis.

Heterogeneous Parameters. The preceding analysis assumes homogenous preferences. However, parameter heterogeneity can be incorporated into the bunching approach. Kleven (2016) shows that in the presence of heterogeneous elasticities bunching at a pure budget set kink can be related to a local average retirement elasticity. Consider a joint distribution $\hat{f}(n,\epsilon)$ and a joint counterfactual density of retirement ages $\tilde{h}_0(R,\epsilon)$, such that $h_0(R) = \int_\epsilon \tilde{h}_0(R,\epsilon)d\epsilon$. Denoting by ΔR^*_ϵ the response of the marginal buncher at ϵ, total bunching can be written as

$$B = \int_\epsilon \int_{\hat{R}}^{R^*_\epsilon} \tilde{h}_0(R,\epsilon)\, dR\, d\epsilon \approx h_0(\hat{R})E[\Delta R^*_\epsilon]$$

where the approximate equality holds if $\tilde{h}_0(R,\epsilon)$ is constant on $[\hat{R}, R^*_\epsilon]$ for each ϵ. Hence, R^* can be replaced by $E[\Delta R^*_\epsilon]$ in equation (8) to account for the local average response.
Similarly, joint distributions of (n,ϵ,λ_c) or (n,ϵ,λ_l) can be incorporated into the bunching quantities leading to equations (11), (13) and (14). For instance, with heterogeneity in reference dependence in consumption,

$$B = \int_{\lambda_c} \int_\epsilon \int_{\hat{R}}^{R^*_{\epsilon,\lambda_c}} \tilde{h}_0(R,\epsilon,\lambda_c)\, dR\, d\epsilon\, d\lambda_c \approx h_0(\hat{R})E[\Delta R^*_{\epsilon,\lambda_c}]$$

where $\tilde{h}_0(R,\epsilon,\lambda_c)$ is the counterfactual and $\Delta R^*_{\epsilon,\lambda_c}$ is the response of the marginal buncher at (ϵ,λ_c). The approximate inequality holds if $\tilde{h}_0(R,\epsilon,\lambda_c)$ is constant on $[\hat{R}, R^*_{\epsilon,\lambda_c}]$ for each (ϵ,λ_c). Thus, equation (11) is identified off the average response $E[\Delta R^*_{\epsilon,\lambda_c}]$.

Income/wealth effects. The standard bunching formula (9) applies to small kinks where income effects are small (Saez 2010). Equivalently, the formula can be derived from a quasi-linear utility function as above. For larger kinks, however, there may be income effects arising from the change in the implicit net wage. Kleven (2016) argues that in this case, bunching recovers a weighted average between a compensated and an uncompensated elasticity. In other words, if one views the bunching elasticity as an estimator of a compensated elasticity, it is downward biased towards the uncompensated elasticity (assuming leisure is a normal good). The intuition behind this result is that income effects attenuate responses to price changes, since they work in the direction opposite to the substitution effect.
Appendix ... [to be completed] shows a similar intuition applies to bunching in response to reference points: The presence of income or wealth effects attenuate the response of the marginal buncher. For instance, the marginal buncher responding to a consumption reference point by increasing their retirement age described by equation (11), is willing to postpone retirement by less if the marginal utility of the additional consumption available at higher retirement ages is lower. In other words, with income effects, the bunching equations (8), (11), (13) and (14) overstate the response at given parameter values. Therefore, estimated parameters can be interpreted as lower bounds on the "compensated" ϵ, λ_c and λ_l in the presence of income effects.

Dynamic Aspects. [to be completed]

7 Model Estimation

7.1 Basic Estimation: Upper Bounds

The reduced-form estimation is able to estimate elasticities and statutory age effects in a simple and transparent way, but there are some advantages to complementing it with structural estimation.[50] First, more externally valid utility parameters governing reference dependence can be recovered. Second, while the reduced-form estimation is a linear approximation, the structural approach can estimate an exact relationship under the parametric assumptions from section 6. Third, bunching can be simulated under some counterfactual assumptions regarding parameters and policy variables. Taking the model from the previous section to the discontinuity-level data in the bunching sample, equations (8) and (14) imply that bunching at discontinuity i is given by

$$\frac{b_i}{\hat{R}_i} = \left[\left(\frac{1-t_i}{1-t_i-\Delta t_i-\sum_s \lambda_l^s D_i^s}\right)^{\epsilon} - 1\right] + \left[1 - \left(\frac{1}{1+\sum_s D_i^s \lambda_c^s}\right)^{\epsilon}\right] + \xi_i \tag{15}$$

where ξ_i is an error term. A key issue with the estimation is that λ_c^s and λ_l^s cannot be separately identified for a given statutory age type based solely on equation (15). Intuitively, both reference

[50] Appendix E.4 shows that reduced-form regression can be interpreted as a linear approximation of the structural equation (14) for small Δt and λ_l, and shows how the reduced-form coefficients can be linked to the model parameters.. Actual values of the two objects accord relatively well with this criterion. In the sample, the average Δt is 0.18. This section shows structural estimates of λ_l between 0.1 and 0.4.

dependence in consumption and leisure lead to sharp bunching at the threshold $\hat{R}$ such that a given amount of excess mass could be rationalized by a range of combinations of λ_c^s and λ_l^s. In other words, one bunching equation per discontinuity is not sufficient to separately identify the two parameters. A first solution to this problem is to estimate upper bounds on both types of reference dependence, assuming that all reference point bunching is only driven by loss aversion in consumption *or* loss aversion in leisure. This can be done by restricting λ_l^s and λ_c^s to zero, respectively.

Table 9 presents non-linear least squares estimates based on equation (15). Column (1) reports upper bounds on λ_c^s obtained from estimating the model with all λ_l^s set to zero. The elasticity of 0.15 is precisely estimated and very similar to the reduced-form results. Upper bounds on the λ_c^s parameters are positive and highly significant. While λ_c^{ERA} can be bounded around 5, λ_c^{NRA} is larger and the estimation does not seem able to bound λ_c^{RRA} in an informative way.[51] Column (2) reports results from the reverse exercise, setting all λ_c^s to zero. Upper bounds on the λ_l^s parameters are also positive and highly significant, with magnitudes varying between 0.1 and 0.4.

7.2 From Parameter Ranges to Point Estimates

Next, a range of possible λ_c-λ_l combinations can be estimated. To see this, it is useful to recall that loss aversion in consumption implies a density shift towards the threshold from the left, whereas loss aversion in leisure implies a shift from the right. Bunching from the right at discontinuity i is

$$\frac{b_i^+}{\hat{R}_i} = \left[\left(\frac{1 - t_i}{1 - t_i - \Delta t_i - \sum_s \lambda_l^s D_i^s} \right)^{\epsilon} - 1 \right] + \xi_i \tag{16}$$

and bunching from the left is

$$\frac{b_i^-}{\hat{R}_i} = \left[1 - \left(\frac{1}{1 + \sum_s D_i^s \lambda_c^s} \right)^{\epsilon} \right] + \xi_i \tag{17}$$

where $b_i = b_i^+ + b_i^-$. Now the full range of parameter combinations consistent with equation (15) can be estimated by varying the bunching shares from each side between their minimum and maximum possible values. Denoting α_i the share of excess mass originating from the right, this share can be varied between a minimum $\hat{\alpha}_i$ and 1. The minimum right bunching share $\hat{\alpha}_i$ is given by the fraction of bunching that would persist of workers only bunch due to the budget constraint kink.[52] Appendix figure A6 plots all possible combinations of λ_c^s and λ_l^s for each statutory age type, obtained from a simulation where the bunching share from the right at each discontinuity is gradually moved from its minimum to 1 as described above. The negative slope of the relationship illustrates the intuition that the two types of reference dependence are substitutes in terms of rationalizing observed excess mass. However, the simulated ranges are wide, including large positive values of λ_c^{RRA}, and negative values of λ_l^{NRA}, indicating the need for further narrowing down the parameter estimates.

[51] Notice also that confidence intervals of λ_c^s are skewed to the right due to the nonlinearity of the relationship.
[52] Appendix E provides for further details of the implementation of this and the other estimation strategies.

In order to make progress and obtain point estimates of both λ_c^s and λ_l^s, i.e. to quantify the relative importance of reference dependence in consumption and leisure, empirical estimates of α_i are needed. Under some additional assumptions, the empirical density around thresholds can be used to this avail. To illustrate this idea, appendix figure A7 plots pooled distributions around the different statutory age types, omitting the bunching region. There seems to be some "missing" density to the left of the ERA, and a clear drop in the density to the right of the RRA, while the situation is less clear around the NRA. As a first attempt to use this information, column (3) of table 9 estimates reference point effects under an ad-hoc assumption based on this visual inspection, where all reference point bunching is assumed to be due to λ_c^s at the ERA and NRA and due to λ_l^s at the RRA. Results remain highly significant and suggest that this combination of different types of reference dependence produces tighter bounds on the underlying parameters than previous specifications.

Finally, bunching shares from both sides can be computed based on empirical estimates of the corresponding density shifts. Appendix E.2 describes in detail how implied relative density shifts are estimated. Intuitively, the counterfactual density is assumed to be continuous around the threshold, and the relative number of bunchers from the left and from the right is inferred from the vertical difference between the counterfactual density and the one actually observed on both sides of the threshold. In addition, an augmented method measures the horizontal density shift on both sides, taking into account that observed vertical shifts may be confounded by different gradients of the density. In general, this estimation requires an assumption that the true relative density shifts can be reasonably well approximated by locally observed relative shifts.

Appendix table A8 shows estimates of relative bunching from the two sides. Between 64% and 87% of ERA bunching is estimated to originate from the left, and with 80% to 99%, a large majority of RRA bunching is from the right. 56% to 68% of NRA bunching originates from the right. Taking into account the density gradient seems to make little difference to the estimated shares. Columns (4) and (5) of table 9 present parameter estimates based on these estimates. λ_c^{ERA} remains at a magnitude between 3 and 4, indicating that reference dependence in consumption is the most important source of bunching at the ERA. Conversely, most bunching at the RRA seems to be due to reference dependence in leisure as λ_l^{RRA} is virtually the same as its upper bound of 0.38. Bunching at the NRA, on the other hand, seems to be driven by a mixture of the two types of reference dependence. The labeled dots in appendix figure A6 mark the parameter combinations selected by the bunching share estimation, confirming that the estimation successfully bounds parameters in a narrower, positive range.

Overall, the estimated utility parameters are large in magnitude. For instance, $\lambda_c^{ERA} = 4$ implies that marginal utility from consumption just before the ERA is five times larger than just after the ERA. $\lambda_l^{RRA} = 0.38$ a jump in disutility from work by 38% at the RRA. Note that the λ_l^s have an additional, natural interpretation: The estimated magnitudes correspond to the increase in the implicit tax rate at the kink that would produce the same amount of bunching. Moreover, there are interesting differences in the role of reference dependence in consumption and leisure at different types of statutory ages. The estimation suggests that loss aversion in lifetime consumption plays an important role at the earlier statutory ages, which induces workers to postpone retirement until the ERA in particular. The NRA seems to set expectations regarding both consumption and lifetime leisure, implying bunching from both sides. Bunching at the RRA, on the other hand, is mostly due to strongly increased disutility from postponing retirement beyond this age.

7.3 Simulations

Based on the estimates above, bunching can be simulated under a range of counterfactual assumptions on parameters and variables.

Financial Incentives vs. Reference Dependence. A first, natural question may be what fraction of statutory age retirements would prevail in the absence of reference point effects. Panel A of table 10 shows result from a simulation of the job exit age distribution under this assumption. Column (1) reports the actually observed fraction of job exits and average excess mass at discontinuities, while column (2) shows simulated figures based on the structural estimates. Over the entire sample period, 29% of workers are actually retire at statutory ages. In the counterfactual scenario with λ_c^s and λ_l^s set to zero, this fraction is estimated to decrease to only 6 percentage points. In turn, the estimation attributes around 80% of retirements at statutory ages to reference dependence. The average excess mass across all discontinuities is predicted to decrease even more dramatically from 19.2 to between 0.99. This sharp drop is partly a consequence of the simulation predicting negative excess mass (holes) in the job exit age distribution at non-convex kinks. When attention is restricted only to convex statutory age kinks, the average excess mass is predicted to decrease from 14.7 to between 1.71. In addition, columns (3) and (4) show results from analogous simulations based on the lower bound and the upper bound of the reduced-form elasticity estimates, respectively. The fraction of retirements at statutory ages is estimated to decrease to between 5 and 10 percentage points. In other words, at most 35% of statutory age retirements are attributed to financial incentives. Figure 15 shows a graph of the simulated job exit age distribution under the central scenario. In line with the table, the spikes at the main statutory ages are greatly reduced in magnitude. Moreover, the graph illustrates the predicted un-bunching patterns based on the estimated bunching shares from each side. There is visible upward shift in the density below age 60, and even more strongly, at job exit ages above 65.

Panel B of table 10 relaxes the assumption that all additional effects at statutory ages can be attributed to reference dependence. In particular, it allows for the possibility that firms make use of mandatory retirement clauses linked to RRA to lay off older workers. In column (2), a mandatory retirement effect is introduced by assuming that the RRA is viewed by workers as a reference point equally to the NRA, and the remaining bunching at the RRA is attributed to mandatory retirement. Allowing for this effect in combination with financial incentives for workers increases the explained share of statutory age job exits to 26%. Column (3) aims at estimating a lower bound on the role of reference points by making the extreme assumption that all bunching at RRAs is driven by firms. In combination with worker incentives, this would explain 57% of all statutory age job exits, leaving a lower bound of 43% of job exits attributed to reference point effects.

Policy Reforms. [to be completed]

8 Conclusion

Recent years have seen a surge of interest in retirement decisions and their responsiveness to pension system features. While there have been studies on some reforms and idiosyncratic features, the overall evidence is inconclusive. This paper aims at filling this gap by providing a comprehensive view of the effect of two key features of pension systems, namely statutory ages and financial incentives. The results highlight the important role of statutory ages: around 30% of job exits occur at a statutory age, and around 50% to 80% of those are estimated to be driven by reference point effects. Nevertheless, workers also respond to financial incentives, as is particularly visible in bunching at notches. Job exit age elasticities with respect to the net-of-tax rate are larger than those found in previous studies, with estimates around 0.1 to 0.3.

There are implications for the design of pensions. Having established their direct impact on behavior, statutory age thresholds themselves can be viewed as a policy instrument independent of the design of financial incentives. Raising statutory ages can be a highly effective and virtually costless way of increasing average retirement ages. However, it is an open question to what extent policy can exploit workers' behavior regarding established thresholds by arbitrarily shifting those, since workers' notion of reference points may originate to some degree from a "real" incentive. Moreover, this raises important new issues of distribution since certain types of workers, for instance with lower education, seem to be more prone to responding to these reference points.

The result also have implications for the interpretation of bunching more generally. Incentive schemes in other contexts are also framed by statutory thresholds that may serve as reference points. For instance, taxes and social insurance contributions are often defined in terms of thresholds, and many other policies divide the choice space into discrete categories rather than emphasizing continuous choices. This may reduce complexity and thus help individuals make decisions, but the results of this paper highlight that strongly framed thresholds can become reference points somewhat independently of the original incentive.

A limitation of the paper may be that the quantitative strength of statutory age effects is somewhat specific to the institutional context. In other countries, pensions may be framed differently and labor supply contracts may not play the same role. However, the conceptual notion that statutory age thresholds serve as reference points is likely to carry over to other pension systems. Another limitation of the approach of this paper is that firms cannot be observed directly due to the nature of the administrative data. It may be worthwhile for future research to study the role of firms more explicitly, for instance to test for the presence of firm "retirement policies" or the presence of peer effects at the firm level.

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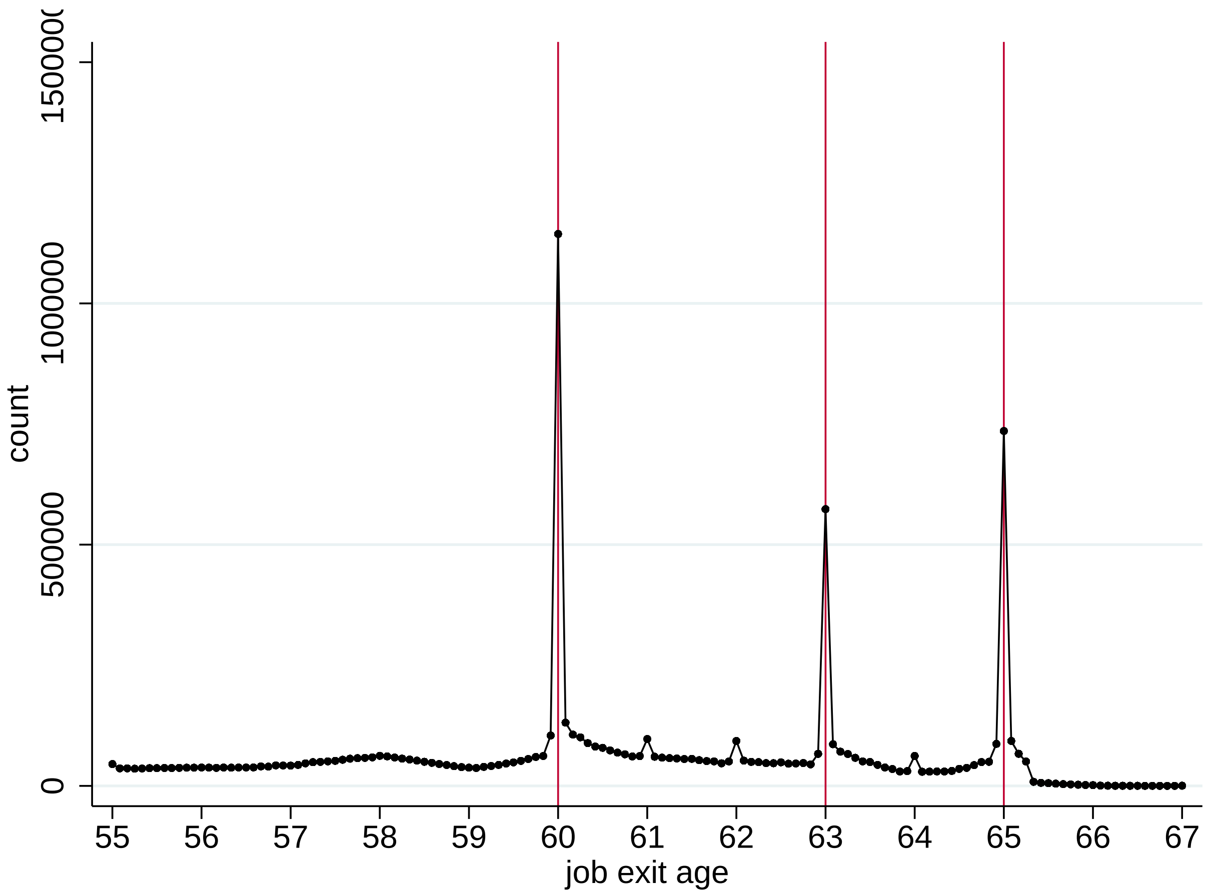
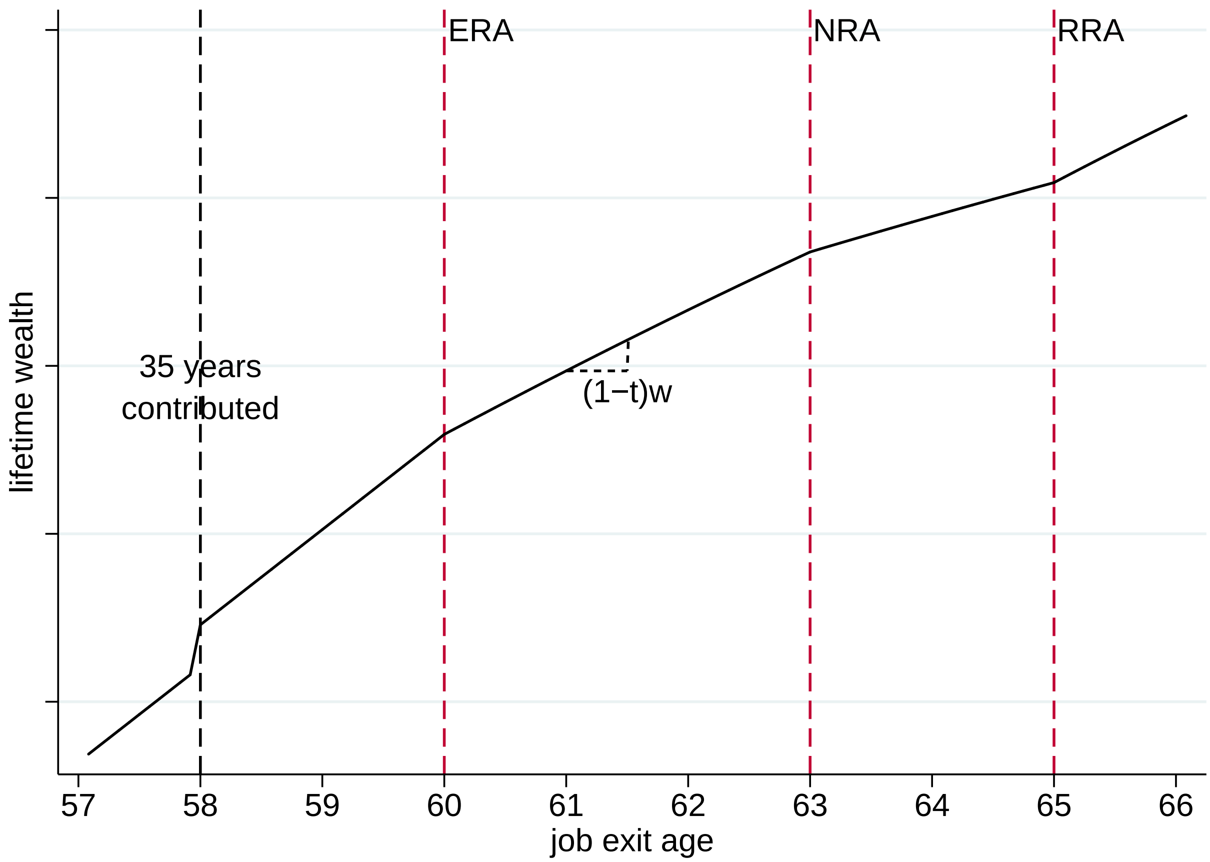
Figure 1: Full sample job exit age distribution



Note: This figure shows the pooled distribution of job exit ages for all workers born between 1932 and 1949. The connected dots show the count of job exits within monthly bins. Vertical red lines indicate the location of main statutory ages throughout the sample period.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

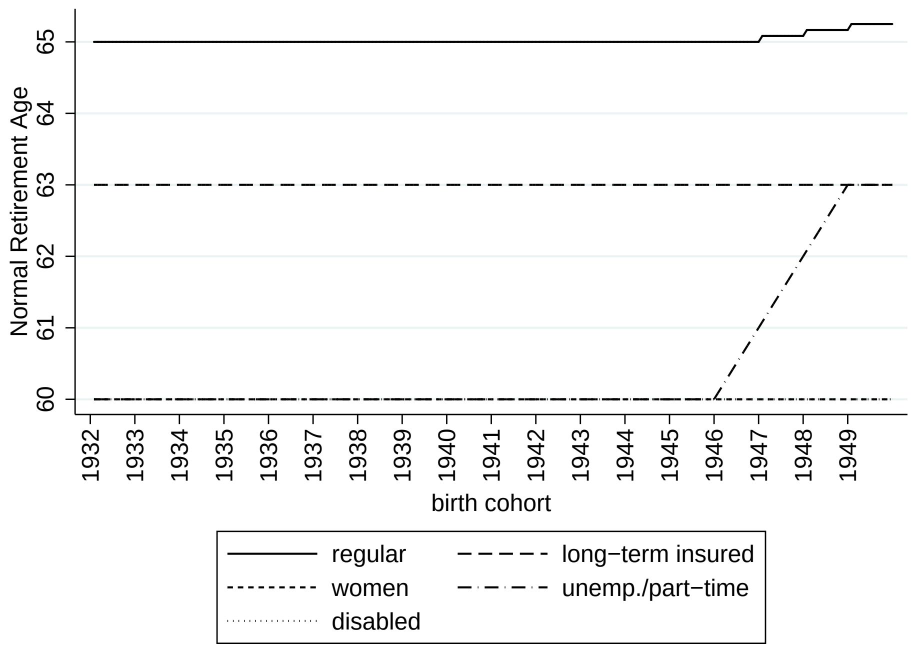
Figure 2: Stylized lifetime budget constraint



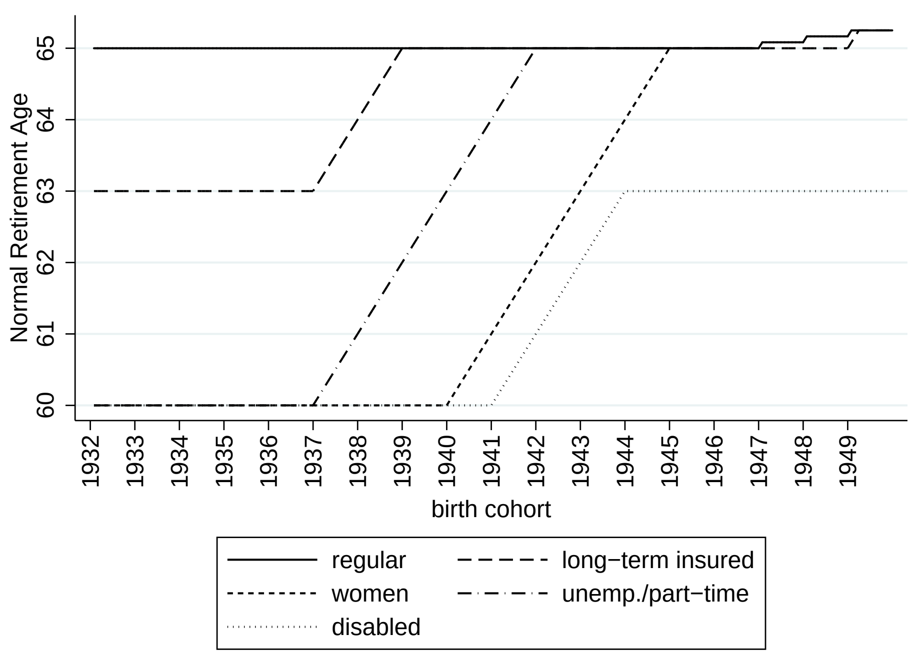
Note: The figure shows a stylized lifetime budget constraint for a worker who faces an ERA of 60, an NRA of 63 and an RRA of 65, who becomes eligible for a pathway requiring 35 years of contributions at age 58. The slope of the BC is the implicit net-of-tax wage where $w_i^{net} = (1 - \tau_i)w_i$ as shown in section 2.3.

Figure 3: Evolution of statutory ages

Panel A: Early Retirement Ages (ERA)



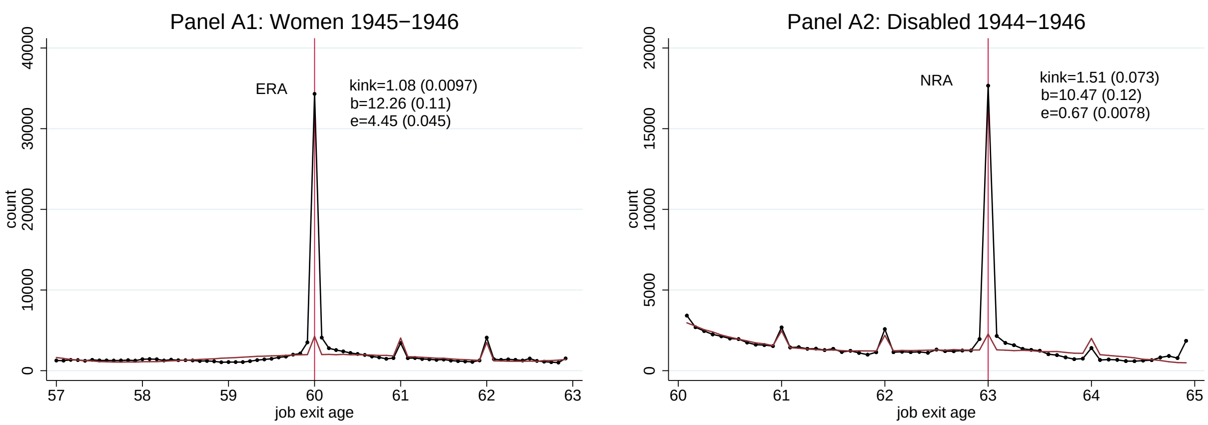
Panel B: Normal Retirement Ages (NRA)



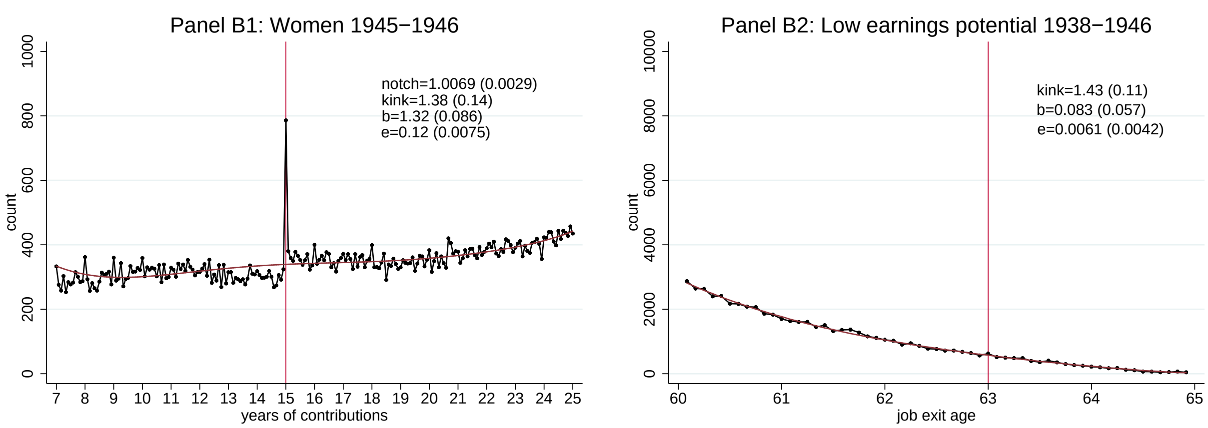
Note: The figures show the evolution of ERAs and NRAs of different pathways across monthly birth cohorts. In Panel A, the regular ERA is increased from 65 to 65/3 between 1947 and 1949 and the unemployed/part-time ERA is gradually increased from 60 to 63 between 1946 and 1948. In Panel B, the long-term insured NRA is increased from 63 to 65 between 1937 and 1938 and from 65 to 65/3 for cohort 1949, the women's NRA from 60 to 65 between 1940 and 1944, the unemployed/part-time NRA from 60 to 65 between 1937 and 1941, the disabled NRA from 60 to 63 between 1941 and 1943, and the regular NRA 65 to 65/3 between 1947 and 1949.

Figure 4: Group-level bunching graphs

Panel A: Statutory ages



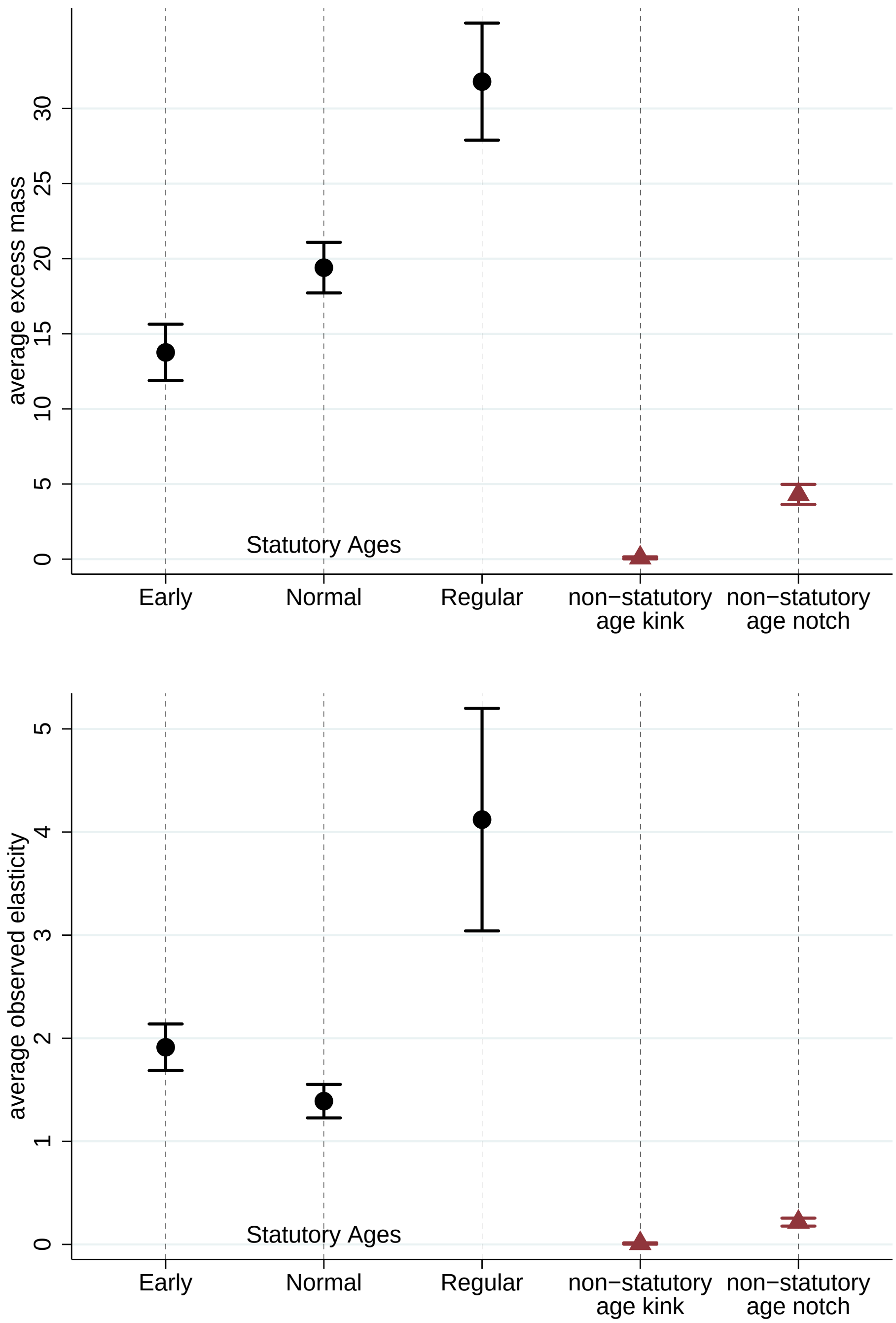
Panel B: Other discontinuities



Note: In panels A1, A2 and B2, the connected black dots show counts of job exit ages in monthly bins for the group indicated by the respective panel title. In panel B1, the black dots show counts of years of contributions instead. In all panels, the red line shows the counterfactual distribution estimated as a 7th-order polynomial, including round-age dummies in panels A1 and A2. Vertical red lines indicate the location of the discontinuity. See appendix figure A1 for the lifetime budget constraints of the four groups.

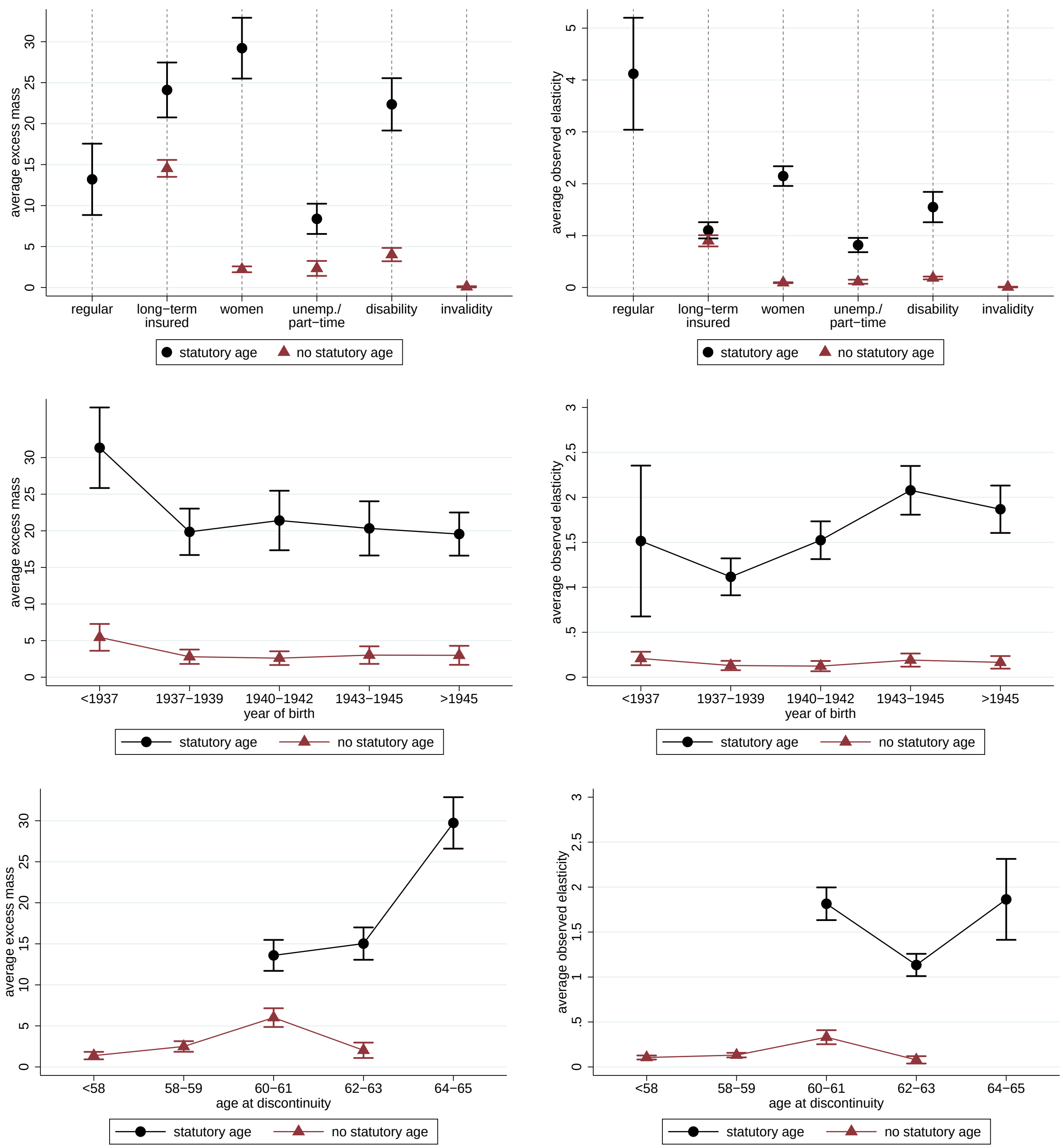
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure 5: Summarizing bunching



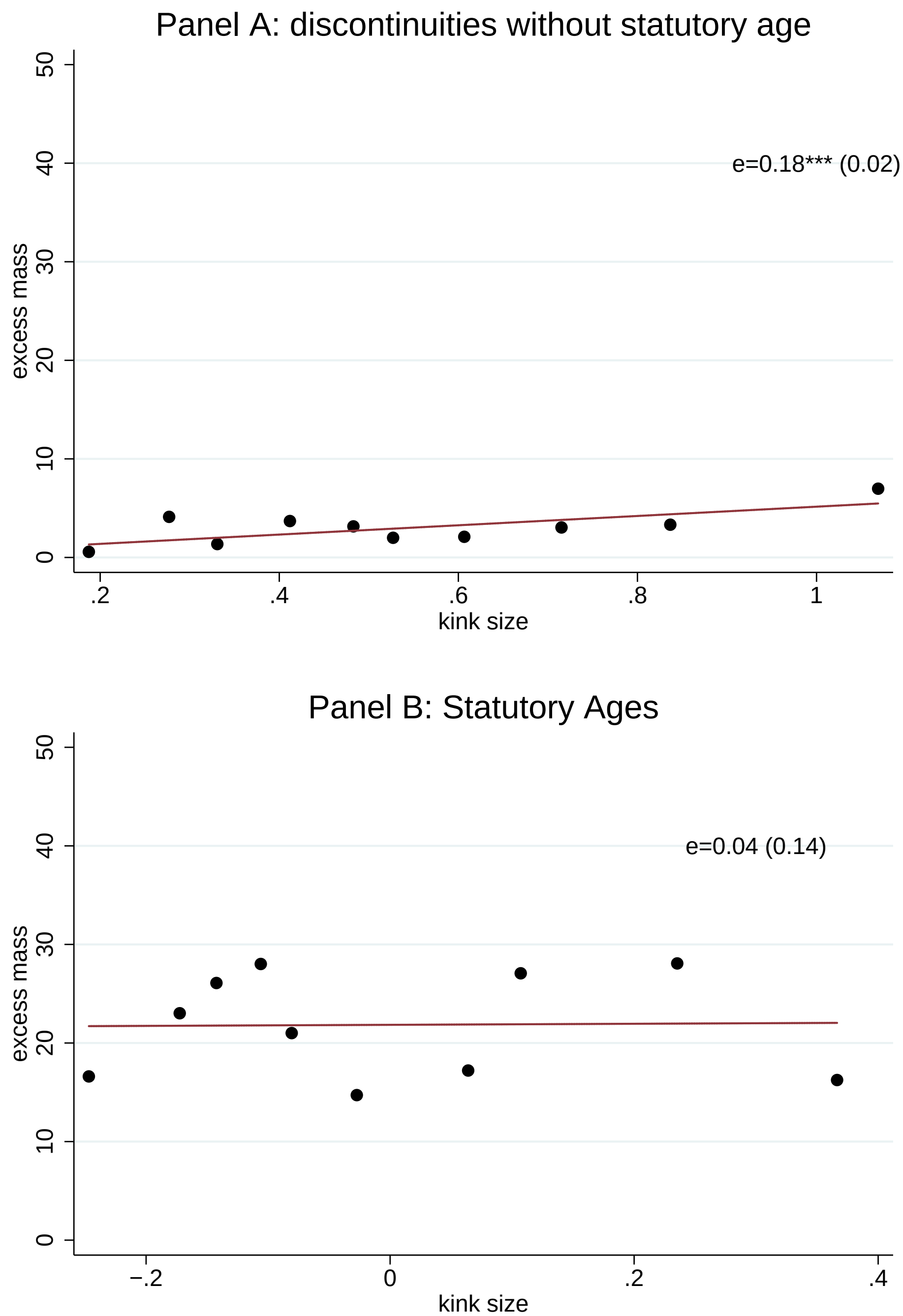
Note: The figure shows average excess mass (panel A) and average observed bunching elasticities (panel B) by type of discontinuity as in table 4. The horizontal bars around the point estimates mark confidence intervals based on bootstrapped standard errors. Observed elasticities in panel B are only calculated at convex kinks.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure 6: Bunching across groups and discontinuities



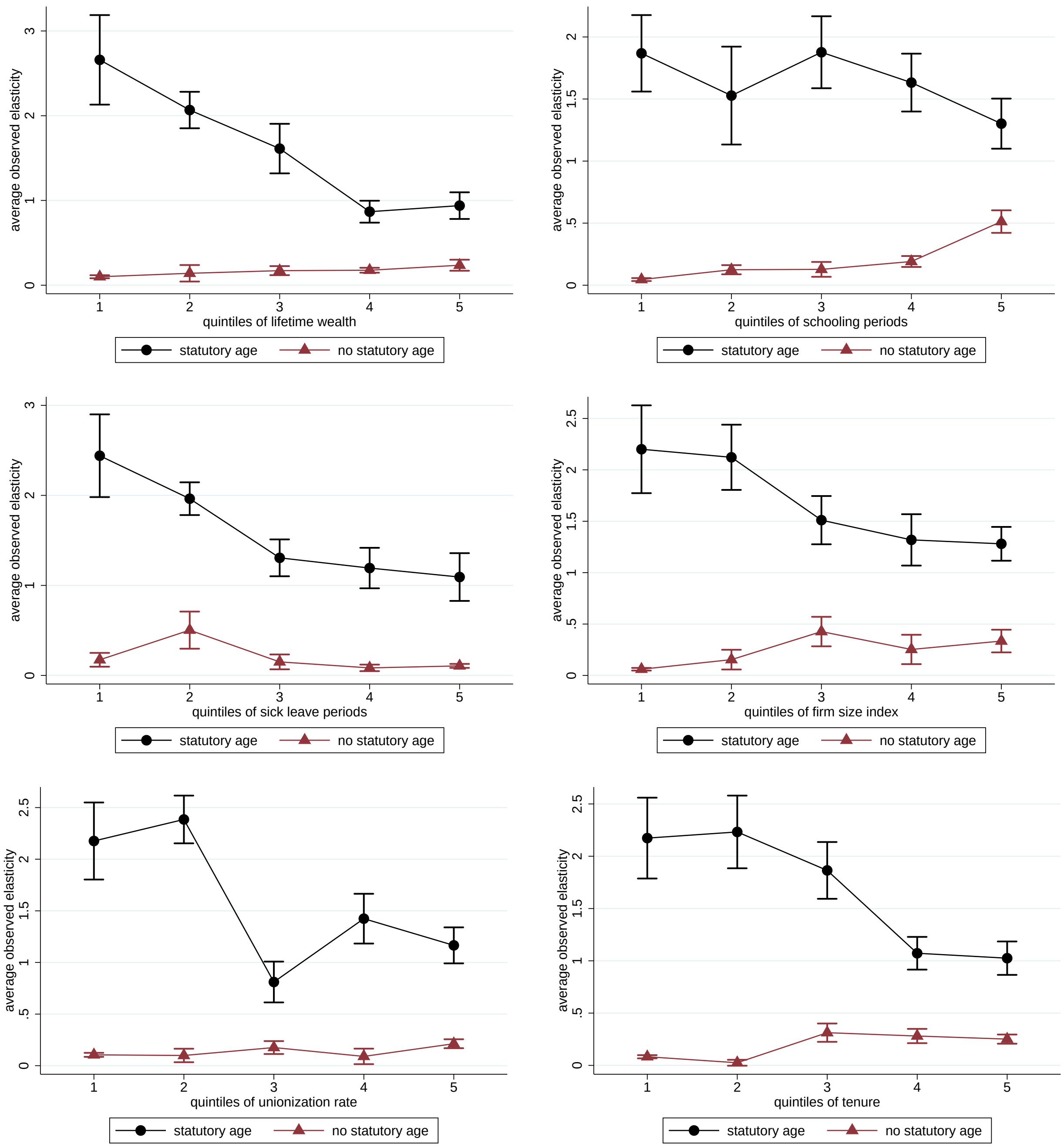
Note: The figure shows average excess mass (left panels) and average observed bunching elasticities (right panels) by retirement pathway, year of birth and the retirement age at the discontinuity. Black dots indicate bunching at statutory ages, whereas red triangles are for bunching at non-statutory age discontinuities. The horizontal bars around the point estimates mark confidence intervals based on bootstrapped standard errors. Observed elasticities in panel B are only calculated at convex kinks.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure 7: Bunching and financial incentives



Note: The figure shows binned scatterplots of the excess mass at non-statutory age discontinuities (panel A) and statutory ages (panel B) against kink size. In panel B, the type of statutory ages $s \in (ERA, NRA, RRA)$ is controlled for. Each panel also includes the coefficient from a regression of normalized excess mass $b/\hat{R}$ on kink size, which can be interpreted as a difference-in-bunching elasticity, with bootstrapped standard error in parantheses.
Data sources: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

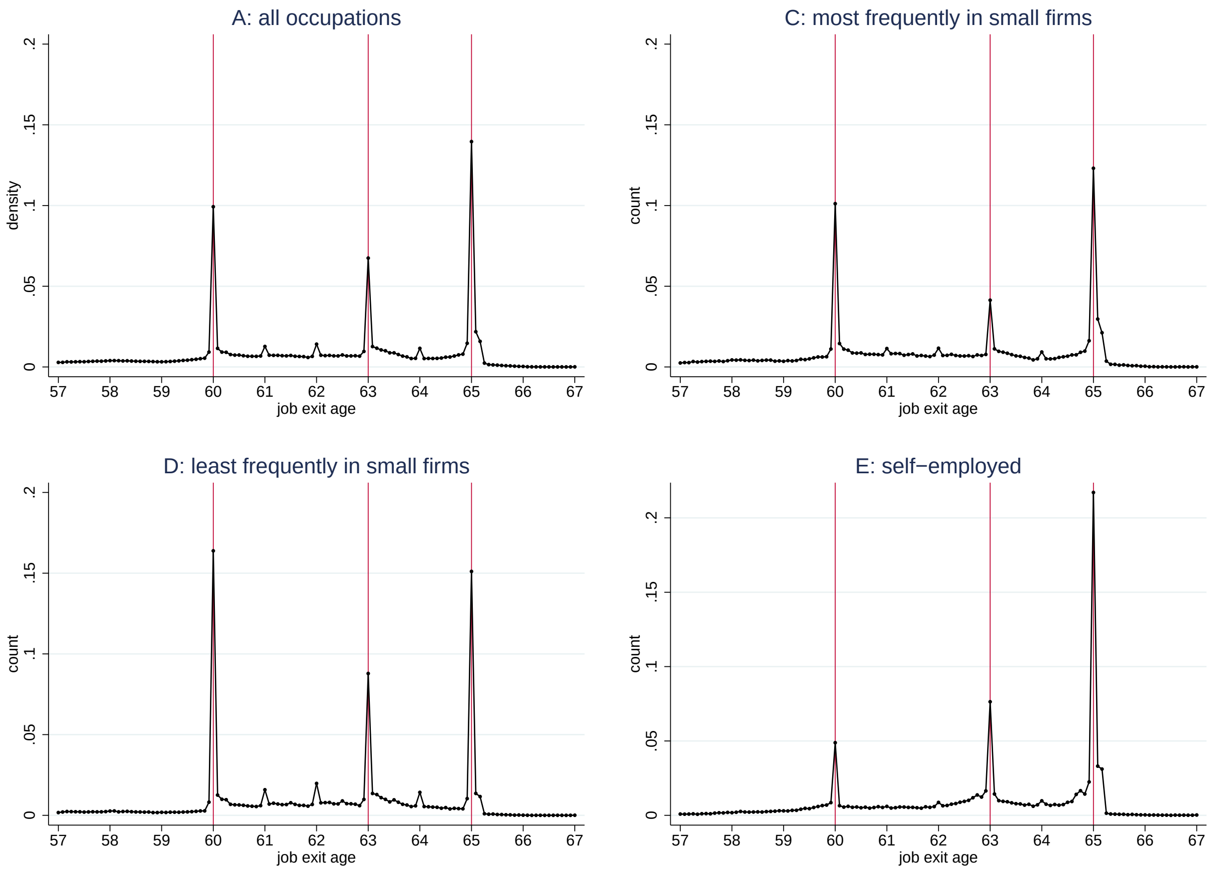
Figure 8: Observed Elasticities and group-level characteristics



Note: The figure shows average observed bunching elasticities by quintiles of estimated lifetime wealth, schooling periods, sick leave periods, a firm size index computed from discrete size categories, unionization rate and tenure. The latter three variables are at the occupation-level. Black dots indicate bunching at statutory ages, whereas red triangles are for bunching at non-statutory age discontinuities. The horizontal bars around the point estimates mark confidence intervals based on bootstrapped standard errors. Observed elasticities in panel B are only calculated at convex kinks. The corresponding excess mass is in appendix figure A3.

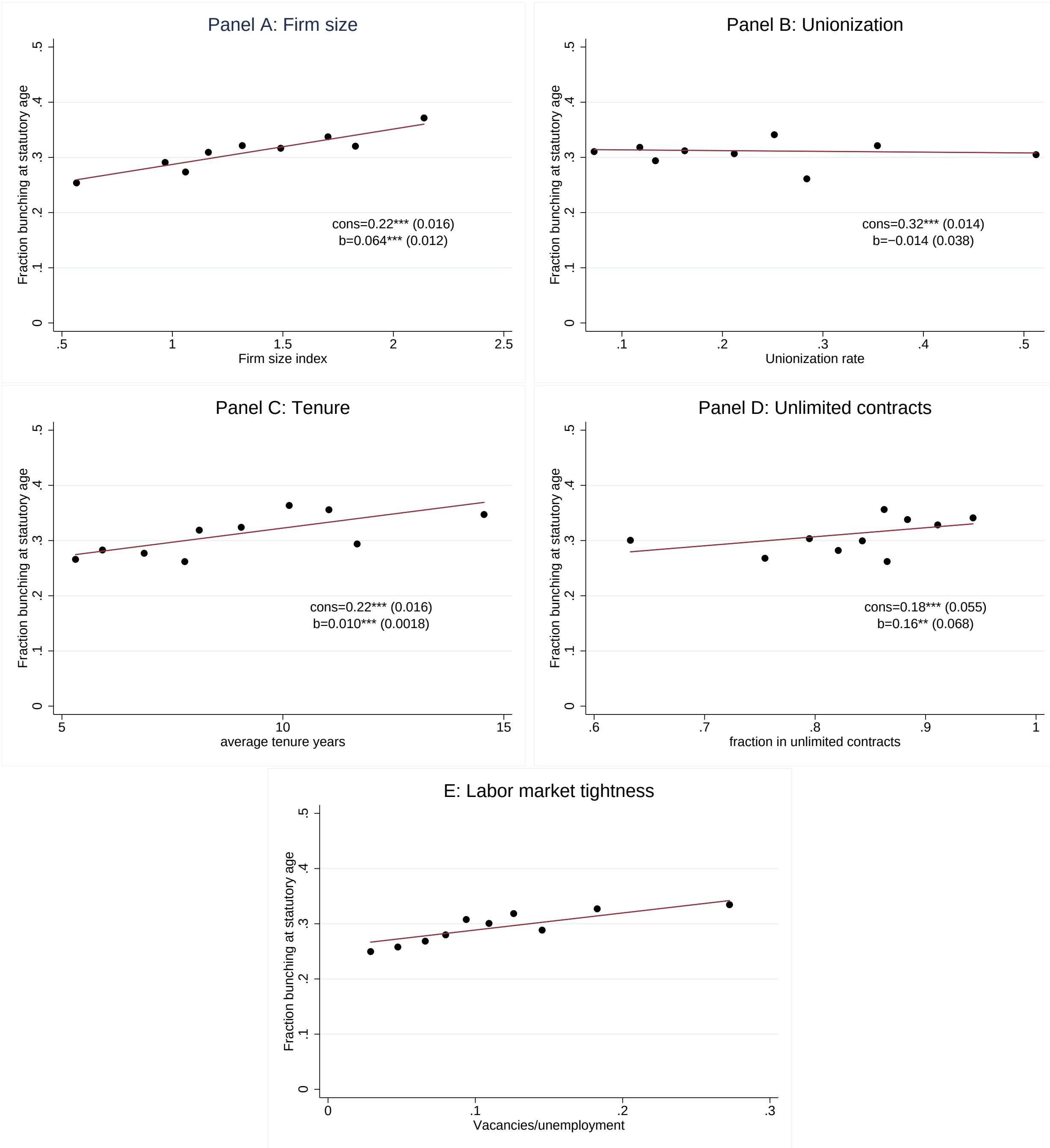
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure 9: Occupation-Level Distributions



Note: This figure shows the pooled distribution of job exit ages for all workers in the occupation-matched sample (panel A), the 20 occupations most frequently in small firms with less than 20 employees (panel B), the 20 occupations least frequently in small firms (panel C), and self-employed workers (panel D). The connected dots show the count of job exits within monthly bins. Vertical red lines indicate the location of main statutory ages throughout the sample period.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure 10: Statutory age job exits across occupations

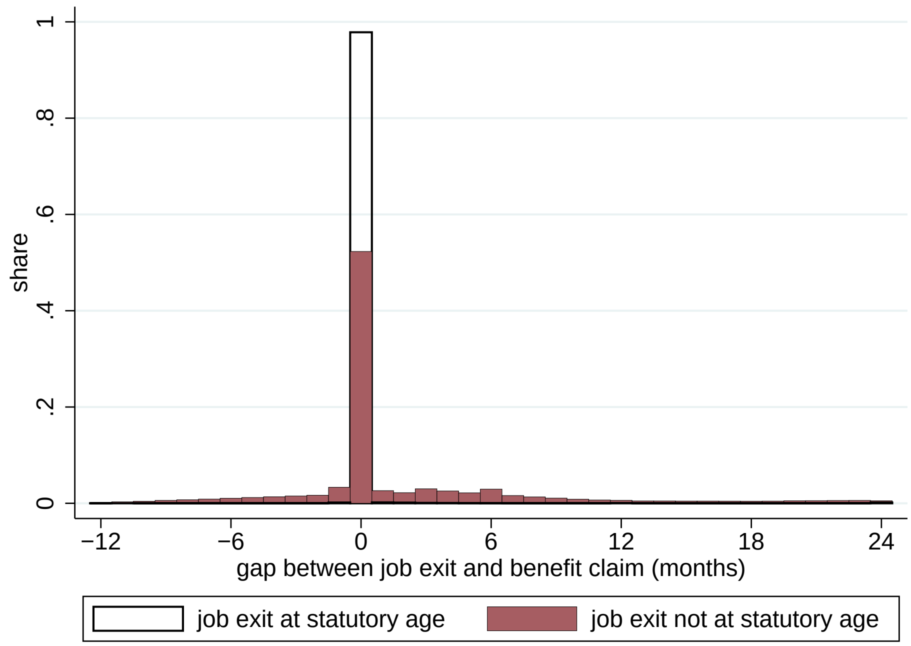


Note: This figure plots the fraction of workers in an occupation exiting their jobs at a statutory age against a number of variables related to firm incentives. Black dots show average values by decile of the respective explanatory variable. The red line is fitted by a univariate occupation-level regression whose constant and slope coefficient are also shown with robust standard errors in parantheses. Main data collapsed at 3-digit occupation level and merged with occupation-level averages of explanatory variables obtained from SOEP data. Firm size index is average value out of four size categories, 0=below 20 employees, 1=20 to 200, 2=200 to 2000, 3=above 2000. Unionization rate is fraction with union membership. Average tenure years is workers of all ages in an occupation. Fraction in unlimited contracts is fraction with term limit in their employment contract. The occupation-level data is weighted by group size for both bin calculation and regressions. Labor market tightness is calculated as the vacancies-unemployment ratio at the state-year level.

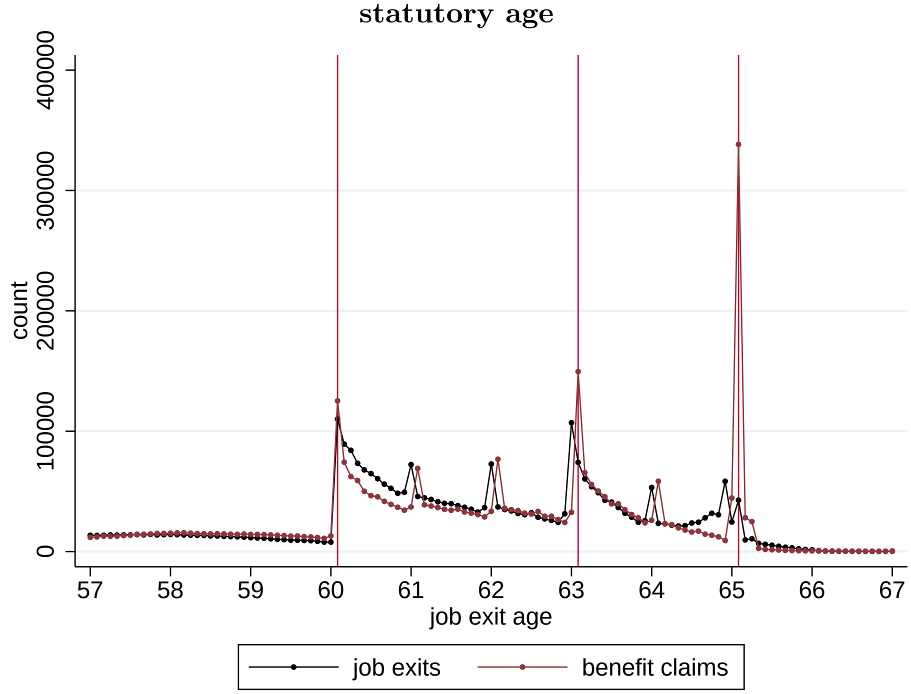
Data sources: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold; SOEP v30i

Figure 11: Benefit claiming

Panel A: Claiming gaps of workers eligible to claim immediately

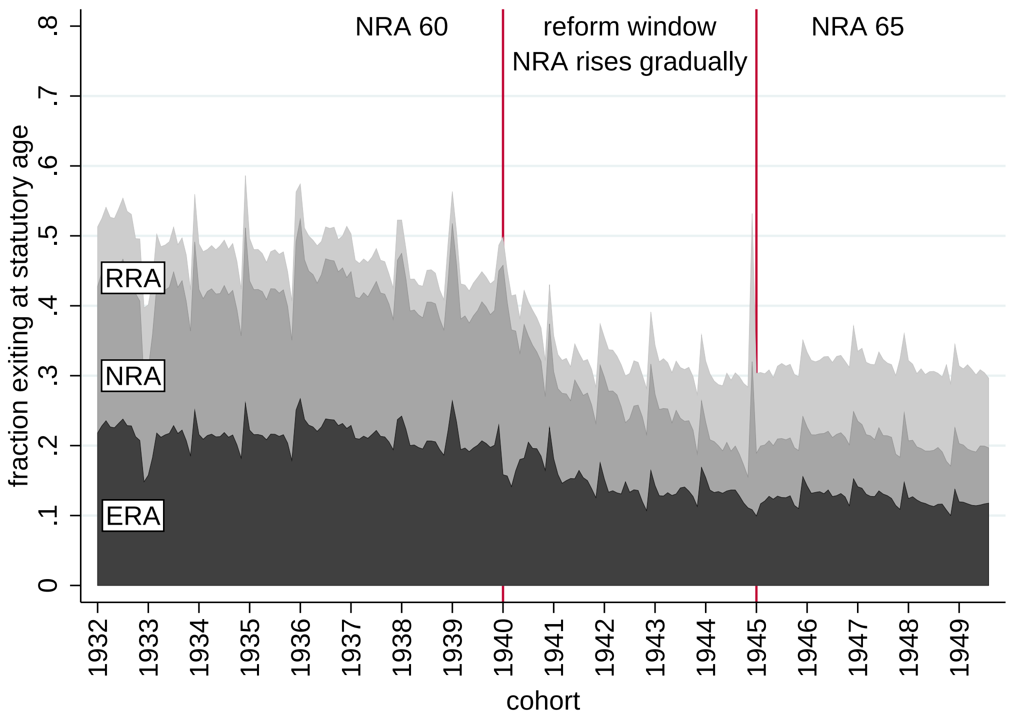


Panel B: Claiming ages of workers eligible to claim immediately who do not exit at statutory age



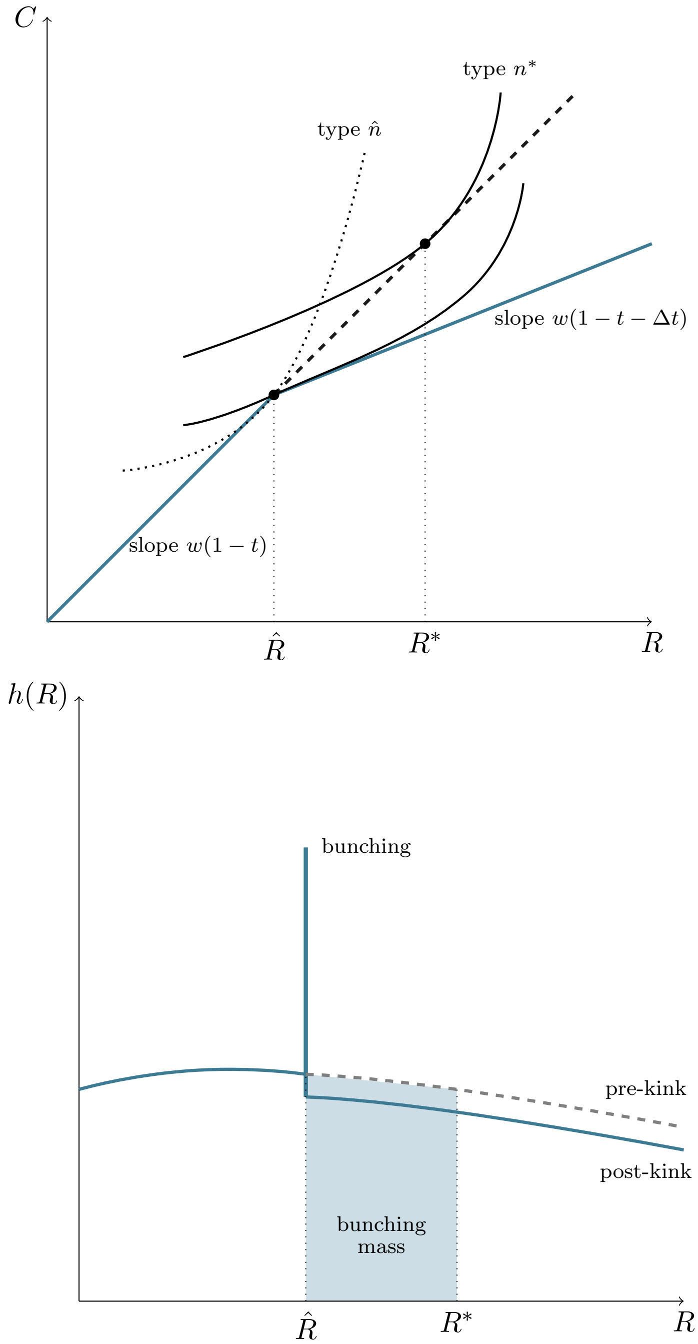
Note: Panel A of the figure shows a histogram of the gap in months between workers' job exit and benefit claim among those exiting their job at a statutory age (white bars) and those exiting at other ages (red bars). Only workers who are already eligible to claim are included in both groups. Panel B plots the distribution of job exit ages (black connected dots) and benefit claiming ages (red connected dots) among workers who are eligible to claim immediately.
Data sources: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold; SOEP v30i

Figure 12: Fraction exiting at statutory ages during a reform period



Note: The area shows the fraction or workers in the women's pathway exiting their job precisely in the month when they reach a statutory age. Different colors indicate at which statutory age type the job exit occurs. The dark area represents the ERA, dark grey the NRA and light grey the RRA. Fractions are computed at the month-of-birth level. If the split by statutory age type is ambiguous because more than one type coincide, the nearest instance of separate types is used to impute the split.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure 13: Bunching at a Budget Set Kink

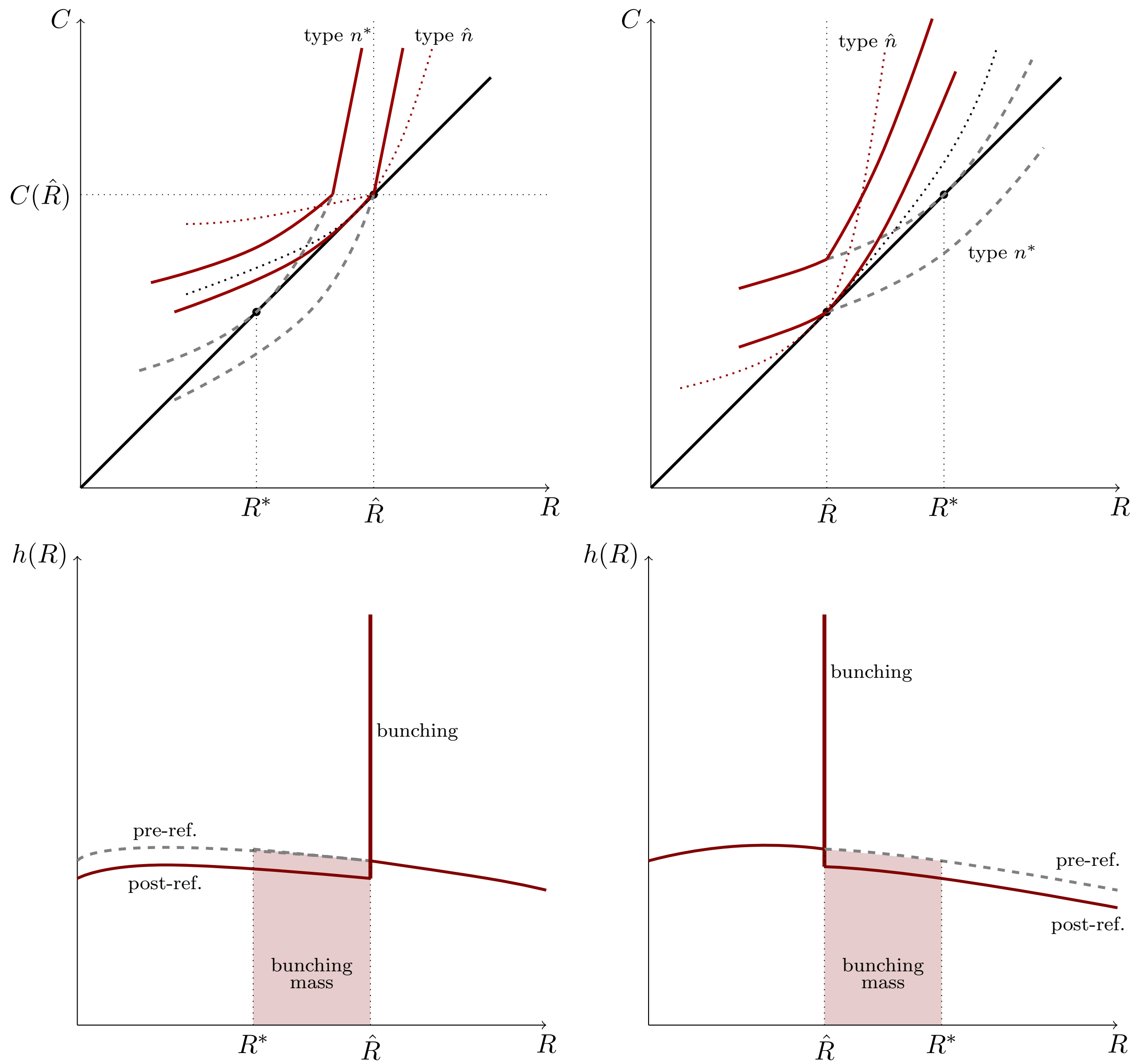


Note: This figure shows bunching responses to a budget set kink in an indifference curve diagram (upper panel) and a density diagram (lower panel). In the upper panel, the blue line is the post-kink budget set, whereas the dashed grey line is the pre-kink budget set. The dotted curve is an indifference curve of an individual with ability $\hat{n}$ who retires at $\hat{R}$ before and after the change. The solid curves are indifference curves of the marginal buncher with ability n^* who is tangent to the old budget set at R^* and tangent to the upper part of the new budget set at $\hat{R}$. In the lower panel, the solid blue line denotes the post-kink density, whereas the dotted line denotes the pre-kink density. The blue shaded area is the initial location of the mass of workers bunching in response to the kink.

Figure 14: Bunching at a Reference Point

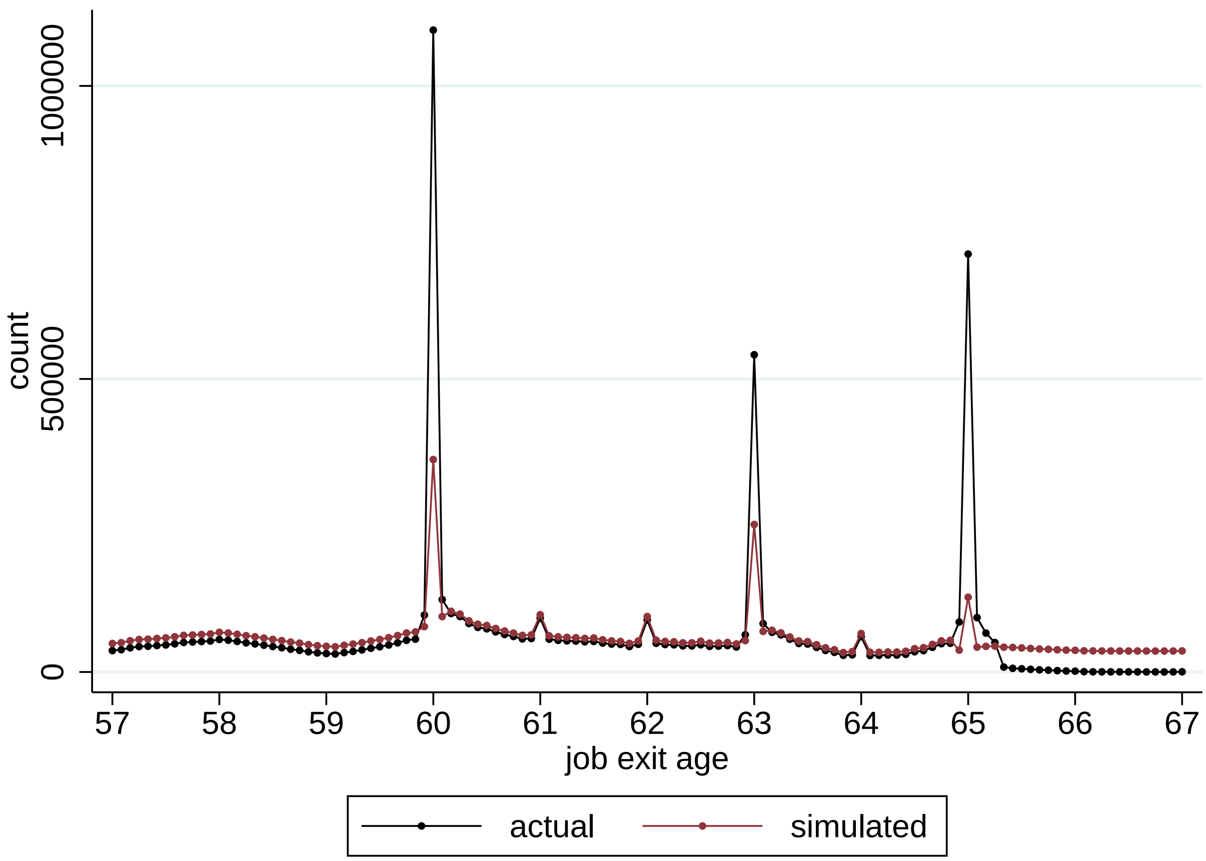
Left Panel:
Kink in Utility from Consumption

Right Panel:
Kink in Disutility from Work



Note: This figure shows bunching responses to a kink in utility from consumption (left panel) and to a kink in disutility from work (right panel) in an indifference curve diagram. In the top diagram of the left panel, the dashed grey curves are the pre-reference point indifference curves of the marginal buncher with ability n^*, whereas the solid red curves are her post-reference point indifference curves. The dotted curves are indifference curves pre-ref. (grey) and post-ref. (red) of an individual with ability $\hat{n}$ who retires at $\hat{R}$ before and after the change. The marginal buncher is tangent at R^* in the absence of the reference point, and tangent at $\hat{R}$ with the reference point. In the bottom diagram of the left panel, the solid red line denotes the post-ref. density, whereas the dotted line denotes the pre-ref. density. The red shaded area is the initial location of the mass of workers bunching in response to the kink. In the top diagram of the right panel, the dashed grey curves are the pre-ref. indifference curves of the marginal buncher with ability n^*, whereas the solid red curves are her post-ref. indifference curves. The dotted curves are indifference curves pre-ref. (grey) and post-ref. (red) of an individual with ability $\hat{n}$ who retires at $\hat{R}$ before and after the change. The marginal buncher is tangent at R^* in the absence of the reference point, and tangent at $\hat{R}$ with the reference point. In the bottom diagram of the right panel, the solid red line denotes the post-ref. density, whereas the dotted line denotes the pre-ref. density. The red shaded area is the initial location of the mass of workers bunching in response to the kink.

Figure 15: Simulated job exit age distribution: financial incentives only



Note: The black connected dots show the actual distribution of job exit ages for all workers born between 1933 and 1948. The red connected dots show the distribution of job exits among the same workers, simulated under a counterfactual scenario with no reference point effects. Bunching at each discontinuity is simulated based on equation (15) and the remaining bunching mass is distributed over the remaining density according to the estimated bunching shares from the two sides.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 1: Pathway overview

Pathway	Required contributions	Other requirements	NRA after 1990s reforms	ERA
Regular	5 years	-	65	65
Long-term insured	35 years	-	65	63
Women	15 years 10 years full	female	65	60
Unemployed/part-time	15 years 8 years full	unemployed or in old-age part-time work before retirement	65	60
Disabled	35 years	disability	63	60
Low earnings potential	5 years 3 years full	stricter disability	-	-

Note: For the unemployed/part-time pathway, unemployment for at least 1 year or old-age part-time work for at least 2 years after age 58 is required. For the disabled pathway, an officially recognized disability of a certain degree is required; low earnings potential entails a stricter disability requirement such that the worker is not able to work more than 3 hours a day in any job. Full contribution years excludes periods where contributions were paid voluntarily. "1990s reforms" denotes any reforms phased up until cohort 1945.

Table 2: Summary statistics

	(1) individual sample	(2) occupation-matched sample	(3) bunching sample
job exit age	59.66	61.26	60.87
	(3.92)	(3.46)	(1.46)
benefit claiming age	61.66	62.63	62.12
	(2.77)	(2.34)	(1.44)
lifetime wealth	1,047,749	1,101,822	1,074,722
	(420,029)	(433,622)	(258,461)
career length	42.87	43.96	43.60
	(6.88)	(6.98)	(2.35)
contribution points	35.90	38.44	36.76
	(17.03)	(17.94)	(10.67)
female	0.46	0.45	0.48
	(0.50)	(0.50)	(0.43)
east	0.16	0.20	0.18
	(0.37)	(0.40)	(0.09)
married	0.76	0.76	0.76
	(0.43)	(0.43)	(0.06)
sick leave (years)	0.081	0.058	0.07
	(0.27)	(0.21)	(0.04)
schooling (years)	10.57	10.72	10.64
	(1.53)	(1.76)	(0.28)
small firm		0.27	
		(0.18)	
large firm		0.44	
		(0.18)	
tenure		8.90	
		(2.79)	
unlimited contract		0.83	
		(0.09)	
Obs. (individuals)	10,429,748	4,262,339	
Obs. (groups)			644

Note: Benefit claiming ages, earned points, gender, East German residence and married are directly observed in data. Job exit ages and lifetime wealth are calculated as described in appendix C.1. Career length is time between first and last contribution. No. claims is the number of workers observed to claim in a pathway in the data. Small firm and large firm are indicators for firms with less than 20 employees and more than 200 employees, respectively. Standard deviations in parantheses.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 3: Summarizing discontinuities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Statutory Ages				Others (no statutory age)		
	all	Early	Normal	Regular	all	kinks	notches
Mean kink size $\frac{\Delta t}{1-t}$	0.08	0.32	0.41	-0.35	0.80	0.47	0.94
s.d. across groups	0.42	0.28	0.34	0.15	0.61	0.21	0.67
s.d. within group		[to be completed]					
No. discontinuities	387	117	258	94	258	78	180

Note: This table shows average bunching statistics by type of discontinuity. Standard errors in parantheses. Note that the number of discontinuities and individual observations in columns (2) to (4) are larger than the total in column (1) because some kinks are linked to more than one type of statutory age. †Average observed elasticity calculated only at convex kinks, that is excluding non-convex RRA kinks.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 4: Summarizing bunching observations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Statutory Ages				Others (no statutory age)		
	all	Early	Normal	Regular	all	kinks	notches
Excess mass b	21.8	13.8	20.6	31.8	2.99	0.09	4.31
	(0.88)	(0.96)	(0.87)	(1.99)	(0.27)	(0.04)	(0.34)
Observed	1.64	1.91	1.39	4.12	0.15	0.009	0.22
elasticity $\hat{\epsilon}$	(0.07)	(0.12)	(0.08)	(0.55)	(0.01)	(0.003)	(0.02)

Note: This table shows average bunching statistics by type of discontinuity. Excess mass and observed elasticities are computed as described in appendix D. All statistics are weighted by group sizes. Standard errors in parantheses. Observed elasticities are only calculated only at convex kinks, that is excluding non-convex RRA kinks.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 5: Reduced-Form Estimation

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Excess mass $b/\hat{R}$				
kink size $\frac{\Delta t}{1-t}$	0.11***	0.092***	0.087	0.049	0.074
	(0.026)	(0.026)	(.)	(.)	(.)
Statutory Age at kink:					
Early Retirement Age	0.23***	0.15***	0.17	0.18	0.18
	(0.027)	(0.027)	(.)	(.)	(.)
Normal Retirement Age	0.23***	0.27***	0.34	0.35	0.35
	(0.043)	(0.038)	(.)	(.)	(.)
Regular Retirement Age	0.77***	0.85***	0.83	0.80	0.82
	(0.073)	(0.078)	(.)	(.)	(.)
Observations (discontinuities)	644	644	644	644	583
R-squared	0.66	0.70	0.85	0.88	0.86
Stat. age interactions	no	yes	yes	yes	yes
Worker controls	no	no	yes	yes	yes
Pathway FE, year-of-birth FE	no	no	yes	yes	yes
Pathway × year-of-birth FE	no	no	no	yes	yes
Occupation-level controls	no	no	no	no	yes

Note: This table shows results from group-level regressions of excess mass normalized by the retirement age $\frac{b}{R}$ on kink size as well as dummies for the presence of statutory age types $s \in (ERA, NRA, RRA)$ based on equation (**??**). Statutory age interactions are interactions between dummies for each statutory age type. Worker controls include ... . Occupation-level controls include ... . Regressions weighted by group size. Bootstrapped standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 6: Reduced-Form Estimation: Heterogeneous Coefficients

	(1)	(2)	(3)	(4)
	Dependent variable: Excess mass $b/\hat{R}$			
kink size $\frac{\Delta t}{1-t}$	0.092***	0.29***	0.16***	0.26***
	(0.026)	(0.056)	(0.039)	(0.035)
Statutory Age at kink:				
Early Retirement Age	0.15***	0.21***	0.26***	0.30***
	(0.027)	(0.015)	(0.036)	(0.036)
Normal Retirement Age	0.27***	0.31***	0.34***	0.42***
	(0.038)	(0.037)	(0.039)	(0.056)
Regular Retirement Age	0.85***	1.05***	1.00***	1.00***
	(0.078)	(0.063)	(0.097)	(0.082)
Observations (discontinuities)	644	627	627	627
R-squared	0.69	0.87	0.81	0.96
Stat. age interactions	yes	yes	yes	yes
Heterogeneous coefficients:				
by pathway	no	yes	no	yes
by year of birth	no	no	yes	yes

Note: This table shows results from group-level regressions of excess mass normalized by the retirement age $\frac{b}{\hat{R}}$ on kink size as well as dummies for the presence of statutory age types $s \in (ERA, NRA, RRA)$ based on equation (**??**). Columns (1) and (2) report coefficients from regressions according to (5). Columns (3) to (5) report weighted averages of heterogeneous coefficients estimated according to eq. (6), where column (3) defines groups by pathway, (4) defines groups by year of birth, and (5) by pathway*year of birth. Groups with no variation in $\mathbb{1}(R = stat)$ are excluded from the within-group estimation in columns (3) to (5) since group-specific coefficients cannot be estimated in this case. Regressions weighted by group size. Block bootstrapped standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1.

Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 7: Firm incentives

	(1)	(2)	(3)	(4)
	Dependent variable: Dummy for job exit at...			
	ERA/NRA	RRA	other round age	non-stat. age discontinuity
firm size index	0.023***	0.009***	0.018***	-0.0003**
	(0.002)	(0.001)	(0.001)	(0.0002)
union	0.019***	-0.073***	-0.004	0.002***
	(0.005)	(0.004)	(0.003)	(0.0007)
tenure	-0.0009***	0.0002	-0.0009***	0.0000
	(0.0002)	(0.0001)	(0.0001)	(0.0000)
unlimited	0.002	-0.034***	-0.011***	0.001***
contracts	(0.004)	0.003	(0.004)	(0.0005)
labor market	-0.093*	0.50***	-0.062***	0.036***
tightness	(0.05)	(0.057)	(0.023)	(0.005)
Mean dep. var.	0.18	0.14	0.07	0.005
Observations	3,537,802	3,537,802	3,537,802	3,537,802
R-squared	0.08	0.17	0.09	0.02
Ind. controls	yes	yes	yes	yes
Year of birth FE	yes	yes	yes	yes
Pathway FE	yes	yes	yes	yes

Note: [**regression from Fernrechnen 3.**] Standard errors clustered at the pathway*month of birth level.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 8: Worker characteristics

	(1)	(2)	(3)	(4)
	Dependent variable: Dummy for job exit at...			
	ERA/NRA	RRA	other round age	non-stat. age discontinuity
schooling	-0.006***	0.015***	-0.002***	0.0001***
	(0.0004)	(0.0005)	(0.0002)	(0.00002)
female	0.11***	-0.14***	0.026***	-0.004***
	(0.004)	(0.005)	(0.003)	(0.0004)
married	-0.004***	-0.023***	-0.001***	0.004***
	(0.001)	(0.002)	(0.0005)	(0.0001)
life earnings	0.10***	-0.045***	0.015***	-0.016***
	(0.003)	(0.004)	(0.002)	(0.0005)
last earnings	0.020***	0.063***	0.020***	0.001***
	(0.002)	(0.002)	(0.001)	(0.0001)
Mean dep. var.	0.18	0.14	0.07	0.005
Observations	3,707,918	3,707,918	3,707,918	3,707,918
R-squared	0.10	0.18	0.10	0.02
Ind. controls	yes	yes	yes	yes
Year of birth FE	yes	yes	yes	yes
Pathway FE	yes	yes	yes	yes
Occupation FE	yes	yes	yes	yes

Note: [**regression from Fernrechnen 3.**] Standard errors clustered at the pathway*month of birth level.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 9: Structural Estimates

parameter	(1) upper bounds on λ^c	(2) upper bounds on λ^l	(3) ad-hoc comb. of upper bounds	(4) basic density shares	(5) gradient-corrected density shares
ϵ	0.15***	0.15***	0.15***	0.15***	0.15***
	[0.14,0.17]	[0.14,0.17]	[0.14,0.17]	[0.13,0.17]	[0.13,0.17]
λ^c_{ERA}	4.75***		4.79***	4.36***	3.15***
	[3.18,7.49]		[3.19,7.73]	[2.82,7.69]	[1.87,6.34]
λ^c_{NRA}	57.16***		41.72***	2.28***	4.48***
	[18.99,216.58]		[12.47,125.76]	[1.56,3.54]	[2.27,10.00]
λ^c_{RRA}	437,346***			3.28***	0.48***
	[7649,7.76e+09]			[1.94,5.76]	[0.12,1.00]
λ^l_{ERA}		0.15***		0.099***	0.083***
		[0.14,0.16]		[0.062,0.13]	[0.049,0.12]
λ^l_{NRA}		0.077***		0.068*	0.077***
		[0.0035,0.079]		[-0.0036,0.073]	[0.0035,0.079]
λ^l_{RRA}		0.38***	0.38***	0.38***	0.38***
		[0.38,0.45]	[0.38,0.45]	[0.38,0.45]	[0.38,0.45]
Discontinuities	644	644	644	644	644

Note: This table shows results from a non-linear least squares estimation of the structural equation (15). The estimation proceeds in two steps: First, estimation is run on the subsample of non-statutory age discontinuities, thus obtaining an estimate of ϵ. Second, the remaining coefficients are estimated using the full sample. The specification in column (1) estimates upper bounds on λ^s_c by assuming that all $\lambda^s_l = 0$. Conversely, column (2) estimates upper bounds on λ^s_l by assuming that $\lambda^s_c = 0$. Columns (3) estimates an ad-hoc combination by assuming that $\lambda^{RRA}_c = 0$ and $\lambda^{ERA}_l = \lambda^{NRA}_l = 0$. Estimates in columns (4) and (5) are based on observed density shares on both sides of the threshold as described in appendix E.2. Block bootstrapped 95% confidence intervals are shown in square brackets. *** p<0.01, ** p<0.05, * p<0.1.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table 10: Counterfactual bunching simulations

A: Incentives only

	(1)	(2)	(3)	(4)
	actual	counterfactual		
		structural ϵ	reduced-form ϵ	
		$\epsilon = 0.15$	$\epsilon = 0.092$	$\bar{\epsilon}_g = 0.29$
Percentage of job exits at statutory ages	29.0	6.04	4.92	10.1
% explained (of actual)		20.8%	17.0%	34.8%
Average excess mass				
at all discontinuities	19.2	0.99	0.48	2.00
% explained (of actual)		5.16%	2.50%	10.43%
at all statutory age kinks	21.8	0.65	0.27	1.81
% explained (of actual)		2.98%	1.24%	8.29%
at convex statutory age kinks	14.7	1.71	1.04	3.61
% explained (of actual)		11.6%	7.08%	24.6%

B: Incentives and firms use mandatory retirement

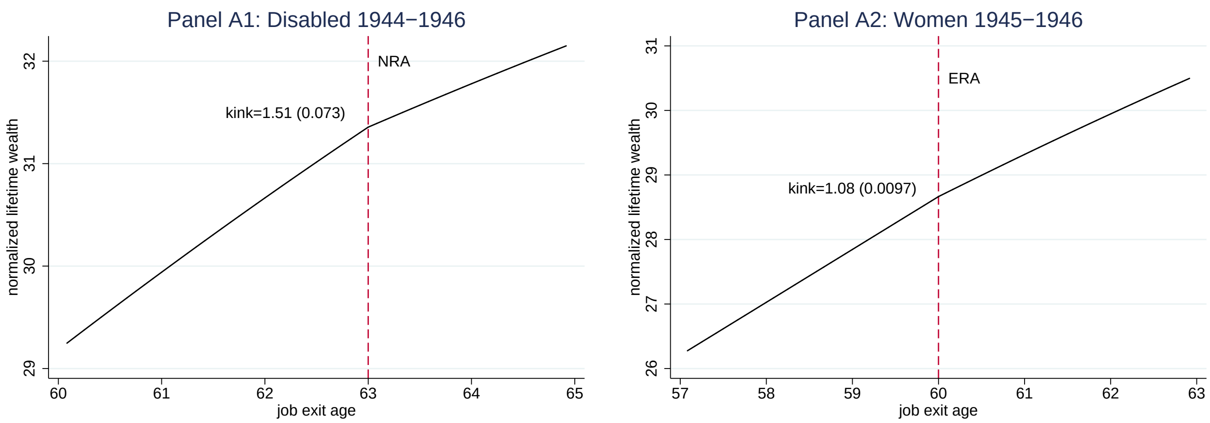
	(1)	(2)	(3)
	actual	counterfactual	
		$\lambda_l^{RRA} = \lambda_l^{NRA}$	all RRA due to mandatory
Percentage of job exits at statutory ages	29.0	7.41	16.6
% explained (of actual)		25.6%	57.2%
Average excess mass			
at all discontinuities	19.2	1.73	12.7
% explained (of actual)		9.01%	66.1%
at all statutory age kinks	21.8	1.51	14.3
% explained (of actual)		6.93%	65.6%
at convex statutory age kinks	14.7	1.83	2.24
% explained (of actual)		12.4%	15.2%

Note: This table shows results from a simulation of bunching at budget constraint discontinuities in the absence of statutory age effects. Column (1) shows the actually observed percentage of job exits at statutory ages and average excess mass. Columns (2) and (3) show figures from simulating bunching, using the elasticity estimates from columns (2) and (3) of table (**??**), respectively. Bunching at each discontinuity is simulated based on equation (15) and the remaining bunching mass is distributed over the remaining density according to the estimated bunching shares from the two sides. All statistics weighted by group size.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

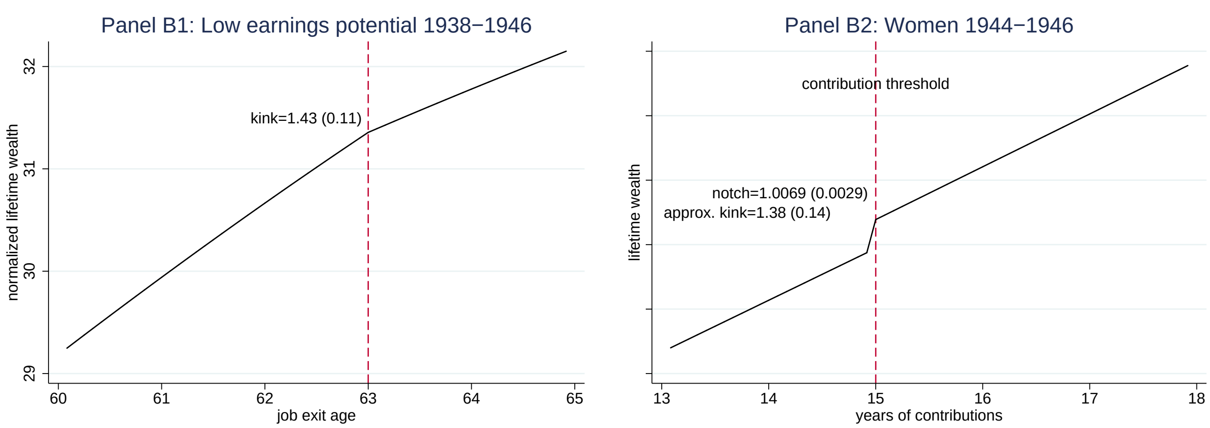
A Appendix Figures and Tables

Figure A1: Budget constraint discontinuities

Panel A: Statutory age kinks

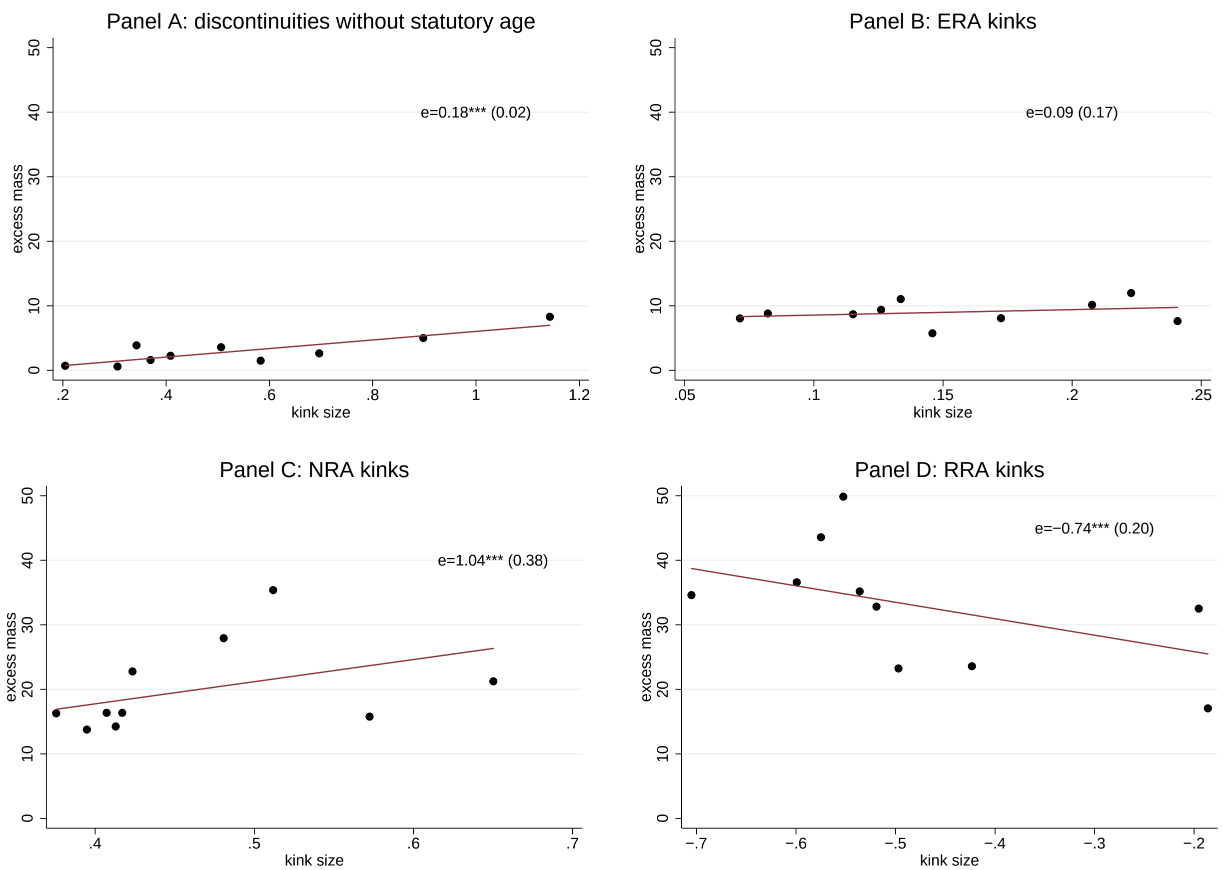


Panel B: Other discontinuities



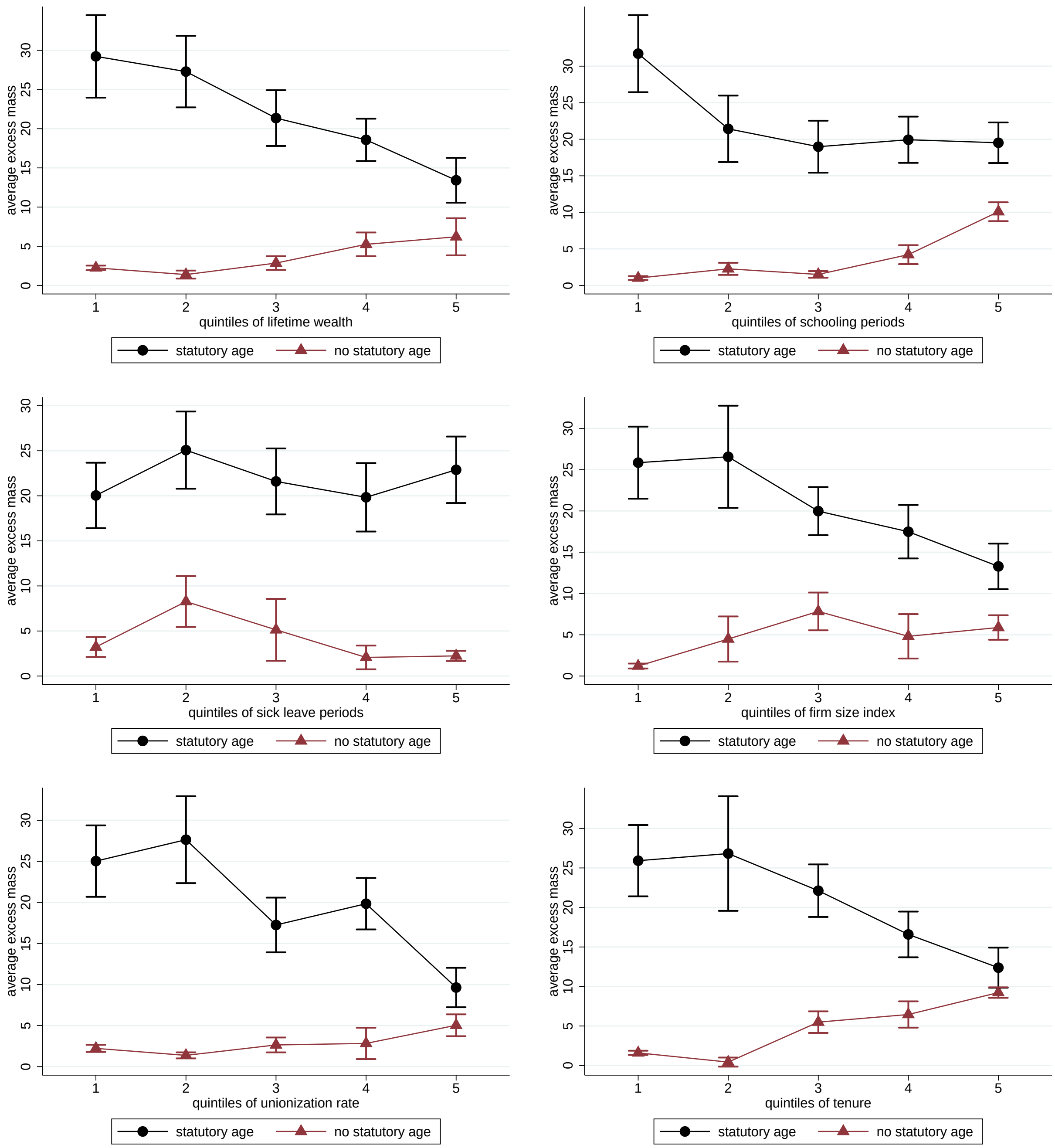
Note: This figure shows the lifetime budget constraint discontinuities around which bunching is estimated in figure 6. Panels A1 and A2 show kinks linked to the NRA in the disabled pathway and the ERA in the women's pathway, respectively. Panel B1 shows a kink due to financial adjustment of pensions in the LEP pathway, and panel B2 shows a notch arising from the 15-year contribution requirement in the women's pathway. Note that the size of the discontinuity varies across workers, and graphs show actual slopes for an average-income worker. "kink" denotes average kink size defined as the implicit marginal net-of-tax rate just below the kink relative to above, with standard deviations in parantheses. "notch" denotes average notch size defined as the implicit average net-of-tax rate just below the kink relative to above.

Figure A2: Bunching and financial incentives



Note: The figure shows binned scatterplots of the excess mass at non-statutory age discontinuities (panel A), ERAs (panel B), NRAs (panel C) and RRAs (panel D)against kink size. Each panel also includes the coefficient from a regression of normalized excess mass $b/\hat{R}$ on kink size, which can be interpreted as a difference-in-bunching elasticity, with bootstrapped standard error in parantheses.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

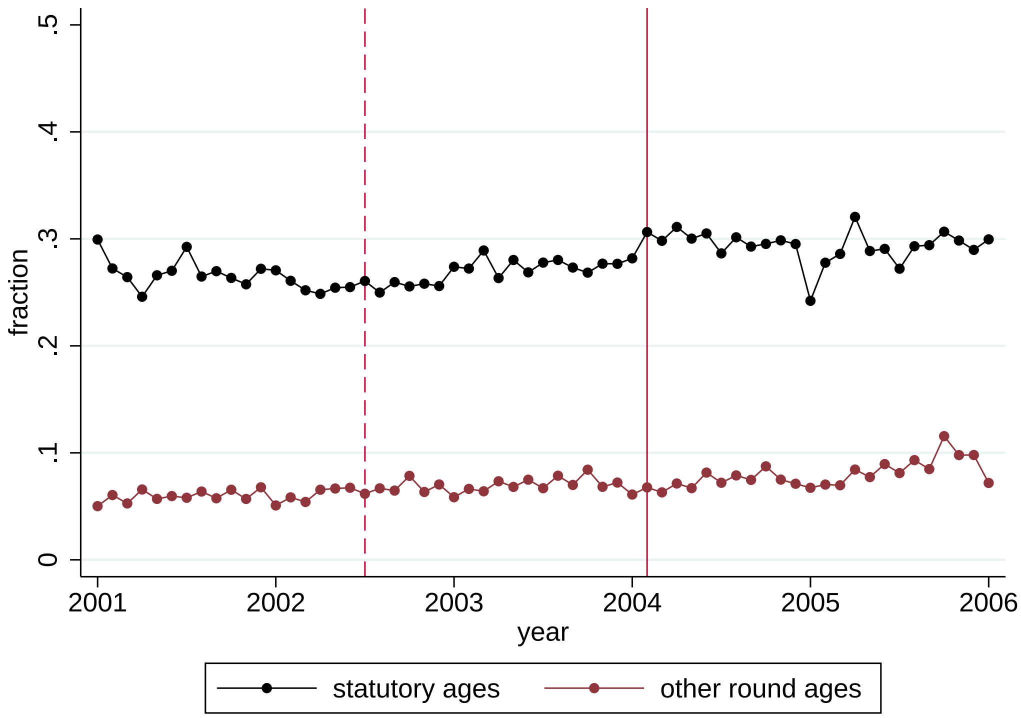
Figure A3: Bunching and group-level characteristics



Note: The figure shows average observed bunching elasticities by quintiles of estimated lifetime wealth, schooling periods, sick leave periods, a firm size index computed from discrete size categories, unionization rate and tenure. The latter three variables are at the occupation-level. Black dots indicate bunching at statutory ages, whereas red triangles are for bunching at non-statutory age discontinuities. The horizontal bars around the point estimates mark confidence intervals based on bootstrapped standard errors. Observed elasticities in panel B are only calculated at convex kinks. The corresponding excess mass is in figure 8.

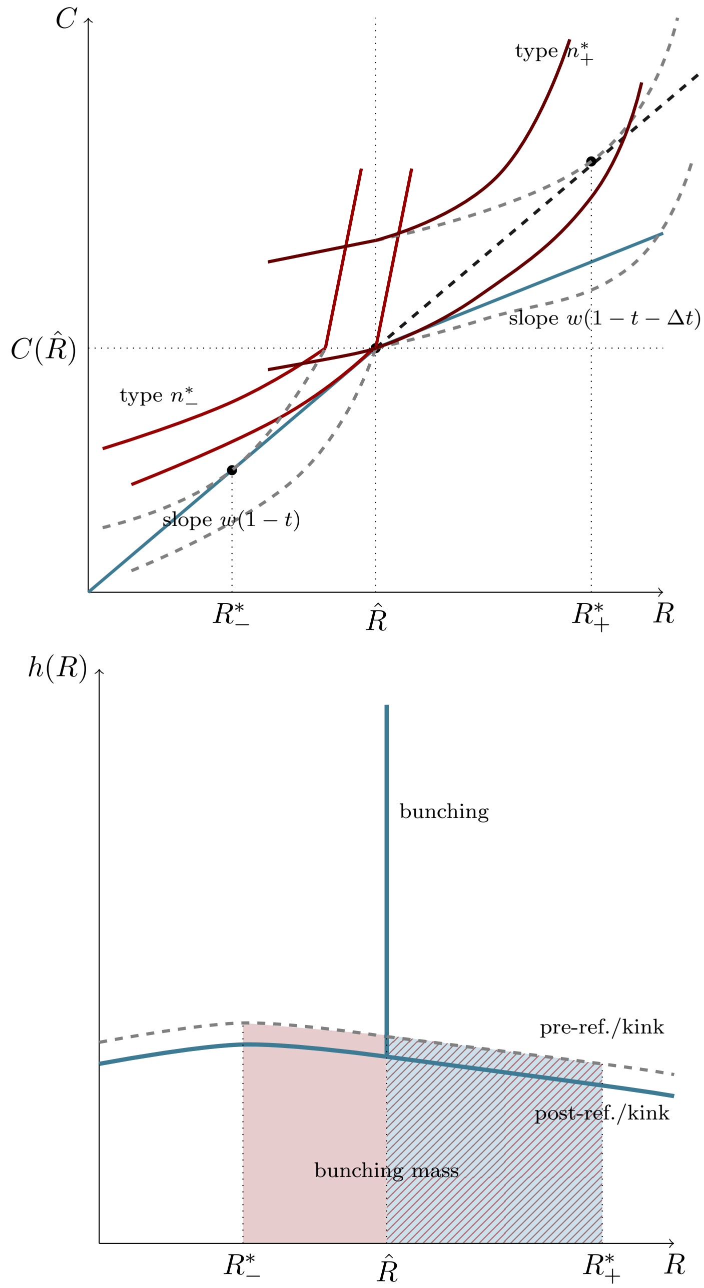
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure A4: Information provision and statutory age retirements



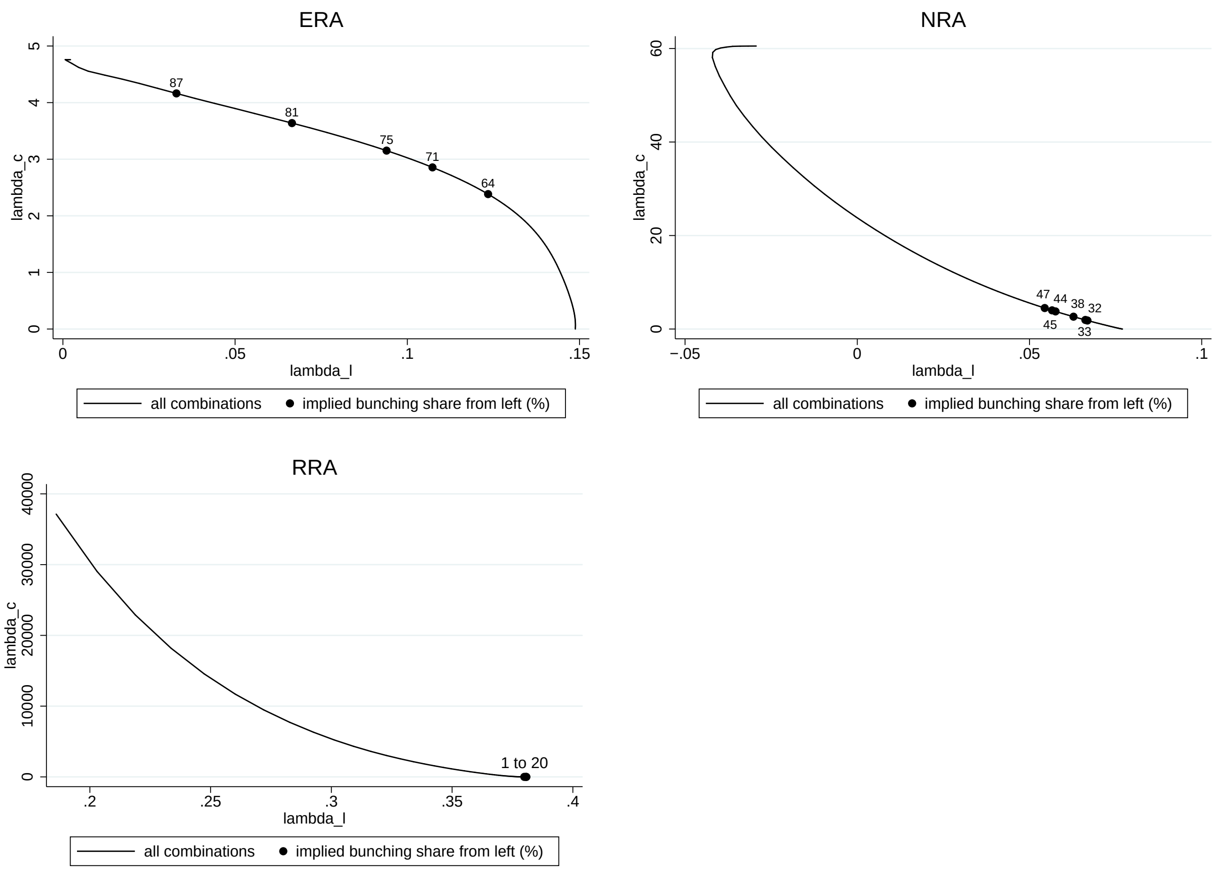
Note: This graph shows the fraction of job exits at ages 55 and above occurring at statutory ages and other round ages through a period where the pension fund increased the amount of information provided to workers. Before the reform, a detailed letter was sent to each worker only once. Under the new regime, a basic letter is sent to workers every year, and a detailed letter is sent every 3 years. The dotted vertical line indicates the beginning of the phase-in in June 2002 and the solid vertical line in December 2003 indicates the time when the reform was fully phased in. The black connected dots show the fraction exiting their job at any statutory age, while the red connected dots show the fraction exiting their job at other round ages.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure A5: Bunching at a Budget Set Kink with a Reference Point



Note: This figure shows bunching responses to a threshold combining a budget set kink, a kink in utility from consumption and a kink in disutility from work in an indifference curve diagram (upper panel) and a density diagram (lower panel). In the upper panel, the blue line is the kinked budget set, whereas the dashed grey line is the initial budget set. The dashed grey curves to the left of $\hat{R}$ are the initial indifference curves of the lower marginal buncher with ability n^*_- without the reference point, whereas the solid red curves are her indifference curves with the reference point. The lower marginal buncher is tangent at R^*_- in the absence of the reference point and the budget set kink, and tangent at $\hat{R}$ with the reference point and the budget set kink. The dashed grey curves to the right of $\hat{R}$ are the initial indifference curves of the upper marginal buncher with ability n^*_+, whereas the solid red curves are her indifference curves with the budget set kink and the reference point. The upper marginal buncher is tangent at R^*_+ in the absence of the reference point and the budget set kink, and tangent at $\hat{R}$ with the reference point and the budget set kink. In the lower panel, the solid blue line denotes the post-ref./kink density, whereas the dotted line denotes the pre-ref./kink density. The red shaded area is the initial location of the mass of workers bunching from the left in response to the kink in utility from consumption, while the blue and red shaded area is the initial location of the mass of workers bunching from the right in response to the budget set kink and the kink in disutility from work.

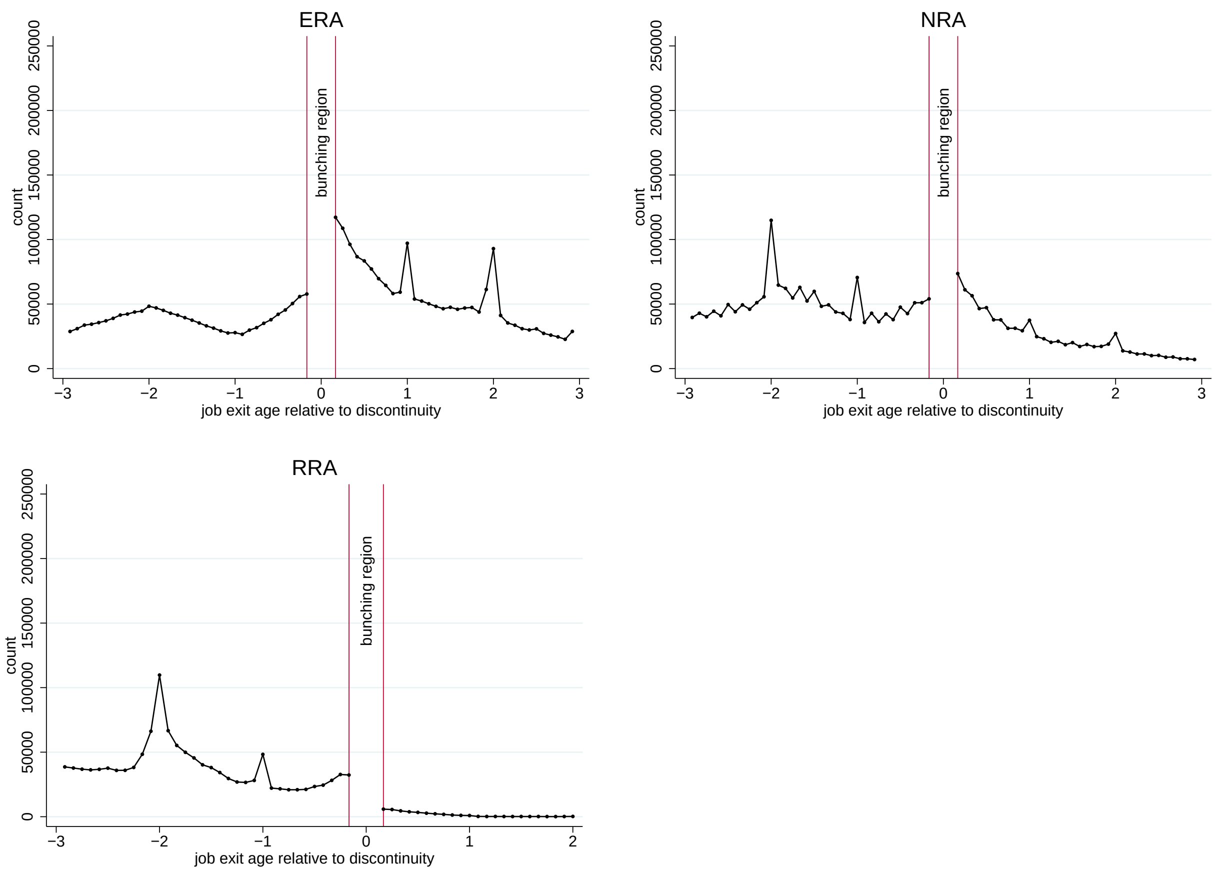
Figure A6: Structural Parameter Estimates



Note: This figure shows a range of estimated combinations of the parameters λ_c^{stat} and λ_l^{stat} for each statutory age type. The solid line in each panel shows the full range of possible combinations obtained from a simulation moving the share of bunching from the left at each discontinuity from 0 to its maximum in one-percentage point steps as described in appendix E.2. The labeled dots mark parameter combinations corresponding to the estimated bunching shares based on the different methods and estimation windows shown in table A8.

Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Figure A7: Pooled density around statutory ages



Note: The connected black dots show the pooled density around all ERAs (panel A), NRAs (panel B), and RRAs (panel C), each excluding the threshold +/- 1 month.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A1: Pathway summary statistics

	(1) all	(2) regular	(3) long-term	(4) women	(5) unemp.	(6) disabled	(7) low EP
job exit age	59.66	60.54	62.76	59.67	58.67	60.00	56.31
	(3.92)	(4.91)	(2.81)	(3.59)	(3.55)	(3.14)	(3.11)
benefit cl. age	61.66	65.19	64.00	61.75	61.29	61.68	57.37
	(2.77)	(0.74)	(0.93)	(2.05)	(1.51)	(1.84)	(2.90)
lifetime wealth	1,047,749	423,870	1,275,394	836,205	1,257,272	1,200,459	1,059,651
	(420,029)	(230,244)	(404,222	(304,148)	(358,880)	(366,003))	(351,895)
career length	42.87	36.70	46.35	42.41	43.70	44.44	39.33
	(6.88)	(13.12)	(4.76)	(6.66)	(5.27)	(4.34)	(6.18)
earned points	35.90	12.64	46.36	26.94	45.51	42.08	33.08
	(17.03)	(8.54)	(16.87)	(12.16)	(14.16)	(14.70)	(13.21)
female	0.46	0.59	0.10	1	0.078	0.25	0.35
	(0.50)	(0.49)	(0.30)	(0)	(0.27)	(0.44)	(0.48)
east	0.16	0.019	0.16	0.21	0.19	0.12	0.11
	(0.37)	(0.14)	(0.37)	(0.40)	(0.39)	(0.33)	(0.31)
married	0.76	0.75	0.82	0.69	0.81	0.78	0.75
	(0.43)	(0.43)	(0.39)	(0.46)	(0.39)	(0.42)	(0.43)
No. claims	10,429,748	1,972,796	1,210,558	2,679,377	2,081,863	1,024,834	1,399,250
No. eligible	10,429,748	603,036	1,764,788	3,280,272	2,143,447	1,176,482	1,400,653

Note: Benefit claiming ages, earned points, gender, East German residence and married are directly observed in data. Job exit ages and lifetime wealth are calculated as described in appendix C.1. Career length is time between first and last contribution. No. claims is the number of workers observed to claim in a pathway in the data. No. eligible refers to pathway eligible assigned as described in appendix C.2. Standard deviations in parantheses.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A2: Explaining observed elasticities

	(1)	(2)	(3)	(4)
	Dependent variable: Observed elasticity			
ERA	1.78***	1.64***	1.44***	
	(0.17)	(0.24)	(0.27)	
NRA	0.91***	0.71***	0.49**	
	(0.063)	(0.19)	(0.22)	
RRA	1.27***	2.05***	2.67***	
	(0.49)	(0.68)	(0.87)	
Discontinuities	568	553	553	553
R-squared	0.465	0.635	0.708	0.265
Controls	no	yes	yes	yes
Statutory age interactions	yes	yes	yes	no
Pathway & year of birth FE	no	no	yes	no

Note: This table shows results from group-level regressions of observed bunching elasticity on explanatory variables and dummies for presence of statutory ages, weighted by group size. Block bootstrapped standard errors in parantheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A3: Reduced-form estimation: Heterogeneous coefficients

Panel A: by pathway

	(1) Long-term Insured	(2) Women	(3) Unemp./ part-time	(4) Disability	(5) Invalidity
ϵ	0.62***	0.13***	0.44*	0.20***	0.0064**
	(0.085)	(0.044)	(0.24)	(0.011)	(0.0030)
β^{ERA}	0.12***	0.24***	0.094**	0.38***	
	(0.028)	(0.019)	(0.042)	(0.016)	
β^{NRA}	0.14*	0.57***	0.12	0.13***	
	(0.078)	(0.052)	(0.11)	(0.018)	
β^{RRA}	1.11***	1.16***	0.53***	1.34***	
	(0.070)	(0.12)	(0.17)	(0.050)	
Discontinuities	98	127	159	165	78
Stat. age interactions	yes	yes	yes	yes	yes

Panel B: by year of birth (selected)

	(1) 1933	(2) 1936	(3) 1939	(4) 1942	(5) 1945	(6) 1948
ϵ	0.082	0.078	0.086**	0.23***	0.25***	0.18*
	(0.61)	(0.34)	(0.036)	(0.080)	(0.059)	(0.10)
β^{ERA}	0.56	0.67**	0.15	0.25***	0.25***	0.30***
	(0.44)	(0.33)	(0.17)	(0.064)	(0.057)	(0.070)
β^{NRA}			0.17***	0.64***	0.14	0.31***
			(0.037)	(0.11)	(0.40)	(0.073)
β^{RRA}	1.02**	0.87***	0.66**	2.12***	1.22***	0.80***
	(0.49)	(0.22)	(0.31)	(0.84)	(0.47)	(0.22)
Discontinuities	15	15	46	58	23	37
Stat. age interactions	yes	yes	yes	yes	yes	yes

Note: This table shows heterogeneous coefficients whose weighted averages are presented in table **??**. Panel A presents heterogeneous coefficients by pathway, where the regular pathway is excluded because there is no variation in the presence of statutory ages. Panel B shows heterogeneous coefficients cohort for selected years of birth. Regressions weighted by group size. Block bootstrapped standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1. "Individual obs." is the sum of group sizes used for bunching estimation. This number exceeds the sample size if groups of workers are part of more than one bunching estimation because they face more than one discontinuity in their budget set.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A4: Reduced-form estimation excluding RRA discontinuities

	(1)	(2)	(3)	(4)	(5)
ϵ	0.14***	0.14***	0.26***	0.18***	0.26***
	(0.012)	(0.012)	(0.027)	(0.039)	(0.037)
β^{ERA}	0.24***	0.23***	0.21***	0.26***	0.30***
	(0.020)	(0.015)	(0.012)	(0.039)	(0.036)
β^{NRA}	0.39***	0.37***	0.32***	0.33***	0.34***
	(0.029)	(0.024)	(0.028)	(0.027)	(0.056)
Discontinuities	551	551	551	551	551
R-squared	0.74	0.74	0.87	0.77	0.88
Stat. age interactions	yes	yes	yes	yes	yes
Heterogeneous coefficients:					
by pathway	no	no	yes	no	yes
by year of birth	no	no	no	yes	yes

Note: This table shows results from group-level regressions analogous to table **??**, excluding all discontinuities linked to a RRA. ϵ is the coefficient on $\ln(1-\overline{\tau}/1-\underline{\tau})$. β^{stat} is the coefficient on $\mathbb{1}(\hat{R} = stat)$, where $stat \in (ERA, NRA, ERA = NRA)$. Columns (1) and (2) report coefficients from regressions according to (5). Columns (3) to (5) report weighted averages of heterogeneous coefficients estimated according to eq. (6), where column (3) defines groups by pathway, (4) defines groups by year of birth, and (5) by pathway*year of birth. Groups with no variation in $\mathbb{1}(R = stat)$ are excluded from the within-group estimation in columns (3) to (5) since group-specific coefficients cannot be estimated in this case. Regressions weighted by group size. Block bootstrapped standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1. "Individual obs." is the sum of group sizes used for bunching estimation. This number exceeds the sample size if groups of workers are part of more than one bunching estimation because they face more than one discontinuity in their budget set.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A5: Reduced-form estimation with reform effects

	(1)	(2)	(3)	(4)
	women NRA reform		all reforms	
ϵ	0.14***	0.14***	0.098***	0.079***
	(0.040)	(0.041)	(0.022)	(0.023)
β^{ERA}	0.23***	0.23***	0.22***	0.22***
	(0.019)	(0.019)	(0.020)	(0.020)
β^{ERA}_{ref}			-0.12***	-0.12***
			(0.027)	(0.027)
β^{NRA}	0.69***	0.69***	0.27***	0.27***
	(0.034)	(0.035)	(0.099)	(0.10)
β^{NRA}_{ref}	-0.22***	-0.061	-0.069	0.15
	(0.068)	(0.057)	(0.11)	(0.10)
$\beta^{NRA}_{postref}$		-0.36***		-0.55***
		(0.12)		(0.12)
β^{RRA}	1.11***	1.13***	0.76***	0.83***
	(0.11)	(0.12)	(0.084)	(0.090)
Discontinuities	127	127	540	540
R-squared	0.86	0.87	0.65	0.68

Note: This table shows results from group-level regressions analogous to table **??**, allowing for additional interactions of statutory age dummies with dummies for gradual reform periods. Like in table **??**, ϵ is the coefficient on kink size $\ln(1-\overline{\tau}/1-\underline{\tau})$. β^{stat} is the coefficient on $\mathbb{1}(\hat{R}=stat)$, where $stat \in (ERA, NRA, ERA=NRA)$. β^{NRA}_{ref} and β^{ERA}_{ref} are the coefficients on a dummy for the presence of the respective statutory age type interacted with a dummy for birth cohorts from the beginning of reform periods in each pathway. $\beta^{NRA}_{postref}$ and $\beta^{ERA}_{postref}$ analogous interactions with a dummy for birth cohorts from the time when reforms are fully phased in in each pathway. All columns report coefficients from regressions with homogeneous parameters analogous to (5). In column (1), the sample is limited to the discontinuities linked to the NRA or no statutory age in the women's pathway. In columns (2) and (3), the sample is limited to the discontinuities linked to the NRA or ERA, respectively, or no statutory age across all pathways. Regressions weighted by group size. Block bootstrapped standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1. "Individual obs." is the sum of group sizes used for bunching estimation. This number exceeds the sample size if groups of workers are part of more than one bunching estimation because they face more than one discontinuity in their budget set.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A6: Who retires at statutory ages?

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Dummy for job exit at...					
	any statutory age			statutory ages excluding RRA		
schooling	0.003***	0.009***	0.009***	-0.014***	-0.009***	-0.006***
	(0.0006)	(0.0006)	(0.0005)	(0.0007)	(0.0005)	(0.0004)
female	0.014***	-0.009*	-0.022***	0.12***	0.13***	0.11***
	(0.004)	(0.005)	(0.005)	(0.003)	(0.004)	(0.004)
married	-0.031***	-0.028***	-0.027***	-0.012***	-0.005***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.0013)	(0.001)	(0.001)
life earnings	0.14***	0.048***	0.058***	0.16***	0.10***	0.10***
	(0.007)	(0.004)	(0.003)	(0.008)	(0.004)	(0.003)
last earnings	0.049***	0.090***	0.084***	0.017***	0.021***	0.020***
	(0.005)	(0.002)	(0.002)	(0.005)	(0.002)	(0.002)
firm size index		0.032***			0.023***	
		(0.002)			(0.002)	
union		-0.055***			0.019***	
		(0.005)			(0.005)	
tenure		-0.0007***			-0.0009***	
		(0.0002)			0.0002	
unlimited		-0.032***			0.002	
contracts		(0.005)			(0.004)	
labor market	0.32***	0.41***	0.39***	0.041	-0.093*	-0.093*
tightness	(0.38)	(0.053)	(0.051)	(0.050)	(0.052)	(0.050)
Mean dep. var.	0.29	0.32	0.32	0.20	0.18	0.18
Observations	7,724,149	3,537,802	3,707,918	7,724,149	3,537,802	3,707,918
R-squared	0.17	0.14	0.16	0.14	0.08	0.10
Ind. controls	yes	yes	yes	yes	yes	yes
Year of birth FE	yes	yes	yes	yes	yes	yes
Pathway FE	yes	yes	yes	yes	yes	yes
Occupation FE	no	no	yes	no	no	yes

Note: This table shows results from an individual-level regression of indicators for retiring at the round ages not linked to statutory ages, the month of December, pathway switcher notches, the ERA or NRA, and the RRA on a number of worker characteristics. ln(lifeinc) is log lifetime labor income. ln(lastinc) is last annual income before retirement. eduyears is years of education. female, marrie, east, and foreign national are dummies. sickyears and childyears are years of sick leave and parental leave, respectively. l.m. training is an indicator for having participated in labor market training measures. Standard errors clustered at the pathway*month of birth level.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A7: Reduced-form estimation with salience effects

	(1)	(2)	(3)
ϵ	0.16**	0.16***	0.17***
	(0.066)	(0.062)	(0.022)
ϵ^{stat}	-0.89***	-1.34***	
	(0.29)	(0.27)	
ϵ^{ERA}			0.052
			(0.19)
ϵ^{NRA}			0.039
			(0.32)
ϵ^{RRA}			-1.72***
			(0.38)
β^{ERA}	0.36***	0.35***	0.22***
	(0.052)	(0.050)	(0.034)
β^{NRA}	0.57***	0.80***	0.35**
	(0.12)	(0.12)	(0.14)
β^{RRA}	0.30*	0.14	-0.0018
	(0.16)	(0.15)	(0.22)
Discontinuities	644	644	644
R-squared	0.66	0.70	0.75
Stat. age interactions	yes	yes	yes

Note: This table shows results from group-level regressions analogous to table **??**, allowing for additional interactions of kink size with the presence of statutory ages. Like in table **??**, ϵ is the coefficient on kink size $\ln(1-\overline{\tau}/1-\underline{\tau})$. β^{stat} is the coefficient on $\mathbb{1}(\hat{R} = stat)$, where $stat \in (ERA, NRA, ERA = NRA)$. ϵ^{stat} is the coefficient on kink size interacted with a dummy for the presence of any statutory age, while ϵ^{ERA}, ϵ^{NRA}, ϵ^{ERA} are the coefficients on kink size interacted with dummies for the respective statutory age type. All columns report coefficients from regressions with homogeneous parameters analogous to (5). Regressions weighted by group size. Block bootstrapped standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1. "Individual obs." is the sum of group sizes used for bunching estimation. This number exceeds the sample size if groups of workers are part of more than one bunching estimation because they face more than one discontinuity in their budget set.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

Table A8: Estimated Bunching Shares from the Left vs. Right

	(1)	(2)	(3)	(4)	(5)	(6)
	Basic Estimation			Gradient-Corrected Estimation		
Window	12 months	24 months	36 months	12 months	24 months	36 months
m_{-}^{ERA}	0.71	0.81	0.87	0.64	0.75	0.81
	(0.21)	(0.26)	(0.27)	(0.34)	(0.34)	(0.32)
m_{-}^{NRA}	0.38	0.33	0.32	0.47	0.45	0.44
	(0.25)	(0.34)	(0.37)	(0.41)	(0.44)	(0.46)
m_{-}^{RRA}	0.20	0.054	0.0085	0.058	0.024	0.015
	(0.12)	(0.078)	(0.036)	(0.16)	(0.13)	(0.10)
Discont.	387	387	387	387	387	387

Note: This table shows bunching shares from the left vs. the right of statutory age thresholds based estimated based on the relative density on both sides. m_{-}^{stat} denotes the share of missing density from the left out of total bunching at statutory type *stat*. Missing density is computed as described in appendix E.2. Each column shows averages across all discontinuities of the respective type, with standard deviations in parantheses. All statistics weighted by group size.
Data source: FDZ-RV - Themenfile SUFRTZN1992-2014XVSBB_Seibold

B Institutional Details

B.1 Pathways and Statutory Ages

Pensions in the German public pension system (*gesetzliche Rentenversicherung*) are legally defined in German Social Law, vol. 6 (*Sozialgesetzbuch (SGB) VI*), where a section is devoted to each of the six pathways. First, the *regular pathway* is defined in SGB VI §235. Workers are eligible for this pathway with at least 5 years of contributions (*Wartezeit*, lit. waiting time). A regular pension can only be claimed from the RRA. Hence, the implicit ERA and NRA of the regular pathway coincide with the RRA. The RRA is 65 for workers born until 1946, but for cohorts 1947 to 1964 it increases gradually by one month for each year of birth from 65 to 67 (§235(2)).

Second, the *long-term insured pathway* is defined in §236. Workers are eligible with at least 35 years of contributions. The ERA is 63 throughout the sample period. The NRA is 63 until 1936, is raised gradually by 1 month for each month of birth from 63 to 65 during birth cohorts 1937 and 1938 (SGB VI appendix 21) where it remains until cohort 1948. The NRA increases to 65 and 3 months for cohort 1949 and further increases gradually by one month for each year of birth from 65/3 to 67 for cohorts 1950 to 1964 (§236(2)).

Third, the *women's pathway* is defined in §237a. Women with at least 15 years of contributions are eligible. At least 10 years have to be full contributions, i.e. excluding voluntary contributions, made after their 40th birthday. The ERA is 60 throughout the sample period. The NRA is 60 until 1939, is raised to 65 during cohorts 1940 to 1944 (SGB VI appendix 20) and remains 65 for women born until the end of the sample period. For cohorts born 1952 and later, the pathway will be abolished.

Fourth, the *unemployed/part-time pathway* is defined in §237. Eligibility requires at least 15 years of contributions, and at least 8 out of the 10 years before retirement have to be full contributions. Moreover, the workers must be either unemployed for at least 1 year after age 58 years and 6 months, or in old-age part-time work. Old-age part-time work is a program where workers aged 55 and older reduce their hours to part-time while the decrease in earnings is partly compensated by a government subsidy to the worker. Note that the program has been terminated in 2009. The ERA of this pathway is 60 for workers born until 1945, rises gradually by 1 month for each month of birth from 60 to 63 during birth cohorts 1946 to 1948 (SBG VI appendix 19), and remains 63 until the end of the sample period. The NRA is 60 until 1936, increases gradually by 1 month for each month of birth from 60 to 65 during birth cohorts 1937 to 1940 (SBG VI appendix 19) and remains 65 until the end of the sample period. For cohorts born 1952 and later, the pathway will be abolished.

Fifth, the *disabled pathway* is defined in §236a. Workers with at least 35 years of contributions and with an officially recognized disability of at least degree 50% are eligible. The degree of disability is an index factoring in all types of permanent physical and mental conditions. The ERA is 60 throughout the sample period. The NRA is 60 for workers born until 1940, is raised gradually by 1 month for each month of birth from 60 to 63 during birth cohorts 1941 to 1943 (SGB VI appendix 22), and remains 63 until the end of the sample period.

All these pathways are introduced in conjunction with the relevant statutory ages. The RRA (*Regelaltersgrenze*) is defined in §235 as the age from which a regular pension can be claimed. For the remaining pathways, the NRA (*Altersgrenze*) and the ERA (*Alter der frühestmöglichen Inanspruchnahme*) are specified along with the pathways themselves. The NRA is further described as the "age from which an insured person is eligible", while the ERA is the"age from which early claiming is possible".

The sixth pathway, the *low earnings potential (LEP) pathway* is defined in §43. Workers are required at least 5 years of contributions, and at least 3 out the 5 years before retirement must be full contributions. Moreover, workers must have been officially recognized as "low earnings potential", which entails permanently not being able to work more than 3 hours per day in any job. A partial LEP pension may be available if the worker is deemed to be able to work more than 3 but less than 6 hours per day. LEP pensions can be claimed at any age and there is no ERA or NRA in this pathway. Earned points in LEP are "filled up" (*Zurechnungszeit*) as if the worker had kept on earning their average pre-retirement income until age 60. Hence, LEP features an additional insurance element compared to other pathways since benefits are less dependent on lifetime contributions.

B.2 Pension Adjustment

Explicit pension adjustment for a worker's retirement age was introduced into the pension formula (*Rentenformel*) in 1997 along with the ERA and NRA reforms described above. The adjustment factor (*Zugangsfaktor*) is defined in §77 SGB and is 100% if a worker claims their pension at the NRA of their pathway. For each month of claiming before the NRA, the adjustment factor (and hence the benefit paid) is reduced by 0.3%, with the maximum negative adjustment implied by the distance between the ERA (the earliest claiming age) and NRA. The adjustment factor remains 100% between the NRA and the RRA. Only after the RRA, there are rewards for late retirement: the adjustment factor increases by 0.5% for each month of claiming after the RRA.
Since 2001, LEP pensions are also subject to an adjustment factor defined in §77(2)3. Until the end of the sample period, LEP pensions are decreased by 0.3% for each month of claiming before age 63. There is a maximum negative adjustment of 10.8% that applies to claims below age 60. Moreover, there was a transition period between 2001 and 2003 according to SBG VI appendix 23, where the maximum negative adjustment was gradually increased from 0 to 10.8%. This was done to avoid a notch in the budget set of LEP workers that would have created a strong incentive to retire before 2001. The end of the filling period of earned points was gradually extended from 55 to 60 at the same time.

B.3 Benefit Calculation

Upon submitting her pension claim, a worker's benefits B_i are computed according to the following "pension formula":

$$B_i(R_i) = V \cdot \alpha(\max(R_i, ERA)) \cdot \sum_{t=0}^{R_i-1} \frac{w_{it}}{\bar{w}_t} \tag{18}$$

The formula has three components. The first component is the *sum of earned points*. In the Bismarckian system, the points a worker earns in a year are equal to her earnings w_{it} relative to the average income among the insured population $\bar{w}_t$. Points are then summed across all years in which contributions were paid. Hence, additional contributions always increase the worker's benefits and pensions become roughly proportional to lifetime income. Second, the worker is assigned an *adjustment factor* α as a function of her benefit claiming age. The benefit claiming age $\max(R_i, ERA)$ is the job exit age if the job exit occurs no earlier than the the ERA, or the ERA otherwise. Adjustment is framed around the NRA, where a worker can claim her *full pension*, i.e. $\alpha(NRA) = 100\%$. The adjustment function α follows a kinked schedule, with a penalty of 0.3% for each month of retirement before the NRA, a reward of 0.5% for each month of retirement after the RRA, and no adjustment between the NRA and the RRA. The third component is the *pension value* V which translates adjusted earned points into monthly benefits. V is indexed to annual nominal wage growth (€26.39 in 2014).

C Data

C.1 Variable Definitions

Job exit ages.
A worker's age at benefit claiming and the age of the last contribution can be observed in the data as the distance between the month of birth and the month of claiming or the last contribution. Job exit ages cannot be directly observed, but correspond to the age at the last contribution for most workers. However, for some workers their last month of work does not entail any contributions, or their last month of contributions stems from a status other than employment. To account for this, additional information on the insurance status in the last three years before a worker's benefit claim is used. This status is coded into four categories, 1=work/contributions, 2=no work/no contributions, 3=work/no contributions, 4=no work/contributions. If a worker's last known status is 1 or 2, the last contribution coincides with the job exit. This is the case for 87% of workers in the sample. Categories 3 and 4 pose the problem that the job exit cannot be inferred from the last contribution. However, the timing of job exits can be bounded by the information on workers' status in the three years before retirement. For instance, if a worker is known to be in category 1 20 months before benefit claiming and category 4 8 months before retirement, her job exit is age must have been between 20 months and 8 months before the benefit claiming age. Hence, job exit ages of the remaining workers are imputed via a uniform distribution between the closest known bounds. This imputation is mostly relevant for job exits before the ERA since gaps between job exits and benefit claiming occur in these cases. At the ERA or later, most workers claim benefits right after their job exit so last contributions are not typically confounded by a status other than work.
Years of Contributions.
Pathway eligibility is partly determined by a worker's years of contributions (*Wartezeit*, lit. waiting time). Besides contribution periods (*Beitragszeiten*) from employment, a number of other periods such as voluntary contributions of self-employed individuals and "substitute periods" (*Ersatzzeiten*, e.g. due to political imprisonment in the former GDR) count towards the 15-year threshold. In addition, some periods of education, childcare, sick leave, receipt of some types of unemployment benefits and the LEP filling period (*Berücksichtigungs-, Anrechnungszeiten*) count towards the 35-year threshold. The contribution periods actually used for pension calculation cannot be observed directly in the data, but they can be reconstructed from a variables related to workers' earnings histories. Around the 15-year threshold, contributions are calculated as the sum of contribution (both full and partial) and substitute periods. For the 35-year threshold, other relevant periods are added as far as they are observed.
Lifetime budget constraints.
Lifetime budget constraints are simulated based on the formulas presented in section 2.3. First, a pension benefit calculator is constructed according to equation (18) using a sample period average pension value V, a worker's observed sum of earned points $\sum_{t=0}^{R_i-1} \frac{w_{it}}{\bar{w}_t}$ and the adjustment factor function $\alpha(R_i, ERA)$ that applies to their specific pathway and birth cohort. Individual lifetime wealth at the worker's actual job exit age is then computed according to equation (1) with a discount factor of 3% and remaining life expectancies at age 55 taken from mortality tables by the German Federal Statistics Office taking into account heterogeneity by gender and year of birth. Lifetime gross wage earnings are approximated as the sum of earned points multiplied by an average of mean annual incomes across the sample period. Net earnings are calculated from gross earnings using an tax simulator taking into account personal income tax and social insurance contributions, and income splitting is applied to married individuals. Since the budget constraint abstracts from

periods of inactivity, the starting age is set to 25 years, a value that would generate roughly the observed average earned points if all workers had uninterrupted earnings careers.
In order to simulate lifetime wealth across a range of job exit ages, an approximation of annual earnings w_{it} is needed. A lifetime average of gross annual earnings is computed as lifetime wage earnings divided by the hypothetical uninterrupted career length from age 25 until the observed job exit age. Net annual earnings are calculated using the income tax simulator. A worker's lifetime wealth can then be simulated across a range of job exit ages by extrapolating additional income from work based on annual earnings and simulating pensions across claiming ages, the latter taking into account additional contributions and changing adjustment. Monthly implicit net wages are calculated as the increment in simulated lifetime wealth, and the implicit net-of-tax rate is the implicit net wage divided by gross income.

C.2 Group Assignment

Pathway eligibility.
As explained in section 2.4, workers choose the pathway from which to claim a pension, and reforms induce some partly mechanical switching between pathways. In particular, when NRAs are increased to 65 in a certain pathway, an increase in the number of workers eligible for that pathway claiming regular pensions can usually be observed. This occurs because there is no difference in benefits across pathways at the RRA and beyond, and workers may perceive claiming a regular pension as easier or more natural than claiming a special, non-regular pension. To account for this, pathway assignment is based on eligibility in order to keep group composition as stable as possible. Pathway eligibility is based on observable characteristics where possible, with some imputation to account for unobservables. Workers with at least 35 years of contributions are eligible for the long-term insured pathway. For the women's pathway, women with at least 15 years of contributions are deemed eligible. The additional requirement of full contributions in 8 out of the last 10 years cannot be used since the exact timing of contributions is insufficiently observable. Workers are defined as eligible for the the unemployed/part-time pathway if they have at least 15 years of contributions, and they are observed to be unemployed or in part-time work within the last 3 years before benefit claiming. Unfortunately, disability cannot be observed in the data, but a subset of workers satisfying the contribution requirements of the disabled and LEP pathways of 35 and 5 years, respectively, is identified.
If a worker is eligible for only one pathway, assignment is unambiguous. Moreover, workers who are observed to claim from one of the non-regular pathways are assumed to have chosen their "best" pathway and are thus assigned. Among the remaining workers who are found eligible for more than one pathway, assignment is based on a notion of which of those pathways is most advantageous. For instance, if a woman is eligible for the women's pathway, she must also be eligible for the regular pathway, but the feasible set of retirement age/consumption combinations in the women's pathway dominates that of the regular pathway because both ERA and NRA are lower. Besides, she may be eligible for the unemployed/part-time and/or long-term insured pathways, but those are also dominated by the women's pathway. Hence, women claiming a regular pension who are eligible for the women's pathway (and possibly unemployed or long-term insured) are assigned to the women's pathway rather than regular. Unemployed/part-time is assigned analogously.
Both long-term insured and disabled pathways require at least 35 years of contributions, but among the workers satisfying this, only those with an official disability can choose the disabled pathway. Since counterfactual disability status cannot be observed, the share of workers satisfying the requirement has to be imputed. In particular, it is assumed that the relative shares of disabled individuals among those potentially eligible for both pathways is the same as the shares among

those actually claiming in the pathways at a given age. Hence, the ratio of disabled/long-term insured claimants is computed for each integer retirement age in each year of birth, and ambiguous cases are assigned based on the corresponding ratio. Similarly, LEP and regular pensions both require only 5 years of contributions, and the ratio of actual claimants by year of birth and integer retirement age is used to impute eligibility in ambiguous cases.

As shown in table 2, the most important difference between the number of actual claimers and eligible workers arises in the regular pathway where eligibility is largely overestimated by claiming. Hence, many regular claimers are eligible for more advantageous pathways, particularly long-term insured and women's pathways. The vast majority of these switchers are workers retiring at the RRA and beyond, where they receive the same benefits from the regular pathway as they would from other pathways.

Groups and Discontinuities

Workers are grouped into cells by year of birth and pathway, since this split accounts for most of the variation in statutory ages and lifetime budget constraints faced by workers, while still preserving sufficiently large group sizes for the purpose of bunching estimation. During the cohorts where reforms change statutory ages at the month-of-birth level, workers around the statutory age in the affected pathway are grouped by pathway and month of birth instead. This split yields a total number of 420 groups of whom 108 are at the year-of-birth and 312 at the month-of-birth level.

Moreover, there are seven types of notches created by pathway contribution thresholds. At 5 years of contributions, workers switch from no pension at all to either regular or LEP. At 15 years of contributions, women switch from the regular pathway to the women's pathway. Moreover, workers who are unemployed or in old-age part-time work before retirement switch from regular to that pathway at 15 years of contributions. At 35 years of contributions, regular workers switch to the long-term insured or disabled pathway. Finally, workers previously eligible for the women's or unemployed pathway may switch to the disabled pathway at 35 years. For each year of birth, workers around a notch are identified based on pathway eligibility as described above. Restrictions in terms of years of contributions are relaxed in order to observe workers to the left of the notch who are close to the threshold but, by definition of the threshold, cannot yet be observed to claim the corresponding pathway. In order to account for variation in the notch size depending on retirement ages, each year of birth and type of notch is further divided into two ranges of retirement ages, 55 to 60 and 60 to 65. This yields a total of 78 groups each of whom faces one notch.

D Empirical Methodology

D.1 Bunching Estimation

The bunching estimation is based on Chetty et al. (2011) where a counterfactual density is fitted to the observed distribution of job exit ages around each discontinuity, excluding the data in the bunching region around the discontinuity. The counterfactual C_j is estimated as a regression of the form

$$C_j = \sum_{i=0}^{p} \beta_i (R_j)^i + \sum_{r \in \Gamma} \delta_r \mathbb{1}(R_j = r) + \sum_{k=R^-}^{R^+} \gamma_k \mathbb{1}(R_j = k) + \epsilon_j$$

where C_j is the number of individuals in monthly job exit age bin j, Γ is a set of round retirement age types, and $[R^-, R^+]$ is the excluded range of job exit ages around the discontinuity. Hence, the regression fits a p-th order polynomial to the distribution of job exit ages, while allowing for additional round-number bunching through the coefficients δ_r. The counterfactual density at the discontinuity is then predicted as

$$\hat{C}_j = \sum_{i=0}^{p} \hat{\beta}_i (R_j)^i + \sum_{r \in \Gamma} \hat{\delta}_r \mathbb{1}(R_j = r)$$

thus omitting the contribution of the dummies in the excluded range. The bunching mass $\hat{B} = \sum_{k=R^-}^{R^+} C_j - \hat{C}_j$ is the difference between the observed and the counterfactual distribution in the bunching region. Finally, the excess mass is defined as bunching relative to the counterfactual density:

$$\hat{b} = \frac{\hat{B}}{\sum_{k=R^-}^{R^+} \hat{C}_j / (R^+ - R^- + 1)}$$

In practice, the order of the polynomial is chosen as $p = 7$ and the excluded range $[R^-, R^+]$ as well as the set of round ages Γ to control for are determined separately for each type of discontinuity. Around statutory ages, the bunching region is generally defined as the discontinuity and one additional month on either side. Round-age dummies are included for each full-year age above 55, where additional dummies for full-year ages above 60 and 64 allow for heterogeneity in round-number bunching by age. Other statutory ages that may fall in the estimation range are also netted out of the counterfactual by dummies. Between 24 and 36 bins are included on both sides of the discontinuity for the estimation of the polynomial, with the exception of ERAs where only 12 bins are included to the left. In the regular pathway, LEP and some cohorts of unemployed/part-time, round-number dummies are not included because there is no visible round-number bunching. In LEP, bunching is restricted to the month of the discontinuity itself as there is no visible diffuse bunching mass. For groups at the month-of-birth level, dummies for job exit ages that fall in the calendar month of December are additionally included in Γ. December effects are also allowed to be heterogeneous across 5-year age ranges. The estimation around the pathway switching notches includes 120 bins on each side of the notch in order to increase statistical power, and has no round-number dummies. The month of the notch itself and 12 months to the left are excluded to account for missing mass. Bunching is estimated sharply at the month of the notch. The missing mass is extended to 24 months in the long-term insured pathway to line up with the relatively larger bunching mass.

Observed elasticities are calculated at each discontinuity according to equation (2). Kink sizes are computed as the marginal implicit net-of-tax rate just before the kink divided by the rate at the kink. Notches are approximated as kinks faced by the marginal buncher: The average net-of-tax rate between the location of the marginal buncher and the notch is used as the rate before the kink, and divided by the actual marginal net-of-tax rate after the kink. Standard errors for individual bunching mass estimates are bootstrapped by re-sampling the individual data within the respective group. Standard errors for regressions based on bunching estimates are block bootstrapped, that is the data is re-sampled at the discontinuity level.

D.2 Discontinuities Used for Bunching

The following table lists all discontinuities where bunching is estimated. Note that 10 out of the 655 discontinuities where the local density is too low to estimate a stable counterfactual are excluded from the main analysis.

Pathway	Cohorts	Age Group	Frequency	Source of Discontinuity	Type	Number
Regular	1933-1949	55-67	annual	ERA=NRA=RRA	kink	17
Long-term insured	1933-1936	55-67	annual	ERA=NRA	kink	4
Long-term insured	1937-1949	55-67	annual	ERA	kink	13
Long-term insured	1939-1946	55-67	annual	NRA=RRA	kink	8
Long-term insured	1947-1948	55-67	annual	NRA	kink	2
Long-term insured	1933-1938 1947-1949	55-67	annual	RRA	kink	9
Long-term insured	1937-1938 1949	55-67	monthly	moving NRA	kink	36
Women	1933-1939	55-67	annual	ERA=NRA	kink	7
Women	1940-1949	55-67	annual	ERA	kink	10
Women	1945-1946	55-67	annual	NRA=RRA	kink	2
Women	1947-1949	55-67	annual	NRA	kink	3
Women	1933-1944 1947-1949	55-67	annual	RRA	kink	15
Women	1940-1944	55-67	monthly	moving NRA	kink	60
Unemp./part-time	1933-1936	55-67	annual	ERA=NRA	kink	4
Unemp./part-time	1937-1945 1949	55-67	annual	ERA	kink	9
Unemp./part-time	1942-1946	55-67	annual	NRA=RRA	kink	5
Unemp./part-time	1947-1949	55-67	annual	NRA	kink	3
Unemp./part-time	1933-1941 1947-1949	55-67	annual	RRA	kink	12
Unemp./part-time	1937-1941	55-67	monthly	moving NRA	kink	60
Unemp./part-time	1946-1948	55-67	monthly	moving ERA	kink	36
Disabled	1933-1940	55-67	annual	ERA=NRA	kink	8
Disabled	1941-1949	55-67	annual	ERA	kink	9
Disabled	1944-1949	55-67	annual	NRA	kink	6
Disabled	1933-1949	55-67	annual	RRA	kink	17
Disabled	1941-1943	55-67	monthly	moving NRA	kink	36
LEP	1938-1949	55-67	annual	pension adjustment around age 63	kink	12
LEP	1938-1943	55-67	monthly	adjustment introduction in 2001	kink	72
Long-term insured	1937-1949	55-63/0	annual	35 year contribution threshold (from regular)	notch	13
Long-term insured	1938-1943	63/1-65	annual	35 year contribution threshold (from regular)	notch	17
Women	1937-1949	55-60/0	annual	15 year contribution threshold (from regular)	notch	13
Women	1933-1949	60/1-65	annual	15 year contribution threshold (from regular)	notch	17
Unemp./part-time	1937-1949	55-60/0	annual	15 year contribution threshold (from regular)	notch	13
Unemp./part-time	1933-1949	60/1-65	annual	15 year contribution threshold (from regular)	notch	17
Disabled	1937-1949	55-60/0	annual	35 year contribution threshold (from regular)	notch	13

Disabled	1933-1949	60/1-65	annual	35 year contribution threshold (from regular)	notch	17
Disabled	1937-1949	55-60/0	annual	35 year contribution threshold (from unemp.)	notch	13
Disabled	1933-1949	60/1-65	annual	35 year contribution threshold (from unemp.)	notch	17
Disabled	1937-1949	55-60/0	annual	35 year contribution threshold (from women)	notch	13
Disabled	1933-1949	60/1-65	annual	35 year contribution threshold (from women)	notch	17
total						655

E Derivation of Estimation Equations

E.1 Structural Equation and Upper Bounds

The theoretical framework predicts that bunching at a pure budget set kink is given by equation (8), while bunching at a combined threshold is given by equation (14). Allowing for the possibility of reference dependence in utility from consumption and disutility from work at all statutory age types $stat \in (ERA, NRA, RRA)$, bunching at any discontinuity can be expressed as

$$\frac{b}{\hat{R}} = \left[\left(\frac{1-t}{1-t-\Delta t-\sum_s \lambda_l^s D^s}\right)^{\epsilon} - 1\right] + \left[1 - \left(\frac{1}{1+\sum_s D^s \lambda_c^s}\right)^{\epsilon}\right]$$

The equation can be used to structurally estimate ϵ along with the set of λ_c^s or λ_l^s across discontinuities.

To obtain upper bounds on λ_l^s, set all $\lambda_c^s = 0$ in the above equation, resulting in

$$\frac{b}{\hat{R}} = \left[\left(\frac{1-t}{1-t-\Delta t}\right)^{\epsilon} - 1\right] + \left[1 - \left(\frac{1}{1+\sum_s D^s \lambda_c^s}\right)^{\epsilon}\right]$$

Conversely, setting $\lambda_l^s = 0$ can yield upper bounds on λ_l^s:

$$\frac{b}{\hat{R}} = \left[\left(\frac{1-t}{1-t-\Delta t-\sum_s \lambda_l^s D^s}\right)^{\epsilon} - 1\right]$$

E.2 Bunching from the Left vs. Right

Bunching from the right at any discontinuity is

$$\frac{b^+}{\hat{R}} = \left[\left(\frac{1-t}{1-t-\Delta t-\sum_s \lambda_l^s D^s}\right)^{\epsilon} - 1\right]$$

and bunching from the left is

$$\frac{b^-}{\hat{R}} = \left[1 - \left(\frac{1}{1+\sum_s D^s \lambda_c^s}\right)^{\epsilon}\right]$$

where $b = b_i^+ + b_i^-$. Hence, when the shares of bunching from the left and from the right are known, λ_c and λ_l can be separately identified. This idea is also implicitly used above, where upper bounds on λ_l^s is obtained by setting the bunching share from the left to zero, and the upper bound on λ_c^s is obtained by setting the bunching share from the right to its maximum. This maximum is given the amount of bunching from the right that would be implied by the budget set kink only, and is strictly less than 1 if there is a convex budget set kink at the threshold. The full range of possible parameter combinations can then be estimated by varying bunching shares from the right α_i between 0 and $\hat{\alpha}_i$ in $B_i^+ = \alpha_i B_i$, $B_i^- = (1-\alpha_i)B_i$, where $\hat{\alpha}_i$ is the maximum right bunching share at i. $\hat{\alpha}_i$ can be be calculated as

$$\hat{\alpha}_i = \frac{\left(\frac{1-t_i}{1-t_i-\Delta t_i}\right)^{\epsilon} - 1}{b_i} \tag{19}$$

E.3 Measuring Bunching Shares from both Sides

E.3.1 Basic Approach

Bunching at the threshold must equal the total missing density from both sides:

$$B = \int_{R_{min}}^{\hat{R}} (h_0(R) - h(R))\, dR + \int_{\hat{R}}^{R_{max}} (h_0(R) - h(R))\, dR$$

where R_{min} and R_{max} bound the support of the density.
Measuring the true density shift over the full support is impossible in practice for two reasons. First, the shift $h_0(R) - h(R)$ may vary across R in an unknown way so that $h_0(R)$ cannot be measured for all R based on the observed density. Second, the full support of the counterfactual density may not be observed. Even if the full support of the actual density could observed, this does not necessarily correspond to the counterfactual support since some counterfactual density is predicted to "disappear" at the bounds because all individuals shift out a certain range.[53]
One solution to this problem is to approximate the true density shift by a constant shift over a certain range on each side. Denote by h_+ and h_- the observed density immediately to the right and left, respectively, of the threshold $\hat{R}$. Furthermore, denote by h^0_+ and h^0_- the corresponding counterfactual density in the absence of the threshold. The approximation is

$$B \approx \left(h^0_- - h_-\right)(\hat{R} - R^-) + \left(h^0_+ - h_+\right)(R^+ - \hat{R})$$

where a constant density shift observed immediately to the left of the threshold over a range $[R^-, \hat{R}]$ approximates for the true shift on the left and a constant shift observed immediately to the right of $\hat{R}$ over $[\hat{R}, R^+]$ approximates for the shift on the right.
Assume also that the counterfactual density is continuous at $\hat{R}$ such that $h^0_+ = h^0_- = h_0$. Then h_0 can be recovered as

$$h_0 \approx \frac{B + (\hat{R} - R^-)h_- + (R^+ - \hat{R})h_+}{R^+ - R^-}$$

From this, the implied bunching shares from both sides can be computed as $B^- = (h_0 - h_-)(\hat{R} - R^-)$ and $B^+ = (h_0 - h_+)(R^+ - \hat{R})$ since bunching from either side must be equal to the total density shift from that side. Finally, the structural parameters ϵ, λ_c and λ_l can be estimated by plugging the implied bunching shares into the equations in section E.2.

E.3.2 Correcting for the Density Gradient

Approximating the true density shift by an observed vertical shift extrapolated over a given range comes with problems. To see this, consider a situation where the density is decreasing towards the threshold. In this case, the underlying density shift towards the threshold translates into an *upward* shift just beside the threshold combined with a large "disappearing" mass in the tail of the counterfactual density. More generally, the gradient of the density on each side determines to what extent an underlying horizontal density shift translates into an observed vertical density shift around the threshold.
To correct for this, relative bunching from both sides can be taken as the relative horizontal shift implied by the combination of the observed vertical shift and the gradient of the density beside the threshold. In particular, denoting by h'_- and h'_+ the slope of density to the left and to the right

[53] Besides, although theory predicts individuals responding to the threshold along the entire density, it is unclear in practice whether those far from the threshold perceive it in the same way as those closer.

of threshold, the horizontal shift is given by the vertical shift multiplied with the inverse of this gradient. The true density shift is then approximated as

$$B \approx \frac{h'_- - h'_+}{2}\left[\frac{1}{h'_-}\left(h^0_- - h_-\right)\left(\hat{R} - R^-\right) + \frac{1}{-h'_+}\left(h^0_+ - h_+\right)\left(R^+ - \hat{R}\right)\right]$$

where $(h'_- - h'_+)/2$ is a rescaling factor used to transform the total horizontal shift back into the vertical dimension related to bunching. From this, the counterfactual density h_0 can be recovered as

$$h_0 \approx \frac{B + \frac{h'_- - h'_+}{2h'_-}h_-(\hat{R} - R^-) + \frac{h'_- - h'_+}{-2h'_+}h_+(R^+ - \hat{R})}{\frac{h'_- - h'_+}{2h'_-}(\hat{R} - R^-) + \frac{h'_- - h'_+}{-2h'_+}(R^+ - \hat{R})}$$

The implied bunching shares from both sides can then be computed as $B^- = \frac{h'_- - h'_+}{2h'_-}(h_0 - h_-)(\hat{R} - R^-)$ and $B^+ = \frac{h'_- - h'_+}{-2h'_+}(h_0 - h_+)(R^+ - \hat{R})$, and parameters can be estimated from the equations in section E.2.

E.4 Reduced-Form Decomposition

Consider now a situation where Δt and λ^s_l are small, such that $\log(R^*_+/\hat{R}) \approx \Delta R^*_+/\hat{R}$ where $\Delta R^*_+ = R^*_+ - \hat{R}$, and $\log(1 - (\Delta t + \sum_s \lambda^s_l D^s)/(1-t)) \approx -(\Delta t + \sum_s \lambda^s_l D^s)/(1-t)$. Then

$$\frac{\Delta R^*_+}{\hat{R}} \approx \epsilon\frac{\Delta t}{1-t} + \frac{\epsilon}{1-t}\sum_s \lambda^s_l D^s$$

and

$$\frac{b}{\hat{R}} \approx \epsilon\frac{\Delta t}{1-t} + \frac{\epsilon}{1-t}\sum_s \lambda^s_l D^s + \left[1 - \left(\frac{1}{1 + \sum_s D^s \lambda^s_c}\right)^{\epsilon}\right]$$

Thus, ϵ can be estimated as the coefficient on kink size in the linear reduced-form specification according to equation (5), and the coefficients β^s yield a reduced-form estimate of the combined additional reference point bunching from both sides. More concretely,

$$\beta^s \approx \frac{\epsilon}{1-t}\lambda^s_l + \left[1 - \left(\frac{1}{1 + \lambda^s_c}\right)^{\epsilon}\right]$$

If in addition λ^s_c are small, $\log(1 + \sum_s D^s \lambda^s_c)) \approx \sum_s D^s \lambda^s_c$, and

$$\frac{b}{\hat{R}} \approx \epsilon\frac{\Delta t}{1-t} + \frac{\epsilon}{1-t}\sum_s \lambda^s_l D^s + \epsilon\sum_s D^s \lambda^s_c$$

In this case, the statutory age coefficients simplify to

$$\beta^s \approx \frac{\epsilon}{1-t}\lambda^s_l + \epsilon\lambda^s_c$$