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Abstract

This paper presents new empirical evidence on the effects of retirement benefits on labor force participation decisions. We use administrative data on the census of private sector employees in Austria and variation from mandated discontinuous changes in retirement benefits from the Austrian pension system. We present nonparametric, graphical evidence documenting labor supply responses to the policy discontinuities. Next, based on the nonparametric evidence and mandated financial incentives, we estimate extensive margin labor supply elasticities. We estimate elasticities of 0.12 for men and 0.38 for women. The evidence indicates these elasticities are primarily driven by substitution effects rather than wealth effects.

1 Introduction

Understanding the effects of retirement benefits on labor force participation decisions is important for multiple fields in economics. In macroeconomics, the effects of financial incentives on career length decisions has been identified as a key factor in reconciling cross-country differences in aggregate labor supply. In labor economics, decisions to enter and exit the labor force have been identified as key aspects of labor supply, especially since

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nearly all workers face a retirement decision. In public economics, labor supply responses to implicit tax rates created by social security programs play a crucial role in evaluating the deadweight costs of these programs. Despite this importance, there is widespread debate regarding the magnitude of extensive margin labor supply elasticities.

In this study, we provide new empirical evidence on extensive margin labor supply elasticities using responses to policy discontinuities in retirement benefits in Austria. We first present nonparametric graphical evidence documenting individuals' labor supply responses to the policy discontinuities. Next, we develop a strategy to estimate extensive margin labor supply elasticities nonparametrically. The strategy exploits the observed labor supply responses to the policy discontinuities.

Since the policy discontinuities are fully anticipated and constant over time, our research design allows us to identify intertemporal extensive margin elasticities. There has been significant research on intertemporal labor supply elasticities yielding a wide range of values. Specifically, macroeconomic models explaining aggregate labor supply responses assume relatively high elasticities, while estimates based on micro data typically find small labor supply elasticities.[1] Recent efforts to reconcile higher and lower elasticities have emphasized the importance of distinguishing between the intensive and extensive margins in labor supply decisions.[2] Intuitively, small labor supply responses on the intensive margin (hours of work decisions) may well be compatible with large responses at the extensive margin (participation decisions). As most previous studies examining individual-level labor supply have focused on intensive margin decisions, the responsiveness in labor supply along the extensive margin in micro data has been identified as a key issue.[3]

The policy discontinuities exploited in this study arise because a lump-sum component of retirement benefits in Austria increases discontinuously once individuals complete specific threshold amounts of tenure prior to their retirements. These benefits are fully anticipated by the workers and thus incorporated into lifetime wealth. This allows us to focus on marginal-utility-of-wealth-constant labor supply responses. While the lump-sum benefits

[1] For microeconomic evidence on intertemporal substitution in labor supply, see MaCurdy (1981), Browning, Deaton and Irish (1985), Altonji (1986), Card (1994) and the survey discussions in Blundell and MaCurdy (1999) and Browning, Hansen, and Heckman (1999). For macroeconomic evidence, see Mulligan (1999), Ljungqvist et al (2006), Ohanian et al (2008), Rogerson and Wallenius (2009), Ljungqvist and Sargent (2010) and the survey discussions in Prescott (2006) and Keane and Rogerson (2010).

[2] Other efforts to reconcile higher and lower elasticities have focused on human capital (see Imai and Keane (2009)) and adjustment costs (see Chetty (2009)).

[3] Heckman and MaCurdy (1980), Heckman (1993), Blundell and MaCurdy (1999) and Browning, Hansen, and Heckman (1999) also have emphasized the distinction between the intensive and extensive margins in labor supply decisions.

increase discontinuously by a considerable amount (about 30% of an annual salary), they are small relative to lifetime income.

We examine behavior before and after multiple tenure thresholds to determine if individuals extend their careers in response to the anticipated discontinuous increases in benefits. Nonparametric graphical evidence based on a large sample of individual retirements from administrative records indicates reduced numbers of retirements just prior to the thresholds and excess numbers of retirements just after the thresholds. The empirical analysis provides clear evidence on the nature of labor supply decisions in the face of retirement benefits. Specifically, we can identify how long individuals are willing to delay retirement to become eligible for benefits. Further, heterogeneity analysis allows us to distinguish between individuals who are able to respond to the benefit incentive and others who are constrained by health conditions.

We develop a strategy to estimate extensive margin intertemporal labor supply elasticities based on relating the observed retirement patterns to changes in financial incentives due to the mandated policy discontinuities. This estimator relies on discontinuities in individuals' budget constraints, it is similar in spirit to previous bunching estimators that exploit kinks in individuals' budget constraints (see Saez (1999, 2009) and Chetty et al (2010)). Furthermore, we highlight that the estimation strategy allows for estimation of policy-relevant elasticities without requiring ad hoc distributional or functional form assumptions.[4]

This paper is organized as follows. Section 2 discusses both the institutional background regarding the Austrian pension system and the administrative data from the Austrian Social Security Database. Section 3 presents a nonparametric graphical analysis of the data. Section 4 develops an intertemporal labor supply model based on the empirical evidence presented in section 3. Section 5 develops the elasticity estimation strategy and then presents the estimation results and sensitivity analysis. Section 6 concludes.

[4]It is possible to estimate alternative dynamic structural models, though we lack data on individuals' consumption and savings decisions. We leave these considerations for future work.

2 Institutional Background & Data

2.1 Retirement Benefits in Austria

There are two forms of government-mandated retirement benefits in Austria: (1) government-provided pension benefits and (2) employer-provided severance payments. We start with the description of severance payments since these payments are the primary focus of the current study. The employer-provided severance payments are made to private sector employees who have accumulated sufficient years of tenure by the time of their retirement. Tenure is defined as uninterrupted employment time with a given employer and retirement is based on claiming a government-provided pension. The payments must be made within 4 weeks of claiming a pension according to the following schedule. If an employee has accumulated at least 10 years of tenure with her employer by the time of retirement, the employer must pay one third of the worker's last year's salary. This fraction increases from one third to one half, three quarters and one at 15, 20 and 25 years of tenure respectively. This schedule for the severance payments is illustrated in Figure 1. The payments are made in lump-sum and, since payments are based on an employee's salary, overtime compensation and other non-salary payments are not included when determining the amounts of the payments. Provisions to make these payments come from funds that employers are mandated to hold based on the total number of employees. Severance payments are also made to individuals who are involuntarily separated (i.e. laid off) from their firms if the individuals have accumulated sufficient years of tenure prior to the separation. The only voluntary separation that leads to a severance payment, however, is retirement. Employment protection rules hinder firms from strategically laying off workers to avoid severance payments and there is no evidence on an increased frequency of layoffs before the severance pay thresholds.[5] In general, older workers approaching retirement age enjoy the highest level of job protection in Austria.

The Austrian income tax system, which is based on individual taxation, applies particular rules to tax income from severance payments. Specifically, all mandated severance payments are exempt from social security contributions and subject to a tax rate of 6%. The income taxation of the severance payments differs from the general income tax rules. Generally, gross monthly earnings net of social security contributions [6] are subject to the

[5]For more details regarding the severance payments at times of unemployment, see Card, Chetty and Weber (2007).

[6]Contributions for pension, health, unemployment, and accident insurance of 39% are split in half

income tax with marginal tax rates in the different tax brackets of 0%, 21%, 31% 41% and 50%.[7] [8]

Because the timing of the severance payments relates to pension claiming, eligibility for government-provided retirement pensions interacts with the severance payment system. Austria has a public pension system that automatically enrolls every person employed in the private sector. Fixed pension contributions are withheld from each individual's wage and annuitized benefits during retirement are then based on prior contributions (earnings histories). Replacement rates from the annual payments are roughly 75% of pre-retirement earnings and there are no actuarial adjustments for delaying retirement to a later age. Individuals can retire by claiming Disability pensions, Early Retirement pensions and Old Age pensions. Eligibility for each of these pensions depends on an individual's age and gender, as well as having a sufficient number of contribution years. Beginning at age 55, private sector male and female employees can retire by claiming Disability pensions, where disability is based on reduced working capacity of 50% relative to someone of a similar educational background. At age 55, women also become eligible to claim Early Retirement pensions, but the Early Retirement Age is age 60 for men. Lastly, men and women become eligible for Old Age pensions at age 65 and 60 respectively.[9] Figure 2 illustrates survival functions for exits from the labor force for the sample of private sector employees. The graphs are presented separately for men and women given the different eligibility ages. The survival functions illustrate sharp declines at ages 60 and 65 highlighting a significant amount of entry into the pension system once individuals become eligible for the Early Retirement and Old Age pensions. Additionally, the figure demonstrates that, for both men and women, most retirements occur between ages 55 and 60. Further, the graph shows that roughly 25% of the male sample retire by claiming disability pensions prior to age 60.

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between employer and employee and the employee's share is withheld from gross annual earnings up to a contribution cap.

[7] These tax brackets are based on legislation in 2002; there have subsequently been relatively small changes due to several small tax reforms.

[8] Additionally, Austrian employees are typically paid 13th and 14th monthly wage payments in June and December. These payments, up to an amount of one sixth of annual wage income, are also subject to a 6% tax rate; amounts in excess of one sixth of annual income are subject to the regular income tax rates.

[9] Benefits from disability and early retirement are entirely withdrawn if an individual earns more than about 300 Euros per month; therefore we see very few individuals returning to the labor force once they are retired.

2.2 Administrative Data & Sample Restrictions

Our empirical analysis is based on administrative registers from the Austrian Social Security Database (ASSD, see Zweimüller et al (2009)), which is collected with the principle aim of verifying individual pension claims. The data provide longitudinal information for the universe of private sector workers in Austria throughout their working lives. Specifically, information on employment and earnings as well as other labor market states relevant for computing insurance years such as military service, unemployment, and maternity leave is collected. Detailed electronic records with employer identifiers that allow the measurement of tenure are recorded in the period from 1972 onwards; here we use information up to 2006. For the years prior to 1972 retrospective information on insurance relevant states is available for all individuals who have retired by the end of the observation period. Combining the administrative data from 1972 onwards and the retrospective data prior to 1972 yields information on complete earnings and employment careers of retirees. Because firm identifiers are available only from 1972 onwards, uncensored tenure can be measured for jobs starting after January 1, 1972.

To investigate the effect of severance pay eligibility on retirement decisions we consider all individuals born between 1930 and 1945. For these individuals we observe sufficiently long uncensored tenure at retirement.[10] We focus on workers who are still employed after their 55th birthday and follow them until entry into retirement or up to the age of 70. We make several restrictions to the original sample of about 650,000 workers, which are su arized in the top panel of Table 1. Most importantly, we exclude individuals who worked as civil servants or whose last job was in construction, because they are subject to different pension and severance pay rules. As we are interested in tenure at retirement, we further exclude workers with left censored tenure at retirement and we only consider retirement entries which occur within 6 months of the worker's last job. Individuals with longer gaps between employment and retirement are only followed until the end of the last employment. We also exclude individuals with top-coded earnings at retirement since we are not able to accurately compute severance payments. With these restrictions, we have a final sample of 231,251 retiring individuals.

Table 2 presents su ary statistics separately for the full retirement sample and for the sub-sample of individuals that are used in the elasticity estimation. Specifically, the estimation sample consists of individuals with at least 6 years of tenure at retirement but

[10] In addition, these individuals retire after a pension reform in 1985 which changed the assessment basis for benefit calculation and the thereby the type of information recorded.

not more than 28 year of tenure at retirement; this sample corresponds to Figure 3 which is discussed below. The median retirement age is 58.5 years in both groups, which reflects that most individuals retire through disability or early retirement (30% and 27% in the full sample and estimation sample, respectively).[11] Years of employment and annual earnings in the last year before retirement are slightly higher for workers with longer tenure and these workers also have lower years of unemployment. Overall the differences between both groups are minor.

3 Nonparametric Graphical Analysis

3.1 Distribution of Tenure at Retirement

Figure 3 presents the distribution of tenure at retirement for the full sample; tenure at retirement is measured at a monthly frequency. Several features are i ediately evident from this graph. First, the plot shows discontinuous spikes in the number of retirements at the tenure thresholds. Second, there are dips in the number of retirements just before the tenure thresholds. These patterns are regularly repeated at each tenure threshold but are not apparent at any other point in the tenure distribution. This evidence suggests that individuals who would have retired just before the thresholds in the absence of the severance pay discontinuities end up delaying their retirements until they just qualify for the (larger) severance payments. Third, the plot indicates a seasonal pattern illustrated by small spikes in the number of retirement at each integer value of years of tenure at retirement. The seasonality can be explained by a relatively large fraction of job starts in January and corresponding retirement exits in December. Fourth, even though there are decreases prior to the thresholds, the frequency of retirements never goes to zero just prior to the thresholds. This means there appears to be a substantial number of individuals who are unresponsive to the severance pay system at retirement.

3.2 Accounting for Covariates

We exploit panel variation in the probability of retirement to examine whether or not other observable characteristics change around the tenure thresholds. In particular, we

[11] The actual share of retirements through early retirement is higher than the presented number, as separate insurance categories for early retirement are only recorded as of 07/1993 and individuals retiring before the statutory pension age before that are coded as old age pension entries.

estimate the following regression

$$r_{it} = \sum_{\tau=0}^{34} \gamma_\tau d_\tau + X_{it}\beta + \epsilon_{it}$$

where r_{it} is an indicator equal to 1 if individual i retires within time period t. The set of observations per individual covers all quarters from age 55 to retirement or age 70. The sample used for estimation includes all 380,737 individuals left at the last step of sample selection in Table 1, not only those observed retiring within 6 month of their last job. Including all job exits allows us to examine whether or not regularities in general job exits (as opposed to just retirements) after 5, 10, 15, ... year intervals are responsible for the observed retirement patterns in Figure 3. For computational reasons, time is measured at a quarterly frequency instead of the monthly frequency presented in Figure 3.

The regressors in the estimated equation are a set of indicators d_τ equal to 1 if the individual's quarterly tenure at time t equals τ. Further, we include a large set of time-varying control variables X_{it} relating to age, gender, calendar years, citizenship, industry, region, seasonality, earnings histories, firm size, health and experience.[12] All of the variables in the regression are demeaned to that the coefficients on the tenure du ies reflect the mean probabilities of retirement within each tenure level.

Figure 4 plots the coefficients on the quarterly tenure du ies from the estimated regressions. The graph shows a pattern of dips before and large spikes at the thresholds that is very similar to Figure 3. The yearly seasonality pattern is now removed by controls for quarter of the year. Overall, Figure 4 confirms that incentives in the severance pay system are driving the retirement pattern around the tenure thresholds rather than other observable characteristics or regularities in job-leaving behavior.

[12] The estimated regression includes dummies for gender, calendar year, age measured at a quarterly frequency, birth month, birth year, Austrian citizenship, quarter of the year, industry, region, firm size, blue collar job status, job starting month, health status between age 42 through age 54, contribution years between age 42 through 54, sick leave in the current quarter, unemployment in the current quarter, top-coded earnings, insurance years (interacted with gender), and real earnings. Firm size is grouped into the following categories: ≤ 5, $6-10, 11-25, 26-99, 100-499, 500-999, \geq 1000$. Health status between age 42 through age 54 is based on the following categories of sick leave from age 42 through age 54: ≤ 0.03 years, $0.03-0.18$ years, $0.18-0.33$ years, and ≥ 0.33 years. Health and unemployment in the current quarter are based on the following categories for sick leave and unemployment days in the current quarter: 0 days, $1-30$ days, $31-60$ days, and ≥ 61 days. Contribution years between ages 42 through age 54 is based on the following categories of contribution years: ≤ 5 years, $5-8$ years, $8-13$ years, and $=13$ years. Real earnings dummies are created by creating 25 percentiles based on average earnings between ages 42 through 54.

3.3 Job Starts

We investigate whether individuals time the beginning of new jobs so that they can retire at the Early Retirement Ages (ERAs, respectively 55 and 60 for women and men) and also claim severance payments at the time of their retirements. To explore this idea, Figure 5 plots the number of individuals starting new jobs (vertical axis) against age measured at a quarterly frequency (horizontal axis). If individuals are timing the beginning of their new jobs so that they can just complete 10, 15, or 20 years of tenure at the ERAs, then we would expect to see sharp increases in the number of individuals starting new jobs at ages 50, 45, and 40. The evidence in Figure 5 shows no discernible change in job starts at any age prior to the ERAs. This smoothness across age emphasizes that, while there is evidence that some individuals delay their retirements to qualify for (larger) severance payments at retirement, there is no evidence that individuals reallocate their labor supply (or participation) at earlier ages in response to the sizeable anticipated incentives from the severance payments.

3.4 Heterogeneity

We start by investigating heterogeneity related to health status. We measure health based on the fraction of time between age 54 and retirement spent on sick leave.[13] We define an individual as unhealthy if the fraction of time between age 54 and retirement spent on sick leave is above the median fraction of time for individuals with positive sick leave days (this median is 0.076). Figure 6 presents frequency plots for unhealthy and healthy individuals, respectively. As expected, unhealthy individuals are not very flexible in the timing of their retirements. We basically see no response to the thresholds among retirees with health problems. Thus, some of the pre-threshold retirement is likely to be driven by negative health shocks and also more permanently poor health status.

Figure 7 examines heterogeneity related to gender and retirement age. Men and women are separately divided into age groups that are chosen based on the survival functions illustrated in Figure 2 and the Early and Normal Retirement Ages (respectively 55 and 60 for women and 60 and 65 for men). The top row of the figure plots the distributions of tenure at retirement within each age group for men, and the plots for women are in the

[13] Roughly 35% of individuals in our sample have no sick leave days over their entire careers and 68% have no sick leave between ages 54 and retirement. Health status is highly correlated with the likelihood of claiming disability pension; about 64% of individuals with some sick leave between age 54 and retirement claim disability pensions as opposed to 15% of those with no sick leave between age 54 and retirement.

bottom panel. The plots for men indicate that the relative spike sizes tend to increase across individuals retiring at higher ages. This consistent with the heterogeneity based on health since men with lower health status are more likely to qualify for disability and retire prior to age 60. For women, the responsiveness to the severance pay threshold decreases across individuals retiring at higher ages. Importantly, these patterns should be interpreted as heterogeneity across individuals with different retirement ages rather than heterogeneity due to aging since there is clearly selection into different retirement ages.

Figures 8 and 9 examine heterogeneity across groups facing different financial incentives at retirement. In Figure 8, we focus on financial incentives related to pensions and earnings at retirement by computing implicit tax rates at retirement. We compute implicit tax rates by taking the sum of social security contributions, income taxes and pensions relative divided by gross annual earnings in the calendar year prior to retirement. Intuitively, this implicit tax rate captures the gains from continuing to work. Individuals with high pensions relative to their earnings will have higher implicit tax rates reflecting low incentives to continue working. Similarly, individuals with high earnings relative to their pensions will have lower implicit tax rates. Figure 12, which is discussed more in the estimation section below, plots the mean implicit tax rates within each level of tenure at retirement. At lower tenure levels, mean implicit tax rates are roughly between 0.75 and 0.80; the mean implicit tax rates increase at higher levels of tenure and are generally between 0.80 and 0.90.

To construct Figure 8, we compute percentiles of implicit tax rates, and within each percentile, we compute the total numbers of people retiring just before and just after a tenure threshold. The figure highlights that the number of people retiring just prior to a tenure threshold does not vary based on implicit tax rates. In contrast, the number of people retiring just after a tenure threshold is relatively low at lower and higher implicit tax rates. Intuitively, individuals with relatively generous pensions or with relatively high earnings may have lower marginal utilities of consumption from delaying their retirements to qualify for the (larger) severance payments.

Figure 9 examines heterogeneity relative to a tenure-adjusted measure of permanent income. Specifically, we compute average earnings by computing total earnings between ages 42 and 54 divided by 13 years. To account for returns to tenure and compare higher and lower earnings individuals with similar tenure levels at retirement, we create groups using tenure at age 55. Specifically, we group individuals by the calender year when they turn 55 and by tenure at the end of age 54; within each group, we compute percentiles of average earnings. Within each earnings percentile, we use tenure at retirement to compute the total number of people retiring within one quarter prior to a tenure threshold and within one quarter after a tenure threshold. Figure 9 plots the series of pre-threshold retirements and retirements at the thresholds across the earnings percentiles. Similar to the plot based on implicit tax rates, the figure highlights that the pre-threshold retirements do not vary across the earnings percentiles. Overall, individuals retiring just prior to a tenure threshold appear insensitive or unresponsive to financial incentives at retirement. In contrast, the number of people retiring at a tenure threshold diminishes at higher earnings percentiles. Individuals at higher earnings percentiles may have lower marginal utility of consumption at retirement and hence may be less likely to delay their retirement in response to the severance pay incentives.

Lastly we examine heterogeneity across firm sizes in Figure 10. Using the sample of firms that have retirements, we compute firm size percentiles. Within each firm size percentile, we compute the ratio of the total number of people retiring within one quarter after a tenure threshold to the total number of people retiring within one quarter prior to a tenure threshold.[14] Figure 10 plots this ratio across the different firm size percentiles. The plot suggests that individuals at larger firms are more likely to retire just after reaching a tenure threshold compared to individuals are smaller firms. Even though larger firms may have more strategic incentives to layoff workers or make side payments to employees to avoid having to pay (larger) severance payments, the highest responsiveness is observed at these firms. This suggests that firms' legal and reputational costs of engaging in strategic behaviors is likely to be relatively high. Focusing more on smaller firms, individuals employed in smaller firms may be more restricted in choosing their retirement dates around the tenure thresholds. Small employers may face lower reputational costs and may put more pressure on their employees to retire prior to qualifying for a (larger) severance payment. Additionally, employees at smaller firms may have less ability to leave their firms just after reaching a tenure threshold since their employers may rely on them to complete their projects since there are fewer substitutable employees available to do so. The evidence presented in Figure 10 is consistent with these intuitions.

[14] We focus on this ratio rather than the numerator and denominator separately since, by definition, there are more individuals retiring at larger firms.

4 Quantitative Analysis I: Elasticity Estimation

4.1 Conceptual Framework

We develop a basic conceptual framework to translate the observed increases in retirements just after the tenure thresholds into extensive margin labor supply responses. Specifically, we focus on retirement decision in the periods right after each tenure threshold. In each period an individual's earnings Y under the alternatives of employment or retirement are given by

$$Y = \begin{cases} y(1-\tau_y) & \text{if employed} \\ y * \pi_b + y * \gamma_{sp} & \text{if retired} \end{cases}$$

where y denotes gross per period earnings from employment and τ_y denotes the marginal tax rate (taking social security contributions and income taxes into account). For a retired individual π_b represents the replacement rate of pension benefits, and $\gamma_{sp} = \gamma_{sp}(\text{tenure})$ denotes the amount of severance pay as a fraction of last year's earning which depends on tenure. We use an additively separable utility to derive labor supply decisions. The decision is based on income and the marginal utility of income λ, which we assume to be constant, as the period is short relative to the lifetime. Preferences are represented by

$$U = \begin{cases} \lambda\left[y(1-\tau_y)\right] - \alpha & \text{if employed} \\ \lambda\left[y\pi_b + y\gamma_{sp}\right] & \text{if retired} \end{cases}$$

where α denotes the marginal disutility of work. The individual decides to retire if the marginal utility from retiring exceed the marginal utility from working,

$$\begin{aligned} \lambda\left[y\pi_b + y\gamma_{sp}\right] &> \lambda\left[y(1-\tau_y)\right] - \alpha \\ \Rightarrow \alpha &> \lambda\left[y(1-\tau_y-\pi_b-\gamma_{sp}\right] = \lambda y(1-\tau). \end{aligned}$$

Here τ denotes the implicit tax rate on earnings taking social security contributions, income taxes, pensions and severance payments into account. This expression highlights that an individual will retire when the marginal disutility of work is relatively high or when implicit tax rate is relatively high.

This labor supply framework incorporates individual heterogeneity in earnings, the marginal tax rate, tenure, pension benefits, and the disutility of work. We su arize the observable characteristics in the vector X and express the distribution of α conditional on observables by $F(\alpha|X)$. With this description of heterogeneity, the probability that individuals with observables X retires is given by

$$p = \Pr(\alpha > \lambda(1-\tau)y|X) = 1 - F(\lambda(1-\tau)y) = R(\lambda(1-\tau)y).$$

Using this expression for the probability or retirement, the extensive margin labor supply elasticity with respect to the implicit tax rate is defined as $\varepsilon = \frac{d\ln p}{d\ln(1-\tau)}$.

In our empirical setup the level of severance payments varies discontinuously at the tenure thresholds, which allows us to identify the elasticity from this variation at the thresholds. This implies that we can estimate a discrete approximation for ε at each tenure threshold. Denote the severance pay rates by $(\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4)$ in each tenure interval (zero to 10 years, 10 to 15 years, etc.) and the corresponding implicit tax rates by $(\tau_0, \tau_1, \tau_2, \tau_3, \tau_4)$. The elasticity at each threshold $j = 1, ..., 4$ is then given by

$$\begin{aligned} \varepsilon_j &= \frac{\frac{R(\lambda(1-\tau_j)y) - R(\lambda(1-\tau_{j-1})y)}{R(\lambda(1-\tau_{j-1})y)}}{\frac{(1-\tau_j)y - (1-\tau_{j-1})y}{(1-\tau_{j-1})y}} \\ &= \frac{\Delta p/p}{\Delta y/y} \end{aligned}$$

Intuitively, the extensive margin elasticity captures the percentage change in participation due to a 1% change in after-tax earnings, so we estimate the extensive margin elasticity given by

We describe the steps to estimate the changes in the levels of participation and after-tax earnings due to the severance payments in the next section.

4.2 Estimation Procedures

Estimating $\Delta p/p$

We estimate $\Delta p/p$ by computing differences between the increased retirement frequencies just after the tenure thresholds and estimated counterfactual frequencies just after the tenure thresholds. While we describe each step in detail, Figure 11 illustrates the estimation of $\Delta p/p$.

First, we use the observed retirement frequencies by tenure at retirement, as illustrated in Figure 3, to estimate seasonally adjusted retirement frequencies. We denote the observe retirement frequency at tenure t by R_t and we estimate the following regression,

$$\begin{aligned} R_t \quad &= \quad 1(t < 10) * g_1(t) + 1(10 < t < 15) * g_2(t) + 1(15 < t < 20) * g_3(t) \\ +1(20 < \quad & t < 25) * g_4(t) + 1(25 < t < 15) * g_5(t) \\ +\gamma_{10}1(t = \quad & 8|t = 12) + \gamma_{15}1(t = 13|t = 17) + \gamma_{20}1(t = 18|t = 22) + \gamma_{25}1(t = 23|t = 27) \\ +\beta_{10}1(t = \quad & 10) + \beta_{15}1(t = 15) + \beta_{20}1(t = 20) + \beta_{25}1(t = 25) + \varepsilon_t. \end{aligned}$$

In this specification, $g_1(t), ..., g_4(t)$ are 4th order polynomials in tenure at retirement; these polynomials are interacted with du ies for separate tenure intervals so that we estimate separate continuous functions between each severance pay threshold. We also include dummies at integer values around the tenure thresholds to capture seasonal effects at the tenure thresholds; i.e., some of the spike at 10 years of tenure may be drive by 10 years being an integer value of tenure. We use integer values at +/- 2 years around the threshold rather than at +/- 1 year because some of the seasonal effects at +/- 1 year around the thresholds may be more likely to be affected by the severance pay thresholds. Lastly, we include du ies for tenure exactly equal to the tenure thresholds to capture the *discontinuous* increases in the retirement frequencies exactly at the severance pay thresholds. After estimating this regression, we obtain the seasonally adjusted frequencies, denoted by R_t^{sa}, by setting all of the du ies to 0 and predicting retirement frequencies using only the estimated continuous polynomial functions, $\hat{g}_1(t), ..., \hat{g}_4(t)$. The frequencies exactly at the severance pay thresholds are then set to $R_t^{sa} = \hat{\beta}_t - \hat{\gamma}_t$ for $t = 10, 15, 20, 25$ to capture the discontinuous increases at the severance pay thresholds while still netting out any seasonal effects at the thresholds. We re-scale the seasonally adjusted frequencies so that the total number of retirements is preserved. Figure 11A compares the observed retirement frequencies with the seasonally adjusted frequencies.

Second, we use the seasonally adjusted retirement frequencies to estimate counterfactual frequencies. Specifically, the counterfactual frequencies are estimated using the following regression specification,

$$R_t^{sa} = h(t) + \sum_{\tau \in \{10,15,20,25\}} \sum_{k=-18}^{18} \alpha_{\tau+k} 1(t = \tau + k) + \varepsilon_t^{sa}.$$

In this specification, $h(t)$ is a 6th order polynomial in tenure at retirement and the remaining indicator variables are du ies for tenure levels +/- 18 months around the tenure thresholds. After estimating this regression, the counterfactual frequencies are obtained by setting the indicator variables to 0 and predicting retirement frequencies using only $\hat{h}(t)$. We denote these counterfactual frequencies by $\hat{R}_t$. We re-scale these counterfactuals so that the total number of counterfactual retirements is equal to the total number of observed retirements. Figure 11B illustrates the seasonally adjusted retirement frequencies and the counterfactual frequencies.

Obtaining the counterfactual frequencies using only the polynomial $h(t)$, which is continuous through the severance pay thresholds, highlights our identifying assumption. In particular, we are assuming that, in the absence of the severance payments, individuals retiring at the tenure thresholds would behave like individuals retiring further away or between the tenure thresholds.

We use the seasonally adjusted and counterfactual frequencies to calculate the change in participation just after the tenure thresholds. Specifically, we specify a number of months after each thresholds m and compute the change in participation after each threshold $t = 10, 15, 20, 25$,

$$\frac{\Delta p_t}{p_t}(m) = \frac{\sum_{k=1}^{m}[R_{t+k}^{sa} - \hat{R}_{t+k}]}{\sum_{k=1}^{m}[\hat{R}_{t+k}]} \text{ for } t = 10, 15, 20, 25.$$

Thus $m = 1, 3, 12$ reflects the increase in participation at a monthly, quarterly and annual frequencies.

We estimate standard errors for the changes in participation using a block bootstrap procedure. Specifically, after estimating the seasonally adjusted frequencies, we obtain the estimated residuals $\hat{\varepsilon}_t$. We draw a new set of errors for each level of tenure, $\hat{\varepsilon}_t^b$, by sampling from the estimated residuals with replacement. We draw these new errors in blocks of 12 beginning at each integer value of tenure at retirement so that we account for the seasonal error structure. We add then create bootstrapped retirement frequencies by adding the new set of errors to the seasonally adjusted retirement frequencies, $R_t^b = R_t^{sa} + \hat{\varepsilon}_t^b$. We use the bootstrapped retirement frequencies and follow the same steps above to compute a new estimate for the change in participation. This bootstrap procedure is repeated 1000 times; the standard error for the change in participation is estimated by computing the standard deviation of the 1000 estimates.

We use this block bootstrap procedure, which samples errors across different levels of tenure at retirement, rather than a bootstrap procedure that samples individuals with replacement because we aim to capture error due to polynomial misspecification rather than errors across individuals. Since we are working with a large sample of individuals, we place less emphasis on errors due to variation across individuals and more emphasis on errors due to misspecification.[15]

Estimating $\Delta y/y$

The change in earnings, $\Delta y/y$, measures the financial incentives to delaying retirement by capturing the difference in after-tax income with and without the severance payments. Consider an individual just prior to a tenure threshold $t = 10, 15, 20, 25$. In the presence of the severance payments, the gain in earnings from working $m > 0$ months and then retiring is given by $\Delta y = (1 - \tau^{sev})ds(t)y^{gross}$ where y^{gross} is gross earnings, τ^{sev} is the marginal tax rate on severance pay income, and $ds(t)$ is the change in the fraction of the last year's salary that determines additional severance pay income; following Figure 1, $ds(t)$ is given by

$$ds(t) = \begin{cases} \frac{4}{12} - 0 & \text{if } t = 10 \\ \frac{6}{12} - \frac{4}{12} & \text{if } t = 15 \\ \frac{9}{12} - \frac{6}{12} & \text{if } t = 20 \\ \frac{12}{12} - \frac{9}{12} & \text{if } t = 25 \end{cases}.$$

Relative to earnings without the severance payments, the change in earnings is given by

$$\frac{\Delta y_t}{y_t}(m) = \frac{(1 - \tau^{sev})ds(t)y^{gross}}{(\frac{m}{12})(1 - \tau)y^{gross}}.$$

To compute this change in earnings, we estimate the implicit tax rate τ at each tenure threshold $t = 10, 15, 20, 25$ using the following steps. First, we compute the implicit tax rate on gross annual earnings in the year before retirement for each individual; this implicit tax rates taxes into account social security contributions ($ss\_contrib$), income taxes (inc_tax) and after-tax pensions ($pension$). The implicit tax rate for each individual is defined via the following equation,

$$\begin{aligned} (1 - \tau)gross\_earn &= gross\_earn - ss\_contrib - inc\_tax - pension \\ &\Rightarrow \tau = \frac{ss\_contrib + inc\_tax + pension}{gross\_earn}. \end{aligned}$$

After computing implicit tax rates for each individual, we compute mean implicit tax rates

[15] We have also computed bootstrapped standard error by sampling individuals with replacement. These standard errors are smaller than the block bootstrapped standard errors presented in the tables.

within each level of tenure at retirement, τ_t. Next, we account for differences in sample composition due to seasonality by estimating the following regression

$$\tau_t = f(t_t) + \sum_{\tau \in \{10,15,20,25\}} \sum_{k=-18}^{18} a_{\tau+k} 1(t = \tau + k) + \varepsilon_t^{\tau}$$

where $f(t)$ is a 6th order polynomial in tenure at retirement and the remaining indicator variables are du ies for tenure levels +/- 18 months around the tenure thresholds. After estimating this regression, the seasonally adjusted implicit tax rates are obtained by setting the indicator variables to 0 and predicting retirement frequencies using only $\hat{f}(t)$. We denote these seasonally adjusted implicit tax rates by $\hat{\tau}_t$. Figure 12 illustrates τ_t and $\hat{\tau}_t$ across all levels of tenure at retirement. The change in earnings is then computed as

$$\frac{\Delta y_t}{y_t}(m) = \frac{(1 - \tau^{sev}) ds(t)}{(\frac{m}{12})(1 - \hat{\tau}_t)} \text{ for } t = 10, 15, 20, 25$$

where $m = 1, 3, 12$ reflects the changes in earnings over a monthly, quarterly or annual time span.

The standard errors for the changes in earnings are computed using a block bootstrap procedure similar to the procedure described above for the changes in participation. After estimating the regression to adjust for seasonal composition changes, we obtain the estimated residuals $\hat{\varepsilon}_t^{\tau}$. We draw a new set of errors for each level of tenure, $\hat{\varepsilon}_t^{\tau,b}$, by sampling from the estimated residuals with replacement. We draw these new errors in blocks of 12 beginning at each integer value of tenure at retirement so that we account for the seasonal error structure. We add then create bootstrapped implicit tax rates by adding the new set of errors to the seasonally adjusted implicit tax rates, $\tau_t^b = \hat{\tau}_t + \hat{\varepsilon}_t^{\tau,b}$. We use the bootstrapped tax rates and follow the same steps above to compute a new estimate for the change in earnings. This bootstrap procedure is repeated 1000 times; the standard error for the change in earnings is estimated by computing the standard deviation of the 1000 estimates.

Combining the estimated numerators and denominators, we estimate elasticities with respect to monthly, quarterly and annual earnings for each threshold,

$$e_t(m) = \frac{\Delta p_t / p_t}{\Delta y_t / y_t}(m) \text{ for } t = 10, 15, 20, 25 \text{ and } m = 1, 3, 12.$$

The standard errors for the estimated elasticities are computed by taking the standard deviation of the 1000 estimates that result from the block bootstrap procedures used to compute the standard errors for the numerators and denominators.

4.3 Estimation Results

Table 3 presents the full sample estimation results. The table presents results at monthly, quarterly and annual levels. Panel A presents estimates of the changes in participation at each of the thresholds; Panel B presents results on the changes in earnings; Panel C combines the results of Panels A and B and presents the estimated elasticities. The results in Panel A indicate that, one month after the 10-year threshold, there is roughly a 110% increase in participation relative to the estimated counterfactual level of retirement. The changes in participation across the remaining thresholds are similarly large, ranging from roughly 130% to 160%. These large changes in participation are consistent with the large spikes observed in Figures 3 and 11. Turning to the annual frequency, the results indicate that, at 10-year threshold, the number of people retiring between 10 and 11 years of tenure increases by roughly 24% relative to the estimated counterfactuals; at the other thresholds, the change in participation at the annual frequency ranges from roughly 29% to 42%.

The increases in participation are accompanied by similarly large increases in earnings in Panel B. For working one month beyond the 10-year threshold, an individual's monthly earnings increases by roughly 164% due to the severance payments. The earnings increases at the 15-year threshold are smaller relative to the 10-year threshold since severance payments only increase by 4 months' pay at the 10-year threshold and two months' pay at the 15-year threshold. Similarly, the increases at the 20 and 25 year threshold are based on 3 additional months' pay. At the annual frequency, the changes in earnings due to the severance payments are still very large because of the relatively high implicit tax rates that results from very generous pensions and high income taxes.

Combining the results in Panels A & B yields the results in Panel C. In particular, even though the changes in participation are clearly evident in the graphical evidence, we estimate relatively small labor supply elasticities because the financial incentives from the severance payments are very large. The elasticities with respect to monthly earnings range from roughly 0.07 to 0.16; the elasticities with respect to quarterly earnings range from 0.10 to 0.23 and the elasticities with respect to annual earnings range from 0.18 to 0.40.

5 Quantitative Analysis II: Heterogeneity & Accounting for Differences in Observables

The graphical analysis in Section 3 suggests that there is heterogeneity in the labor supply responses to the shifts in earnings from severance payments along several dimensions. In Table 3 we have seen that the estimated elasticities differ across tenure thresholds with the largest elasticities estimated at the 15 and 20 year thresholds, but significantly smaller estimated elasticities at the 10 and 25 year thresholds. In this section we explore differences in responsiveness by gender and differences across tenure thresholds in more detail. We start by estimating elasticities for separate sub-samples and then investigate whether differences in these estimates are driven heterogeneity across other dimensions. To see how the gender and tenure dimensions of heterogeneity depend on differences in sample composition, we use a decomposition method based on re-weighting.

5.1 Re-weighting Methods

Our re-weighting strategy relies on methods introduced by and Fortin, Lemieux, Firpo (2010) and DiNardo, Fortin, Lemieux (1996). We first explain the strategy for the example of decomposing differences in elasticity estimates for men and women and then extend to the discussion of differences across the tenure thresholds.

We can apply the method of estimating extensive margin labor supply elasticities described in Section 4 to separate subsamples and estimate an elasticity for females and for males. As indicated by the graphical analysis, responses vary by gender as well as by other observable characteristics such as earnings, implicit tax rates, or firm size. As long as the distribution of these characteristics, e.g. the distribution of earnings varies by gender in our sample, the estimated elasticities for males and females also pick up heterogeneity in earnings. To abstract from compositional differences in the male and female samples in all observable characteristics X we estimate elasticities based on re-weighted samples. Specifically, we generate a re-weighting factor $\Psi(X)$ that replaces the marginal distribution of X for females and the marginal distribution of X for males with the marginal distribution of X in the overall population. Formally the re-weighting factors for females and males are given by

$$\Psi(X) = \begin{cases} \frac{1}{Pr(X|Female=1)} = \frac{Pr(Female=1)}{Pr(Female=1|X)} & \text{for females} \\ \frac{1}{Pr(X|Male=1)} = \frac{Pr(Male=1)}{Pr(Male=1|X)} & \text{for males} \end{cases}$$

DiNardo, Fortin, Lemieux (1996) show that an estimate of $\Psi(X)$ can be generated based on the predictions $\hat{p}$ from a simple probit model for the probability for $Pr(Female = 1|X)$. When estimating the probits for the re-weighting, we include a large set of observable characteristics. In particular, we include covariates X based on age, calendar years, citizenship, industry, region, seasonality, earnings histories, firm size, health and experience.[16] Consequently, we generate weights defined by

$$\hat{\Psi}(X_i) = \begin{cases} \frac{\bar{\hat{p}}}{\hat{p}_i} & \text{for females} \\ \frac{1-\bar{\hat{p}}}{1-\hat{p}_i} & \text{for males} \end{cases}$$

In the case of the four different tenure thresholds, we are concerned whether differences the estimated labor supply elasticities is related to differences in sample compositions. That means whether individuals with characteristics related to lower labor supply elasticities are more likely to be located around the 10 tenure year and 25 tenure year thresholds than at the other thresholds. We split the sample in four subsamples based on tenure intervals. Specifically we compare individuals with tenure between 6 and 12.5 years, 12.5 and 17.5 years, 17.5 and 22.5, and 22.5 and 28 years of tenure; these non-overlapping groups cover all tenure levels illustrated in Figure 3. To these samples we apply a similar re-weighting strategy as before. Our goal now is to generate weights that replace the marginal distribution of X in each of the tenure intervals with the marginal distribution of X in the overall population. This is done by estimating four different probit models for the probabilities of belonging to each of the tenure intervals I_j with $j = 1, ..., 4$; we denote this probability for observation i by $p_{ij} = Pr(I_j = 1|X_i)$. From the probits, we obtain predicted probabilities $\hat{p}_{ij}$ for each observation i in interval j. The weight for observation

[16] The estimated probits include dummies for calendar year, age measured at a quarterly frequency, birth month, birth year, Austrian citizenship, quarter of the year, industry, region, firm size, blue collar job status, job starting month, health status between age 42 through age 54, contribution years between age 42 through 54, sick leave in the current quarter, unemployment in the current quarter, top-coded earnings, insurance years (interacted with gender), and real earnings. Firm size is grouped into the following categories: ≤ 5, $6-10, 11-25, 26-99, 100-499, 500-999, \geq 1000$. Health status between age 42 through age 54 is based on the following categories of sick leave from age 42 through age 54: ≤ 0.03 years, $0.03-0.18$ years, $0.18-0.33$ years, and ≥ 0.33 years. Health and unemployment in the current quarter are based on the following categories for sick leave and unemployment days in the current quarter: 0 days, $1-30$ days, $31-60$ days, and ≥ 61 days. Contribution years between ages 42 through age 54 is based on the following categories of contribution years: ≤ 5 years, $5-8$ years, $8-13$ years, and $= 13$ years. Real earnings dummies are created by creating 25 percentiles based on average earnings between ages 42 through 54.

For the tenure re-weighting, we exclude calendar year, birth year and contribution year dummies because of common support problems. For example, we do not observe many individuals with high contribution years at the lower tenure thresholds since these individuals are very likely to have higher tenure.

i in interval j is then given by

$$\hat{\Psi}_j(X_i) = \frac{\bar{\hat{p}}_j}{\hat{p}_{ij}}.$$

5.2 Re-weighting Results

Table 4 reports estimates for changes in participation, changes in earnings, and the implied labor supply elasticities by gender across the different tenure thresholds. We see that while changes in earnings are generally smaller for women, their participation responses are significantly larger than those for males across all thresholds. Consequently, we estimate larger labor supply elasticities for women than for men. The re-weighted results show how the estimates change when we replace the marginal distribution of observable characteristics among females and males to equal the marginal distribution of observables in the overall population. Across all tenure thresholds the elasticities for men are now closer to those for women mainly due re-weighting the changes in earnings. However, a considerable difference in the labor supply elasticities across genders still remains. We conclude that gender is an important dimension of heterogeneity in labor supply responses even for the older population around retirement.

Table 5 investigates differences in sample composition across tenure thresholds. If we consider gender, we see from the sample sizes around each threshold that the gender composition is almost balanced across thresholds. The fraction of females is between 59% and 57%, except at the 25 year threshold where males dominate. When we re-weight the male and female samples based on observable characteristics, we see that changing the marginal distribution of X affects mainly the participation margins or the magnitudes of the spikes in the frequency graphs; re-weighting does not change the distributions of income changes. The resulting elasticity estimates become more similar across thresholds for both the female and male samples, which implies that some of the differences in responsiveness across thresholds can be explained by composition effects. Using weights based on the relative sample sizes at each tenure threshold, we take weighted averages of the re-weighted elasticities and obtain an average elasticity of 0.12 for men and an average elasticity of 0.38 for women.

Even after re-weighting, the estimated elasticities decrease with the payment sizes so that the elasticity at the 10-year threshold is still significantly smaller than the elasticities at the other thresholds. This decreasing pattern in the elasticities suggests that there is some fraction of the population that is unresponsive to the severance pay incentives regardless of the size of the incentives. Intuitively, a fraction of the population may simply be ignorant or unaware of the program. Additionally, the low elasticity estimate at the 10-year threshold might be a result from assuming that severance pay level jumps from zero to one quarter of the annual earnings at this threshold, which would be the largest jump in the schedule. Since individuals become eligible for severance pay due to layoffs after they complete lower tenure levels, some individuals may be able to negotiate mutual agreements with their employers so that they would retire with some severance pay rather than no severance pay. As a result, there would still be discontinuity at 10 years of tenure when people qualify for a larger payment, but the discontinuity at the 10-year threshold may be smaller than the mandated discontinuity. This issue would not affect the higher tenure thresholds since the severance pay schedules for layoffs and retirements are the same beyond 10 years of tenure. Thus we interpret the re-weighting results as eliminating the main differences in responsiveness across thresholds with the caveat that the elasticity at the 10 year threshold is potentially the least accurately estimated.

5.3 Pre-Threshold Retirement Patterns

We examine the pre-threshold retirement patterns to present nonparametric evidence on the relative importance of substitution and wealth effects in retirement decisions. In a standard intertemporal labor supply model, the increased retirement frequencies at the tenure thresholds could be driven by two effects. First, individuals may anticipate the increased severance pay at a later tenure threshold and, as a result, choose to delay their retirements to qualify for the larger payments. This effect is referred to as a substitution or price effect. Intuitively, individuals may see the price of retirement as relatively high when they are close to a tenure threshold, and hence they may choose to delay their retirements. Forward-looking behavior is an important component of this effect. Second, individuals may realize added wealth from qualifying for a severance payment, and as a result, chose to retire earlier. This effect is referred to as a wealth effect. Intuitively, individuals may chose to retire earlier and consume more leisure because of increased wealth from qualifying for a (larger) severance payment.

We present evidence on the relative importance of these substitution and wealth effects by examining how much of the increased retirement frequencies at the tenure thresholds can be explained by individuals delaying their retirements. First, we set a fixed number of months prior to each tenure threshold; we denote this number of months by $\underline{m}$. Second, prior each threshold, we compute the number of individuals delaying their retirements by taking su ing the differences between the counterfactual frequencies and the seasonally adjusted frequencies,

$$\# \text{ of Delays } = \sum_{k=1}^{m} [\hat{R}_{t-k} - R^{sa}_{t-k}] \text{ for } t = 10, 15, 20, 25.$$

Third, we set a fixed number of months after each threshold to capture the total number of increased retirement frequencies due to the severance payments; we denote this number of months by $\overline{m}$. Fourth, we compute the total number of excess retirements at the severance pay thresholds by su ing differences between the counterfactual frequencies and the seasonally adjusted frequencies,

$$\# \text{ of Excess Retirement } = \sum_{k=1}^{\overline{m}} [R^{sa}_{t-k} - \hat{R}_{t-k}] \text{ for } t = 10, 15, 20, 25.$$

Finally, we compute the ratio of the number of delayed retirements to the total number of excess retirements so see how many of the excess retirements can be explained by delayed retirements,

$$Delay\_Ratio(\underline{m}) = \frac{\# \text{ of Delays}}{\# \text{ of Excess Retirement}} = \frac{\sum_{k=1}^{m} [\hat{R}_{t-k} - R^{sa}_{t-k}]}{\sum_{k=1}^{\overline{m}} [R^{sa}_{t-k} - \hat{R}_{t-k}]} \text{ for } t = 10, 15, 20, 25.$$

Intuitively, if substitution effects dominate wealth effects in retirement decisions, we would expect this ratio to be close to 1 since most of the excess retirements will be due to individuals who have delayed their retirements.

Table 7 presents the estimated values of $Delay\_Ratio$ for each of the tenure thresholds and also for different values of the pre-threshold number of months, $\underline{m}$. Overall, the estimates indicate the substitution effects account for most if not all of the total effects of the severance payments. For men, the results indicate that, within 18 months prior to the 15-year and 20-year thresholds, the delayed retirements account for all of the excess retirements. At the 10-year and 25-year thresholds, there appears to be more room for wealth effects as the delayed retirements within 18 months prior to these thresholds account for about 60% of the total excess retirements. The 10-year threshold creates the largest increase in severance pay and the 25-year threshold is the last severance pay threshold. For women, the results at the 10-year and 15-year thresholds indicate that the delayed retirements within 18 months prior to the thresholds can primarily account for all of the excess retirements at those thresholds. The delayed retirements account for less of the excess retirements at the 20-year threshold; since women retire earlier than men, the 20-year threshold may effectively be the last severance pay threshold that many women consider. Since there are few women close to the 25-year threshold, the results are noisier, though still consistent with the idea of larger wealth effects at the last severance pay threshold.

6 Conclusions

In this study, we provide new empirical evidence on extensive margin labor supply elasticities using responses to policy discontinuities in retirement benefits in Austria. We first present nonparametric graphical evidence documenting individuals' labor supply responses to the policy discontinuities. Next, we develop a strategy to estimate extensive margin labor supply elasticities nonparametrically. The strategy exploits the observed labor supply responses to the policy discontinuities. The results indicate relatively low labor supply elasticities that are driven primarily by substitution effects rather than wealth effects. The evidence also suggests that a significant fraction of the population faces some sort of frictions or ignorance in their retirement decisions as many individuals are observed retiring just before discontinuous increases in their retirement benefits. Models of retirement decisions need to account for such frictions or ignorance, otherwise predicted labor supply responses to retirement benefits will be significantly overstated.

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Table 1

Sample Selection

	Number of Individuals	Percentage change
Individuals in cohorts born 1930 - 1940	1,578,549	
Still employed at age 55	651,336	-59%
More than one year employment experience before age 55	625,251	-4%
Excluding workers ever employed as civil servant	546,308	-13%
Excluding workers withlast job not in construction	487,019	-11%
Excluding left censored tenure in last job	380,737	-22%
Workers retiring withing 6 months of their last job	269,411	-29%
Excluding individuals with un-censored earnings at retirement	231,251	-14%

Notes: Numbers based on the ASSD

Table 2: Summary Statistics

	Full Sample	Estimation Sample
# of Individuals	231,251	155,283
Fraction Female	0.53	0.57
Retirement Age	58.43	58.41
	58.50	58.50
	2.51	2.52
Tenure	11.00	14.68
	10.42	14.17
	7.59	5.50
Annual Earnings	24666.68	25646.12
	23950.24	24821.64
	10923.06	10280.21
Implicit Tax Rate	0.81	0.79
	0.78	0.77
	0.28	0.22
Years of Employment	32.40	33.10
	34.13	34.51
	9.45	8.71
Years of Unemployment	0.55	0.28
	0.00	0.00
	1.23	0.66
Years of Sick Leave	0.21	0.20
	0.05	0.04
	0.36	0.35
Firm Size	1690.73	2186.98
	86.00	129.00
	4919.57	5635.91
Fractions:		
Claiming Disability Pensions	0.303	0.271
Claiming Early Retirement Pensions	0.354	0.360
Claiming Old Age Pensions	0.343	0.369
Agriculture & Mining	0.045	0.036
Manufacturing	0.249	0.245
Sales	0.190	0.178
Tourism	0.048	0.028
Transportation	0.054	0.048
Services	0.415	0.466

Notes: Except for the Fractions, the mean, median and standard deviations are reported for each variable. All earnings variables are expressed in 2008 euros. The Estimation Sample consists of individuals with at least 6 years of tenure at retirement but not more than 28 years of tenure at retirement.

Table 3: Participation Elasticities by Tenure Thresholds

Panel A: Changes in Participation (dp/p)				
Frequency	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Monthly, m=1	0.8436	1.1225	1.1708	1.2641
	(0.0514)	(0.0342)	(0.0581)	(0.1245)
Quarterly, m=3	0.4649	0.5789	0.6941	0.6934
	(0.0231)	(0.0220)	(0.0377)	(0.0791)
Annual, m=12	0.2232	0.2695	0.3735	0.3878
	(0.0130)	(0.0166)	(0.0247)	(0.0604)
Panel B: Changes in Earnings (dy/y)				
Frequency	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Monthly, m=1	16.4315	8.3984	14.1021	16.9955
	(0.2506)	(0.1133)	(0.2161)	(0.4800)
Quarterly, m=3	5.4723	2.8032	4.7120	5.6893
	(0.0834)	(0.0379)	(0.0730)	(0.1599)
Annual, m=12	1.3638	0.7053	1.1912	1.4513
	(0.0205)	(0.0096)	(0.0195)	(0.0393)
Panel C: Elasticities (e)				
Frequency	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Monthly, m=1	0.0513	0.1337	0.0830	0.0744
	(0.0032)	(0.0045)	(0.0042)	(0.0077)
Quarterly, m=3	0.0849	0.2065	0.1473	0.1219
	(0.0045)	(0.0086)	(0.0083)	(0.0146)
Annual, m=12	0.1637	0.3821	0.3136	0.2672
	(0.0102)	(0.0249)	(0.0218)	(0.0436)
N	61,999	44,900	32,607	15,777

Notes: Numbers in parentheses are bootstrapped standard errors based on 1000 replications.

Table 4: Gender Differences, Annual Frequency

	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Panel A: Changes in Participation (dp/p)				
Men	0.1702	0.1707	0.2509	0.3441
	(0.0116)	(0.0155)	(0.0199)	(0.0413)
Women	0.2593	0.3387	0.4678	0.4477
	(0.0166)	(0.0206)	(0.0313)	(0.0961)
Re-weighted Men	0.1965	0.1742	0.2177	0.2670
	(0.0143)	(0.0219)	(0.0284)	(0.0427)
Re-weighted Women	0.3067	0.3156	0.4826	0.4311
	(0.0201)	(0.0234)	(0.0354)	(0.0975)
Panel B: Changes in Earnings (dy/y)				
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Men	1.9769	0.9471	1.4253	1.5524
	(0.0489)	(0.0176)	(0.0373)	(0.0625)
Women	1.1076	0.5961	1.0539	1.3566
	(0.0126)	(0.0071)	(0.0122)	(0.0261)
Re-weighted Men	1.5211	0.7815	1.2204	1.3959
	(0.0533)	(0.0245)	(0.0341)	(0.0578)
Re-weighted Women	1.0205	0.5961	1.1290	1.5163
	(0.0186)	(0.0092)	(0.0181)	(0.0443)
Panel C: Elasticities (e)				
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Men	0.0861	0.1802	0.1761	0.2216
	(0.0064)	(0.0170)	(0.0149)	(0.0301)
Women	0.2341	0.5682	0.4439	0.3300
	(0.0149)	(0.0348)	(0.0306)	(0.0719)
Re-weighted Men	0.1292	0.2229	0.1784	0.1913
	(0.0103)	(0.0287)	(0.0235)	(0.0335)
Re-weighted Women	0.3006	0.5294	0.4275	0.2843
	(0.0190)	(0.0384)	(0.0302)	(0.0631)
Panel D: Sample Sizes (N)				
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Men	26,781	18,377	13,799	8,289
Women	35,218	26,523	18,808	7,488

Notes: Numbers in parentheses are bootstrapped standard errors based on 1000 replications.

Table 5: Heterogeneity across Tenure Thresholds, Annual Frequency

	Men					Women			
Panel A: Changes in Participation (dp/p)									
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold		10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Unweighted	0.1702	0.1707	0.2509	0.3441	Unweighted	0.2593	0.3387	0.4678	0.4477
	(0.0116)	(0.0155)	(0.0199)	(0.0413)		(0.0166)	(0.0206)	(0.0313)	(0.0961)
Re-weighted	0.1924	0.1380	0.1648	0.2418	Re-weighted	0.2755	0.2759	0.3346	0.4452
	(0.0199)	(0.0233)	(0.0273)	(0.0590)		(0.0240)	(0.0219)	(0.0294)	(0.1402)
Panel B: Changes in Earnings (dy/y)									
	Men					Women			
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold		10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Unweighted	1.9769	0.9471	1.4253	1.5524	Unweighted	1.1076	0.5961	1.0539	1.3566
	(0.0489)	(0.0176)	(0.0373)	(0.0625)		(0.0126)	(0.0071)	(0.0122)	(0.0261)
Re-weighted	1.9744	0.9219	1.4122	1.6377	Re-weighted	1.0573	0.5277	0.8469	1.0190
	(0.0442)	(0.0188)	(0.0497)	(0.1155)		(0.0370)	(0.0175)	(0.0229)	(0.0396)
Panel C: Elasticities (e)									
	Men					Women			
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold		10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Unweighted	0.0861	0.1802	0.1761	0.2216	Unweighted	0.2341	0.5682	0.4439	0.3300
	(0.0064)	(0.0170)	(0.0149)	(0.0301)		(0.0149)	(0.0348)	(0.0306)	(0.0719)
Re-weighted	0.0975	0.1497	0.1167	0.1476	Re-weighted	0.2606	0.5228	0.3951	0.4369
	(0.0106)	(0.0251)	(0.0190)	(0.0373)		(0.0247)	(0.0454)	(0.0363)	(0.1374)
N	26,781	18,377	13,799	8,289	N	35,218	26,523	18,808	7,488

Notes: Numbers in parentheses are bootstrapped standard errors based on 1000 replications.

Table 6: Elasticities by Retirement Age, Annual Frequency

	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Men				
Retirement Age 55-59	0.0250	0.1340	0.1047	0.0890
	(0.0097)	(0.0130)	(0.0132)	(0.0244)
	12404	8061	5519	2748
Retirement Age 60	0.1404	0.1895	0.1524	0.2984
	(0.0221)	(0.0450)	(0.0305)	(0.0519)
	10248	7685	6094	3976
Retirement Age $\geq$ 61	0.1729	0.3066	0.4419	0.2667
	(0.0154)	(0.0296)	(0.0476)	(0.0665)
	4129	2631	2186	1565
Women				
	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
Retirement Age 55-59	0.2255	0.5512	0.4832	0.3872
	(0.0196)	(0.0382)	(0.0310)	(0.0903)
	24477	18189	13364	5342
Retirement Age 60	0.2383	0.4458	0.3169	0.2954
	(0.0179)	(0.0350)	(0.0383)	(0.0863)
	8234	6502	4076	1464
Retirement Age $\geq$ 61	0.2827	1.0097	0.2768	0.0427
	(0.0317)	(0.1305)	(0.0637)	(0.0904)
	2507	1832	1368	682

Notes: Numbers in parentheses are bootstrapped standard errors based on 1000 replications. Sample sizes around each tenure threshold are given below the standard errors.

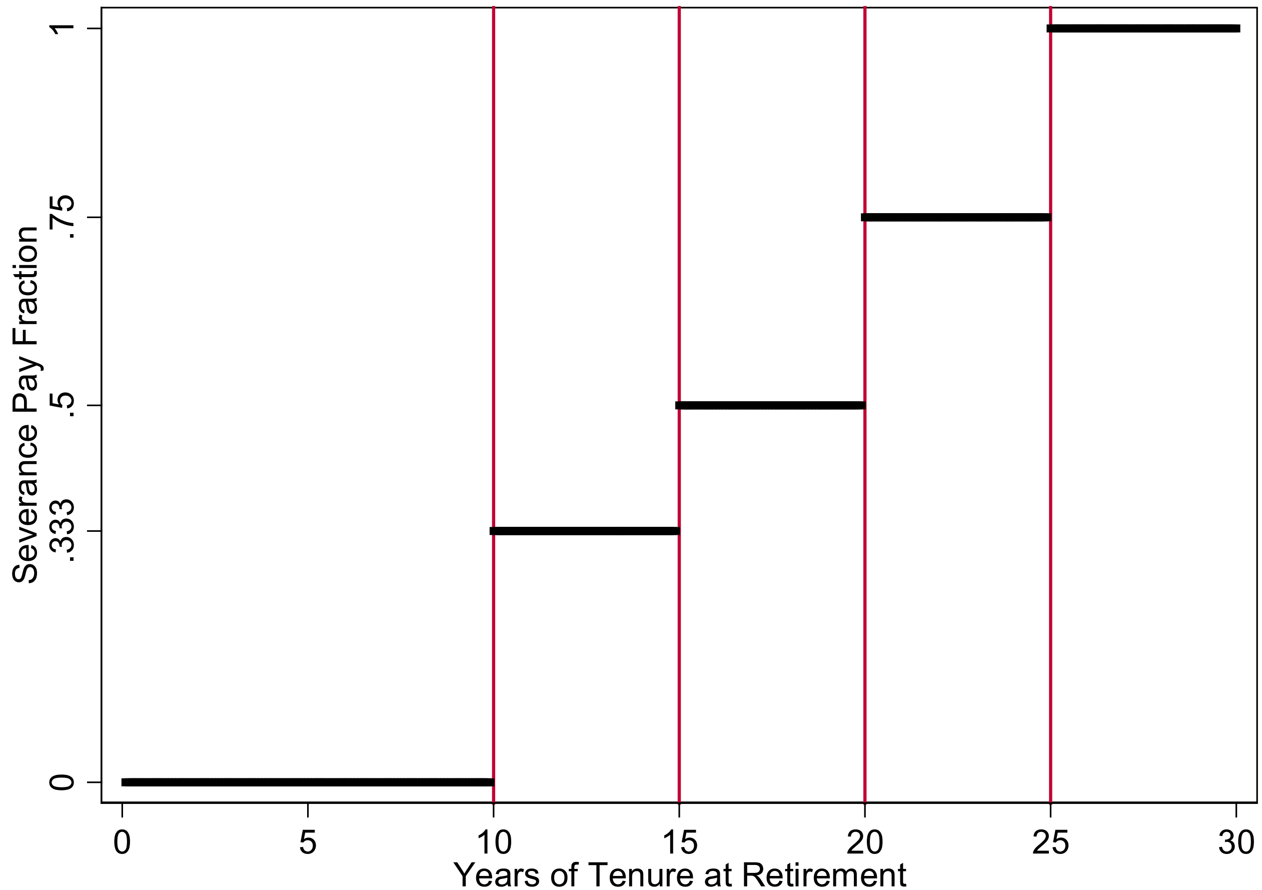
Table 7: Pre-Threshold Retirement Patterns

Ratio of Delayed Retirements to Excess Retirements (Within 18 Months after Threshold)

	Men			
Months Prior to Tenure Threshold	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
12	0.5370	0.8985	0.8871	0.5364
	(0.0891)	(0.1140)	(0.1307)	(0.1057)
18	0.5677	1.0555	1.0507	0.5823
	(0.1057)	(0.1305)	(0.1515)	(0.1219)
24	0.5875	1.1460	1.1348	0.6036
	(0.1190)	(0.1393)	(0.1616)	(0.1310)
36	0.7051	1.2525	1.1939	0.6807
	(0.1201)	(0.1417)	(0.1591)	(0.1311)
	Women			
Months Prior to Tenure Threshold	10 Year Threshold	15 Year Threshold	20 Year Threshold	25 Year Threshold
12	0.8691	0.7420	0.5326	0.6457
	(0.1051)	(0.0883)	(0.0918)	(0.2276)
18	0.9777	0.8327	0.5757	0.6615
	(0.1191)	(0.1013)	(0.1028)	(0.2468)
24	1.0223	0.8778	0.5975	0.6958
	(0.1275)	(0.1083)	(0.1083)	(0.2592)
36	1.1380	0.9872	0.6977	0.9206
	(0.1326)	(0.1091)	(0.1075)	(0.2707)

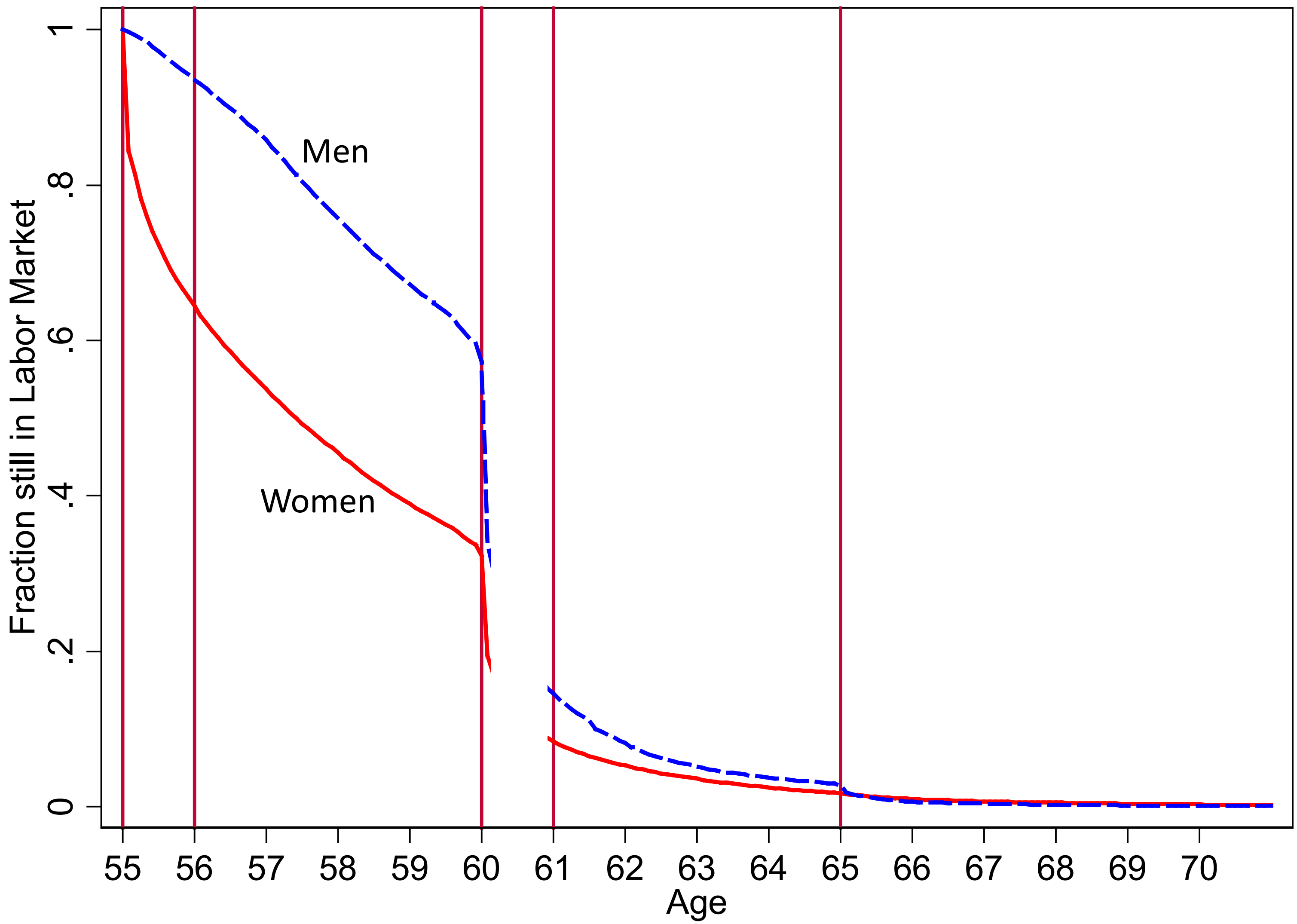
Notes: Numbers in parentheses are bootstrapped standard errors based on 1000 replications.

Fig. 1. Payment Amounts based on Tenure at Retirement



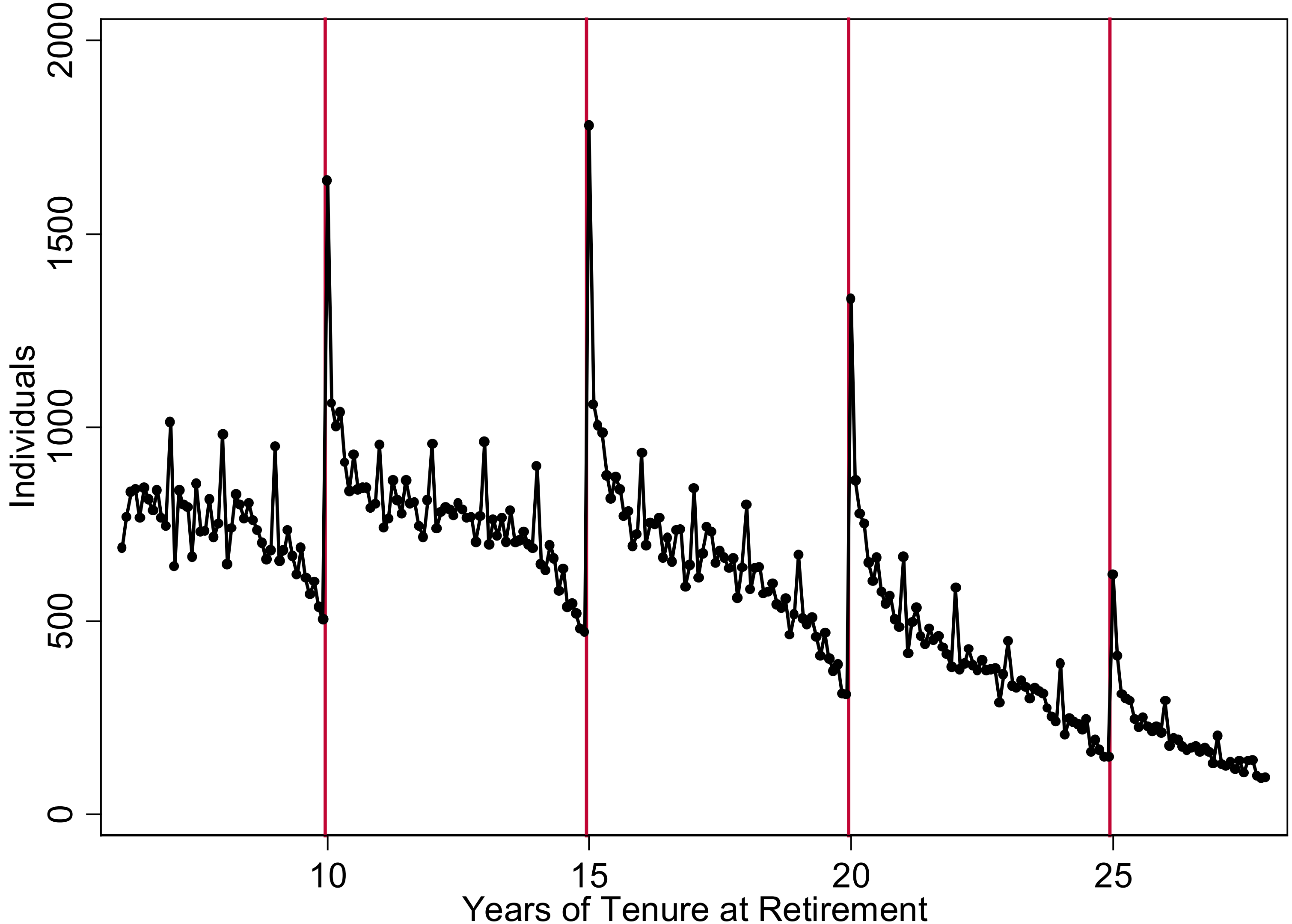
Notes: There are two forms of government-mandated retirement benefits in Austria: (1) government-provided pension benefits and (2) employer-provided severance payments. The employer-provided severance payments are made to private sector employees who have accumulated sufficient years of tenure by the time of their retirement. Tenure is defined as uninterrupted employment time with a given employer and retirement is based on claiming a government-provided pension. The payments must be made within 4 weeks of claiming a pension according to the following schedule. If an employee has accumulated at least 10 years of tenure with her employer by the time of retirement, the employer must pay one third of the worker's last year's salary. This fraction increases from one third to one half, three quarters and one at 15, 20 and 25 years of tenure respectively. Since payments are based on an employee's salary, overtime compensation and other non-salary payments are not included when determining the amounts of the payments. Provisions to make these payments come from funds that employers are mandated to hold based on the total number of employees. Severance payments are also made to individuals who are involuntarily separated (i.e. laid off) from their firms if the individuals have accumulated sufficient years of tenure prior to the separation. The only voluntary separation that leads to a severance payment, however, is retirement. Employment protection rules hinder firms from strategically laying off workers to avoid severance payments and there is no evidence on an increased frequency of layoffs before the severance pay thresholds.

Fig. 2. Exits from Labor Force into Retirement



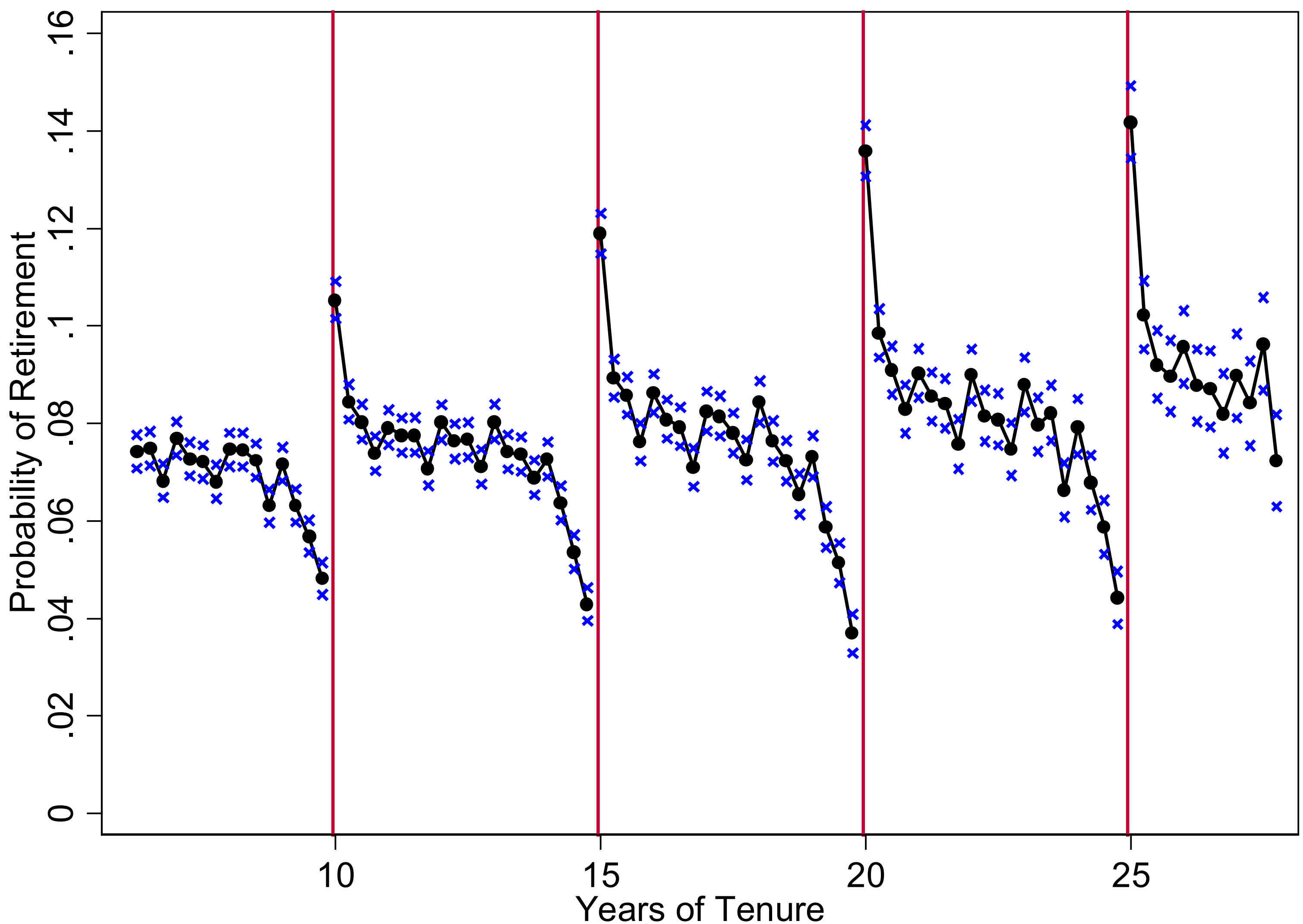
Notes: This figure plots the survival functions for exits from the labor force for the sample of private sector employees; the survival functions are computed at a monthly frequency using birthdates and last observed job ending dates. The solid red line is the survival function for women; the Early Retirement Age and Normal Retirement Age for women are respectively 55 and 60. The dashed blue line is the survival curve for men; the Early Retirement Age and Normal Retirement Age for men are respectively 60 and 65. Prior to age 60, men can retire through disability pensions.

Fig. 3. Distribution of Tenure at Retirement, Full Sample



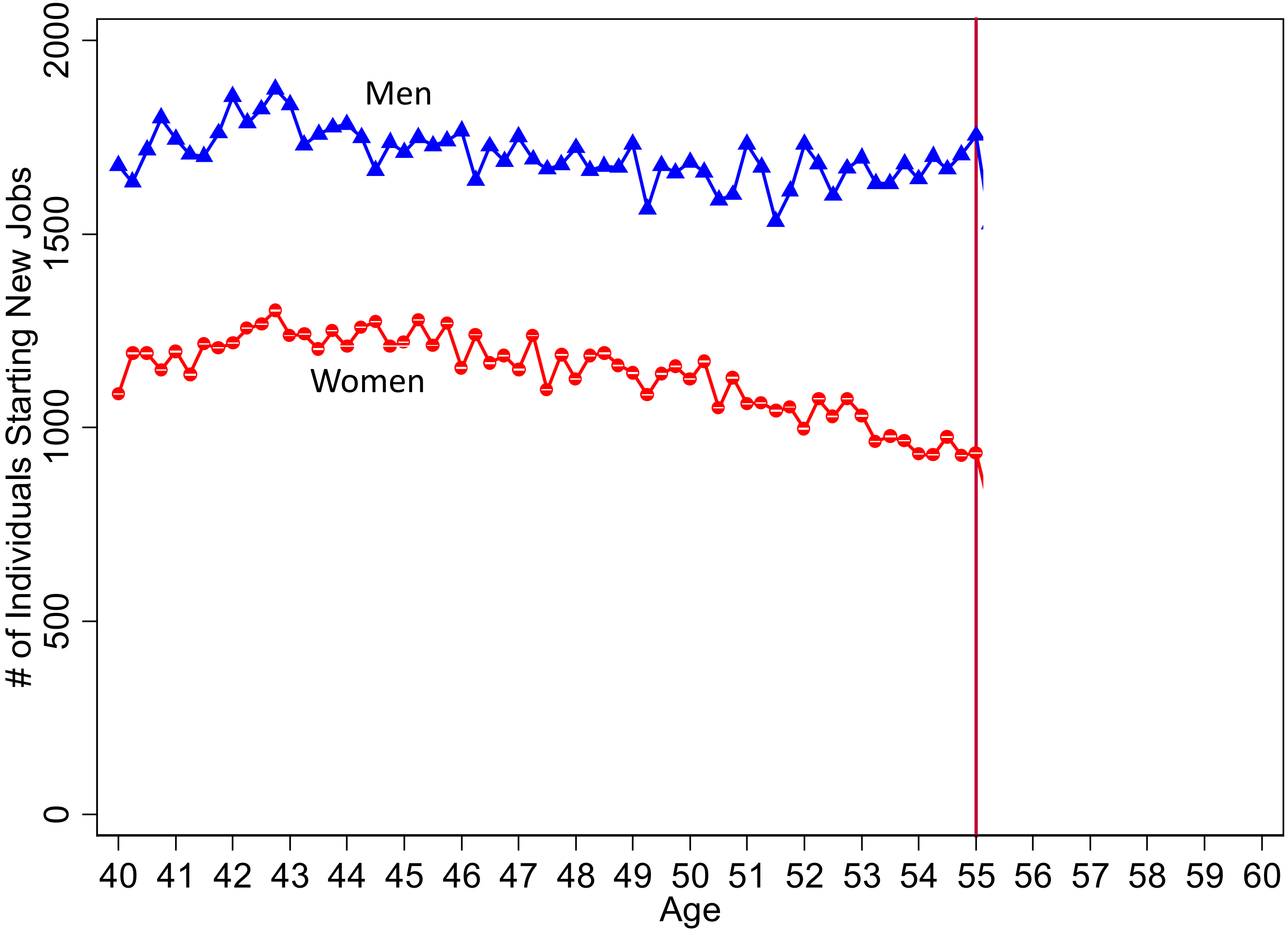
Notes: This figure plots the distribution of tenure at retirement at a monthly frequency. Each point captures the number of people that retire with tenure greater than the lower number of months, but less than the higher number of months. Tenure at retirement is computed using observed job starting and job ending dates. Since firm-level tenure is only recorded beginning in January 1972, we restrict the sample to individuals with uncensored tenure at retirement (i.e. job starting after January 1972).

Fig. 4. Controlling for Covariates



Notes: We regress a quarterly retirement indicator on quarterly tenure dummies and controls for age, gender, calendar years, citizenship, blue collar job status, industry, region, current calendar quarter, job starting month, earnings histories, firm size, health and years of experience. The black circles are the estimated coefficients on the tenure dummies. The blue x's above and below each circle represent +/- 2 standard errors around each point estimate.

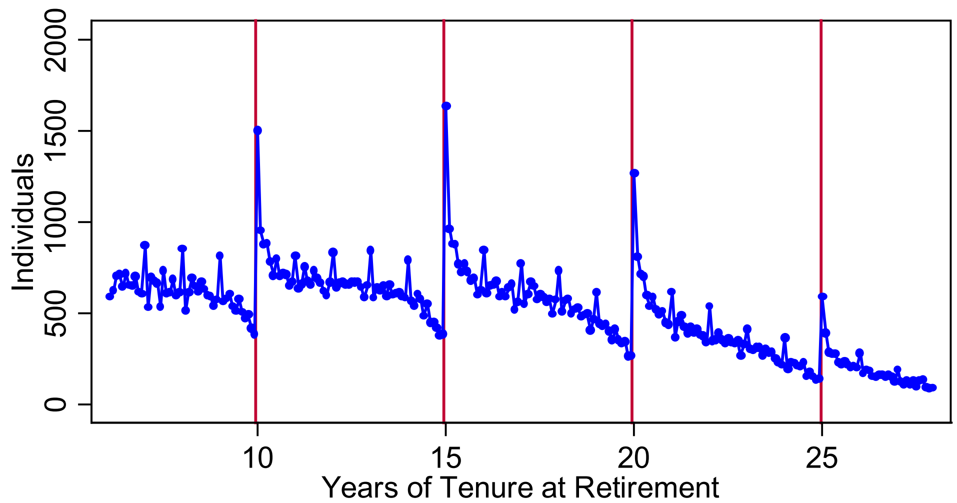
Fig. 5. Job Starts by Age



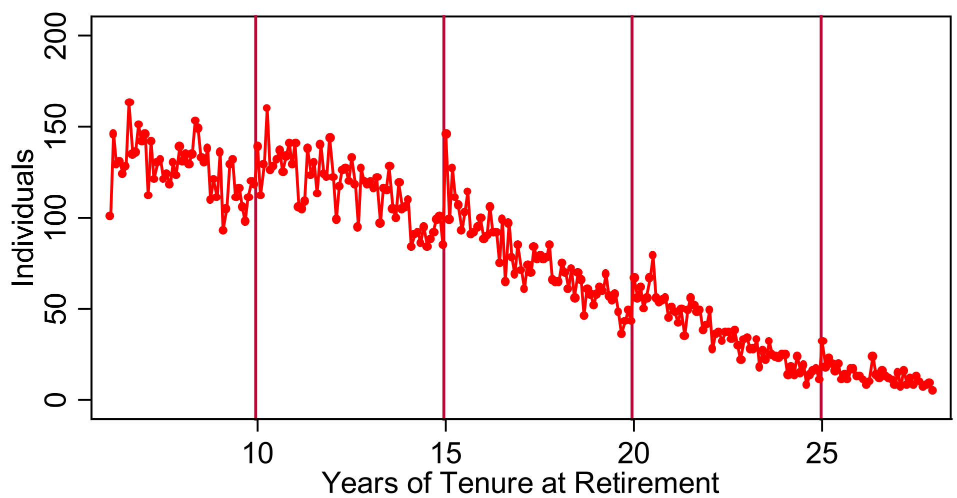
Notes: This figure plots the number of men and women starting new jobs at each age. The sample consists of all men and women, including those with uncensored tenure at retirement. Age is measured at a quarterly frequency. The blue triangles capture the number of men starting new jobs and the red circles captures the number of women starting new jobs.

Fig. 6. Tenure at Retirement by Health Status

Healthy

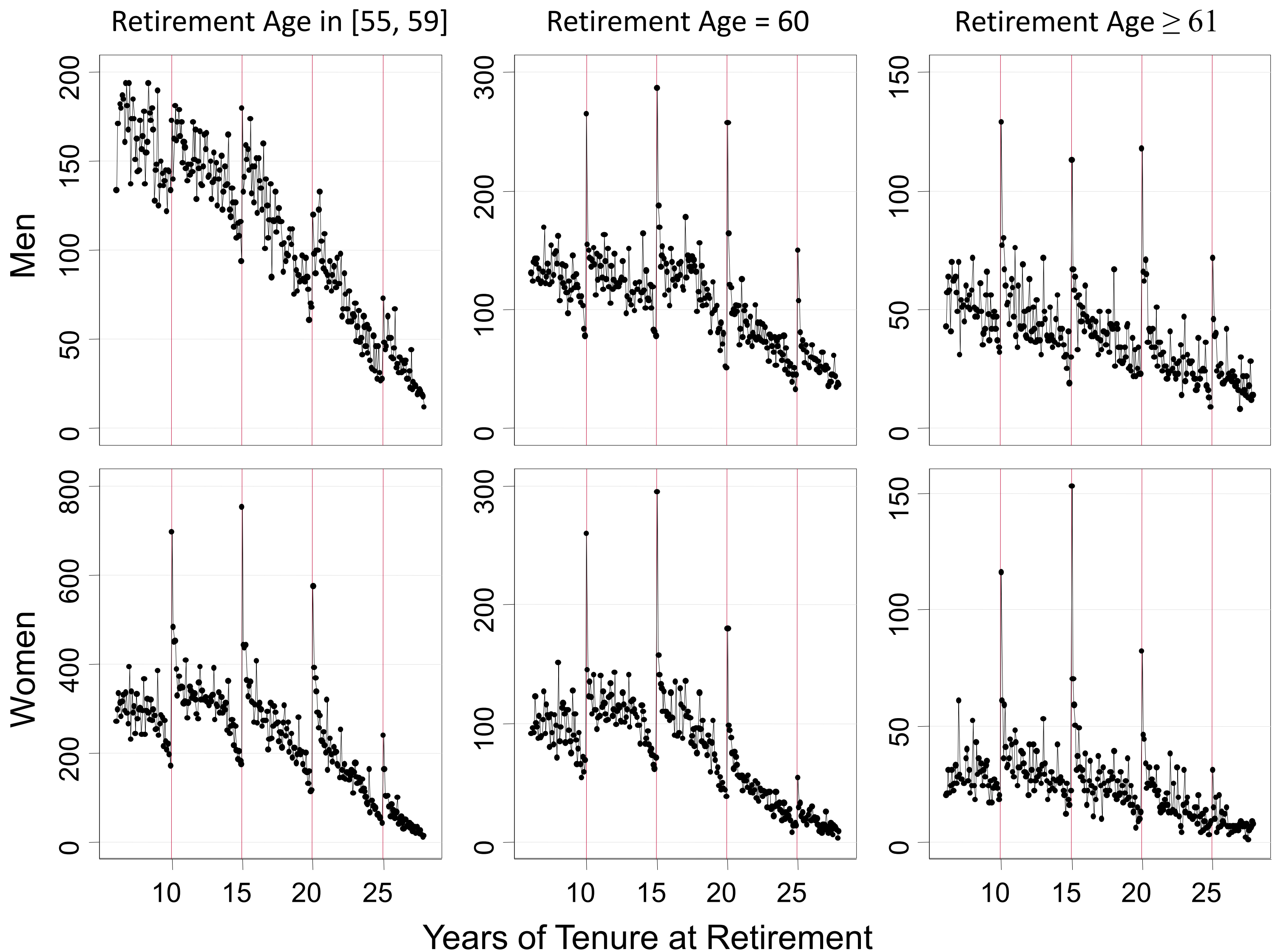


Unhealthy



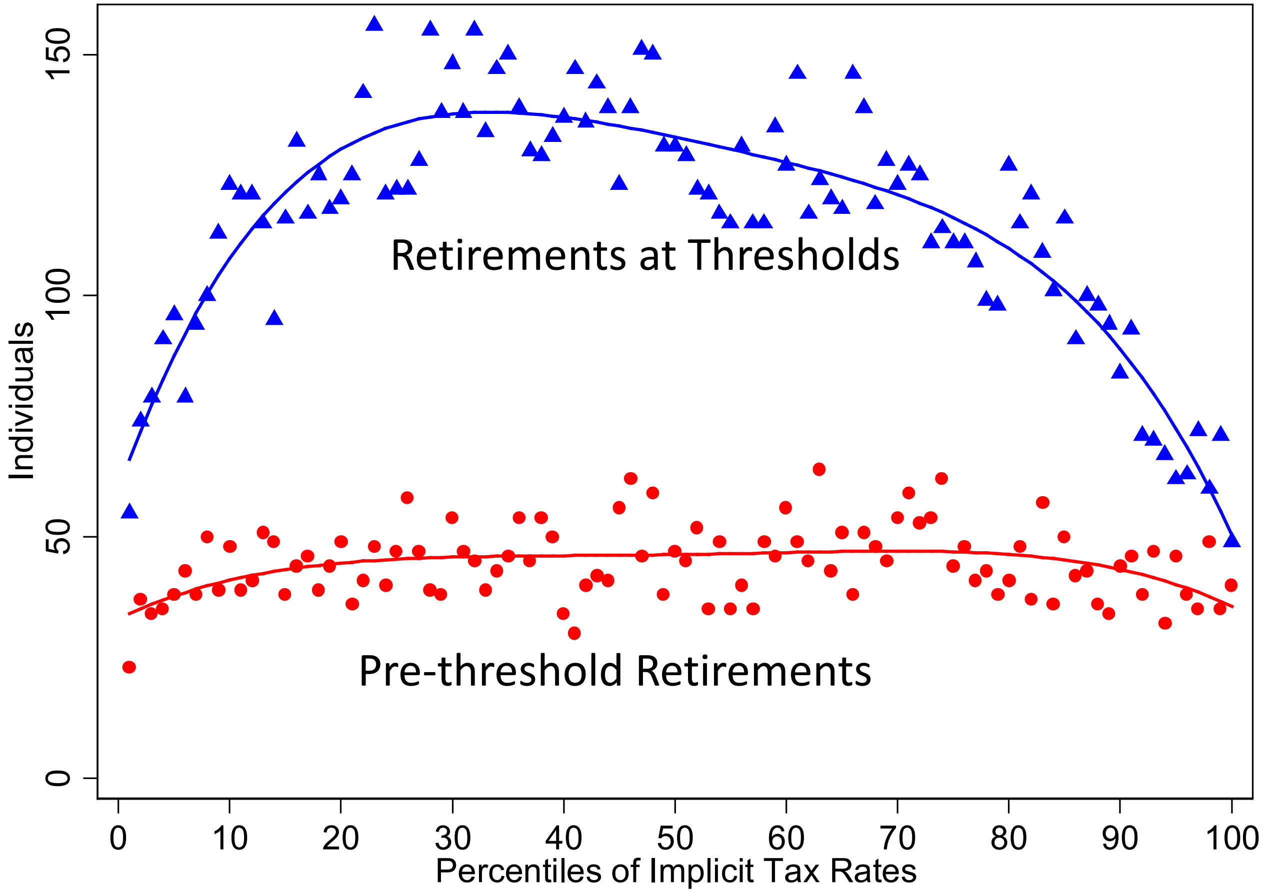
Notes: Health status is measured based on the fraction of time between age 54 and retirement that is spent on sick leave. An individual is classified as unhealthy if his health status is below the median level. The median health status is computed within the sample of individuals with positive sick leave and uncensored tenure at retirement.; this median health status is 0.076.

Fig. 7. Tenure at Retirement by Gender & Retirement Age



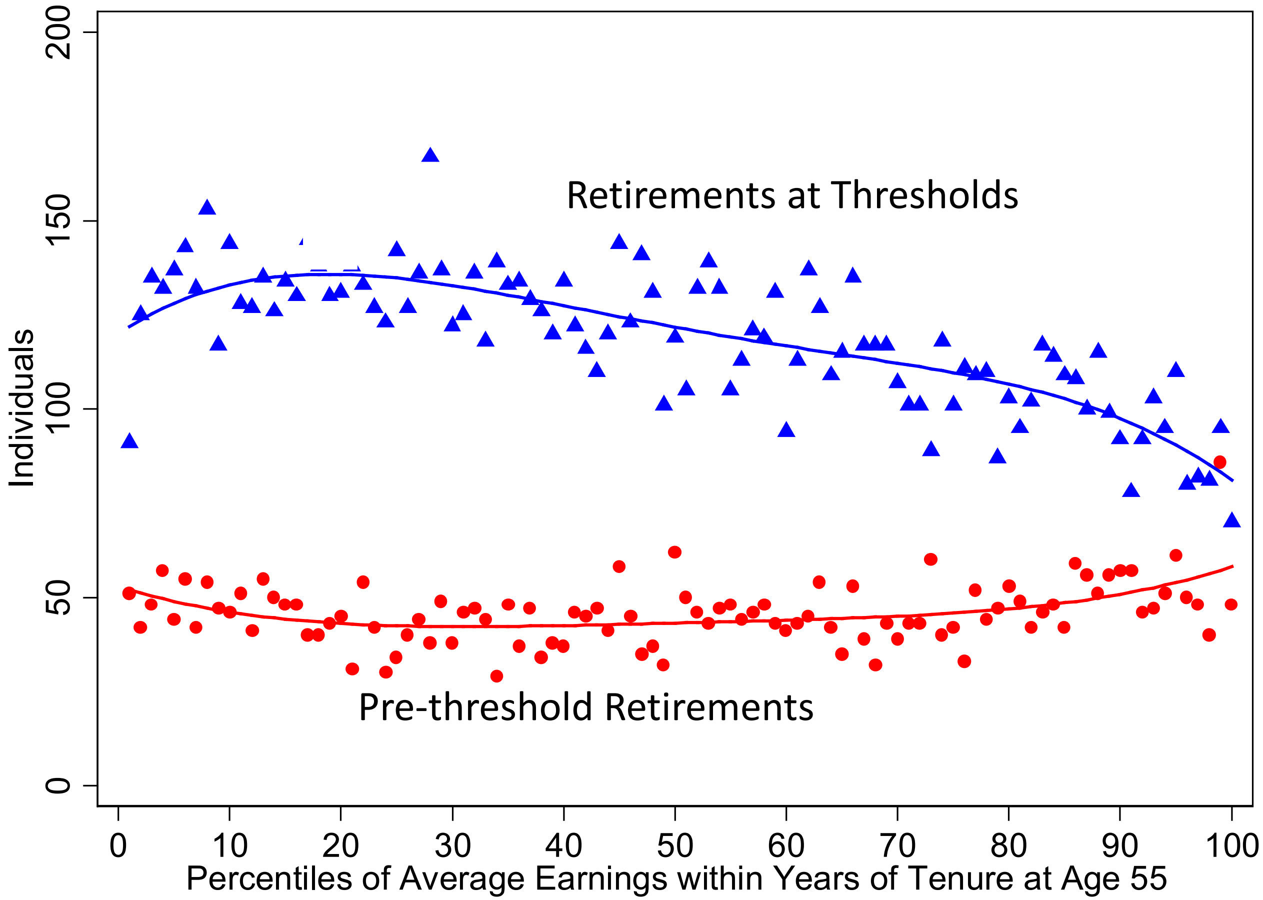
Notes: The age groups for men and women are chosen based on the survival curves illustrated in Figure 2. The Early Retirement Age and Normal Retirement Age for women are 55 and 60; the corresponding ages for men are 60 and 65 respectively. Prior to age 60, men can retire and claim disability pensions.

Fig. 8. Tenure at Retirement by Implicit Tax Rates



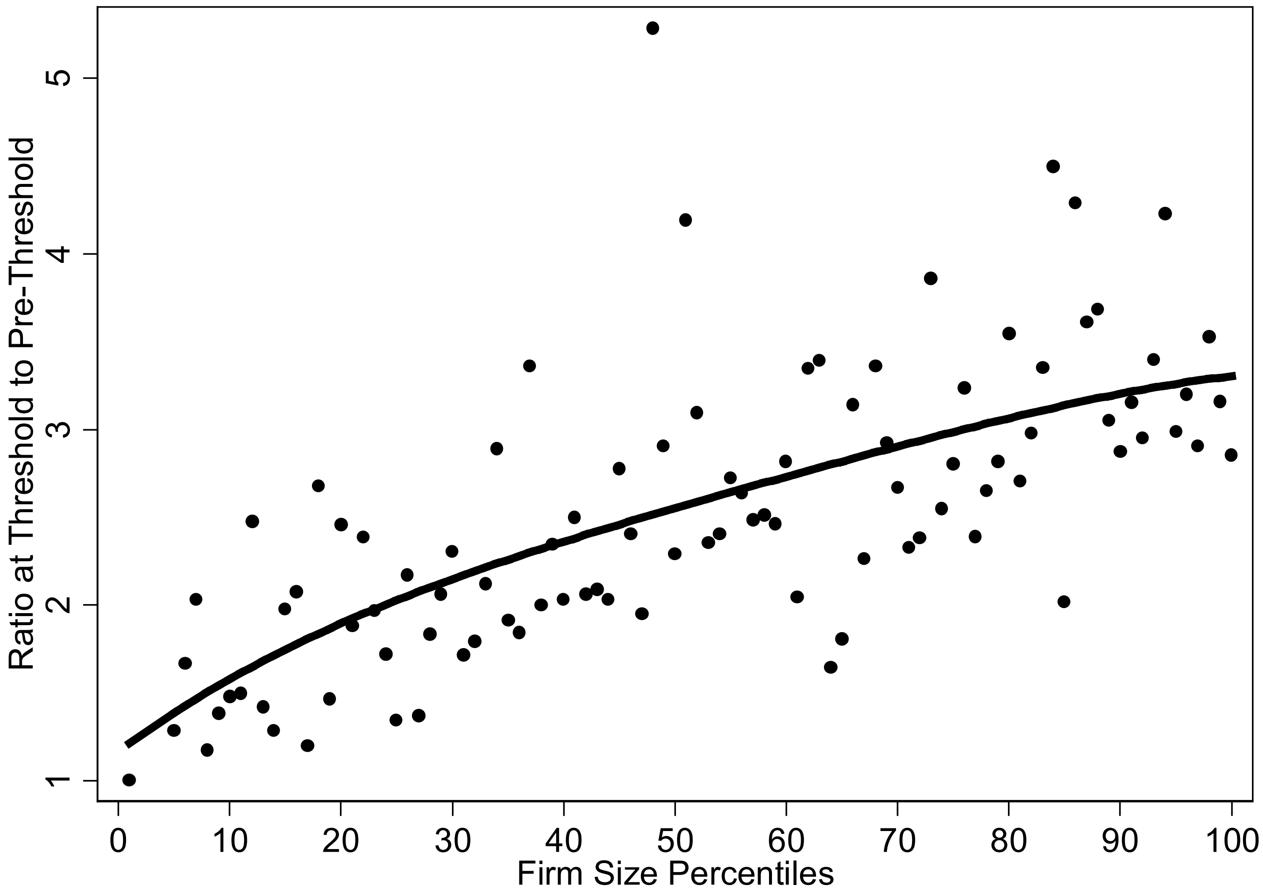
Notes: This figure is constructed via the following steps. First, we compute percentiles of implicit tax rates across the sample of individuals with uncensored tenure at retirement. Second, we calculate tenure at retirement at a quarterly frequency. Third, within each percentile of implicit tax rates, we compute the total number of people retiring within one quarter prior to a threshold; this series or pre-threshold retirements across implicit tax percentiles is plotted in red circles. The solid red line captures predicted values from regressing the pre-threshold counts on a 4^{th} order polynomial in percentiles of implicit tax rates. Fourth, within each percentile of implicit tax rates, we also compute the total number of people retiring within one quarter after a threshold; this series or retirements at thresholds across implicit tax percentiles is plotted in blue triangles. The solid blue line captures predicted values from regressing the threshold counts on a 4^{th} order polynomial in percentiles of implicit tax rates.

Fig. 9. Tenure at Retirement by Tenure-Adjusted Permanent Income



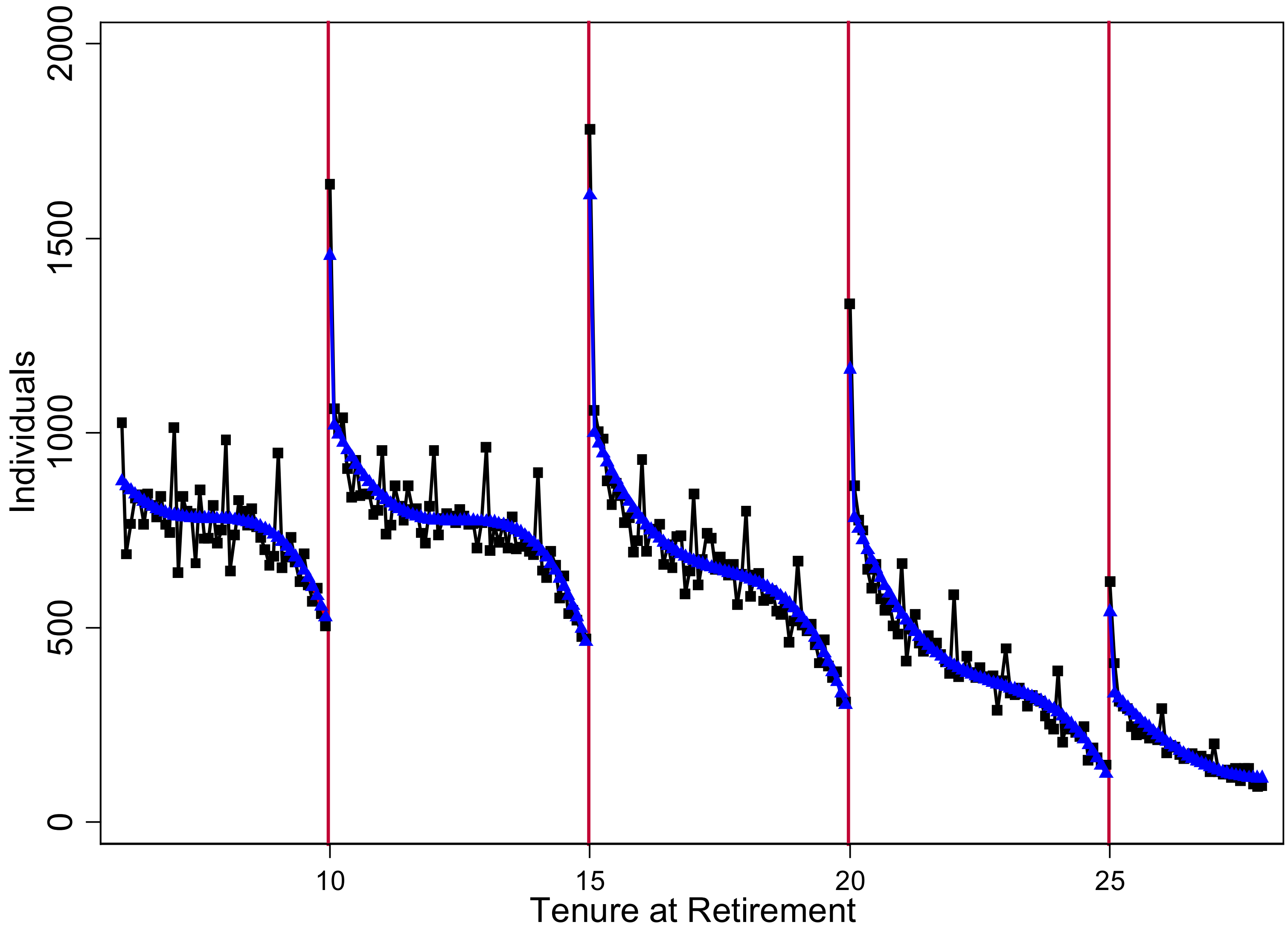
Notes: This figure is constructed via the following steps. First, we compute average earnings between ages 42 through 54 for all individuals in the sample. We sum earnings over these ages and divide by 13. Second, we compute tenure at age 55 for each individual. Third, within each calendar year and integer value of tenure at age 55, we compute percentiles of average earnings. Fourth, we compute tenure at retirement at a quarterly frequency. Fifth, within each percentile of average earnings, we compute the total number of people retiring within one quarter prior to a tenure threshold. This series of pre-threshold retirements across earnings percentiles is plotted in red circles; the solid red line captures predicted values from regressing the pre-threshold retirements on a 4^{th} order polynomial in earnings percentiles. Lastly, within each percentile of average earnings, we compute the total number of people retiring within one quarter after a tenure threshold. This series of retirements at thresholds is plotted in blue triangles; the solid blue line captures predicted values from regressing the retirements at thresholds on a 4^{th} order polynomial in earnings percentiles.

Fig. 10. Retirements at Tenure Thresholds by Firm Size



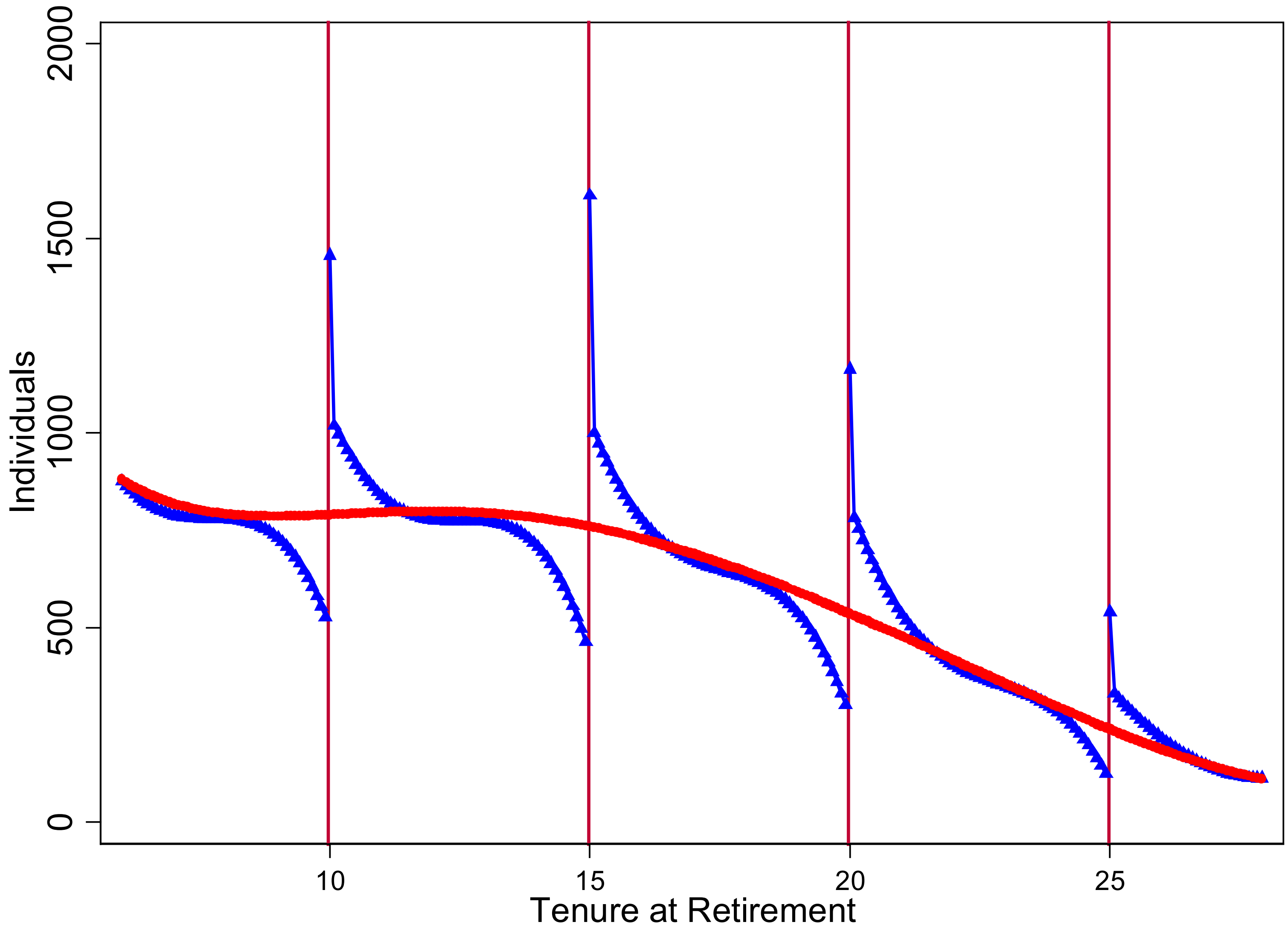
Notes: Firm size is computed as the number of employees at the beginning of each calendar quarter. We construct firm size percentiles using the sample of firms with retirements. For each individual at retirement, we keep the firm identifier and calendar date of the last employment date. We create a dataset with the sample of firms with retirements by dropping any duplicates so that the resulting dataset has one observation per unique firm-calendar date observation. Within each calendar date, we compute firm size percentiles. Next, we compute tenure at retirement at a quarterly frequency. Finally, within each firm size percentile, we compute the ratio of the total number of people retiring within one quarter after a tenure threshold to the total number of people retiring within one quarter prior to a tenure threshold. Each point in the figure plots this ratio within each firm size percentile. The solid line captures predicted values from regressing the ratios on a 4th order polynomial in firm size percentiles.

Fig. 11A. Estimating the Changes in Participation



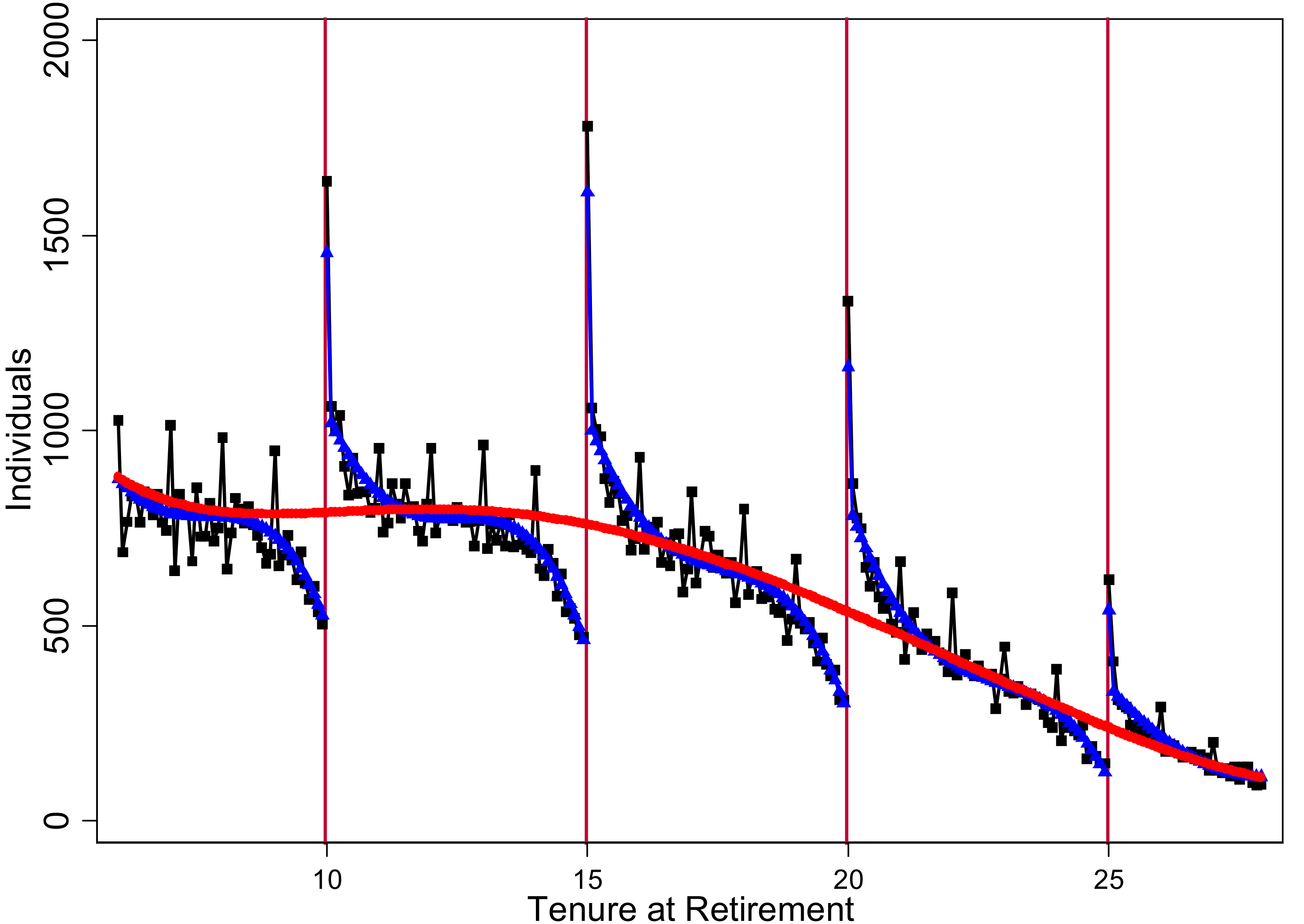
Notes: The black squares plot the observed retirement frequencies at each monthly level of tenure at retirement, as in Figure 3. The blue triangles plot retirement frequencies adjusted for seasonality patterns. The adjustment for seasonality is based on estimating separate polynomials in tenure at retirement between each tenure threshold and discontinuous spikes at each tenure threshold. The spikes at each threshold are adjusted for seasonality by adjusting for being at an integer value of tenure at retirement. The seasonally adjusted retirement frequencies are re-scaled so that the total number of seasonally adjusted retirements is equal to the total number of observed retirements.

Fig. 11B. Estimating the Changes in Participation



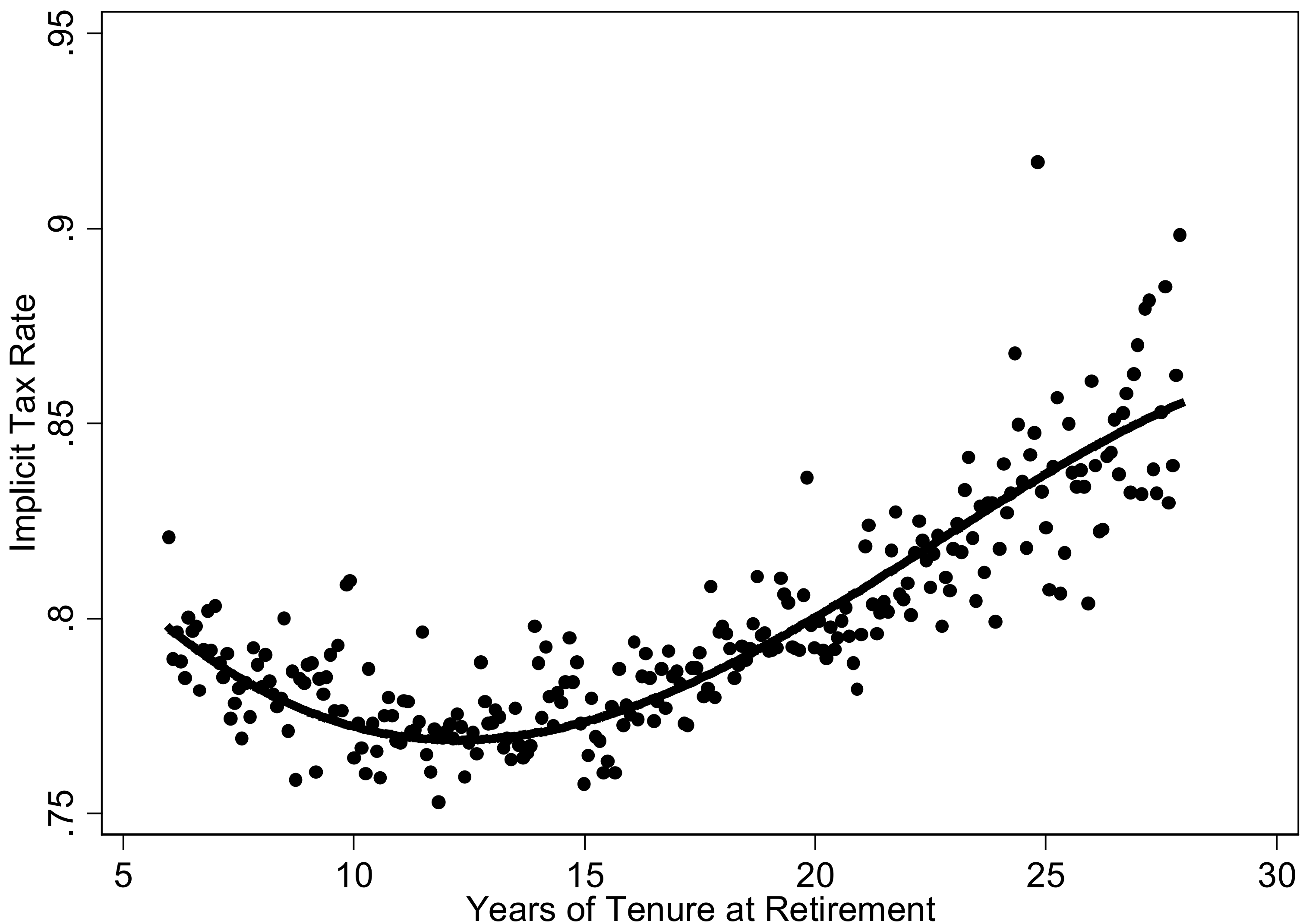
Notes: The blue triangles plot retirement frequencies adjusted for seasonality patterns. The red circles plot estimated counterfactual retirement frequencies. The counterfactual frequencies are estimated by regressing the seasonally adjusted frequencies on a continuous 6th order polynomial in tenure at retirement and dummies around each tenure threshold. The dummies around each threshold are set to 0 and the counterfactual frequencies are obtained by predicting frequencies using only the estimated continuous polynomial function. The counterfactual frequencies are re-scaled so that the total number of counterfactual retirements equals the total number of observed retirements.

Fig. 11C. Estimating the Changes in Participation



Notes: This figure combines plots for the observed retirement frequencies (black squares), the seasonally adjusted retirement frequencies (blue triangles) and the counterfactual retirement frequencies (red circles).

Fig. 12. Implicit Tax Rates



Notes: Implicit tax rates for each individual are computed based on gross annual earnings in the calendar year prior to claiming a pension. The implicit tax rate is the sum of social security contributions, income taxes and pensions divided by gross annual earnings. Each point in the figure reflects the mean implicit tax rate amongst individuals retiring with the corresponding level of tenure at retirement. The solid line captures predicted values from regression the mean implicit tax rates on a 4th order polynomial in tenure at retirement .

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