Breaking the Implicit Contract: Using Pension Freezes to Estimate the Labor Supply Elasticity *

Dhiren Patki †

This version: November 2018

PRELIMINARY AND INCOMPLETE

Abstract

The extensive margin labor supply elasticity is an important parameter in many economic models. Prior estimates of its value, derived almost exclusively from samples of younger workers, are often near zero. This study exploits firm's decisions to renege on implicit pension promises to study the labor supply behavior of older workers. Using rich administrative and survey data in tandem, it finds an extensive margin labor supply elasticity of 0.75 for workers aged 56-64 — an estimate that is 3 times larger than prevailing values based on younger workers. The findings in this paper quantify the importance of age in the participation margin, shed light on the role of implicit contracts in the labor market, and indicate that policies aimed at lengthening the working lives of older Americans can be effective.

JEL codes: J22, J26, J32, J41, M52

*I am indebted to Matthew Shapiro, Charles Brown, and Melvin Stephens for advice and support. I thank John Bound, R. Andrew Butters, Jamie Fogel, Parag Mahajan, and seminar participants at the University of Michigan for valuable comments. I am grateful to Kristin McCue for help with the Census disclosure process and Janet Keller for her assistance with access to restricted HRS data. This research uses data from the Census Bureau's Longitudinal Employer Household Dynamics Program, which was partially supported by the following National Science Foundation Grants SES-9978093, SES-0339191 and ITR-0427889; National Institute on Aging Grant AG018854; and grants from the Alfred P. Sloan Foundation. Any opinions and conclusions expressed herein are those of the author and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed. This research was supported by the Alfred P. Sloan Foundation Pre-doctoral Fellowship on the Economics of an Aging Workforce, awarded through the NBER, and by the F. Thomas Juster Economic Behavior Research Award. All errors are my own.

†Department of Economics, University of Michigan, 611 Tappan Ave., Ann Arbor, MI 48109. Email: dpatki@umich.edu.

1 Introduction

The extensive margin labor supply elasticity is of central importance in many economic models. Prior studies that estimate this parameter, particularly those that rely on quasi-experimental variation, consistently find it to be small. Averaging across estimates in a meta analysis, Chetty et al. (2012) report a value of 0.25. Notably, these estimates are all derived from samples of the prime age population (i.e. individuals between the age of 25-54).

As population aging and increasing life expectancy strain public budgets, policy makers and researchers have examined ways of lengthening the working lives of older individuals.[1] While the extensive labor supply elasticity is a critical input in assessing the impact of policies aimed at delaying retirement, there are important theoretical reasons why estimates obtained from samples of prime age workers do not generalize well to older workers. As highlighted by Cogan (1981), and emphasized in the context of aging by French (2005), the presence of fixed costs of working generates a reservation level of labor disutility. As they age, workers accumulate assets, experience adverse changes to their health, and become eligible for old age pensions. These age dependent forces raise older workers' reservation labor disutility thereby generating variability along the participation margin and making their labor supply more responsive relative to younger workers. Along similar lines, Rogerson and Wallenius (2013) illustrate the importance of non-convexities such as fixed costs in generating retirement and show that prime-age-based estimates of the labor supply elasticity are too small to rationalize the abrupt drop in hours that occurs around retirement.

Relying on new data and a novel source of identification, I build on these findings by providing quasi-experimental estimates of the extensive margin labor supply elasticity among older workers. I find that workers aged 56-64 exhibit an extensive margin labor supply elasticity of 0.75 which is 3 times larger than prevailing estimates based on the prime-age population. This result quantifies the importance of age in the participation margin and sheds light on the influence of age dependent labor taxation in dampening the gradual decline in labor force participation that occurs as workers age (see, e.g., Weinzierl (2011) and Laitner and Silverman (2012)).

To estimate labor supply elasticities of older workers, I exploit an ongoing trend of independent interest that has received scant attention in the literature due to data limitations. Over the last two decades, private

[1] Based on amendments passed in 1983, the age at which older Americans can claim full Social Security benefits (the full retirement age or FRA) is slowly being raised from 65 to 67. Motivated by evidence that it impeded labor supply among older workers, the social security earnings test was abolished for individuals above the FRA by the Senior Citizens Freedom to Work Act of 2000.

sector sponsors of defined benefit (DB) pensions have increasingly reneged on implicit promises to support future pension accruals for their workers in actions known as pension freezes. The left panel of Figure 1 simulates the impact of these shocks using a sample of DB eligible respondents from the Health and Retirement Study (HRS). Workers unaffected by pension freezes earn deferred compensation based on the solid blue path, whereas those affected by pension freezes experience accumulation patterns represented by the dashed red paths. The impacts of the shock vary based on the age at which workers are affected. As shown in the figure, a 54 year-old experiences a persistent negative shock to overall compensation whereas a 64 year-old experiences a positive shock.

To study why employers have increasingly reneged on implicit contracts and to examine how employees respond to these defaults, I create a new dataset that combines information from Internal Revenue Service (IRS) administrative records on the universe of private sector pension plans with longitudinal employer-employee linked data from the Census Bureau. Using these data, I first illustrate the importance of deteriorating plan funding ratios and increasing sponsor contributions as important explanatory factors in the pension freeze trend. Next, I exploit a quasi-experimental research design pooling together thousands of firm-level experiments and comparing the labor supply of workers whose employers freeze their DB plans with workers whose employers keep their DB plans intact. This identification strategy exploits the transition paths shown in Figure 1, wherein workers affected at different ages experience wealth and substitution effects of different magnitudes. The data reveal that substitution effects play a dominant role in the wake of freezes: Workers who stand to lose compensation retire early, whereas those who stand to gain compensation delay retirement. These behavioral patterns reveal substantial heterogeneity in individual tastes for work.

The administrative microdata I rely on do not include information on the dollar value of changes to pension accruals necessary to scale observed behavioral responses into structural elasticities. To estimate these parameters, I turn to rich data from the Health and Retirement Study (HRS) that provides measures of pension wealth and retirement expectations for a representative sample of older, DB eligible, workers. Using these data, I simulate the effect of changes in total compensation engendered by pension freezes . This novel two-sample strategy demonstrates the value of combining information from administrative data with survey based measures.

This paper adds to the literature that has sought to estimate extensive labor supply elasticities using microdata and quasi-experimental methods (see, e.g., Eissa and Liebman (1996), Meyer and Rosenbaum

(2001), Devereux (2004), Eissa and Hoynes (2004), Blundell et al. (2011), and Manoli and Weber (2016)). Its chief contribution to this body of work is to quantify the increase in labor supply elasticity that occurs as workers age. These results have implications for a broader literature on the macroeconomic, public finance, and labor market implications of an aging workforce. Secondary to these findings, the paper provides direct evidence of the influence that implicit contracts can have on labor supply, and illustrates key factors driving a growing trend towards ruptures in the implicit bargains made between employers and employees with respect to DB pensions. These results add to a literature that has found a greater tendency towards spot market arrangements through fissuring of the workplace in recent years (see, e.g., Abraham and Taylor (1996), Dey et al. (2010), Katz and Krueger (2017), and Goldschmidt and Schmieder (2017)).

The plan of this paper is as follows. Section 2 provides institutional details on the DB pension landscape in the United States and explains important recent changes influencing firm's decisions to continue sponsoring DB plans. Section 3 outlines a model of the worker's response to a freeze, and makes several testable predictions. Section 4 discusses three different sources of administrative data and provides details about the HRS linked pension sample. Section 5 outlines the empirical framework and presents summary statistics. Section 6 interprets individual level outcomes estimated using administrative data. Section 7 combines labor supply responses to freezes obtained from the administrative data with simulated estimates of compensation changes from the HRS to estimate Marshallian extensive margin labor supply elasticities. Section 8 concludes.

2 Institutional Background

In 1980 DB plans covered 61 percent of pension eligible private sector workers. By 2015 the same statistic had fallen to 16 percent. This overall decline occurred not only because of a surge in new 401(k) DC plans but also because of stagnation in the creation of new DB plans. For most of this period, DB plans continued to operate normally with only rare instances of distressed plan terminations triggered by firm bankruptcy. Starting in the late 1990's, however, several firms began converting their DB plans to cash balance (CB) plans. CB conversions switched DB benefit accruals from formulas based on years of service and earnings, to formulas that guaranteed a specific rate of return on the value of pension wealth workers had already earned. In the early 2000's this shift was amplified as many employers altogether ended traditional DB

pension accruals in actions known as hard freezes.[2] The incidence of CB conversions and hard freezes between 1999 and 2015 is shown in Figure 2. The most recent data indicate that about half of all private sector single employer DB plans have either been converted to cash balance plans or hard frozen, affecting about 40 percent of active participants.

2.1 Costs of DB plan provision rise

Firm's decisions to renege on DB promises through CB conversions and hard freezes occurred in a deteriorating financial environment that rapidly raised the cost of DB pension provision. As shown in Figure 3, the wake of the dot-com bubble and ensuing recession lowered the asset value of pension funds substantially. In 2000, the private sector DB system had $1.87 in assets for each dollar of future liabilities. By 2004, the funding ratio had slipped to just 0.62. As the funding position of DB plans worsened, statutory provisions required firms to increase annual contributions; consequently, aggregate payments into DB pension funds rose five-fold from $26 billion in 2000 to $126 billion in 2003. Low interest rates and stock market losses during the Great Recession weakened firms' funding positions drawing further increases in required pension contributions thereby raising costs. The role of declining funding positions as predictors of pension freezes is further demonstrated in Appendix B, which relies on firm-level microdata.[3]

In the midst of major changes to the finances of DB pension funds, the Pension Protection Act (PPA) was signed into law in 2006. The PPA established more conservative standards on the interest rates that sponsors could use to discount future liabilities, reduced the period over which sponsors needed to amortize funding deficits from 15 years to 7 years, and required that plans with funding ratios of 80 percent or below make additional minimum contributions and pay higher insurance premiums to the Pension Benefit Guarantee Corporation (PBGC).[4] These key provisions of the PPA, which were phased-in as of 2008, raised statutory minimum pension contributions and imposed greater cost pressure on DB sponsors.

[2] Over the same period, employers also began closing their DB plans to new entrants in actions known as soft-freezes.

[3] Munnell and Soto (2007), Bovbjerg et al. (2008), and Rauh et al. (2017) find that cost savings are paramount in the firm's decision to freeze its DB plan. An internal compliance investigation on frozen DB plans conducted by the IRS in 2012 and obtained through a Freedom of Information Act (FOIA) request for this research project revealed that sponsors typically froze their plans due to financial hardship and related funding deficiencies. Some plans were stuck in a frozen state because sponsors were not able to fully fund the plan prior to termination as required by law.

[4] Some of the PPA's requirements were relaxed during the Great Recession as pension sponsors sought relief from strict funding targets. For instance, The Preservation of Access to Care for Medicare Beneficiaries and Pension Relief Act of 2010 allowed firms to elect extended amortization periods for any two plan years between 2008 and 2011. The extensions were for 9 or 15 years rather than the 7 year requirement of the PPA.

2.2 Legal constraints alleviated

Between 1998 and 2000, a handful of prominent employers converted traditional DB plans to CB plans. Older employees, who stood to lose substantial pension accruals as a result these transitions, brought class action lawsuits against their employers claiming that CB conversions violated the age discrimination provisions of the Employee Retirement Income Security Act of 1974 (ERISA) (see, e.g., Zelinksy (2000)). As these cases played out in the court system, the legality of CB conversions, and potentially of pension freezes, remained uncertain. The threat of litigation along with large potential settlement costs for class action lawsuits likely constrained other employers from freezing or converting traditional DB plans. In 2006, however, a Federal appeals court ruled that IBM's CB conversion was age-neutral, thereby ending uncertainty surrounding the legality of what was seen by many as an important test for restructuring traditional DB plans.[5] In the same year, and perhaps more importantly, the new PPA law provided guidelines that CB conversions needed to meet in order to be considered age-neutral. Together, the appeals court ruling and the PPA's new provisions gave willing employers the legal cover they needed to restructure their DB plans.

2.3 The public sector remains largely unaffected

The economic forces affecting private sector DB sponsors also affected sponsors in the public sector where DB pensions are more common. Indeed, as of 2017, unfunded pension liabilities in the public sector stood at $3.84 trillion, substantially larger than the $0.76 trillion funding gap in the private sector.[6] Despite this stark difference in funding, however, hard freezes are exceedingly rare in the public sector affecting less than 0.5 percent of eligible state and local government workers.[7] The reason for the difference in the incidence of hard frozen pensions between the private and public sectors lies in differing legal protections. ERISA, which governs private pensions, explicitly allows sponsors to modify future pension rules provided that earned pension benefits are not reduced. In the public sector, which is not subject to the provisions of ERISA, both earned and unearned pension benefits are protected under the Federal Constitution's Contract Clause which prevents the passage of laws that impair the obligation of contracts.[8]

[5] See, e.g., Mary Williams Walsh, "Issues Left Unresolved on Pensions," *New York Times*, Jan. 17, 2007.

[6] See, e.g., Rauh (2017) for public sector estimates and Pension Benefit Guarantee Corporation (PBGC) for private sector estimates https://www.pbgc.gov/prac/data-books. Multiemployer pension plans (i.e. plans that are formed between multiple employers and potentially multiple labor unions) account for the bulk of funding deficiencies in the private DB system as of 2017.

[7] See Bureau of Labor Statistics (BLS), National Compensation Survey data from 2017. These data indicate that 56 percent of state and local government workers were in DB plans closed to new entrants (i.e. soft frozen).

[8] In seven states, including New York and Illinois, specific protections for public pensions have been written into state constitutions. See Munnell and Quinby (2012) for details on differing legal protections by state.

During recent periods of fiscal strain, prominent city and state governments including Detroit and New Jersey have successfully challenged some of these protections.[9] More recently, the governor of California has suggested that state courts would likely modify a legal theory known as the "vested rights doctrine" which protects future accruals in California's public pensions system from impairment.[10] Surmounting legal protections currently available in the public sector would likely trigger a substantial increase in the incidence of hard freezes making the findings of this study germane to about 14 million state and local government employees currently covered by traditional DB pensions.

In the remainder of this paper, I focus my attention on CB conversions and hard freezes in the private sector. For the sake of brevity, I jointly refer to both types of changes as "freezes" unless otherwise noted. Having laid out the instititional context in which freezes occur, I examine their effect on individual labor supply decisions using a life-cycle model in the next section.

3 Theoretical Framework

3.1 Defined benefit pensions as implicit contracts

Starting at least from Lazear (1979), a number of studies have emphasized that total compensation paid to a worker may not equal her marginal product in every period. By paying a worker less than her marginal product when young and more than her marginal product when old, employers can elicit higher levels of effort (or obtain the same level of effort with less monitoring), benefit from greater retention, and obtain more investment in firm specific human capital throughout the worker's career (see, e.g., Lazear (1984) and Lazear and Moore (1988)). This pattern in lifetime compensation is particularly evident with DB pension plans which defer the largest accruals in pension wealth to the last phase of a worker's career – a practice commonly known as "backloading." The right-hand panel of Figure 1 illustrates these non-linearities by showing DB pension wealth at for a variety of prospective retirement ages.

A corollary of this view of the employer-employee relationship is that DB pensions function like implicit contracts: workers give up compensation when young in return for the unenforceable promise that their

[9] A hard freeze of legacy pension accruals was one among the many provisions that Detroit negotiated after it filed for bankruptcy in 2013 (see, e.g., Urahn et al. (2018)). Notably, unearned pension accruals are not protected by Michigan law. In a 2016, the New Jersey Supreme Court upheld a 2011 state law that froze cost of living adjustments (COLAs) for retirees covered by the state's pension plan. Plaintiff's had argued that COLAs were subject to the same protections as pension accruals themselves.

[10] See, e.g., Adam Ashton, "Pensions will be 'on the chopping block' in next recession, Jerry Brown says," *Sacramento Bee*, January 12, 2018. The fate of the vested rights doctrine is being tested by two cases that have been granted review by the California Supreme Court as of 2018 (Marin Assoc. of Public Employees v. MCERA and Cal Fire Local 2881 v. CalPERS).

employer will pay them the full value of their marginal product by the time they retire. In the implicit contract view of DB pensions, workers *expect* to be retained until retirement and they *expect* to earn the full value of pension benefits that they would be entitled to at retirement.[11]

In the following subsection I outline a model of retirement choice for workers covered by DB pensions that draws on Stock and Wise (1990a), Stock and Wise (1990b), and Lumsdaine et al. (1992) and emphasizes the implicit contract view of DB pensions. Using the model, I characterize the effect of pension freezes and enumerate three empirically testable implications.

3.2 Model of labor supply and asset accumulation

Workers enter the labor market at $t = 0$ and live for a maximum of T years. While working, they earn cash compensation, DB pension accruals, and can elect to defer compensation into a DC account in each period. Total compensation in each period is

$$\mathcal{C}_t = \underbrace{y_t(1 - m_t^W)}_{\text{cash earnings}} + \underbrace{\Delta\mathcal{W}_t^{DB}}_{\text{increment in DB wealth}} + \underbrace{\Delta\mathcal{W}_t^{DC}}_{\text{increment in DC wealth}} \tag{1}$$

where m^W is the fraction of earnings that workers defer to DC pensions. DC wealth evolves according to

$$\mathcal{W}_t^{DC} = \mathcal{W}_{t-1}^{DC}(1 + r) + y_t(m_t^W + m_t^F) \tag{2}$$

where r is the interest rate and m^F is the fraction of earnings that the employer contributes to the DC plan (often m^F is a function of m^W). DB pension wealth is earned passively as deterministic function of earnings (y_t) and tenure (s) and is paid out upon retirement as an annuity denoted by b_t. DB wealth, $\mathcal{W}_t^{DB}$, is the mortality-adjusted present value of future annuity payments. In addition to pension assets, workers accumulate non-pension wealth which is denoted by A_t. For a worker who retires in period t, non-annuitized wealth is denoted by $X_t = A_t + \mathcal{W}_t^{DC}$.

During each period, workers face a stochastic fixed cost of working, f, which is drawn from a distribution F. The fixed cost can be thought of as a non-parametric way of summarizing the labor-leisure trade-off and includes factors such as health status, spousal labor supply, work related consumption costs (see, e.g,

[11] See, e.g., Ippolito (1985) and Kotlikoff and Wise (1985) for theory and evidence on the implicit contract view of DB pensions. An alternative view of DB pensions is the legal theory wherein workers do not form long term expectations of pension promises (see, e.g., Bulow (1982)).

Aguiar and Hurst (2013)), and the psychic costs of working past statutory retirement ages (see, e.g., Lumsdaine et al. (1996) and Siebold (2017)). Casting the workers problem this way abstracts away from the intensive margin labor supply choice and focuses purely on the participation margin.

3.2.1 Value of retirement

Denote period t variables by v and period $t+1$ variables by v'. The value of retirement is given by

$$V^R(b, X) = \max_c \left\{ u(c) + \beta V^R(b, X') \right\} \tag{3}$$

$$\text{s.t. } c + \frac{X'}{1+r} \leq b + X \tag{4}$$

where $u(\cdot)$ is a concave function. In this framework, retirement is a self-absorbing state. While this assumption excludes the possibility of bridge employment, I provide empirical evidence in Section 6.1, that workers affected by pension freezes tend to follow a once-and-for-all retirement pattern.

3.2.2 Value of working

The value of working is

$$V^W(y, f, A) = \max_{c, m^W} \left\{ u(c) - f + \beta E \left[\max \left\{ V^R(b', X'), V^W(y', f', A') \right\} \right] \right\} \tag{5}$$

$$\text{s.t. } c + \frac{A'}{1+r} \leq y(1 - m^W) + A \tag{6}$$

The budget constraint imposes the assumption that pension wealth is illiquid until retirement. The expectation operator integrates over the random variable f which is the only source of uncertainty in the model.

3.2.3 Optimal retirement decision

A worker retires when $V^R(b, X) \geq V^W(y, f, A)$. This condition defines a cutoff value $\bar{f}$ so that any draw of $f \geq \bar{f}$ will lead to retirement. Solving for $\bar{f}$ yields

$$\bar{f} = u(c^W) - u(c^R) + \beta \Bigg[\underbrace{\overbrace{E \left[\max \left\{ V^R(b', X'), V^W(y', f', A') \right\} \right]}^{\text{1: Continuation value of working}} - \overbrace{V^R(b, X)}^{\text{2: Continuation value of retiring}}}_{\text{Option value of working one more period}} \Bigg] \tag{7}$$

where c^W and c^R are the optimal consumption choices in the work and retirement states respectively. Consider terms 1 and 2 on the right side of equation (7). The increased value of future pension benefits raises term 1 and increases the option value of continuing to work. On the other hand, higher pension wealth raises term 2, thereby generating an incentive to retire. These two offsetting incentives are key determinants of the optimal retirement decision, which is summarized by the cutoff value $\bar{f}$.

In this framework, the decision about whether to continue working or to retire is determined by the option value channel which embodies an implicit contract of continued employment with the firm. As a result, labor supply varies not due to period-by-period changes in flow compensation, as in a spot market, but due to changes to the long-term contractual value of employment. This distinction is of substantive importance in the definition and estimation of labor supply elasticities which I take up in Section 7.

3.2.4 The effect of a pension freeze is theoretically ambiguous

Treating DB pensions as implicit contracts, workers expect to be paid the full value of their marginal product over the life-cycle. If employers renege on this implicit bargain by freezing DB pensions, workers face changes to the total value of compensation that they had previously expected on earning by retirement. These changes are simulated using data from the HRS in the left-hand panel of Figure1. Averaging across wave 2010 HRS respondents with private sector DB plans, the solid blue line plots the real value of total pension wealth ($\mathcal{W}^{DB} + \mathcal{W}^{DC}$) over a range of potential retirement ages. In these data, total pension wealth is computed for each potential retirement age, so the plot reflects plan-specific changes to accruals and not changes in sample composition due to retirement. Growth in pension wealth flattens out after age 65 because the real value of DB accruals becomes negative after that age as shown in the right-hand panel.[12] The dashed red lines simulate the effect of a pension freeze for workers aged 54 and 64 respectively. To construct these plots, I stop all future DB accruals as of age 54 and 64. Workers in the sample who participate in DC plans are assumed to continue to do so at the same rate, whereas those who do not are assumed to start contributing to DC plans at the sample average rate. As the graphs show, pension freezes substantially reduce the value of deferred compensation for 54 year-old workers but have the effect of increasing total compensation for 64 year-old workers.[13]

To investigate the impact of employer's decision to freeze on the retirement decision, consider terms 1

[12] This pattern in traditional DB accruals is commonplace; see, e.g., Gustman et al. (2000). Plan specific provisions that limit the actuarially adjusted value of DB pension accruals are designed specifically to induce retirement.

[13] Further details on the sample and the simulation are discussed in Appendix C.

and 2 on the right side of equation (7) once again. Suppose that in period $t = t_F$ the worker's employer chooses to freeze DB accruals. Then, in any period following t_F, b no longer changes so $b_t = b_{t_F}\ \forall t > t_F$. For workers under age 64, this change causes term 1 to drop and generates a substitution effect away from work toward retirement. The substitution effect translates to a lower value of $\bar{f}$. Nevertheless, the fact that b is frozen causes term 2 to fall as well. This reduction induces a wealth effect that raises $\bar{f}$ and lowers the value of retirement in favor of working. The opposite signs are at play for workers over the age of 64: freezes eliminate the penalty for continued work thereby increasing $\bar{f}$ through the substitution effect. At the same time, greater pension wealth accumulation raises the continuation value of retirement thereby lowering $\bar{f}$ via the wealth effect. In both cases, substitution and wealth effects work against each other so the effect on retirement behavior cannot be signed. While the overall impact of the freeze on labor supply is theoretically ambiguous, there are three testable predictions of these changes in compensation:

1. *Wealth effects decline in the age at which workers are affected.* As shown in Figure 1, for workers under the age of 65, the magnitude of the compensation change due to a pension freezes becomes progressively weaker. As such, the wealth effect of the freeze should diminish with age up through age 65.

2. *The effect of the freeze is reversed after age 65.* Because workers over the age of 65 experience a net increase in total compensation, their labor supply response should be opposite in sign to workers under the age of 65 (see Figure 1).

3. *Workers with stronger preferences for working will seek to delay retirement.* Workers who expect to stay in the labor market for longer periods of time — i.e. those with persistently low values of f — will ultimately experience increases in total compensation. As shown in Figure 1, workers aged 54 at the time of the freeze will obtain greater total pension wealth if they persist in the labor market past the age of 66. Because of this effect, individuals who have stronger tastes for work will experience substitution effects in favor of continued work, whereas those with weaker tastes for work will experience weaker substitution effects in favor of continued work.

4 Data

To shed light on the response of individual behavior to pension freezes, I create a new data source that links together on three distinct sources of administrative information: IRS Form 5500 (F500), the Census Business Register (BR), and the Census Bureau's Longitudinal Employer Household Dynamics (LEHD) dataset. In this section, I first discuss each administrative data source in turn and then explain how I use these sources together to analyze the impact of pension freezes on labor supply. Detailed descriptions of the data and linking methodology are provided in Appendix A.

Because the pecuniary costs of pension freezes cannot be observed directly in the administrative data sources that I employ, I turn to restricted data on pension eligible respondents in the HRS. Using detailed information on the DB pension plan provisions drawn from employers, these data provide precise measures of DB pension wealth at hypothetical retirement ages. I use these measures to simulate the effects of pension freezes on total compensation. In the latter part of this section, I provide details about the HRS linked pension sample.

4.1 Administrative Data

4.1.1 Form 5500

F5500 is an annual filing that is collected jointly by the IRS, Department of Labor (DoL), and the PBGC to ensure compliance with ERISA. These data, which are publicly available, contain very rich information on the universe of privately sponsored pension plans. When DB plans are converted to cash balance plans or hard frozen, this information is reported on F5500, thereby allowing me to identify plans whose participants were affected by freezes.[14]

F5500 filings are identified by a combination of a Federal Employer Identification Number (EIN) and a employer designated Plan Number (PN) that remain consistent over time. While these identifiers allow me to create a panel data set of plans, I cannot use them to directly match plan sponsors to establishments in other Census Bureau datasets. This is because payroll records for establishments that are part of a multi-unit firm may be recorded under a different EIN than the one used in F5500. Attempting to match the F5500 to establishment level data on EIN alone would therefore generate many false non-matches. To overcome this

[14]Plans are considered frozen in F5500 if they meet the following condition: "[a]s of the last day of the plan year, the plan provides that no participant will get any new benefit accrual (whether because of service or compensation)."

issue, I turn to the Census Business Register (BR).

4.1.2 Census Business Register

The BR is a database of the universe of establishments in the United States.[15] It includes information on business location, organization, industry, and information on revenue, payroll, and employment that is collected from administrative tax records as well as survey data. The relationship between establishments belonging to multi-unit firms are determined using responses to the company organization survey, the economic census, and the annual survey of manufactures. Establishments that are part of the same multi-unit firm share the same Census assigned firm identification number even if they have unique EINs.

I rely on the presence of EINs in both the F5500 and the BR to create an initial link between the two files. Secondary to this link, I obtain the Census firm identifier that allows me to identify *all* the establishments associated with a multi-unit F5500 pension plan sponsor.[16]

4.1.3 Longitudinal Employer Household Dynamics

F5500 and the BR provide information at the plan and the firm level. To study outcomes at the individual level, I turn to the LEHD which is a quarterly matched employer-employee dataset constructed from state-level unemployment insurance (UI) records.[17] These data cover almost all wage and salary workers in the United States but exclude individuals who are self-employed. In the LEHD, employers are identified using a state unemployment insurance account number known as the SEIN. I rely on the crosswalk between the SEIN and the Census firm identifier developed in Haltiwanger et al. (2014) to link pension plans in the matched F5500-BR data to employers in the LEHD.[18]

An important feature of the LEHD is that states enter the data at different points in time. For example, Maryland enters in 1985:Q2 whereas Mississippi enters only in 2003:Q3. Because of staggered entry, the scope of the data grows continuously over time.[19] As a consequence, when I link an employer from the BR

[15] Information about the BR is confidential and protected by Title 13 and Title 26, U.S. Code. Information in the following paragraph is drawn from https://www.census.gov/econ/overview/mu0600.html

[16] In the absence of the Census firm identifier, I would only be able to identify those multi-unit establishments that shared the same EIN as the one reported on F5500, thereby generating a false non-match problem.

[17] See Abowd et al. (2009) for details.

[18] I rely on the 2014 snapshot of the LEHD, which incorporates UI data from all fifty states through the first quarter of 2015. My sample excludes data from Alabama due to a file access problem.

[19] A number of populous states enter the data relatively early. Illinois enters in 1990, California and Pennsylvania in 1991, Florida in 1992, and New York and Texas enter in 1995.

to the LEHD in a given period, I only capture those individuals who work in a state that has already entered the data as of that period.

4.1.4 Connecting all three administrative data sources together

I start by linking all F5500 EINs to the BR forplan-years 1997 to 2011. The massive scope of the BR, allows me to match approximately 92 percent of DB plan-years in the F5500 files to establishments in the BR. I then use the Census firm identifiers from the BR to find all establishments that are associated with a given employer in a given year. Many firms sponsor multiple DB plans. For instance, a firm may have different plans for salaried and hourly wage workers or different plans for unionized and non-unionized workers. I limit my sample to firms that have a single plan throughout their history of filing F5500. When firms have multiple plans, I retain only those employers who choose either to never freeze their plans, or freeze them all at the same time. This restriction allows me to cleanly apportion workers at a given firm to the freeze and no-freeze state in any year. The large majority of firm's do not sponsor more than one DB plan, so this restriction allows me to retain about 94 percent of all DB sponsoring firm-years matched from the F5500. Because multiple-plan firms are extremely large employers, however, the restriction implies that I retain only 29 percent of DB covered employee-years at DB sponsoring employers.

I turn next to the assignment of treatment and comparison groups thereby defining the research design. Let each year from 2002 to 2011, indexed by c, be a cohort-year. Workers who experience freezes in a given cohort-year constitute the treated group, while workers who do not experience freezes constitute the comparison group. From the sample of F5500 plans linked to the BR, I retain those that are observed continuously for 5 years prior to the cohort-year.[20] By requiring plan stability in the lead up to the cohort-year, I eliminate firms that ceased to file F5500 due to mergers and acquisitions, plan termination, or firm death. Having imposed this restriction, I compute the annual DB coverage rate as the ratio of the total active participants in the plan (from F5500) to the total employment in the firm (from the BR).[21] When firms have multiple DB plans, I aggregate plan level data up to the firm level.[22]

Because of the staggered nature of state level data coverage in the LEHD, I recover 90 percent of firm-

[20] In practice this means that the sponsor filed F5500 under the same EIN-PN for 5 years preceding the experiment year (i.e. for a total of 6 years).

[21] In some cases, the coverage rate is greater than 1. This likely occurs because active participant counts reported on F5500 and total employment drawn from the BR are recorded at different points of time within a calendar year. In these cases, I edit the coverage rate to equal 1.

[22] When firms sponsor multiple plans, I sum up assets, liabilities, and participant counts across all plans at the firm. I compute the weighted average of the retirement age reported on F5500 using the number of participants in each plan as weights.

cohort-years and 96 percent of employee-cohort-years from the F5500-BR linkage.[23] When considering the implications of pension freezes on worker decisions, it is important to note that I do not observe individual information on pension plan eligibility. Given substantial variation in DB coverage between firms in the panel, including all workers employed at DB sponsoring firms would erroneously incorporate individuals who were ineligible for DB pensions and therefore not directly affected by freezes. To mitigate this form of misclassification error, I create a sample of linked worker-firm observations where the DB eligibility is near universal. To do this, I retain only those firms where the coverage rate averages 80 percent or more between $c-5$ and $c-2$.[24] Finally, I select all workers employed at the firm as of $c-5$ who will be between the age of 50 and 70 in year c. To analyze age specific heterogeneity, I further split the sample into three age categories as of year c: 50-55, 56-64, and 66-70. These splits allow me to study important variation in the impact of pension freezes based on curvature of the accrual function.

4.1.5 Imputing retirement in the LEHD

I infer LFP in the LEHD based on the earnings history of an individual. Workers who receive positive earnings in a calendar year are deemed to be in the labor force, whereas those that receive zero earnings in a calendar year are deemed to be out of the labor force. I classify an individual as having retired in year t if the last year in which she received non-zero earnings was $t-1$. In this definition, retirement only occurs when an individual completely withdraws from the labor force, and is therefore a self-absorbing state. Recall, however, that both definitions exclude labor force participation through self-employment because the LEHD data are based only on UI covered earnings and therefore exclude self-employment. To examine the potential for misclassification of retirement in administrative data, I compare the retirement rate of employed, DB covered, respondents from the 2004 wave of the HRS with a comparable sample of individuals in the LEHD drawn from the 2004 cohort-year whose pensions have not been frozen. These contrasts are shown in the three panels of Figure 4, which splits the samples into three age categories as of 2004. The retirement rates align fairly well for the first two age groups, but diverge substantially in the third. Discordance in the far right panel may stem from self-employment bias in the LEHD or from the fact the sample of working, DB eligible, respondents over the age of 65 in the HRS is small and potentially

[23] It is possible to link a firm-year from the F5500-BR panel to the LEHD but not obtain information on all its employees in that year. This can happen when the firm has a presence in multiple states but not all of them have entered the LEHD yet.

[24] Restricting the sample this way likely eliminates soft freezes in which the firm's plan is closed to new workers. A firm that imposes a soft freeze is likely to see its DB coverage rate decline as workers quit or retire but are not replaced with new eligible workers.

unrepresentative. In subsequent analyses that rely on the HRS for comparisons, I focus on the first two age groups because labor supply outcomes are consistent between the HRS and the LEHD.

4.2 Pension wealth in the Health and Retirement Study

The HRS obtains pension summary plan descriptions (SPDs) that provide details on the pension plan provisions of survey respondents. Information from these documents is coded along with relevant data on the earnings histories and job tenure of linked respondents to calculate pension wealth at prospective retirement ages.[25] Because these calculations are developed using employer provided plan benefit formulas, they provide a very high quality measure of pension wealth for a representative sample of older workers.

Linked pension data are available for the 1992, 1998, 2004, and 2010 waves of the HRS. The 2004 and 2010 samples are most relevant because they coincide with the time period that I analyze using administrative data. In the analyses developed in subsequent sections of this paper, I rely on the 2010 linked pension sample for two key reasons. First, the 2010 sample separately identifies workers in the private and public sectors. Focusing on private sector workers makes the DB eligible HRS sample more comparable to workers who I identify as being eligible for DB pensions through the F5500.[26] Second, the 2010 sample separates CB and hard frozen plans from those that continue to follow legacy DB formulas. By isolating the subsample where the evolution of pension accruals occurs under the status-quo — i.e. where participants do not experience a freeze — I can accurately characterize the difference in pension accruals in the no-freeze and freeze condition. Appendix C provides additional detail on these data and explains how I use them to simulate the difference in total compensation under frozen and non-frozen scenarios.

5 Identification framework

5.1 Regression specification

To identify the effects of pension freezes on labor supply, I rely on the assumption that the firm's decision to renege on its implicit promise to support further DB pension accruals is uncorrelated with unobserved determinants of labor supply. This identification strategy mirrors the research design adopted in the literature on the causal effects of job loss wherein mass layoffs are employer decisions deemed to be unrelated to

[25] See Fang et al. (2016) for more details.

[26] F5500 covers the universe of private sector pension plans governed by ERISA.

unobserved employee characteristics. Consider the following regression specification for a single cohort-year:

$$y_{jsagt} = \boldsymbol{\alpha} + \boldsymbol{x}'_{jsag}\boldsymbol{\theta} + \sum_{k=-5}^{8} \boldsymbol{z}'_{jk} \times \mathbf{1}\{k \leq 0\} \boldsymbol{\phi}_k + \sum_{k=-5}^{8} \delta_k Freeze_{jk} + \epsilon_{jsagt} \tag{8}$$

In equation (8) individual data is collapsed into age (a) , gender (g), state (s), and calendar year (t) cells for each DB sponsoring firm (j). The dependent variable, y_{jsagt}, is either the log of the labor force participation rate (LFPR) or the log of the retirement rate for workers in cell $jsag$ as of calendar year t.[27] $\boldsymbol{\alpha}$ is a vector that collects together employer (j), state (s), employee age (a), employee gender (g), industry (l), and calendar year (t) fixed effects. $\boldsymbol{x}_{jsag}$ represents a vector of time invariant worker characteristics averaged within a firm-state-age-gender cell including the proportion of workers with college degrees or higher, the proportion of workers with some college education, the proportion of workers with a high school degree, and the log of average annual earnings in years prior to $c-5$. $\boldsymbol{z}_{jk}$ is a vector of time varying controls that include the log of firm size, log of cell level average annual earnings, log of earned pension benefits per participant, the average age at which workers claim benefits from the plan, and age structure of employment at the firm.[28] The index k counts the number of periods since the cohort-year, so $k = t - c$. The indicator variable $\mathbf{1}\{k \leq 0\}$ is turned on in the pre-freeze period, so the ϕ_k coefficients account for pre-freeze characteristics. The variable $Freeze_{jk} = 1$ if the current period is k and firm j freezes its DB plan in cohort-year c. The coefficients of interest are the $\{\delta_k\}_{k=-5}^{8}$ which capture the effect of the freeze on LFPR and retirement starting 5 years prior and ending 8 years after the freeze. The residual ϵ_{jsagt} represents unobserved determinants of labor supply.

Consistent estimation of the δ_k terms in specification (8) relies on a conditional independence assumption. In particular, I assume that unobserved determinants of labor supply (the ϵ_{jsagt}) are uncorrelated with the firm's decision to freeze DB pensions (the $Freeze_{jk}$ indicator variables), conditional on covariates. Two substantive threats to this identification strategy are mitigated by the rich set of conditioning variables available in the BR and F5500. First, the inclusion of pre-event firm size controls for the potentially confounding effect of pre-freeze reductions in firm labor demand on post-freeze outcomes of interest. Second, the in-

[27] In practice, I employ the inverse hyperbolic sine transformation, $\ln\left(x + \sqrt{1 + x^2}\right)$, rather than the natural log so as to retain cases where the LFPR or retirement rate is zero.

[28] The average age at which workers claim benefits from the plan is reported on Schedule B of F5500 because of its importance in conducting actuarial calculations. Sponsors completing F5500 are permitted to enter either the plans normal retirement age or the weighted average age at which workers claim benefits when completing.

clusion of cash earnings, pension wealth per participant and the age at which workers claim benefits from the plan account for differences in total compensation as well as potentially unobserved differences in the health of workers, both of which influence labor supply.

Beyond these key concerns, other confounding effects are potentially at play. For instance, it is possible that the cost concerns that lead firm's that freeze their DB plans also result in cut backs to health insurance benefits. These unobserved changes could generate their own income and substitution effects on labor supply choices. While some firms may scale back health benefits, it is also possible that firms choosing to freeze their DB plans would attempt to maintain these benefits in order to limit the negative reputation costs of freezing.[29] Finally, it is feasible that observed changes in labor supply are influenced by network effects within the firm. This breakdown of the so called stable unit treatment value assumption (SUTVA) could occur if freeze-affected workers' labor supply choices are influenced not only by changes in compensation but also changes in the labor supply of their peers. Hamman et al. (2016), who use large-scale linked employer-employee data from Germany to investigate these spillovers on retirement behavior, find precisely estimated peer effects that are extremely small. Based on this evidence, I ignore peer-effects as a first order confounder when interpreting the results.[30]

I estimate specification (8) by stacking data for each of the 10 cohorts together and cluster standard errors at the firm (j) level.[31] This implementation assumes that the coefficients in specification (8) are constant across each cohort-year. From a practical standpoint, the estimation strategy allows workers in the comparison group in a given cohort-year to enter the treated group in a subsequent cohort-year if their employer decides to freeze pensions in the future. As such, the contrast between the treatment and comparison group is not one between the ever-treated and the never-treated which induces unrealistic selection bias.[32]

5.2 Summary Statistics

Before showing the impact of freezes on labor supply choices, I present a summary of raw data garnered from the F5500, the BR, and the LEHD on pre-event characteristics of workers, employers, and pension

[29] There are no reports of changes to health benefits in a sample of 17 large publicly traded firms that froze their plans between 2004 and 2008 as compiled by the Boston College Retirement Research Center (see `http://crr.bc.edu/uncategorized/fact-sheets/`). Similarly, a Government Accountability Office (GAO) survey of freezing employers indicates no reported changes to health benefits (see Bovbjerg et al. (2008)).

[30] Instrumental variable based estimates in Hamman et al. (2016) indicate that one additional peer retirement (at the establishment level) increases the probability of retirement for men by .01 percentage points and produces no detectable effect on women.

[31] In the stacked specification, I include calendar year-by-cohort-year fixed effects (γ_{tc}) instead of calendar year fixed effects.

[32] This approach mirrors recent literature on the impact of job loss on earnings. See, e.g., Krolikowski (Forthcoming) and Flaeen et al. (Forthcoming).

plans. Table 1 shows characteristics of firms and DB plans split across freezing and non-freezing firms. These statistics are averaged over the five year period prior to each cohort-year and therefore represent pre-freeze characteristics. Apart from firm size, the two groups of firms are of the same vintage and employ workers of the same age structure.[33] Over the five year period prior to the cohort year, both types of firms are equally likely to have experienced a mass-layoff event which is labeled "firm distress". This variable is measured as a year-on-year loss of firm-wide employment in excess of 30 percent. The fact that both freezing and non-freezing firms experience the same likelihood of distress prior to the cohort-year is important because it indicates that absence of a downward trend in labor demand at freezing firms. The next set of statistics show plan characteristics and provide evidence about the cause of the freeze. Average DB wealth for plan participants is approximately equal across both groups as is the value of accruals earned year-on-year and the average age at which workers claim benefits from the plan. This similarity suggests that freezing and non-freezing firms sponsor plans that induce the same incentive effects with regard to labor supply, thereby buttressing the validity of the identification strategy. Similarity in claim ages further suggests that workers are not differentially selected on the basis of health or other unobserved determinants of labor supply across the two types of firms.

The final set of statistics in Table 1 shows that deteriorating plan financing plays an important role in firm's decisions to freeze their DB plans. The average ratio of assets to the present value of liabilities is 8 percentage points lower among freezing firms than non-freezing firms; moreover, freezing firms are about 4 percentage points more likely to have slipped beneath the 80 percent at-risk funding threshold described in the PPA which is labeled "plan distress". The rate of freeze activity is 3 percentage points higher in industries represented by freezing firms relative to non-freezing firms — a statistic that could indicate that the firms freeze decision could be governed by what its industry competitors have chosen to do. Finally, collective bargaining, although low in the sample as a whole, is about twice as high in the non-freezing firms relative to the freezing firms. This statistic is indicative of the fact that unions are more likely to preserve the full value of contracted benefits, thereby reducing the likelihood that firms subject to collective bargaining agreements will renege on pension promises. While the comparisons highlighted in Table 1 are restricted to the high coverage rate sample, Appendix B examines the unrestricted set of DB sponsors and provides a variety of evidence complementary to the patterns discussed here.

Table 2 shows pre-freeze characteristics for workers split into three different age groups as of the cohort-

[33] Firm age is left censored in the BR. The earliest year that firms appear in the data is 1975.

year. All workers in the sample are employed with DB sponsoring firms as of $c-5$, but need not remain employed at the same firm or even be in the labor force in subsequent years. Looking through demographic characteristics across the three age group panels in the table shows that workers employed at firms that subsequently freeze are more likely to be male and white. While their educational attainment is broadly aligned with workers who do not experience freezes, their annual earnings are approximately 7-9 percent lower. Tenure, which is left censored in the LEHD, is about one year lower among workers at firms that freeze.[34] The last three columns show pre-event differences in employer attachment and labor supply, which are key outcomes of interest in the post-freeze period. Workers in the two groups are remarkably similar in these dimensions exhibiting no differential tendency to leave their employer or to quit the labor force altogether in the five year period prior to the cohort-year. This similarity reinforces the notion that freezing firms were not selectively losing workers to other employers or to retirement in the pre-event period. In addition to the retirement claim age similarity shown earlier, these statistics provide further support for the validity of the quasi-experimental research design.

The data shown in Tables 1 and 2 provides evidence, from large samples of workers and firms, about the validity of the research design adopted in this paper. Having illustrated these firm, plan, and worker characteristics, I turn next to the impact of pension freezes on labor supply.

6 Labor supply and employer attachment

In this section, I use the regression framework and identification strategy developed earlier to investigate the causal impact of pension freezes on the labor supply and employer attachment. These results shed light on the testable implications developed in the theoretical model and form the basis for the estimation of the extensive margin labor supply elasticity.

6.1 Labor force participation, retirement, and earnings

Figure 5 plots the δ_k coefficients from specification (8) using the log of the labor force participation rate (LFPR) as the outcome variable. To investigate age specific heterogeneity in labor supply responses, I split the data into three equally spaced age bins and estimate the regression model on each sub-sample separately.

[34] States can enter the LEHD data after a given employer-employee relationship is established, thereby leading to left censoring of employer-employee history and understatement of true tenure.

The three panels in the figure show coefficients for workers aged 50-55, 56-64, and 65-70 years old in the cohort-year.

Treated workers in the youngest age group (50-55) have a constant half percent higher LFPR in the five years prior to the freeze.[35] In contrast, the older two age splits appear to exhibit small declines in LFP prior to the freeze. Nevertheless, a test that pre-event coefficients are jointly zero cannot be rejected for the 56-64 year-old and 65-70 year-old workers. The p-values for these F-tests are 0.29 and 0.50 respectively. After the freeze there is a marked reduction in LFP — for the youngest workers, the drop between $k = 0$ and $k = 3$ is about 1.5 percent, whereas the drop for 56-64 year-old workers over the same time period is about 2.5 percent. While LFPR for the oldest workers (right panel) increases by almost 3 percent in the three year period after the freeze, these coefficients are not precisely estimated.

These initial patterns in labor supply are consistent with dominant substitution effects across all three age groups. Workers who are still some distance away from the peak of the DB accumulation phase experience a drop in total compensation and reduce their labor supply. In contrast, those over the DB peak, who would otherwise face declining DB accruals, experience an increase in total compensation and increase their labor supply. The magnitude of the LFPR response is larger for 56-64 year-old workers as compared with 50-55 year-old workers. This result shows that the declining magnitude of wealth losses engenders stronger substitution away from work towards retirement thereby providing support for the first prediction of the model. Finally, the reversal in the sign of the labor supply response for workers over the age of 65, who would otherwise begun to experience declining DB accumulation, provides support for the second prediction.

The dynamics of the post-freeze patterns in LFPR also reveal important differences in latent tastes for work among affected individuals, which relates to the third prediction of the model. Workers with strong tastes for work (equivalent to low draws of f in the model), remain in the labor force and begin to experience enhanced deferred compensation accumulation starting about three to four years after the freeze. These workers drive a reversal in the labor supply pattern that is most evident in the central panel of Figure 5 — the substitution effect is again dominant as higher compensation leads to increased labor supply. The same rebound is not evident among the oldest workers because they experience no inflection point in deferred compensation, and is only evident at the tail end of the sample period for the youngest workers who are

[35] A test the the pre-event coefficients are jointly zero cannot be rejected at the 10 percent significant level (the p-value for the associated F-test is 0.093).

farthest away from the inflection point. These patterns are important from a policy perspective because they reveal latent preferences for work that would have been unmet but for the freeze induced change in compensation.

Figure 6 shows the impact of freezes on retirement, which is defined as a permanent departure from paid employment in the LEHD. These estimates are virtually mirror images of the LFP effects shown in Figure 5, indicating that non-participation and retirement are essentially equivalent for the set of workers affected by freezes.[36] The retirement patterns reinforce the LFP-based findings discussed above and provide further evidence supporting the four key labor supply implications of pension freezes implied by the model. To retiterate: wealth effects diminish the closer workers get to peak DB accumulation, labor supply responses for affected workers over the DB accumulation peak is opposite in sign to workers under the peak, and lastly, latent preferences for work dictate the dynamic response of affected workers.

Figure 7 shows the impact of freezes on annual earnings. These estimates are based on the same estimating framework as LFP and retirement but earnings themselves are not in the pre-event conditioning set. The pre-freeze coefficients exhibit a slight downward trend that appears to continue up through $k = 6$ for 50-55 year-old workers and $k = 4$ for 56-64 year old workers. The pattern for 65-70 year old workers is not precisely estimated. These initial earnings penalties are similar to the overall effect of freezes on firm-wide average pay which are shown in the right panel of Figure B1. As such, they more likely reflect firm-wide reductions in earnings associated with post-freeze distress as opposed to intensive margin labor supply reductions, although the latter cannot be ruled out. In the final two periods of the left-most panel and the final four periods of the right-most panel, there is a clear upward trajectory in the earnings of affected workers. These responses are coincident with the LFP increase and retirement reduction and therefore reflect differential labor supply among treated individuals who are incentivized to lengthen their careers. Because the contrast is between individuals with non-zero earnings, the late spikes in earnings reflect continuation in full-time employment among treated workers versus transition into part-time or bridge employment among comparison group workers.

[36] This finding substantiates the model's assumption of self-absorbing retirement. When using retirement as the outcome, F-tests that the pre-event coefficients are jointly zero cannot be rejected for any of the three age groups. The p-values for these tests are 0.23, 0.32, and 0.67 for the 50-55, 56-64, and 65-70 year-old age groups respectively. Note that non-participation and retirement are mechanically equal for $k = 8$ because of censoring.

6.2 Employer attachment

Given the importance of the substitution effect in explaining in the labor supply patterns, a natural extension is to ask whether cuts to total compensation engender substitution not only towards leisure but also towards or other employers. Figure 8 investigates this conjecture by showing the impact of freezes on employer attachment which is defined as the probability of being attached to one's $k = -5$ employer in each subsequent year. Interestingly, there is no detectable difference in employer attachment between workers who experience freezes and those who do not. This finding shows the general lack of available outside options for older workers. This pattern could be explained, for instance, by age discrimination in hiring. It could also derive from the fact that older workers at DB firms, even after suffering the loss of pension freezes, are paid more than their marginal product (e.g., as in Lazear (1979)) at their long term employers and therefore struggle to find work at comparable compensation rates at other firms.

Regardless of the underlying cause, this finding sheds new light on the role of employer specific human capital in the length of older workers' careers. In particular, it illustrates that robust demand for the labor services of older workers at their long-term career employers is a key requirement for policies aimed at delaying retirement. This result complements findings in Ameriks et al. (2018) indicating that the limited availability of suitably flexible work schedules is an important constraint on the continued labor force participation of older workers.

7 Two-sample estimates of the extensive margin labor supply elasticity

The F5500, the BR, and LEHD data, while rich in several important dimensions, do not contain information on pension accrual rates. As such, I cannot use these data to directly infer the labor supply elasticity, because I do not observe changes to total compensation in administrative data. In this section, I describe a two-sample procedure to estimate labor supply elasticities by combining behavioral responses observed in the administrative data sample with simulated changes in total compensation that would occur in the wake of a pension freeze that are derived from the HRS.

I consider the Marshallian (or uncompensated) labor supply elasticity (η^M) because I cannot parse wealth and substitution effects in my setting.[37] Under the assumption that leisure is a normal good, the

[37] In ongoing work, I structurally estimate the labor supply and asset accumulation model using quasi-experimental moments from administrative data to discipline the estimation. The structural model's parameters will allow me to decompose wealth and substitution effects and study counterfactual policies.

Marshallian elasticity is smaller than the Hicksian (or compensated) elasticity (η^H) which holds utility constant. As shown, for example, in MaCurdy (1981) and Ziliak and Kniesner (1999), the Hicksian elasticity is smaller than the Frisch labor supply elasticity (η^F) which holds the marginal utility of wealth constant. The three elasticities can therefore be ordered as follows

$$\eta^M < \eta^H < \eta^F \tag{9}$$

The Frisch elasticity governs intertemporal labor supply responsiveness to temporary and predictable changes in compensation. In contrast, the Hicksian elasticity is relevant for evaluating the welfare effects of permanent changes in compensation; it is typically used to understand the steady state effects of permanent changes in tax rates. Due to the inequalities described in (9), the estimates I present are lower bounds for the Hicksian and Frisch elasticities.

7.1 Labor supply elasticity with implicit long-term contracts

Relative to workers in the comparison group, workers in the treated group experience an unexpected shift in the path of total compensation, $\mathcal{C}_t$ after the freeze due to potential changes in y_t, $\Delta\mathcal{W}^{DB}$, and $\Delta\mathcal{W}^{DC}$ (see equation (1)). These changes are driven not only by the zeroing out of $\Delta\mathcal{W}^{DB}$ in the post-freeze period, but also by changes in cash earnings and changes in DC pension accumulation. Define R^* as the optimal retirement age for a worker whose compensation path is unaffected. Recall that R^* can vary not only due to financial considerations such as earnings and pension accruals, but also because of differences in the fixed costs of work, health expectations, spousal labor supply, and the focal effect of statutory retirement thresholds.

In this context, define the extensive margin Marshallian labor supply elasticity by

$$\eta_a^M := -\frac{\partial \log(\text{RR}_a)}{\partial \log(\omega_a)} \tag{10}$$

where RR_a is the retirement rate of workers aged a and ω_a is the annuitized value of the stream of earnings that a worker expects to earn with their current employer from age a till the workers expected retirement age

R^*. Assuming away job-destruction or job-switching, the annuity value of total compensation is given by

$$\omega_a = \frac{1}{R^* - a} \sum_{t=a}^{R^*} \left(\frac{1}{1+r} \right)^{t-a} \mathcal{C}_t \tag{11}$$

The measure of compensation in equation (11) is relevant when the association between employers and employees is captured by long-term implicit contracts rather than spot markets. Because of this distinction, the long-term contractual value of compensation rather than the flow value of compensation is allocative for labor supply decisions.

7.2 Two-sample estimates

The impulse responses based on administrative data presented in Figure 6 describe changes in the numerator of expression (10). To obtain estimates of the denominator, I exploit rich information in the HRS's linked pension data sample. Splitting survey respondents into the same age-based categories that I use in the administrative data samples, I compute estimates of each component of $\mathcal{C}_t$ starting from age at the time of being surveyed in the 2010 wave and projected out to the respondent's self-reported expected retirement age (R^*).[38] Because the retirement patterns of the oldest workers (those 65-70 years-old) diverge substantially between the LEHD and the HRS, I focus on the first two age-based sample splits (see Section 4.1.5).

For each respondent, I estimate the path of $\mathcal{C}_t$ under two scenarios: The first assumes no changes to the status-quo; i.e. earnings, DB pension accruals, and DC accruals grow under normal projections. The second scenario assumes that a freeze occurs. Under this scenario, all future DB accruals are set to 0. I adjust projected future earnings for each respondent by using estimates of post-freeze changes obtained from estimating equation (8) on LEHD data with log earnings as the outcome. When respondents report positive DC balances, I assume that both the respondent and their employer would continue to contribute at the same rate in the post-freeze period. When respondents who report no DC balances, I assume that both the respondent and their employer initiate contributions using the average in-sample rate for both variables.[39] Further details on these calculations are presented in Appendix C.

Armed with estimates of behavioral responses from the LEHD and simulated price changes from the

[38] Self-reports of R^* prove valuable in making these calculations because they incorporate unobserved, individual specific, expectations about retirement.

[39] This assumption imposes saving choices rather than using the model to solve for them. In ongoing research, I rely on the structural model to solve for optimal consumption and saving choices in the post-freeze environment.

HRS, I estimate (10) using analog's from both samples as

$$\hat{\eta}_k^M = -\frac{\Delta\hat{E}\left[\log(\text{RR}_k)\right]^{\text{LEHD}}}{\Delta\hat{E}\left[\log(\omega_i)|a_{i0}+k\leq R_i^*\right]^{\text{HRS}}} \tag{12}$$

In equation (12), k denotes periods since the freeze, i indexes HRS respondents, and a_{i0} is the age of respondent i when $k=0$. I focus on post-freeze periods where the freeze induces workers to retire, i.e. those k where $\Delta\hat{E}\left[\log(\text{RR}_k)\right]^{\text{LEHD}}>0$. I impose this restriction because the change in ω_i is calculable for workers who retire before R^*, but unknown for those workers who choose to delay retirement.[40]

Table 3 shows estimates of η^M that pool over the periods where workers are induced into early retirement by the freeze. The left panel shows the composite elements of equation (12) and the resulting two-sample elasticity for 50-55 year-old workers, while the right panel shows estimates for 56-64 year old workers. I compute standard errors using the delta method.[41] The extensive margin Marshallian elasticity estimate for 50-55 year-old workers is 0.14, while the estimate for 56-64 year-old workers is 0.75. The point estimate for 50-55 year old workers is in the range of compensated estimates of the extensive margin elasticity obtained using quasi-experimental approaches which average 0.25 (see Chetty et al. (2012)). In contrast, the point estimate for 56-64 year-old workers is three times larger. Note that the two-sample based estimates do not isolate pure substitution effects and are therefore smaller in magnitude than the associated compensated elasticities.

The Marshallian elasticities presented here provide two benchmarks relative to prior estimates. First, workers more proximate to the prime-age population share similar extensive margin labor supply elasticities indicating that the two-sample results broadly concur with prior research. Second, and more importantly, the two-sample estimates indicate that workers nearing conventional retirement ages exhibit a three-fold increase in their participation responsiveness given proportional changes in the return to working. This finding quantifies the extent to which the disutility of working increases with age and brings more individuals closer to the the non-participation margin. Conditional on adequate demand for their labor services — a condition that appears to exist within but not outside of workers' long-term employers — these results

[40] Strictly speaking, $\Delta\hat{E}\left[\log(\omega_i)|a_{i0}+k\leq R_i^*\right]^{\text{HRS}}$ is an overestimate for individuals induced to retire early due to the freeze. This is because workers who retire prior to R^* experience smaller losses in compensation that they would have if they persisted until R^*. Consequently, estimate of η^M are downward biased in the two-sample procedure that I adopt here.

[41] The 56-64 year old sample estimates are obtained by running a regression as in equation (8) pooling the dummy variables for $k\in[1,4]$. A similar regression was not disclosed from the Census RDC for the 50-55 year-old sample, so those estimates simply average across the δ_k coefficients for $k\in[1,7]$. The standard error estimates obtained from this exercise are invalid as they assume independence across the δ_k coefficients and ignore covariance between the period-by-period estimates. These statistics will be updated in subsequent research.

indicate that tax and transfer policies aimed at lengthening older workers' careers can be effective.

8 Conclusion

This paper exploits important and understudied changes in employer sponsored pension benefit programs to better understand how individual labor supply behavior changes with age. In particular, it examines the private sector DB environment where many employers have reneged on promises to continue supporting traditional retirement benefits in the face of rising costs of provision. Creating a new data that brings together detailed administrative information on plan characteristics with matched employer-employee data, I study the impact of these unexpected changes on labor force participation, retirement, and employer attachment. Pension freezes alter future compensation in complex ways, not only inducing offsetting wealth and substitution effects, but also differentially affecting workers with heterogenous tastes for working. Pooling together thousands of natural experiments, I find that the substitution effect plays a dominant role: workers who face reductions in compensation respond by reducing their LFP and vice-versa. Those who leave the labor force early do so permanently, thereby hastening their transition into retirement. In contrast, workers with stronger tastes for work face lower implicit taxes on continued employment and respond by working longer. These findings suggest that accounting for heterogeneity in labor supply preferences is important when considering the design and implementation of policies aimed at lengthening workers' careers. Secondary to the effects of pension freezes on LFP and retirement, I find that freeze induced reductions in the value of continued employment appear not to engender substitution towards alternative employers. This result quantifies limited mobility in the labor market for older workers and shows that robust labor demand within long-term employers is an important pre-condition for meeting latent preferences for continued work.

I combine estimates of the labor supply response to freezes with estimates of their impact on total compensation simulated among HRS respondents. Using this two-sample approach, I obtain estimates of the uncompensated extensive margin elasticity of labor supply. For 56-64 year old workers, I obtain an estimate of 0.75 which is approximately 3 times as large as prevailing prime-age-based compensated estimates. This estimate quantifies the role of age in the participation margin and indicates that policies such as age dependent payroll taxes can be effective at prolonging the working lives of older Americans.

Important aspects of this analysis are still underway. Future iterations of this paper will estimate latent properties of the distribution of labor disutility and examine how this changes with age using the simulated

method of moments. With these parameters, I will be able to separate wealth and substitution effects and better align elasticity estimates with the literature.

References

Abowd, John, Bryce E. Stephens, Lars Vilhuber, Fredrik Anderson, Kevin L. McKinney, Marc Roemer, and Simon Woodcock, "The LEHD Infrastructure Files and the Creation of the Quarterly Workforce Indicators," in Timothy Dunne, J. Bradford Jensen, and Mark J. Roberts, eds., *Producer Dynamics: New Evidence from Micro Data*, University of Chicago Press, 2009, pp. 149–230.

Abraham, Katherine G. and Susan K. Taylor, "Firms' Use of Outside Contractors: Theory and Evidence," *Journal of Labor Economics*, 1996, *14* (3), 324–424.

Aguiar, Mark and Erik Hurst, "Deconstructing Life Cycle Expenditure," *Journal of Political Economy*, 2013, *121* (3), 437–492.

Ameriks, John, Joseph S. Briggs, Andrew Caplin, Minjoon Lee, Matthew D. Shapiro, and Christopher Tonetti, "Older Americans Would Work Longer If Jobs Were Flexible," 2018. NBER Working Paper No. 24008.

Blundell, Richard, Antonie Bozio, and Guy Laroque, "Labor Supply and the Extensive Margin," *American Economic Review Papers and Proceedings*, 2011, *101* (3), 482–486.

Bovbjerg, Barbara D., Charles A. Jeszeck, Charles Ford, Isabella Johnson, Luann Moy, Mark Ramage, Joe Applebaum, Craig Winslow, Gene Kuehneman, Brian Friedman, Melissa Swearingen, Marietta Mayfield, Sue Bernstein, and Walter Vance, "Defined Benefit Pensions: Freezes Affect Millions of Participants and May Pose Retirement Income Challenges," Technical Report, United States Government Accountability Office 2008.

Bulow, Jeremy, "What are Corporate Pension Liabilities," *Quarterly Journal of Economics*, 1982, *97* (3), 435–452.

Chetty, Raj, Adam Guren, Day Manoli, and Andrea Weber, "Does Indivisible Labor Explain the Difference between Micro and Macro Elasticity," in Daron Acemoglu, Jonathan Parker, and Micheal Woodford, eds., *NBER Macroeconomics Annual 2012*, University of Chicago Press, 2012, pp. 1–56.

Cogan, John, "Fixed Costs and Labor Supply," *Econometrica*, 1981, *49* (4), 945–963.

Devereux, Paul J., "Changes in Relative Wages and Family Labor Supply," *Journal of Human Resources*, 2004, *39* (3), 696–722.

Dey, Matthew, Susan Houseman, and Anne Polivka, "What Do We Know about Contracting Out in the United States? Evidence from Household and Establishment Surveys," in Katherine G. Abraham, James R. Spletzer, and Michael Harper, eds., *Labor in the New Economy*, University of Chicago Press, 2010, pp. 267–304.

Eissa, Nada and Hilary Hoynes, "Taxes and the Labor Market Participation of Married Couples," *Journal of Public Economics*, 2004, *88* (9-10), 1931–1958.

_ **and Jeffrey B. Liebman**, "Labor Supply Response to the Earned Income Tax Credit," *Quarterly Journal of Economics*, 1996, *111* (2), 605–637.

Fang, Chichun, Charles Brown, and David Weir, "Cohort Changes in Social Security Benefits and Pension Wealth," 2016. Michigan Retirement Research Center Working Paper WP 2016-350.

Flaeen, Aaron, Matthew D. Shapiro, and Isaac Sorkin, "Reconsidering the Consequences of Worker Displacements: Firm versus Worker Perspective," *American Economic Journal: Macroeconomics*, Forthcoming.

French, Eric, "The Effects of Health, Wealth, and Wages on Labor Supply and Retirement Behaviour," *Review of Economic Studies*, 2005, *72* (2), 395–427.

Goldschmidt, Deborah and Johannes F. Schmieder, "The Rise of Domestic Outsourcing and the Evolution of the German Wage Structure," *Quarterly Journal of Economics*, 2017, *132* (3), 1165–1217.

Gustman, Alan, Olivia Mitchell, Andrew Samwick, and Thomas L. Steinmeier, "Evaluating Pension Entitlements," in Olivia Mitchell, P. Brett Hammond, and Anna M. Rappaport, eds., *Forecasting Retirement Needs and Retirement Wealth*, University of Pennsylvania Press, 2000, pp. 310–326.

Haltiwanger, John, Henry Hyatt, Erika McEntarfer, Liliana Sousa, and Stephen Tibbets, "Firm Age and Size in the Longitudinal Employer-Household Dynamics Data," *Center for Economic Studies Working Paper 14-16*, 2014.

Hamman, Mary K., Daniela Hochfellner, John M. Nunley, and Christopher Ruhm, "Peer Effects and Retirement Decisions: Evidence from Pension Reform in Germany," 2016. Unpublished working paper.

Ippolito, Richard, "The Labor Contract and True Economic Pension Liabilities," *American Economic Review*, 1985, *75* (5), 1031–1043.

Katz, Lawrence F. and Alan B. Krueger, "The Rise and Nature of Alternative Work Arrangements in the United States 1995-2015," 2017. NBER Working Paper No. 22667.

Kotlikoff, Laurence J. and David A. Wise, "Labor Compensation and the Structure of Private Pension Plans: Evidence for Contractual versus Spot Labor Markets," in David A. Wise, ed., *Pensions, Labor, and Individual Choice*, University of Chicago Press, 1985, pp. 55–88.

Krolikowski, Pawel, "Choosing a Control Group for Displaced Workers," *Industrial and Labor Relations Review*, Forthcoming.

Laitner, John and Daniel Silverman, "Consumption, Retirement, and Social Security: Evaluating the Efficiency of Reform that Encourages Longer Careers," *Journal of Public Economics*, 2012, *96* (7-8), 615–634.

Lazear, Edward P., "Why Is There Mandatory Retirement?," *Journal of Political Economy*, 1979, *87* (6), 1261–1284.

_ , "Pensions as Severance Pay," in Zvi Bodie and John B. Shoven, eds., *Financial Aspects of the U.S. Pension System*, University of Chicago Press, 1984, pp. 57–85.

_ **and Robert L. Moore**, "Pensions and Turnover," in Zvi Bodie, John B. Shoven, and David A. Wise, eds., *Pensions in the U.S. Economy*, University of Chicago Press, 1988, pp. 163–190.

Lumsdaine, Robin L., James H. Stock, and David A. Wise, "Three Models of Retirement: Computational Complexity versus Predictive Validity," in David A. Wise, ed., *Topics in the Economics of Aging*, University of Chicago Press, 1992, pp. 21–60.

_ **,** _ **, and** _ , "Why are Retirement Rates So High at Age 65?," in David Wise, ed., *Advances in the Economics of Aging*, University of Chicago Press, 1996, pp. 61–82.

MaCurdy, Thomas E., "An Empirical Model of Labor Supply in a Life-Cycle Setting," *Journal of Political Economy*, 1981, *89* (6), 1059–1085.

Manoli, Dayanand S. and Andrea Weber, "Nonparametric Evidence on the Effects of Financial Incentives on Retirement Decisions," *American Economic Journal: Economic Policy*, 2016, *8* (14), 160–182.

Meyer, Bruce and Dan T. Rosenbaum, "Welfare, the Earned Income Tax Credit, and the Labor Supply of Single Mothers," *Quarterly Journal of Economics*, 2001, *116* (3), 1063–1114.

Munnell, Alicia H. and Laura Quinby, "Legal Constraints on Changes in State and Local Pensions," Technical Report, Center for Retirement Research at Boston College August 2012.

_ **and Mauricio Soto**, "Why are Companies Freezing their Pensions?," 2007. Working Paper 2007-22. Center for Retirement Research, Boston College.

Rauh, Joshua D., "Hidden Debt, Hidden Deficits: 2017 Edition: How Pension Promises are Consuming State and Local Budgets," Technical Report, Hoover Institution 2017.

_ **, Irina Stefanescu, and Stephen P. Zeldes**, "Cost Saving and the Freezing of Corporate Pension Plans," 2017. Columbia Business School Research Paper No. 16-4.

Rogerson, Richard and Johanna Wallenius, "Nonconvexities, Retirement, and the Elasticity of Labor Supply," *American Economic Review*, 2013, *103* (4), 1445–1462.

Siebold, Arthur, "Reference Dependence in Retirement Behavior: Evidence from German Pension Discontinuities," 2017. Unpublished working paper.

Stock, James H. and David A. Wise, "The Pension Inducement to Retire: An Option Value Analysis," in David A. Wise, ed., *Issues in the Economics of Aging*, University of Chicago Press, 1990, pp. 205–229.

_ **and** _ , "Pensions, the Option Value of Work, and Retirement," *Econometrica*, 1990, *58* (5), 1151–1180.

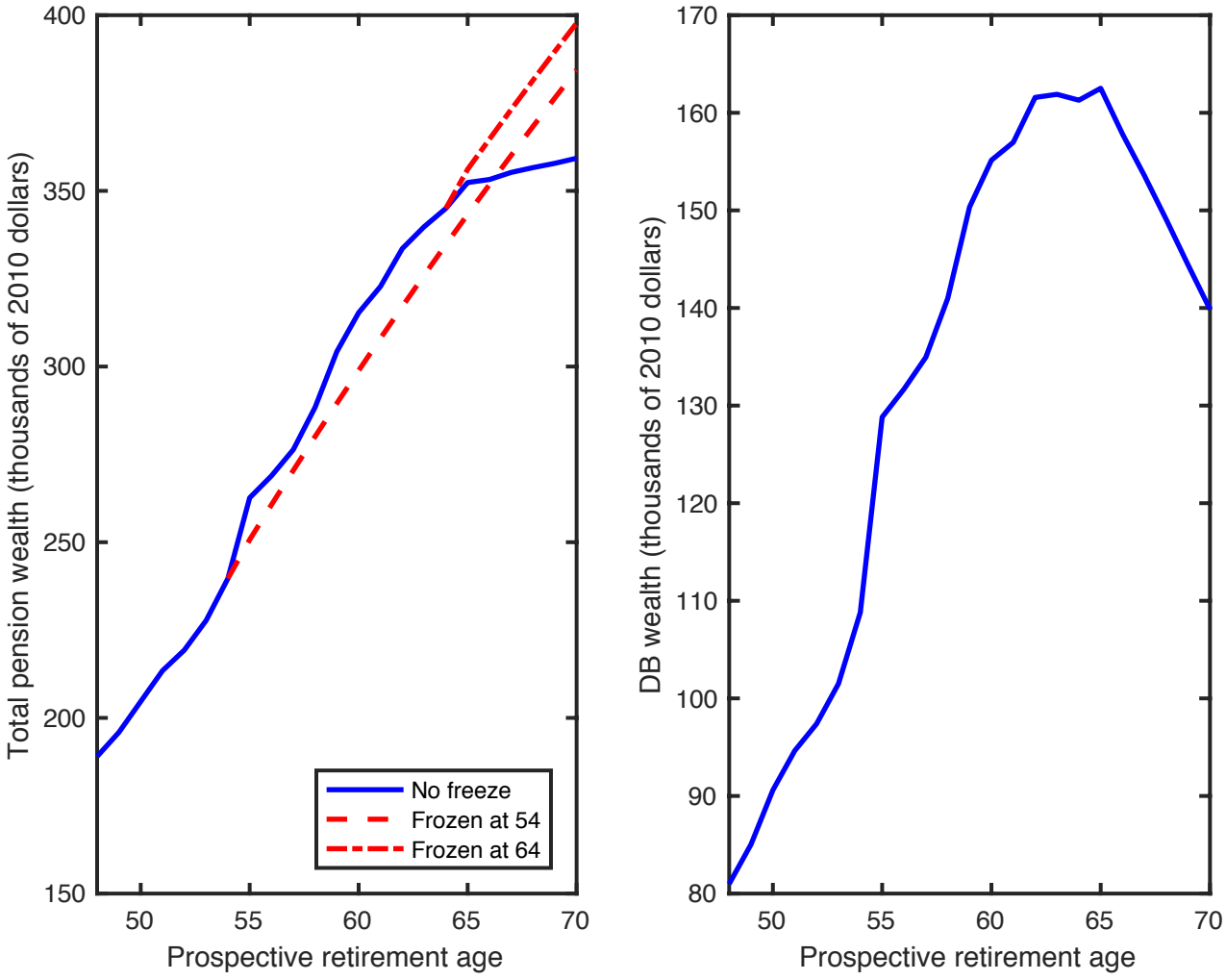
Urahn, Susan K., Greg Mennis, Susan Banta, David Draine, Aleena Oberthur, Nicholas Heitger, and Fatima Yousofi, "The Challenge of Meeting Detroit's Pension Promises," Technical Report, The Pew Charitable Trusts March 2018.

Weinzierl, Matthew, "The Surprising Power of Age-Dependent Taxes," *The Review of Economic Studies*, 2011, *78* (4), 1490–1518.

Zelinksy, Edward A., "The Cash Balance Controversy," *Virginia Tax Review*, 2000, *19*, 683–762.

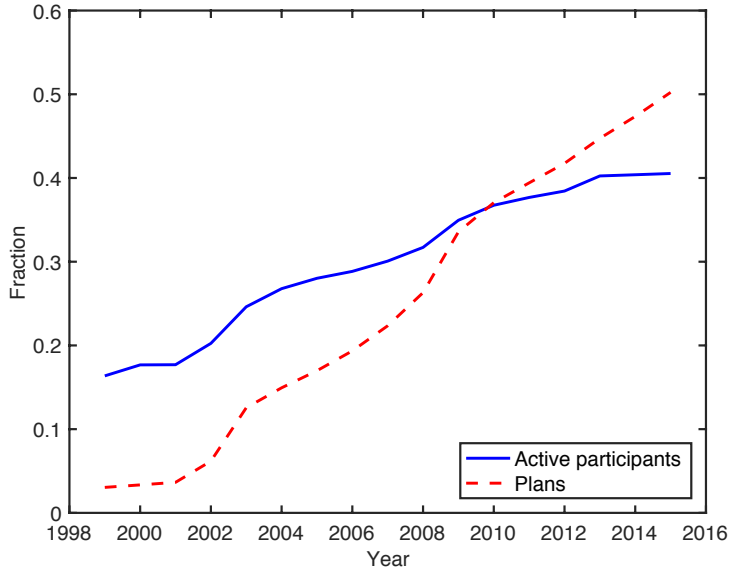
Ziliak, James P. and Thomas J. Kniesner, "Estimating Life Cycle Labor Supply Tax Effects," *Journal of Political Economy*, 1999, *107* (2), 326–359.

Figure 1: Simulated effect of pension freezes on deferred compensation



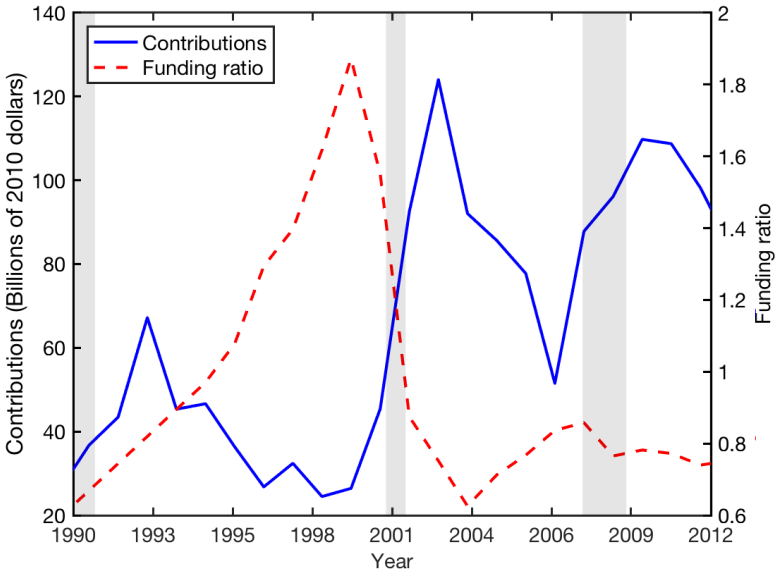
Notes: This figure is based on data from HRS respondents in the 2010 wave who are employed in the private sector. See Appendix C for details on the sample and simulation of post-freeze pension wealth.

Figure 2: Hard frozen and cash balance DB Plans



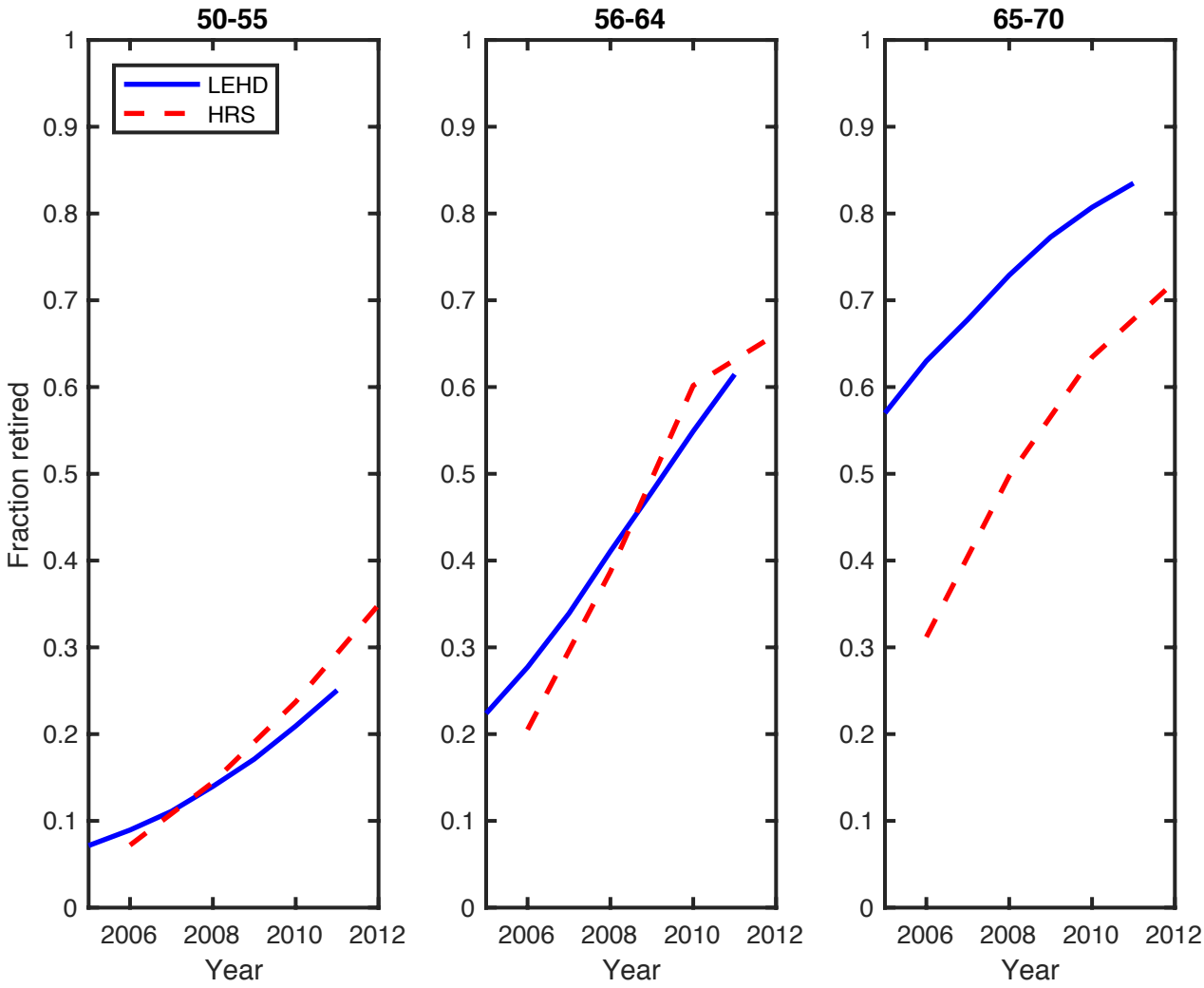
Notes: Time series are based on 1999-2015 F5500 microdata. See Appendix A for details.

Figure 3: Pension Costs and Funding Ratios



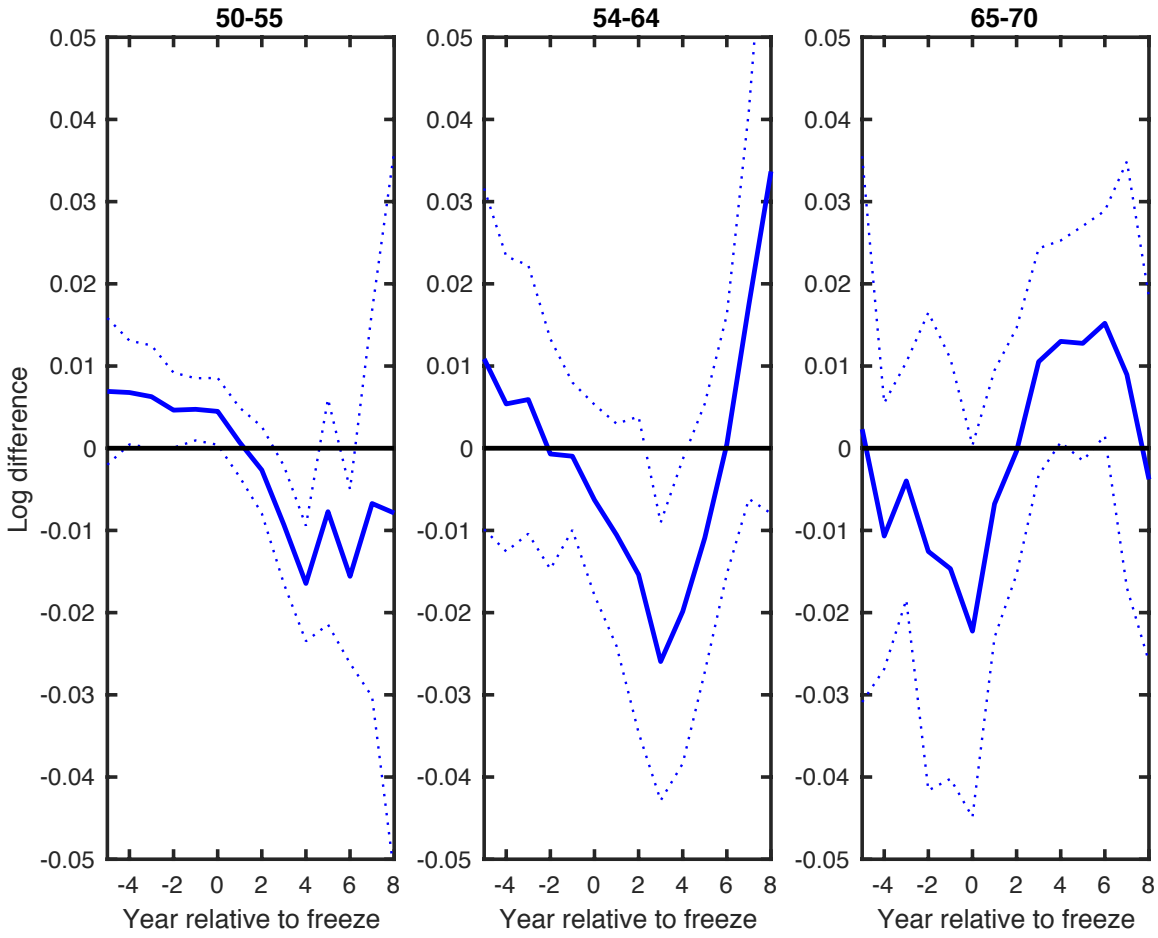
Notes: Contributions data are drawn from the Department of Labor's Private Pension Plan Bulletin Historical Tables and Graphs 1975-2015. Funding ratios are drawn from the PBGC Pension Insurance Data Book, 2016. Funding ratios between 1990 and 1995 are interpolated. Contributions and funding data are based on single employer DB plans. Shaded areas indicate NBER recessions.

Figure 4: HRS versus LEHD retirements



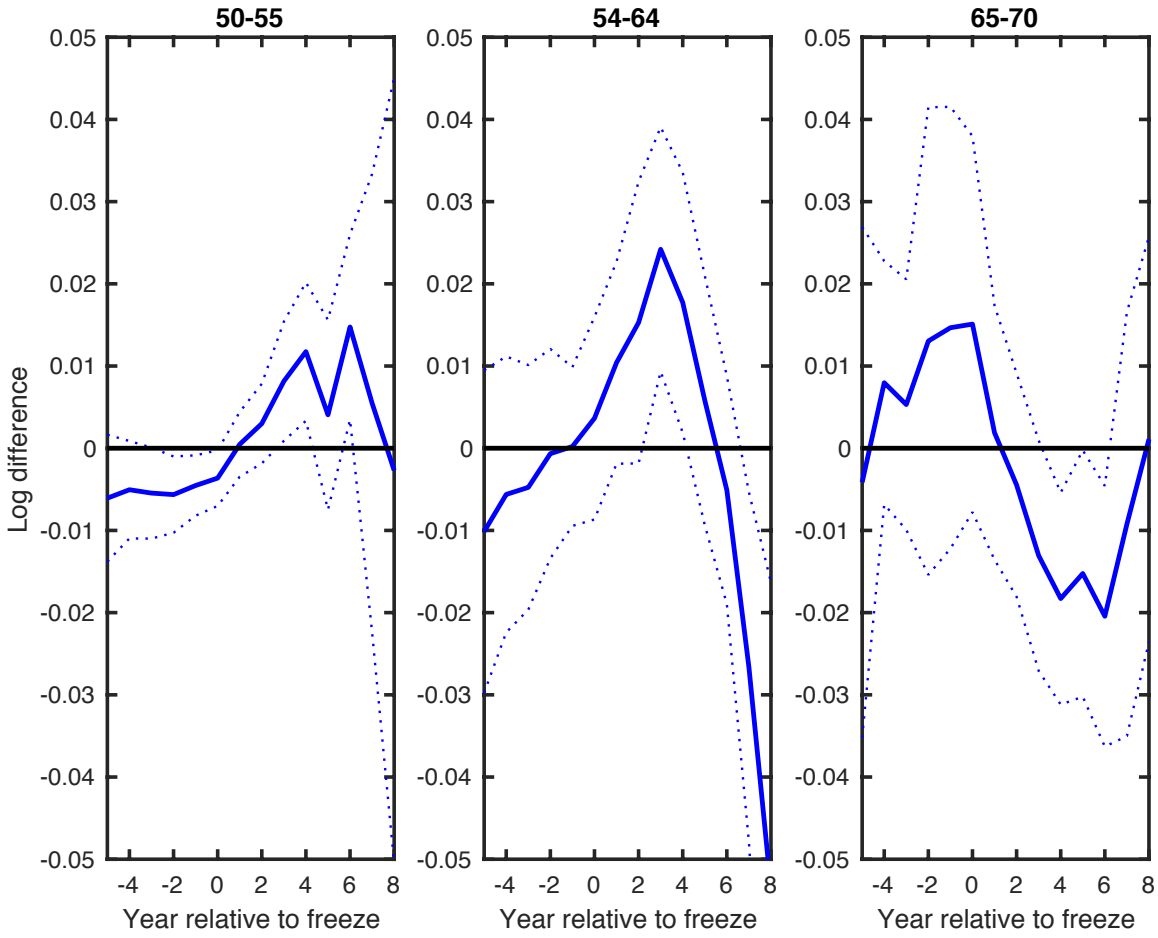
Notes: HRS data are based on the sample of respondents working as of 2004 who are eligible for employer sponsored DB pension plans. LEHD data are based on the sample of individuals employed at DB sponsoring firms as of 2004 where the firm-wide coverage rate is $\geq$ 80 percent. Sample splits are based on age as of 2004.

Figure 5: Impact of freezes on LFPR



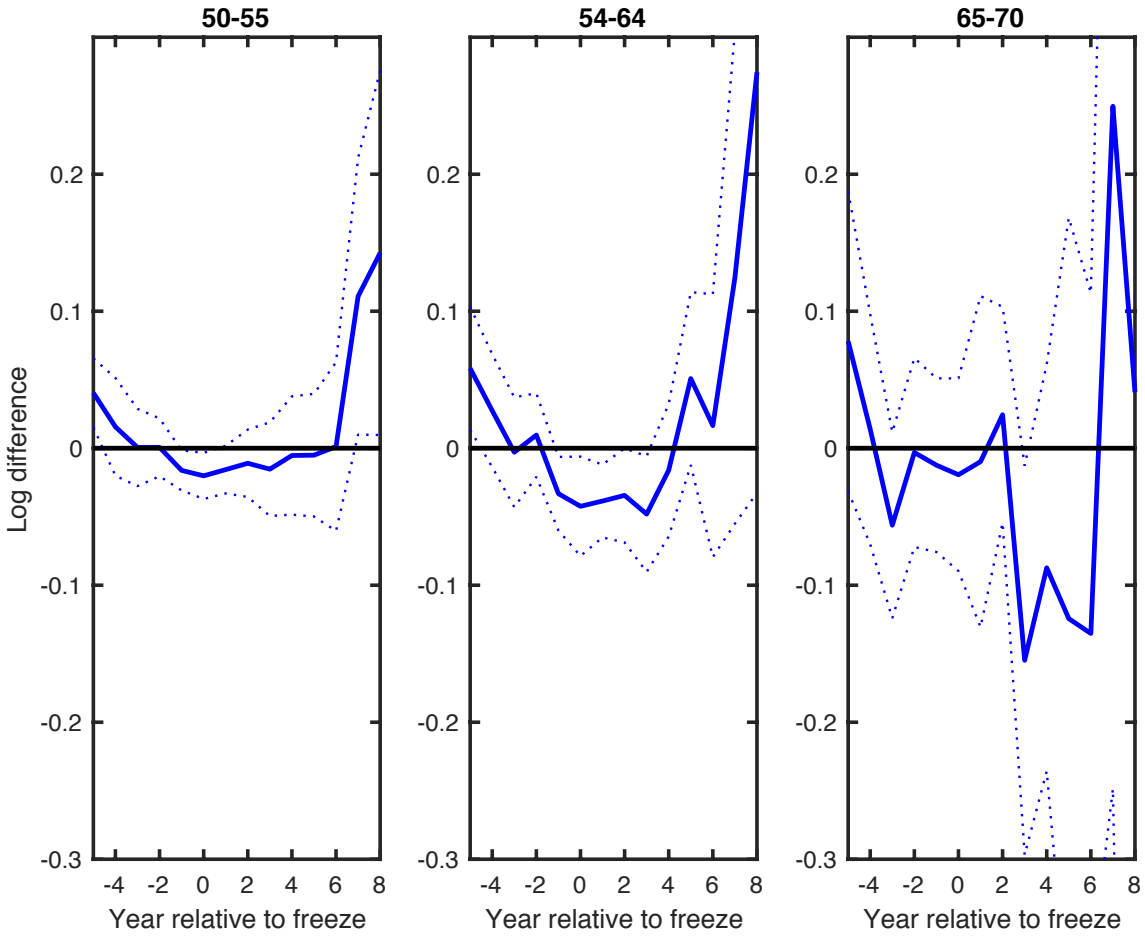
Notes: Dotted lines show 95 percent confidence intervals which are based on standard errors clustered at the firm level.

Figure 6: Impact of freezes on retirement



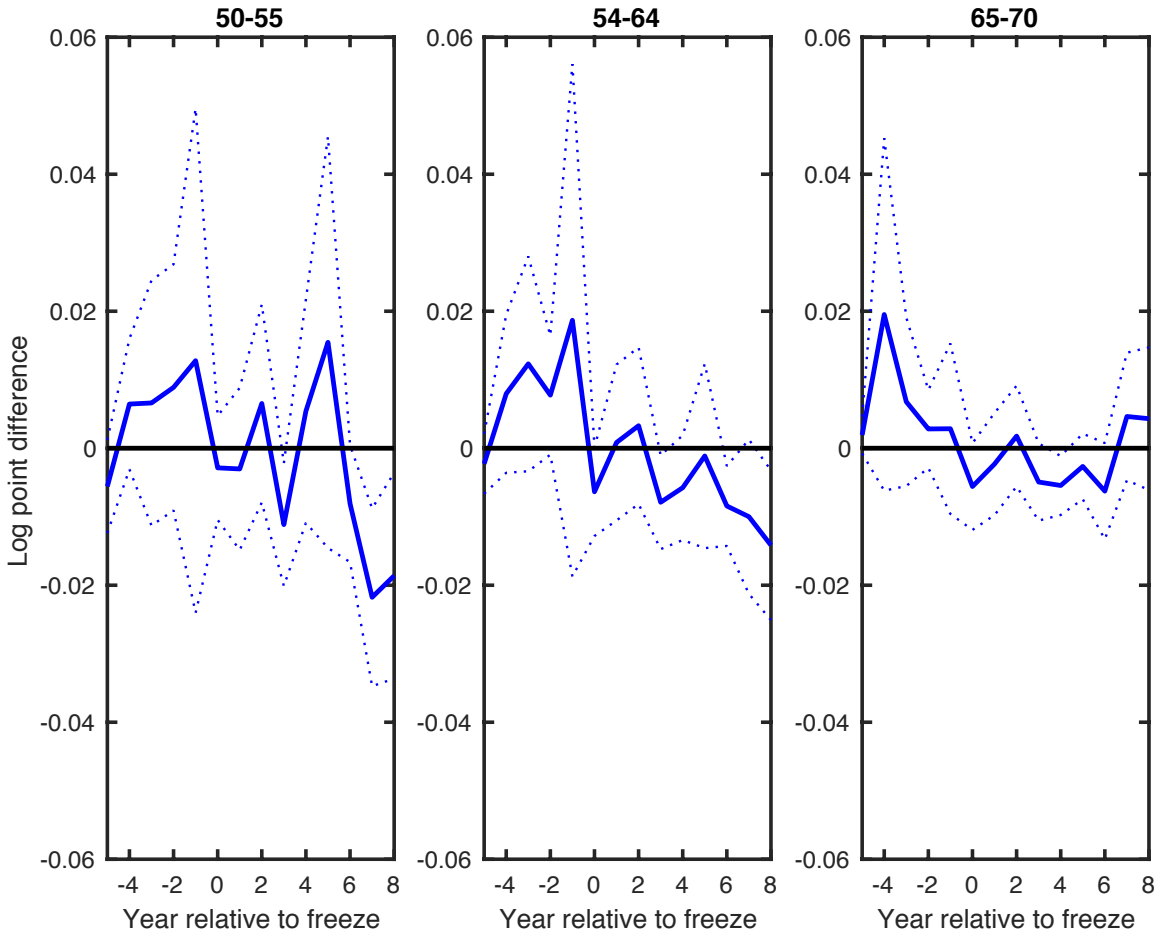
Notes: Dotted lines show 95 percent confidence intervals which are based on standard errors clustered at the firm level.

Figure 7: Impact of freezes on annual earnings



Notes: Dotted lines show 95 percent confidence intervals which are based on standard errors clustered at the firm level.

Figure 8: Impact of freezes on employer attachment



Notes: Dotted lines show 95 percent confidence intervals which are based on standard errors clustered at the firm level.

Table 1: Ex-ante firm and plan characteristics (high-coverage sample)

	No freeze		Freeze	
Variable	Mean	SE	Mean	SE
Size	185.1	5.44	127.7	12.47
Age	19.7	0.028	19.4	0.116
Average earnings	69910	860.7	67520	228.7
Fraction workforce <= 50	0.651	0.0008	0.648	0.0032
Fraction workforce [51,55]	0.125	0.0005	0.123	0.0021
Fraction workforce [56,60]	0.109	0.0005	0.115	0.0021
Fraction workforce [61,65]	0.065	0.0004	0.068	0.0016
Fraction workforce >=66	0.050	0.0004	0.046	0.0014
Distressed firm	0.051	0.0007	0.050	0.0028
Pension liability/participant	108300	469.9	109700	1782
Pension accrual/participant	16920	243	19570	1573
Plan avg retirement age	63.1	0.012	63.2	0.044
Plan funding ratio	1.14	0.0015	1.06	0.0051
Distressed plan	0.164	0.0012	0.204	0.0052
Industry freeze rate	0.112	0.0004	0.142	0.0014
DB coverage rate	0.913	0.0004	0.910	0.0016
Collectively bargained plan	0.024	0.0005	0.014	0.0015
Firm-cohort-years	95430		6080	
Firms	6000		1200	

Notes: Statistics reported in the table average over years [c-5,c]. All dollar values are measured in 2010 dollars. Pension liability per participant is computed as the present value of the liability owed to active participants divided by the number of active participants. Plan-years are coded as distressed if their ratio of assets to liabilities is under 80 percent — the threshold below which DB plans are considered "at risk" in the Pension Protection Act of 2006. Firm-years are coded as distressed if firm-wide year-on-year employment shrank by 30 percent or more.

Table 2: Ex-ante worker characteristics

	Age in year c ∈ [50-55]				Age in year c ∈ [56-64]				Age in year c ∈ [65-70]			
	No freeze		Freeze		No freeze		Freeze		No freeze		Freeze	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Male	0.453	0.0008	0.486	0.0018	0.466	0.0007	0.527	0.0016	0.496	0.0012	0.532	0.0025
White	0.789	0.0004	0.825	0.0008	0.817	0.0003	0.862	0.0006	0.832	0.0005	0.881	0.0011
Black	0.099	0.0002	0.067	0.0004	0.084	0.0002	0.053	0.0004	0.073	0.0003	0.054	0.0007
Hispanic	0.066	0.0002	0.079	0.0006	0.053	0.0002	0.058	0.0004	0.051	0.0003	0.040	0.0007
Asian	0.036	0.0001	0.021	0.0003	0.037	0.0001	0.019	0.0002	0.036	0.0002	0.017	0.0004
Other race	0.010	0.0001	0.008	0.0001	0.009	0.0001	0.008	0.0001	0.009	0.0001	0.007	0.0002
Less than high school	0.057	0.0002	0.050	0.0004	0.064	0.0002	0.059	0.0004	0.100	0.0004	0.088	0.0009
High school degree	0.228	0.0003	0.216	0.0007	0.233	0.0003	0.229	0.0007	0.275	0.0006	0.287	0.0014
Some college	0.328	0.0003	0.323	0.0007	0.310	0.0003	0.304	0.0007	0.289	0.0006	0.277	0.0013
College or more	0.387	0.0004	0.411	0.0009	0.394	0.0004	0.408	0.0009	0.336	0.0007	0.348	0.0016
Earnings	55370	80.82	51610	158.4	57660	102.6	53600	183.3	48570	178.7	43730	413.4
Tenure	8.2	0.0057	7.4	0.0124	8.7	0.0053	7.7	0.0113	8.4	0.0090	7.6	0.0196
Switched employer since c-5	0.037	0.0002	0.041	0.0004	0.034	0.0001	0.037	0.0003	0.036	0.0003	0.036	0.0006
Retired since c-5	0.019	0.0001	0.018	0.0002	0.051	0.0001	0.052	0.0003	0.167	0.0005	0.169	0.0011
Labor force participation rate	0.968	0.0001	0.969	0.0002	0.933	0.0002	0.930	0.0004	0.803	0.0005	0.802	0.0012
Person-cohort-years	2343000		439000		2519000		465000		661000		116000	

Notes: Annual earnings are measured in 2010 dollars. The LEHD history of an employee does not reflect the complete history of the employer-employee relationship because states can enter the data after a given employee-employer relationship is established. This left consoring of the employer-employee history induces downward bias in tenure statistics drawn from the LEHD.

Table 3: Two-sample estimates of Marshallian extensive margin elasticity

	50-55		56-64	
	$\Delta\hat{E}\left[\log(\text{RR})\right]^{\text{LEHD}}$	$\Delta\hat{E}\left[\log(\omega_i)\vert a_{i0}+k\leq R_i^*\right]^{\text{HRS}}$	$\Delta\hat{E}\left[\log(\text{RR})\right]^{\text{LEHD}}$	$\Delta\hat{E}\left[\log(\omega_i)\vert a_{i0}+k\leq R_i^*\right]^{\text{HRS}}$
	0.007	-0.048	0.016	-0.022
	(0.024)	(0.006)	(0.007)	(0.005)
$\hat{\eta}^M$		0.144		0.752
		(0.517)		(0.369)

Notes: Standard errors in parentheses. Two-sample standard error estimates are obtained using the delta method. The age 50-55 estimate pools over $k \in [1, 7]$ while the age 56-64 estimate pools over $k \in [1, 4]$.

A Data Appendix

Form 5500

F5500 is an annual filing collected jointly by the IRS, DoL, and the PBGC to ensure compliance with ERISA.[42] Each plan in the F5500 database is identified by a combination of an EIN and plan number (PN). The PN is assigned by the plan's sponsor and stays fixed over the life of the plan. For form years 2000-2015, the DoL has prepared an edited research sample of the data in which logical and arithmetic errors are corrected and multiple filings for the same plan are de-duplicated.[43] From 2000-2009, the research data include all pension plans with more than 100 participants and a 5 percent sample of plans with less than 100 participants. I use records from the research data where possible and add back small plans (i.e. those with less than 100 participants) from the raw data if they are excluded from the research sample. I de-duplicate multiple filings for the same plan in the raw data files by retaining the most recent filing in a given year. I obtained pre-1999 data through a FOIA request to the DoL. The sample that I use covers plan years ending 1997-2011.

Using these data, I focus on plans with DB characteristics. Plan characteristics are coded using a set of numbers and letters. In post-1999 F5500 data, DB plans have prefix 1, DC plans have prefix 2 and 3, and welfare benefit plans — such as employer provided health insurance — have prefix 4.[44] Hard frozen DB plans are recorded using code 1I. Cash balance plans are recorded using code 1F. I eliminate supplemental plans which I identify by searching for any case versions of the string "supplemental" in the plan name field. I restrict my sample to single employer plans, thereby eliminating multiemployer DB plans.[45]

In addition to the main form, I include data taken from the actuarial information attachment. Prior to 2007 this attachment was labeled Schedule B. After 2009 it was labeled Schedule SB for single employer plans. For 2008, I impute data by interpolating values from 2007 and 2009 filings because actuarial information for form year 2008 is unavailable in electronic format. The actuarial attachment contains several

[42] Raw data for form years 1999-2017 are available at https://www.dol.gov/agencies/ebsa/about-ebsa/our-activities/public-disclosure/foia/form-5500-datasets.

[43] The research files are available at https://www.dol.gov/agencies/ebsa/researchers/data/private-pension-plan-data.

[44] The codes are different prior to 1999. See page 9 of the 1998 F5500 instructions for details.

[45] Multiemployer plans are arrangements between a group of firms and/or unions to provide pension benefits to eligible employees within the group.

valuable pieces of plan level data including detailed breakouts of plan assets and liabilities, incremental liabilities, and the average retirement age/benefit claim age.

Linking to the Census Business Register

The BR is a database of the universe of establishments in the United States.[46] It includes information on business location, organization, industry, and information on revenue, payroll, and employment that is collected from administrative tax records as well as survey information. The relationship between establishments belonging to multi-unit firms are determined using responses to the company organization survey, the economic census, and the annual survey of manufactures. Establishments that are part of the same multi-unit firm share the same Census assigned firm identification number even if they have unique EINs.

To link the F5500 files to the BR, I rely on the Form 5500 - Business Register Bridge (F55BRB), a crosswalk file that matches each F5500 plan filing to an establishment in the BR. The F55BRB file matches the EIN-plan-end-years in F5500 to EIN-years in the BR.[47] Because the massive scope of the BR, I am able to match approximately 92 percent of DB plan-years in the F5500 files to specific establishments in the BR. Non-matches occur when a plan EIN does not map to any establishment with positive payroll in the BR which could happen, for example, when a plan is sponsored by a union or an employer-association.

On the basis of the F5500-BR linkage described above, I rely on Census firm identifiers from the BR to find all establishments that are associated with a given employer in a given year. To cleanly apportion workers to the freeze and no-freeze state in a given year, I limit my sample to firms that have a single plan throughout their history of filing F5500. When firms have multiple plans, I retain only those employers who choose either to never freeze their plans or freeze them all at the same time. The large majority of firm's do not sponsor more than one DB plan, so this restriction allows me to retain about 94 percent of all DB sponsoring firm-years matched from the F5500. Because multiple-plan firms are extremely large employers, however, the restriction implies that I retain only 29 percent of DB covered employee-years at DB sponsoring employers.

[46] Information about the BR is confidential and protected by Title 13 and Title 26, US Code. The following information is drawn from https://www.census.gov/econ/overview/mu0600.html.

[47] Between 1999 and 2011, about 83 percent of plans start and end in the same calendar year (i.e. begin in Q1 and end in Q4). The remaining 17 percent of plans span calendar years.

Linking to the Longitudinal Employer Household Dynamics

The LEHD is a quarterly matched employer-employee dataset constructed from state-level unemployment insurance (UI) records. While the UI system covers 96 percent of wage and salary employment nationally, the data exclude independent contractors, the unincorporated self-employed, railroad workers covered by railroad unemployment insurance, and some other minor categories of workers who are not covered by state-level UI laws. State and local government employees are included in the data but elected officials, members of the judiciary, and some emergency employees are excluded. Federal government workers are excluded from the version of the data that I use in this paper.

An important feature of the LEHD is that states enter the dataset at different points in time. For example, Maryland enters in 1985:Q2 whereas Mississippi enters only in 2003:Q3. Because of staggered entry, the scope of the data grows continuously over time.[48] I use the 2014 snapshot version of the LEHD, which provides matched employer-employee histories from each state's entry quarter up through 2015:Q1.[49]

In the LEHD, employers are identified using a state UI account number known as the SEIN while workers are identified using a variable known as a protected identification key (PIK). I begin by matching data from the F5500-BR link to the T26 Employer Characteristics File (ECFT26) in the LEHD. The ECFT26 is a SEIN-quarter-year level file that contains the Census firm identifier associated with each SEIN. Using this common unique identifier, I can match national level plan and employer characteristics from the F5500-BR linked file to state level employers in the LEHD. Because of the staggered nature of state level data coverage in the LEHD, I recover 90 percent of firm cohort-years which corresponds to 96 percent of employee-cohort-years from the F5500-BR linked file.

Next, I move to the Employment History File (EHF) to obtain matched employer-employee data. The EHF is a SEIN-PIK-year level file that provides the earnings history associated with each employer-employee combination. To these data, I add information on date of birth, race and ethnicity, and education from the Individual Characteristics File (ICF). I define my sample of workers as individuals between the age of 50 and 70 in cohort year c who were employed at a DB sponsoring firm as of year $c-5$. If a worker has multiple employers in year $c-5$, I retain the worker's dominant employer: i.e. the employer that paid the worker that most in that year.

[48] A number of populous states enter the data relatively early. Illinois enters in 1990, California and Pennsylvania in 1991, Florida in 1992, and New York and Texas enter in 1995.

[49] My sample excludes data from Alabama due to a file access problem.

Table A1 shows the count and match rates associated with each major step of the data linkage and sample restriction outlined above:

Table A1: Administrative data linkage

Match/restriction	N	Match rate	Person weighted rate
F5500-BR (plan-years)	637000	0.921	0.951
Multi-plan restriction (firm-years)	478000	0.943	0.287
BR-LEHD (firm-cohort-years)	546000	0.902	0.961

B Firm and plan characteristics

This appendix investigates the firm's decision to freeze using information drawn from F5500 and the BR. In these analyses, I use data on freezing and non-freezing firms that meet the sample restrictions documented in Appendix A, but do not impose coverage rate restrictions as I focus on employer level outcomes rather than employee level outcomes. Table B1, which is analogous to Table 1 in the main text, provides summary statistics for the full set of firms in theses analyses. These statistics are computed in the five year period prior to the cohort-year and therefore reflect pre-event characteristics for freezing and non-freezing firms. This broader sample of data reiterates the patterns in the high-coverage rate sample. In particular, freezing firms are slightly smaller in terms of total employment but otherwise exhibit similar characteristics in terms of average pay and pension compensation, age structure of workforce, and likelihood of mass layoffs. That said, freezing firms sponsor plans that are 7 percentage points more underfunded and about 5 percentage points more likely to have slipped under the 80 percent, "at-risk", funding threshold. They are also less likely to have struck collective bargaining agreements with their workers.

Table B2 examines the importance of DB costs and funding positions, size, age structure, and coverage rates on firms' likelihood of freezing within a regression framework that accounts for firm, firm age, industry, and calendar year fixed effects. The estimates are based on the following linear probability model which stacks cohort-years together:

$$Freeze_{jct} = \boldsymbol{\mu} + \boldsymbol{x}'_{j,c,t-k}\boldsymbol{\zeta} + u_{jct} \tag{13}$$

where $Freeze_{jct} = 1$ if firm j freezes its plan in year t and cohort-year c and $\boldsymbol{\mu}$ is a vector of firm, industry, calendar-year-by-cohort-year fixed effects, and firm age fixed effects. The vector $\boldsymbol{x}_{j,c,t-k}$ captures firm and plan specific characteristics k years prior to the freeze including the log of the funding ratio, the log of firm size, the log of the DB coverage rate, the log of the increase in DB liability per participant, and controls for the age structure of the workforce. The residual u_{jct} absorbs determinants of the firms decision to freeze that are not captured in $\boldsymbol{\mu}$ or $\boldsymbol{x}_{j,c,t-k}$. In Table B2 , I show estimates for the vector $\boldsymbol{\zeta}$ based on one, two, and three lags of firm and plan characteristics. The estimates show that the decision to freeze is a product chiefly of declining funding positions. A 1 percent decline in the funding ratio raises the likelihood of a freeze in the subsequent period by 3.26 percentage points. Larger firms appear slightly less likely to freeze their plans, as

are firms with a higher rate of workers with DB coverage. Size may be protective because larger firms may have access to greater liquidity thereby allowing the continued operation of DB pensions even with higher costs. Incremental liabilities are not economically meaningful explanatory variables, nor is the fraction of workers aging into the peak phase of DB accruals. The declining position of assets to liabilities embodied in freezing firms' funding ratios are therefore explained not by (presumably expected) increases in pension obligations, but by (presumably unexpected) declines in pension assets. Given the statutory obligations for DB sponsors to make up funding shortfalls, the microdata based evidence shown here indicates that asset market driven increases in the costs of DB sponsorship are the key drivers of pension freezes.

Next, I adopt an event study framework to examine how firm size and average pay change before and after the freeze. These analyses rely on the following regression model, which stacks cohort-years together:

$$y_{jct} = \boldsymbol{\mu} + \sum_{k=-5}^{8} \tau_k Freeze_{jck} + v_{jct} \tag{14}$$

where y_{jct} is an outcome of interest for firm j, in cohort-year c, and calendar year t, and $\boldsymbol{\mu}$ is a vector of firm, industry, calendar-year-by-cohort-year fixed effects, and firm age fixed effects. $Freeze_{jck} = 1$ if the current year is k and firm j freezes its plan in cohort-year c, and v_{jct} is the error term. The τ_k coefficients capture the average difference in the path of the outcome between freezing and non-freezing firms which, in this regression are descriptive and not intended to be causal. The left-hand panel of Figure B1 plots the τ_k coefficients using log firm size as the dependent variable while the right-hand panel uses log firm average pay as the dependent variable. Conditional on firm fixed effects, freezing firms are consistently about 2 percent larger prior to the freeze. Starting one year prior to the freeze, the firm size gap starts to expand growing from about 0 at $k = -1$, dropping by about 3 percent in the immediate post-freeze period, and recovering by $k = 8$. The pattern for average pay is similar: conditional on firm fixed effects, freezing firms start out paying about 1.5 percent more than non-freezing firms at freezing. This trend turns negative at $k = -2$ and recovers by $k = +8$.

Table B1: Ex-ante firm and plan characteristics (full sample)

	No freeze		Freeze	
Variable	Mean	SE	Mean	SE
Size	293.6	4.79	201.6	9.19
Age	20.0	0.018	20.0	0.067
Average earnings	58770	427.8	57390	123.1
Fraction workforce <= 50	0.704	0.0004	0.706	0.0016
Fraction workforce [51,55]	0.109	0.0003	0.108	0.0009
Fraction workforce [56,60]	0.090	0.0003	0.091	0.0009
Fraction workforce [61,65]	0.054	0.0002	0.054	0.0007
Fraction workforce >=66	0.044	0.0002	0.041	0.0007
Distressed firm	0.052	0.0005	0.051	0.0017
Pension liability/participant	93730	478.5	93780	1732
Pension accrual/participant	15620	140.6	16500	904.6
Plan avg retirement age	63.0	0.0078	63.2	0.0263
Plan funding ratio	1.13	0.0010	1.06	0.0032
Distressed plan	0.176	0.0008	0.222	0.0032
Industry freeze rate	0.114	0.0002	0.140	0.0009
DB coverage rate	0.706	0.0006	0.680	0.0021
Collectively bargained plan	0.036	0.0004	0.025	0.0012
Firm-cohort-years	232400		17090	
Firms	12000		3400	

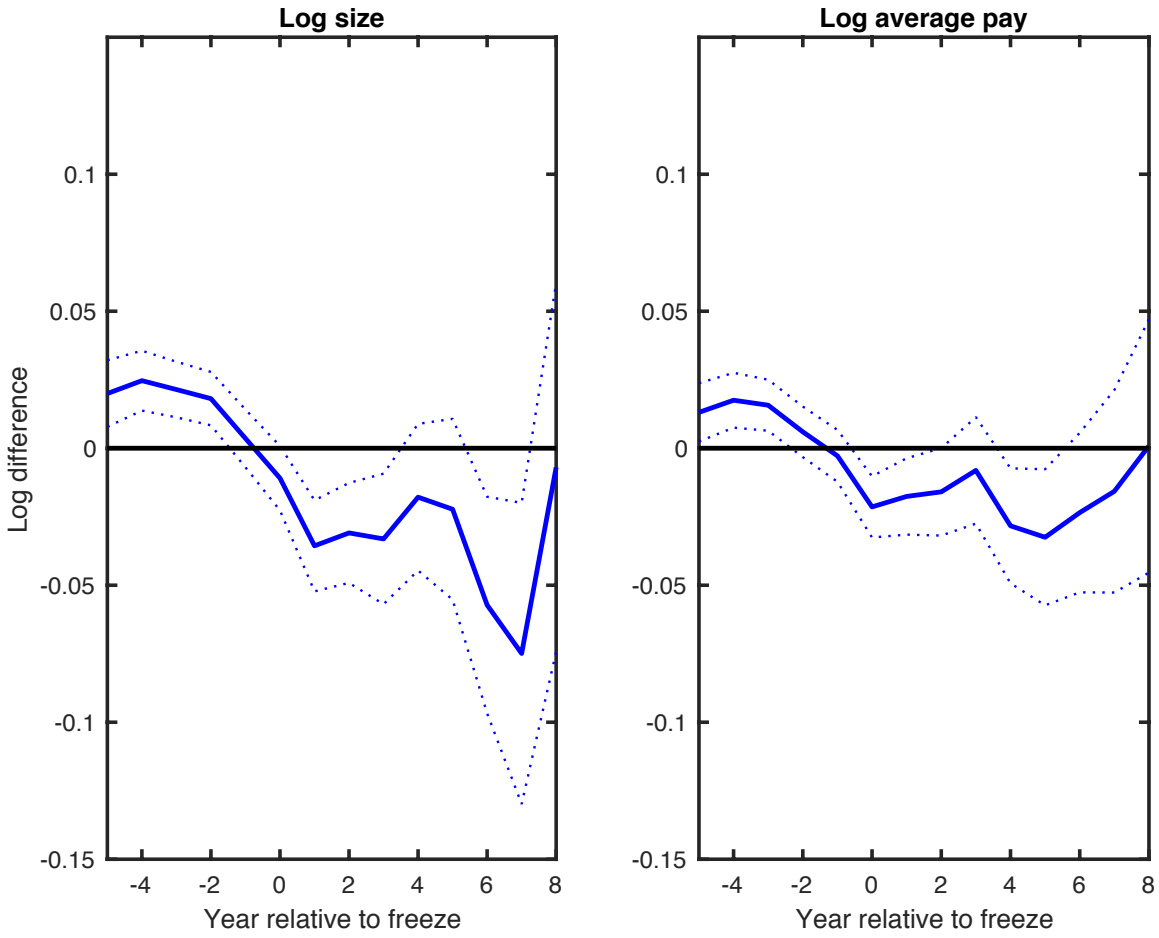
Notes: Statistics reported in the table average over years [c-5,c]. All dollar values are measured in 2010 dollars. Pension liability per participant is computed as the present value of the liability owed to active participants divided by the number of active participants. Plan-years are coded as distressed if their ratio of assets to liabilities is under 80 percent — the threshold below which DB plans are considered "at risk" in the Pension Protection Act of 2006. Firm-years are coded as distressed if firm-wide year-on-year employment shrank by 30 percent or more.

Table B2: Predictors of future freezes (linear probability model)

	Lag		
Variable	$k = 1$	$k = 2$	$k = 3$
Log funding ratio	-0.0326***	-0.0172***	-0.0052*
	(0.003)	(0.0032)	(0.0027)
Log accruals earned/participant	-0.0058***	-0.0033***	-0.0016***
	(3.58e-04)	(3.58e-04)	(3.24e-04)
Log total liability/participant	0.0007	0.0011*	5.88e-04**
	(6.82e-04)	(6.08e-04)	(2.54e-04)
Log size	-0.0082***	-0.0052**	-0.0034
	(0.0024)	(0.0023)	(0.0022)
Log coverage rate	-0.0171***	-0.0174***	-0.0104**
	(0.0055)	(0.0053)	(0.0050)
Log fraction workforce <=50	0.0089	0.0186	0.0134
	(0.0116)	(0.0117)	(0.0118)
Log fraction workforce [51,55]	0.0026	0.0129	0.00507
	(0.0112)	(0.0113)	(0.0117)
Log fraction workforce [56,60]	0.0076	0.0201*	0.0051
	(0.0113)	(0.0113)	(0.0117)
Log fraction workforce [61,65]	0.0172*	0.0161	0.0178
	(0.0102)	(0.0106)	(0.0112)
Observations	148000	148000	148000
R-squared	0.198	0.193	0.192

Notes: Robust standard errors, clustered at the firm level, in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All models include firm, calendar-year-by-cohort-year, industry, and firm age fixed effects.

Figure B1: Firm size and average pay before and after freezes



Notes: Dotted lines show 95 percent confidence intervals which are based on standard errors clustered at the firm level.

C Counterfactual compensation after a freeze

DB pension wealth in the HRS sample with linked pension plans is calculated using the following formula

$$\mathcal{W}_{T_0}^{DB} = \sum_{t=T_0}^{119} P_t \left(\frac{1 + COLA}{1 + i} \right)^{t-T_0} B_{t|T_0} \tag{15}$$

where $\mathcal{W}_{T_0}^{DB}$ is the present value of pension wealth at retirement age or quit date T_0, P_t is the probability of survival at age t conditional on being alive in T_0, $COLA$ (cost of living adjustment) is the plan specific annual growth rate of payments (for most DB plans in the HRS $COLA = 0$), i is the nominal interest rate and $B_{t|T_0}$ is the annual pension benefit at age t conditional on retiring or quitting at T_0.[50] In the HRS, these values are adjusted from T_0 to 2010 to facilitate comparisons across a variety of hypothetical retirement ages. Earnings are a critical component of the DB formulas used to compute $B_{t|T_0}$. In the linked HRS pension sample, earnings at prospective retirement ages are calculated by applying in-sample wage growth that is based on the average earnings changes among HRS respondents who stay in the same jobs and have no missing earnings information between 2008 and 2010. These growth rates are computed separately for public and private sector workers to account for differential earnings trajectories during and after the Great Recession.[51] See Fang et al. (2016) for more details on earnings projections.

DC accounts constitute the second part of deferred compensation. Recall from equation (2) that DC wealth at time t can be expressed as

$$\mathcal{W}_t^{DC} = \mathcal{W}_{t-1}^{DC}(1 + r) + y_t(m^W + m^F)$$

where $\mathcal{W}_{t-1}^{DC}$ is the stock of DC wealth carried forward from the prior period, r is the real interest rate, y_t is earnings in the current period, and m^W and m^F are the respective proportion of earnings contributed to the DC plan by the worker and the firm. In the HRS, respondents report the value of their DC account balances along with the contribution rates, m^W and m^F.[52] Recall from equation (1) that total compensation is the

[50] P_t are based on the 2010 version of gender-specific cohort mortality tables published by the Social Security Administration (SSA). The 2010 pension wealth calculations assume a nominal interest rate of 5.7 percent and an inflation rate of 2.8 percent according to economic assumptions detailed in the 2010 Annual Report of the Board of Trustees of the old age, survivors, and disability insurance (OASDI) trust funds of the SSA.

[51] Tenure is the other major component of the DB formula. HRS DB wealth estimates rely both on self-reports of tenure and on linked Social Security earnings records which contain employer identifiers to ascertain tenure.

[52] Individual and employer contributions are expressed either as a percentage or as a dollar value in the HRS. When expressed as a dollar value, I divide them by earnings to convert them to a percentage. Some respondents provide intervals rather than point measures of contribution rates. I use the mid-point of the interval to impute these contribution rates.

sum of cash compensation and accruals in deferred compensation is given by

$$\mathcal{C}_t = y_t(1 - m^W) + \Delta\mathcal{W}_t^{DB} + \Delta\mathcal{W}_t^{DC}$$

Define R^* as the optimal retirement age for a worker currently aged a. Recall from equation (11) that the annuity value of a worker's long-term employment with the firm is given by

$$\omega_a = \frac{1}{R^* - a} \sum_{t=a}^{R^*} \left(\frac{1}{1+r}\right)^{t-a} \mathcal{C}_t$$

where all values are expressed in constant dollar terms.If a freeze occurs in period k, then $\Delta\mathcal{W}^{DB} = 0$ in period k and all subsequent periods. I assume that the post-freeze substitution to DC or transition to CB are equivalent.[53] Define ω^F as the annuity value of a worker's long-term employment in the post-freeze environment. Then, for a worker aged a when faced with a freeze:

$$\omega_a^F = \frac{1}{R^* - a} \sum_{t=a}^{R^*} \left(\frac{1}{1+r}\right)^{t-a} \underbrace{\tilde{y}_t}_{\text{Post-freeze earnings}} + \underbrace{\Delta\tilde{\mathcal{W}}_t^{DC}}_{\text{Post-freeze DC accruals}} \tag{16}$$

Simulating changes in compensation due to freezes

I begin by selecting DB eligible respondents in the 2010 linked pension sample, all of whom were working when surveyed. I retain respondents employed in the private sector whose plans are coded as traditional DB plans (i.e. their plans have neither been frozen nor converted to cash balance). I then split the sample into two age groups that match the age bins used with LEHD data: 50-55 and 56-64 (I exclude workers in the 65-70 year-old category because retirement patterns for those workers differ substantially across the LEHD and the HRS; see, e.g., Section 4.1.5). Indexing respondents in the HRS by i, denote the respondent's age as of the 2010 survey wave as a_i. Denote respondent self-reported expected retirement age as R_i^*. Note that these data have a psuedo-panel structure: they provide pension wealth and earnings estimates for each respondent at several hypothetical retirement ages. Let t index time periods in the psuedo-panel,denote $\tilde{a}_{it}$ as the worker's hypothetical retirement age and define $k = \tilde{a}_{it} - a_i$.[54]

[53] This assumption abstracts away from investment risk borne by workers with DC plans. CB plans guarantee a rate of return to the worker, so the investment risk is borne by the employer. Some plans are hybrids of DC and CB where workers earn market based returns on assets but the firm provides a floor on accruals thereby guaranteeing a minimum benefit.

[54] I retain forward and backward projections from age 48 through age 80. Therefore $\tilde{a}_{it} \in [48, 80]$.

With these data I simulate the effect of a pension freeze on total compensation as follows:

1. Earnings (y_{it}) is based on the age specific projection provided by the HRS. $\Delta\mathcal{W}_{it}^{DB}$ is obtained by differencing DB wealth computed using the HRS pension estimation program (PEP). DB pension wealth is based on the maximum of wealth at the plan's normal retirement age, early retirement age, and vested deferred value of benefits. When respondents have wealth in multiple plans, I sum pension wealth over each plan.

2. When respondents report a positive DC account balance, I use the law of motion described in equation (2) to estimate the respondent's DC balance at each hypothetical retirement age. In making this calculation, I set earnings (y_{it}) equal to the age specific projection provided by the HRS. I use the respondent's report of m^W and m^F and the nominal interest rate and inflation rate assumed in the PEP (5.7 percent and 2.8 percent respectively) to complete the calculations. When respondents make contributions to multiple plans or receive employer contributions to multiple plans, I sum the fraction of earnings contributed across all plans to determine the total contribution rate. For about 5 percent of respondents, m^W and m^F are missing even when a positive DC balance is reported. For these respondents, I impute the total contribution rate using the in-sample average.

3. Using y_{it}, $\Delta\mathcal{W}_{it}^{DB}$, and $\Delta\mathcal{W}_{it}^{DC}$ and R_i^* , I compute $\mathcal{C}_{it}$ and ω_i for each respondent.

4. Next, I simulate pension freezes by setting $\Delta\mathcal{W}_{it}^{DB} = 0$ for all $k \geq 0$. When respondents have zero DC account balances at $k = 0$, I initiate DC contributions in the post-freeze period using the in-sample average rates. When respondents report positive balances at $k = 0$, DC accruals continue at the self-reported contribution rates. In the post-freeze period, earnings are adjusted to based on the coefficients in Figure 7. For 50-55 year-old workers I use estimate through $k = 7$ and for workers 56-64, I use estimates through $k = 4$. These adjustments are made to exclude partitipation driven changes in earnings from the individuals post-freeze earnings projection. Using these estimates, I compute ω_i^F for each respondent.

5. For $k = \{0, \ldots, 8\}$, I average over respondents who have yet to reach their anticipated optimal

retirement age, R^*, to compute

$$\Delta\hat{E}\left[\log(\omega_i)|a_{i0}+k\leq R_i^*\right]^{\text{HRS}}=\frac{1}{N_k^{HRS}}\sum_{i=1}^{N_k^{HRS}}\log(\omega_i)-\log(\omega_i^F)$$

where N_k^{HRS} is the count of respondents for whom $a_i+k<R_i^*$.