Labor Supply and the Pension Contribution-Benefit Link*

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Preliminary Draft, July 2020

Abstract

We estimate the labor supply response to a reform that switched the Polish pension system from a Defined Benefit (DB) to a Notional Defined Contribution (NDC) scheme. Central to this reform was a change the link between current pension contributions and future pension benefits. Only those born after December 31st 1948 were affected, creating a sharp cohort-based discontinuity in the contribution-benefit link for individuals in their 50s. Using administrative data on the universe of Polish taxpayers, we examine labor supply responses to the reform at ages 51-54, around 11-15 years before the normal retirement age. In line with the change in incentives, we find that the employment rate decreased by 2% in response to the policy change, which is consistent with an extensive margin elasticity of 0.33. These responses are driven by regions where the incentives had changed the most. Our results imply that changing the contribution-benefit link of public pensions can alleviate the labor supply distortions caused by social security contributions.

JEL Codes: [D15, H55, J22, J26]

Keywords: labor supply, pensions, contribution-benefit link, defined benefit, defined contribution.

*We thank Lucas Finamor and Pawel Struski for excellent research assistance. We thank Alan Auerbach, David Card, Agnieszka Chlon-Dominczak, Hedvig Horvath, Patrick Kline, Wojciech Kopczuk, Leszek Morawski, Emmanuel Saez, Joanna Tyrowicz and seminar participants at IFS/NORFACE conference on "Trends in Inequality: Sources and Policy", and IFS/ESRC conference on "Inequality and the Insurance Value of Transfers Over the Life Cycle" for their insightful comments. We also gratefully acknowledge funding from the the Economic and Social Research Council (for the grants "Centre for Microeconomic Analysis of Public Policy" at the Institute for Fiscal Studies (RES-544-28-50001) and "Inequality and the Insurance Value of Transfers across the Life Cycle" (ES/P001831/1)) and also NORFACE for Grant 462-16-120: "Trends in Inequality: Sources and Policy".

1 Introduction

In most OECD countries the share of labor income going to social-security contributions, which mostly finance public pensions, exceeds the share going to income taxes. Due in part to population aging, these social security contributions for pensions are projected to consume an increasing share of income. In response, many governments have reformed their public pension schemes to encourage labor supply, in some cases by tightening the link between social security contributions and pension benefits

This paper evaluates the labor supply response to a reform that changed the link between social security contributions (SSCs) and pension benefits: a 1999 reform that switched Poland's public pension scheme from a Defined Benefit (DB) to a Notional Defined Contribution (NDC) scheme. Using administrative data on the universe of Polish taxpayers, we examine labor supply responses to the reform at ages 51-54, around 11-15 years before the normal retirement age. In line with the change in incentives, we find that the employment rate decreased by 2% in response to the policy change. This is consistent with an extensive margin elasticity of 0.33 (s.e. 0.09).

The labor supply impact of social security contributions is a long standing question in economics. Economists have long recognized that SSCs and other payroll taxes differ from standard income taxes because there is a link between individual payments and benefits (Browning, 1975; Blinder et al., 1980; Burkhauser and Turner, 1985; Liebman et al., 2009). This "linkage" implies that SSCs might be less distortive than income taxes and also that tightening the link between current contributions and future benefits can alleviate the economic burden of financing pensions. And since the link between SSCs and future benefits is often very tenuous (Blinder et al., 1980; Burkhauser and Turner, 1985; Prescott, 2004) there is scope for substantial efficiency gains from reforming the pension system (Auerbach and Kotlikoff, 1985; Kotlikoff, 1996; Feldstein and Liebman, 2002).

For this reason, many governments and international organizations have considered proposals to tighten the link between current contributions and future benefits and thereby alleviate the tax burden of pension financing. For instance, the World Bank's highly influential 1994 study on pension reform advocated tightening the link between current contributions and future benefits by switching from a DB pension system to an NDC system. IMF research also argued that DB systems create a "loose link between benefits and contributions, transform the contribution rate into tax, reducing employment" (see page 7 of de Castello Bronco, 1998). In the last 20 years many countries followed this guideline. Examples include Italy in 1996, Hungary in 1998, Poland in 1999 and Sweden in 1999. Nevertheless, the World Bank approach has been criticized by leading pension experts, since tightening the link between SSCs and benefits not only increases efficiency, but it may also contribute to increased inequality among pensioners (Orszag and Stiglitz, 1999; Diamond, 1998). Furthermore, so far no empirical evidence has established that changing the contribution-benefit link has a considerable impact on labor supply at younger ages - a key argument posited by the above studies.[1] Pension systems are often extremely complicated: individuals lack a clear understanding of their benefits

[1] It is well established that retirement incentives have a large impact on retirement decisions, and it is often the case that large implicit taxes hinder older age employment (Gruber and Wise, 1999). Nevertheless, if incentives only matter close to retirement age, then tightening the link between benefits and contributions throughout the whole life cycle can have substantial distributional impact among pensioners without having a significant impact on efficiency.

(Crawford and Tetlow, 2010) and this lack of information appears to impact their decisions (Chan and Stevens, 2008; Mastrobuoni, 2011; Liebman and Luttmer, 2015), especially far from the retirement age (Rohwedder and Kleinjans, 2006). It could be the case that tightening the link between pension contributions and benefits might lead to limited efficiency gains, while increasing inequality among pensioners.

This paper provides what is, to the best of our knowledge, the first empirical assessment on how changing the link between SSCs and future benefits affects labor supply responses far from the retirement age. We exploit a Polish Pension reform in 1999 that introduced NDC pension scheme. This new pension system retained the pay-as-you-go nature of the DB pension system, but introduced many of the incentives associated with DC systems and so substantially tightened the link between contributions and benefits.[2] As emphasized by the key architects of this policy change, the most important element of the Polish pension reform was to "introduce a strong link between contributions and benefits" (see page 59 in Chlon et al., 1999).

The reform had a considerable impact on the incentives to work.[3] While the NDC provided better incentives throughout the life cycle, the old DB system in Poland made earnings in certain ages crucial. This is because, in the DB system, pensions are calculated based on average earnings over a selected subset of "best" years (usually 10) in their earnings history, whereas the NDC system uses earnings in all years.

To show labor supply incentives in the two pension schemes throughout the life cycle we start our analysis by simulating the change in pension benefits in response to changing labor supply for individuals with various life cycle earnings profiles. We find that while the NDC system provides better incentives to work in earlier and later years in the life cycle, the pensions in the DB system often depend heavily on earnings near age 50, since these are typically the highest earning years. For many individuals, reducing labor supply at age 50 has a large impact on average earnings in the best years and thus labor incentives at that age. Furthermore, our simulations indicate that the incentives in the DB system depend on the shape of the wage profile: for individuals with high wages near age 50 the incentives to work under the DB rules are stronger, while for individuals with flatter wage profiles the incentives are similar across the ages. We exploit these differences to identify the effect of changing the link between contributions and future benefits.

To assess the responses to the changes in incentives, we exploit the sharp discontinuity created by

[2] In particular, in the NDC system working-age individuals contribute to the system and pay for the benefits of current retirees, while the link between benefits and contributions is tightened by keeping track of each individual's contributions. Furthermore, similarly to the funded defined contribution scheme, the rate of return immediately reflects changes in economic prospects and growth.

[3] Besides the change in incentives, the new NDC scheme also provided less generous pensions for the younger cohorts. Nevertheless, the policy makers' desired goal was to avoid any large differences in projected pension wealth among individuals who were close in age to each other but were placed into different pension systems (Chlon et al., 1999). The policy makers believed at the time of the reform that this desired goal was achieved for men, but not for women (see page 36 and 37 in (Chlon et al., 1999). For women, the projected pension wealth was considerably lower under the new rules even for those who were born just a few days after their counterparts who were grandfathered into the old system. To alleviate this unfairness, the reform was phased in at a slower pace for women. Women born in 1949 received 80% of their pension based on the old rules and 20% based on the new NDC scheme. The share of pensions based on the old rules were gradually decreased to zero. We mainly focus on men in this paper for whom there was a sharp discontinuity in pension incentives for cohorts born around 1949.

the cohort-based nature of this reform. The Polish pension reform was applied only to those who were born after December 31st, 1948, and so were younger than 50 years old at the implementation of the policy. This sharp cohort-based discontinuity implied that two individuals born just a few minutes apart were faced with a completely different pension system from age 50: the older one would still participate in the traditional DB system while his slightly younger counterpart was ushered into the new NDC system.

We implement a regression discontinuity design (RDD) and study the evolution of labor supply responses between 2000 and 2004.[4] Our empirical design identifies the effect of the policy change by comparing two very similar individuals who are just born a few days apart and face a similar labor market and economic environment, but are assigned to a completely different pension scheme from age 50.

We implement the regression discontinuity design using the full population of tax returns from Poland. We merge the Polish tax returns with the population registry of Poland and we can thereby directly assess employment responses to the policy change. Since the employment responses around the policy discontinuity are tightly linked to the change in incentives generated by differential growth trends in the local economy, we study responses to the policy separately at high wage-growth and low wage-growth regions. We find that individuals who faced a decrease in the contribution-benefit link reduced their labor supply by around one percentage point (or two percent) at ages 50-53 as a result of the reform. Importantly, these responses were between 15 and 12 years before the full retirement age was reached by these individuals.[5] Conversely, for individuals where the contribution-benefit link has been tightened we find a slight increase in employment.

The change in labor supply can reflect the effect of the reform on the changes in pension wealth and the changes in incentives to work. The built-in changes in incentives was made explicit at the time of the reform, while it was argued that there is no change in pension wealth around the discontinuity. Nevertheless, contrary to the pension projections of the policy makers, our simulations, similar to those of Lachowska and Myck (2018) who studied consumption responses to the same reform, suggest that there was a substantial reduction in pension wealth for individuals under the new rule.[6] That reduction in pension wealth would predict an increase in labor supply, while we find a reduction in labor supply at high-growth regions. This suggests that the change in incentives must have played an important role in determining labor supply responses. Furthermore, since the change in pension wealth was similar across locations with different earnings growth, we can identify the incentive effects net of wealth effect by comparing employment responses and changes in incentives across regions. The clear difference in employment responses between low and high growth regions line up well with the change in incentives, but cannot be explained by the change in pension wealth.

[4] We stop the analysis in 2004 due to an additional policy reform introduced in 2004, which differentially impacted labor supply incentives of the 1948 and 1949 cohorts. As a result, from 2005 we cannot distinguish the effect of the pension reform from other policy changes.

[5] The expected retirement age for 50-53 years old men in Poland is 63 years according to the 2005-2009 waves of SHARE data.

[6] The pension projections of the policy makers did not take into account the shape of the life cycle earnings profile in their simulations (see the assumptions they made on page 36 and 37 in Chlon et al. (1999)). Similarly to us, Lachowska and Myck (2018) take into account the shape of the earnings profile, but assume it is deterministic and abstract away from unemployment risks. We relax both of these assumptions.

We use our estimates to assess the implied extensive margin elasticity with respect to the net return to work. We calculate that the implied effective change in the net return to work induced by the policy change is 7.4% and so the extensive margin elasticity is 0.33. This elasticity is comparable to the existing estimates in the literature (see, for example, Chetty et al., 2011). Nevertheless, here we show that individuals' labor supply responds in a forward-looking way to the built-in incentives in the pension formula far from the retirement age. A main implication of this finding is that tightening the link between contribution and benefits can alleviate distortions caused by the social security contributions.

We present several robustness checks. The considerable differences in employment between the 1948 and 1949 cohorts are only found where the policy discontinuity is present. We find no evidence of differential employment responses in the "placebo" cohorts between 1946 and 1948 and between 1950 and 1951, where there was no change in the policy. We also show that the change in incentives and the employment responses are tightly linked even if we estimate those at a level more disaggregated than when we focus on high growth and low growth regions. This evidence underlines that the employment changes around the 1948 and 1949 discontinuity is driven by changes in incentives. Finally, we also explore the robustness of our measure of incentive changes to alternative assumptions about the underlying earnings processes.

Our paper relates to several strands of the literature. A number of papers have examined the savings responses to changes in pension wealth using a cohort-based strategy, including Attanasio and Brugiavini (2003) and Attanasio and Rohwedder (2003). The paper by Lachowska and Myck (2018) studies the savings response to the changes in pension wealth to the 1999 Polish pension reform we study in the present paper. Our paper instead focuses on employment. In particular, we focus on the marginal incentive to work due to the change in the contribution-employment link, as we are able to identify individuals who faced similar wealth effects of the reform, but had different incentives for continued work. The latter is important for understanding the distortions caused by social security contributions. Furthermore, the above mentioned papers on savings identify the effect of the policy change by comparing the behavior of cohorts which are distant from each other. Instead, we apply here a regression discontinuity design, which allows us to compare the behavior of very similar individuals under the DB and NDC rules.

There is also an extensive literature examining labor supply responses to changes in incentives for retirement (for reviews, see Diamond and Gruber, 1999; Feldstein and Liebman, 2002; Krueger and Meyer, 2002; Coile, 2015; Blundell et al., 2016). The literature almost exclusively focuses on employment responses close to the retirement age (e.g. Liebman et al., 2009; Fetter and Lockwood, 2018; Gelber et al., 2018; Krueger and Pischke, 1992; Manoli and Weber, 2016). Our paper instead studies employment responses of individuals who are far from the retirement age, and so our results better reflect how built-in incentives in the pension system can distort labor supply responses throughout the life cycle. The aggregate labor supply implications also differ considerably depending on whether pensions only affect a few elderly individuals close to retirement or they have implications for labor supply decisions at much younger ages. Furthermore, a large evolving literature on optimal tax policies in dynamic contexts, the "new dynamic public finance", assumes that agents take into account the relationship between current taxes and future social security contributions throughout the life cycle (see e.g. Kocherlakota, 2010). Our finding, namely that agents respond to forward-looking incentives built in the pension formula, underscores the validity of this crucial assumption.

A few papers study the responses to changes in the minimum pension age or eligibility requirements at younger ages using survey data (Jean-Olivier et al., 2010; Carta and De Philippis, 2019). Our focus here is different since we focus on the link between social security contributions and benefits. Furthermore, we also use here administrative data on universe of taxpayers, which allows us to implement a regression discontinuity design. The closest to our paper is Bovini (2019) who studies labor supply responses of 46-56 years old individuals to the introduction of the NDC in Italy using administrative data. Bovini (2019) estimates the combined effect of changes in pension wealth, tightening the contribution benefit-link and the lengthening of the reference period over which earnings were computed. Even though the findings in Bovini (2019) are in line with ours, a key advantage of our study is that we can identify the effect of the contribution-benefit link separately from the impact of pension wealth. As a result, our findings directly evaluate the efficiency gain coming from tightening the contribution-benefit link.

Our paper is also related to the literature studying the impact of taxes on labor supply. A large strand of the literature treats income taxes and social security contributions in the same way, assuming that they each create the same type of tax wedge between market work and leisure (see e.g. Blundell et al., 1998; Barro et al., 1986; Carey and Rabesona, 2003; Kleven, 2014; Mendoza et al., 1994; Ohanian et al., 2008). Disney (2004) provides cross-country evidence supporting the view that such simplification is misleading, and that public pension contributions are not a tax on employment per-se. In line with this, we find here that a fundamental pension reform that changes the link between benefits and contributions indeed affects labor supply. Other related papers study the economic incidence of payroll taxes (see Bozio et al. (2019), Gruber and Krueger (1990) and Melguizo and González-Páramo, 2013 for reviews). Instead of studying employment responses like in the current paper, this literature mainly focuses on wage responses, which is a function of labor demand and labor supply elasticities. In our set-up, wages around the discontinuity are unlikely to be affected as employers face considerable constraints on discriminating between employees based on the pension system.[7] As a result, our empirical strategy directly identifies the effect of forward-looking pension incentives on labor supply, which can be used for understanding the efficiency loss or gain from tightening the contribution-benefit link.

The remainder of the paper is structured as follows. Section 2 presents a simple framework conveying the key idea of how to measure changes in incentives. Section 3 presents the details of the 1999 reform and introduces the datasets we use. In Section 4 we assess the changes in the contribution-benefit link which arose as a result of the reform. Section 5 presents the RDD empirical strategy, Section 6 presents the results of our estimation exercise. Finally, Section 7 concludes.

[7] We confirm that there is no impact on wages using a supplementary survey on the Structure of Earnings.

2 A Simple Framework

Taxes and social security contributions (SSCs) affect the net return to work and thereby labor supply. Nevertheless, SSCs and other payroll taxes differ from standard income taxes because the individual payments are often linked to future benefits (Browning, 1975). This linkage, if recognized by the individual, impacts the distortions resulting from SSCs.

In this section we devise a framework for considering the labor supply response to switching from a DB scheme to an NDC scheme. Define w_{it} as individual i's wage at age t, and τ is the tax wedge on labor income, which is equal to the sum of the personal income tax, τ^{pi}, and the social security contribution rate τ^{ss}. The net return to work (relative to staying out of the labor force with zero income) under the pension scheme $k = \{DB, NDC\}$ is:

$$(1 - a^k\tau) \times w_{it} = (1 - \tau^{pi} - \tau^{ss}) \times w_{it} + d \cdot E_t(PV_{it}^{\text{Employed}_t,k} - PV_{it}^{\text{Not employed}_t,k}) \qquad (1)$$

where a^k reflects the (perceived) link between today's contribution and future benefits. This link is expressed as the change in (expected) present discounted value of (expected) pension entitlements, $E_t(\Delta PV_{it}^k) = E_t(PV_{it}^{\text{Employed}_t,k} - PV_{it}^{\text{Not employed}_t,k})$, resulting from working at age t under the pension scheme $k = \{DB, NDC\}$, holding constant future labor supply. In the next section, we discuss in detail the two pension schemes and how the reform changed the present value arising from working at age t. The value of d shows how much agents value that change in present value of pension entitlements relative to current income. d might be less than 1 if households do not fully value future benefits because they are borrowing constrained or myopic. It might also be less than 1 if households are not fully informed of their pension incentives. For simplicity, we now assume that $d = 1$. In Section 6 we explore how various values of d affect our estimates.

Our reform switched the pension system from a defined benefit to a defined contribution scheme and so it changed the link between today's contribution and future benefits, a^k. We study the impact of this policy change on the extensive margin elasticity, formally,

$$\eta^P = \frac{\Delta Pr(P_t = 1)/Pr(P_t = 1)}{\Delta(1 - a\tau)/(1 - a^{DB}\tau)} \qquad (2)$$

where $\Delta Pr(P_t = 1) = Pr(P_t = 1|NDC) - Pr(P_t = 1|DB)$ represents the employment change coming from changing the contribution-benefit link, and $\Delta(1 - \tau a)$ represents the change in the net of tax return to work from switching from DB to NDC.

The reform we study led to both changes in incentives and pension wealth. In our analysis below we will focus on employment changes of groups who had similar drops in pension wealth, but different changes in the return to work. In the empirical section we discuss our empirical strategy on how to isolate the effect of changes in incentives from the changes in wealth effect.

Our definition of the extensive margin elasticity is closely related to the standard formula. The main difference here is that the variation in the net return to work is coming from the change in the link, a^k, and not from the change in the tax rate which was held constant. Because there was no change in tax rates from the reform, the change in net return to work can be written as follows (assuming $d = 1$):

$$\Delta(1 - a\tau)w_{it} = d \cdot (E_t(\Delta PV_{it}^{NDC}) - E_t(\Delta PV_{it}^{DB}))$$

The percentage change in the net return to work is given by the following formula:

$$\frac{\Delta(1 - a\tau)}{(1 - a^{DB}\tau)} = \frac{d\cdot(E_t(\Delta PV_{it}^{NDC}) - E_t(\Delta PV_{it}^{DB}))}{(1-\tau^{pi}-\tau^{ss})\times w_{it} + d\cdot E_t(\Delta PV_{it}^{DB})} \tag{3}$$

This measure calculates the "implied" percentage change in net return to work coming from the pension reform. We will use the above formula to assess the effect of the reform on incentives to work. The key of this formula is the change in (expected) present value coming from working at age t, $E_t(\Delta PV_{it}^{k})$, in pension scheme k. In the next section we describe the new and old pension schemes and the institutional details. Then we turn to our calculation of the present value.

3 Institutional setup and data

3.1 Institutional setup

The 1999 Polish pension reform. The 1999 pension reform in Poland introduced NDC pensions for those born after 31st December 1948. Those born in 1948 or earlier retained the DB scheme previously in place. In the new system, a virtual account was opened for every individual and a record of all subsequent contributions to this account was kept by the Polish Social Security Administration, named ZUS[8]. These contributions predominantly go into funding current pension expenditures on a pay-as-you-go basis, as before. As a result, the new system can be described as a *notional* defined contribution system[9]

Importantly for our empirical strategy, the date-of-birth discontinuity is sharp only for men. For women, the new system was introduced gradually. For instance, only 20% of the pension for women born in 1949 would come from the notional DC account, and gradually increasing amounts for each subsequent cohort. Only cohorts of women born in 1954 or after get their benefit fully under the new rules. Due to the gradual introduction of the NDC system by year of birth for women, we focus on

[8]Polish name: Zaklad Ubezpieczen Spolecznych.

[9]The reform also gave the option to accumulate some of the contributions in capital funds managed by private pension funds. Those born between 1949 and 1969 could choose to either accumulate all of their contributions in the state-managed notional or 38% in a private fund and 62% in the notional account. The default option was opting out from the private fund, and the government suggested that those who are older than 45 years (40 years for women) at the time of the reform should not take the risk of opting in. As a result, 93% of the cohort born in 1948 chose to accumulate all their contributions in the state-managed notional account Leifels et al., 2010. In the paper, we assume that all workers are fully enrolled in the notional account.

men, for whom 100% of the pension for those born in 1949 would come from the notional DC account.

DB Benefit formulae. The way past contributions translate into current pensions is very different between the DB and NDC systems. In the old DB system, pensions are a function of two key variables: (1) the number of years an individual made contributions into the retirement system and (2) the ratio of the individual's salary to the average salary in the economy averaged over a subset of years of the individual's work history. An allowance is made for certain cases when an individual was not contributing, such as being on disability benefit, in higher education, maternity leave or sickness leave – periods known as "non-contributory years". Overall, at the age 65 monthly benefit for individual i is calculated according to the formula:

$$b_{i65} = \bar{y}_{65}(1-\tau^{ss})\big(0.24 + \ 0.013 \cdot c_i \cdot aime_i + \ 0.007 \cdot n_i \cdot aime_i\big) \tag{4}$$

where $\bar{y}_{65}$is the average monthly salary for everyone in the economy in the year when the beneficiary turns 65, c_i is the number of contributory years on retirement, and n_i is the number of non-contributory years. Spells of unemployment are counted as contributory years if unemployment insurance benefit is received. Here, we will refer to $c_i + n_i$ as "total accrued years". The variable $aime_i = \frac{1}{\#\text{best}_i}\sum_{j\in\text{best}_i}\frac{y_{ij}}{\bar{y}_j}$ is "Average Indexed Monthly Earnings": i.e. the average of the ratios of the individual's annual earnings y_{ij} relative to the economy's average annual earnings of the employed in individual i's best_i years. The best years are either of two periods, which the individual can choose: the best 10 consecutive years out of the last 20 prior to retirement or, on request, the 20 best years taken from the whole insurance period. Because individual earnings are divided by average economy-wide earnings when constructing $aime_i$, and this amount is then multiplied by the economy's annual earnings when constructing benefits, the DB formula contributions in "best" years are implicitly indexed by average earnings growth.

NDC Benefit formulae. Under the new NDC system, the formula for the pension is a much more direct link between past contributions and the monthly pension amount b_{65} at retirement age of 65. The formula is:

$$b_{i65} = A_{i65}^{NDC}/(E[T|t=65]) \tag{5}$$

where A_{i65}^{NDC} is the value accumulated in the notional account at 65, and $E[T|t=65]$ is remaining life expectancy at the retirement age, measured in months. In the NDC system, capital in the notional account is accrued according to the following formula:

$$A_{it+1}^{NDC} = A_{it}^{NDC} \cdot (1 + r_t^{NDC}) + \tau^{ss} \cdot y_{it+1} \tag{6}$$

where $(1 + r_t^{NDC})$ is the uprating factor on the hitherto accumulated capital and $\tau^{ss} = 0.1952$ is the social security contribution rate. The uprating factor at the time of the reform was CPI inflation and 0.75 times the growth in real aggregate earnings in the economy.[10]

[10]Specifically:

$$(1 + r_t^{NDC}) = \frac{P_{t-1}}{P_{t-2}} + 0.75 \cdot \left(\frac{WageBill_{t-1}}{WageBill_{t-2}} - \frac{P_{t-1}}{P_{t-2}}\right) \tag{7}$$

where $\frac{P_{t-1}}{P_{t-2}}$ is the rate of increase of the CPI in the year preceding indexation, and $WageBill_{t-1} = \bar{y}_{t-1} \cdot$ number of workers in the economy_{t-1} is the total revenue collected by the social security administration in the year preceding uprating. Unlike the DB formula, therefore, a fall in the total level of contributions coming from a fall in

It can be seen that under the old DB system the impact of a given level of contributions depends on a number of factors: whether an individual is in their chosen best 10 consecutive or best 20 overall years of earnings relative to others in the economy before retirement, and on how high the *aime* component is relative to the progressive formula. In the NDC system, on the other hand, a given level of contributions feeds directly into the accumulated amount A_{it}^{NDC} in a given period.

Starting capital in the NDC system. Since the reform took effect on 1st January 1999, and affected individuals born in 1949 onwards, many of those affected would have made significant contributions under the old system and expected to retire under the old rules. Moreover, for a given history of earnings the new system was less generous than the old system. As compensation, such individuals were given starting capital in their notional accounts, calculated out of their past contributions.[11] The starting capital amount was designed so that those born just before and just after Dec. 31, 1948 would have similar benefit amounts.

Contribution rates. The contribution rate to the pension system remained the same between the DB and the NDC system, at 0.1952 of the earnings bill up to the cap. For those on employment contracts, half of these contributions were paid by the employer, and half were paid by the employee. The self-employed paid a lump sum of contributions, equivalent to those paid by an employee earning the minimum wage. These contribution rates were paid up to a cap of 2.5 times average full time earnings in the economy.

Information. The reform was widely discussed and highly publicized at the time in Poland. The policymakers were concerned with informing those affected as to the reform's consequences for their pensions. Indeed, the reform required that each participant in the new NDC system received annually, by the end of March, information on their capital account balance. Moreover, the authorities would provide an estimate of the monthly pension value under different assumptions about the retirement age (Chlon et al., 1999).

Exceptions. While most men born on or after 1st January 1949 faced the new notional DC system, there were some important exceptions. For instance, a large number of workers who operated in occupations outside of the main state social security system were excluded. These included: farmers, the military, police, judges, teachers and rail workers. Also excluded were those in so-called "special occupations". This category included occupations deemed to involve physically demanding conditions in sectors such as: mining, energy, metallurgy, construction, logging, transport, the health sector, glass production, artists and journalists. All individuals born on or after 1st January but before 1st January 1969 in this category were entitled to retirement based on old rules. Using the HBS data, we estimate that the fraction of employed people who were in special occupations was 8%. Although we

the number of workers in the economy would result in lower indexation of past contributions, even if average earnings in the economy remained constant. In the Appendix we document that for the years 2000-2003, which are the focus of this study, the uprating factors were similar in both systems.

[11] The formula used was very similar to the DB pension formula: equation $\mathrm{b}_{i50}^{start} = 0.24 \cdot \bar{y}_{50} \cdot p_{i50} + 0.013 \cdot c_{i50} \cdot aime_{i50} \cdot \bar{y}_{50} + 0.007 \cdot n_{i50} \cdot aime_{i50} \cdot \bar{y}_{50}$ where $c_{i50}, n_{i50}, aime_{i50}$, are the number of contributory years, non-contributory years, and Average Indexed Monthly earnings at the time of the reform, which was age 50 for the cohort we study, and p_{i50} had the role of increasing starting capital with a weighted average of age and total accrued years at the time of the reform: $p_{i50} = \sqrt{\frac{50-18}{65-18} \cdot \frac{n_{i50}+c_{i50}}{25}}$. Starting capital was then calculated as $A_{i50}^{NDC} = b_{i50}^{start} \times E[T|t = 62]$, where $E[T|t = 62]$ is remaining life-span at 62.

are unable to observe whether someone belonged to the excluded sector in our administrative data, we estimate the proportion of individuals in these sectors using our survey data. To calculate our estimated elasticity in equation (2), we adjust the employment probability $Pr(P_t = 1)$ to represent the probability of being employed but not in a special occupation.[12]

Minimum pension. In the period under consideration, all men were eligible for the minimum pension if they had at least 25 accrued years. For those born after 1949, there was also a requirement to have reached the normal retirement age (65 for men) to obtain the minimum pension. The level of this pension, which is the same for those both in the old and the new system, is set by statute every year by the government, and is increased by at least the CPI growth rate.[13] Thus the realized pension benefit would be the greater of the minimum and the benefits described in equations (4) and (5) for the DB and NDC schemes, respectively.

Other relevant institutional features. Individuals were eligible for pre-retirement allowance from age 60 if the termination of employment was caused by the employer. The benefit value was 90% of a hypothetical pension calculated using the DB scheme rules as if the person was retiring that day. In 2002 the age threshold was reduced to age 55, which was in turn repealed in 2004 and so it went up again to age 60. As a result, individuals who were born in 1948 and were 55 years old in 2004 were eligible for the pre-retirement allowance, but individuals who were born in 1949 and who only reached age 55 in 2005 were not eligible anymore. This created a large discontinuity in eligibility for the pre-retirment allowance between the 1948 and the 1949 cohorts from 2004 onwards. To make sure our estimates do not capture this policy change in the pre-retirment allowance, we only use years between 2000 and 2002 in our analysis.

3.2 Data

Our data consists of the entire population of anonymized income tax records filed in Poland in the years 2000-2003.[14] The information in the administrative data includes date of birth, gender, marital status, residence[15], as well as their reported income from employment, self-employment, real-estate

[12]The percentage change in employment in the definition in equation (2) can be obtained by dividing our estimate of the employment response of the reform by the fraction of those who are in employment and not in special occupations:

$$\frac{\Delta Pr(P_t = 1|T)}{Pr(P_t = 1|T)} = \Delta Pr(P_t = 1) \times \frac{1}{Pr(T = 1)} \times \frac{1}{Pr(P_t = 1|T)} = \Delta Pr(P_t = 1) \times \frac{1}{Pr(T = 1 \cap P_t = 1)}$$

where $T = 1$ denotes belonging to the group affected by the reform, and $\Delta Pr(P_t = 1)$ is our estimated employment response. According to the 1999 reform, special occupations were those which gave an individual the option to retire by 2006. To calculate the fraction $Pr(T = 1 \cap P_t = 1)$ of individuals who are in employment and not in special occupations in the years we study, 2000-2002, we find the fraction of those who retired between 2000-2002 and 2006 using the HBS data, and exclude this from the fraction employed in 2000-2002.

[13]The minimum pension is different to the guaranteed component of the DB pension. In our simulations, we find that the minimum pension applies to a very small fraction of men. Recent data from the Polish Social Securities Administration confirm this is borne out in practice. Not more than 2.7% of male pensioners in 2019 received the minimum pension. Source: https://www.zus.pl/documents/10182/39637/Struktura+wysokości+świadczeń+wypłacanych+przez+ZUS+po+waloryzacji+w+marcu+2019+rpdf/a269a76a-636c-aab6-7a4b-f174bef6f207.

[14]For estimating wage processes, we use the full data range 2000-2013.

[15]If an individual did not file taxes in a given year, we have access to the region they were most recently formally registered in, as well as the previous region in which they filed taxes.

transactions and capital gains. We also have access to the population register in Poland, which we can merge into the data. As a result, we can identify for each member of the population whether he/she filed a tax return. Our measure of employment is an indicator for whether employment or self employment income is greater than 0.

4 The Reform Effect on the Net Return to Work

In this section, we show how moving from a DB to an NDC system changed work incentives. As it is clear from the outline of the two pension systems above, the specific impact on incentives likely depends on the details of individuals' earnings history, and in particular on their history of contributions and whether or not they were experiencing one of the "best" 10 or 20 years of earnings in the period preceding retirement.

Figure 1 highlights this intuition by showing the change in replacement rate from working at a given age under both the DB and NDC scheme. The top panel is for an individual with a hump-shaped wage profile that peaks in his early 50s, whereas the right panel is for someone with a relatively flat wage profile. As we described in Section 3, the age 65 pension benefit depends on an individuals' earnings, y_{it} relative to aggregate earnings $\bar{y}_t$. As a result, in both panels we express wages relative to the average earnings in the economy (left axis). To construct the change in replacement rate from working, we first calculate their pension benefit assuming that the individual works up to 65 in *all years but one*. Next, we calculate their pension benefit assuming that the individual works in *all years* up to 65. We use the DB benefit formula (equation 4) and the NDC formula (equation 5) to calculate the change in the benefit level at age 65, $b_{i65}^{\text{Employed}_t,k} - b_{i65}^{\text{Not employed}_t,k}$ resulting from not working at a given age t. We normalize these changes in benefit to the last annual earnings before retirement, which gives us the change in the replacement rate.

The figure shows that the percent increase in NDC pensions parallels the wage profile regardless of the shape of the wage profile. On the other hand, because the DB scheme uses only wage income in the best 10 consecutive years in these examples, the increase in benefits from working is very small in all years but the 10 highest wage years. However, in those best 10 years, the percent increase in benefits is potentially very large if wages in the 10 best years are much higher than at other ages. This highlights a key difference between DB and NDC schemes: both schemes provide work incentives, but at different ages. The DB scheme provides incentives to work in a narrow set of ages, whereas the NDC scheme provides weaker incentives, but at all ages.

These hypothetical examples highlight the crucial role of modeling the earnings profile and incentives throughout the life cycle. We will assess the labor supply response to these incentives using the simple framework developed in Section 2. The key step for that is to calculate the change in present discounted value of pension entitlements coming from working versus not working at a given age. There are many conceivable ways to compute the change in pension entitlements. Here we closely follow the key assumptions used in the existing literature (e.g. Attanasio and Rohwedder, 2003):

- We use the entitlements that people will have acquired by the time they retire according to the current legislation. We take into account any reforms and future uprating rules that have been legislated up to the time of observation. We assume that people expect the current legislation to persist.

- We assume perfect foresight about the key variables in the pension formula such as wage growth, interest rates, etc. when computing future expected benefits.

- We assume that, when forming their expectations, people take their current residence as given and fixed.

- We account for uncertainty about longevity by applying survival probabilities to each period considered in the computations. The maximum attainable age is fixed at 100.

- We calculate lifetime earnings profiles that are needed to compute entitlements separately for various groups defined by residence using earnings information from 15 years of cross sectional data. We also take into account that agents face unemployment risks, where that risk is calculated using the labor force survey. We describe the details of this procedure below.

- We assume that the age at which individuals expect to retire is the official state pension age, currently 65 and 60 for men and women, respectively.

These assumptions lead to the following formula where the change in present discounted value can be expressed as:

$$E_t(\Delta PV_{it}^k) = \frac{1}{\prod_{j=t}^{65}(1+r_j)} \sum_{s=65}^{T_{death}} S_{s|t} \left(\prod_{j=65}^{s} \left(\frac{1+r_j^{index}}{1+r_j} \right) \right) (b_{i65}^{\text{Employed}_t,k} - b_{i65}^{\text{Not employed}_t,k}), \quad (8)$$

where $S_{s|t}$ is the probability of being alive at age s conditional on being alive at age t, $1+r_j$ is the risk free interest rate at age j (and thus $1\frac{}{\prod_{j=t}^{65}(1+r_j)}$ discounts benefits earned at time s to time t.), $1+r_j^{index}$ is the yearly indexation of pensions that occurs after age 65, and $(b_{i65}^{\text{Employed}_t,k} - b_{i65}^{\text{Not employed}_t,k})$ is the difference in benefits between working and not working at age t under the pension scheme k.

The change in (expected) present value of pension benefits has the following components. First, working at age t might increase age 65 pension benefits by $b_{i65}^{\text{Employed}_t,k} - b_{i65}^{\text{Not employed}_t,k}$, which depends on the life cycle income and the pension formula. Second, once the change in benefit at age 65 is calculated, we need to take into account that pensions are indexed by $1+r_j^{index}$ each year. Third, the change in pension benefits is only received if the agent is still alive. As a result, the present discounted value depends on the probability of being alive at age s conditional on being alive at age t. Finally, all these future payouts should be discounted to the present at age t using the risk free interest rate $1+r_j$.

It is relatively straightforward to calculate the change in pension entitlements coming from working at age t in the NDC system. Combining equations (5) and (6) yields[16]

$$b_{i65}^{\text{Employed}_t,NDC} - b_{i65}^{\text{Not employed}_t,NDC} = \frac{\prod_{j=t}^{65}(1+r_j^{NDC})}{E[T|t=65]}\tau^{ss}\cdot w_{it} \tag{9}$$

Since $S_{s|t} = S_{s|65}S_{65|t}$ for $s \geq 65$, we note that $\sum_{s=65}^{T_{death}} S_{s|t} = S_{65|t}\sum_{s=65}^{T_{death}} S_{s|65} = S_{65|t}E[T|t=65]$. Using this, and combining equations (8) with (9) yields

$$\begin{aligned} E_t(\Delta PV_{it}^{NDC}) &= \frac{1}{\prod_{j=t}^{65}(1+r_j)}\sum_{s=65}^{T_{death}} S_{s|t}\left(\prod_{j=65}^{s}\left(\frac{1+r_j^{index}}{1+r_j}\right)\right)\frac{\prod_{j=t}^{65}(1+r_j^{NDC})}{E[T|t=65]}\tau^{ss}\cdot w_{it} \\ &= S_{65|t}\left(\prod_{j=t}^{65}\left(\frac{1+r_j^{NDC}}{1+r_j}\right)\right)\sum_{s=65}^{T_{death}} S_{s|65}\left(\prod_{j=65}^{s}\left(\frac{1+r_j^{index}}{1+r_j}\right)\right)\frac{\tau^{ss}\cdot w_{it}}{E[T|t=65]} \end{aligned} \tag{10}$$

Although the equation is complex, it is easy to see that the expected present value is a function of some key parameters of the economy and the pension system such as interest rate, indexation etc. Furthermore, if $r_j = r_j^{NDC} = r_j^{index}$ for every j and $S_{65|t} = 1$ then $E_t(\Delta PV_{it}^{NDC}) = \sum_{s=65}^{T_{death}} S_{s|65}\frac{\tau^{ss}\cdot w_{it}}{E[T|t=65]} = \tau^{ss}\cdot w_{it}$ and so the NDC system would be an actuarially fair system: the paid contribution at age t would be received back in expectation. Nevertheless, the new NDC scheme's parameter values set by the Polish government were such that working at a given age k yields a smaller increase in pension entitlements than what an actuarially fair system would imply.

Understanding the incentives in the DB system is more complicated as it depends on whether year t is a high earnings year. Furthermore, so far we have abstracted away from the minimum pension in the NDC system. To assess the change in pension benefits across the whole population, we will simulate earnings profiles for individuals around the discontinuity (aged 49-50 on 1st January 1999) and calculate the change in their pension entitlements under both the DB and NDC systems.

Given the heterogeneity in wages, different individuals will have peak wages at different ages. Furthermore, individuals face stochastic wage and unemployment risks, which can affect the individuals' top earnings in the DB formula. As a result, instead of simply focusing on deterministic earnings profiles like in Attanasio and Brugiavini (2003), Attanasio and Rohwedder (2003), and Lachowska and Myck (2018), here we also take into account that earnings have a stochastic component. We estimate the earnings process in the following way. In the first step, we assess the process for annual wages, w_{it}, and simulate wage histories. In the second step we model unemployment risk and the employment choices individuals make.

Earnings are equal to the offered wage w_{it} if working (P_{it}=1) and are 0 if not working ($P_{it} = 0$):

$$y_{it} = \begin{cases} w_{it} & \text{if} \quad P_{it} = 1 \\ 0 & \text{if} \quad P_{it} = 0 \end{cases}. \tag{11}$$

[16] This formula is for individuals for whom the minimum pension is not binding. In our simulations we account for this additional complication.

Wages are assumed to consist of a deterministic and a stochastic component:

$$\log w_{it} = \mathbf{x}_{it}^T \beta + \eta_{it} + \omega_{it} \tag{12}$$

where $\mathbf{x}_{it}$ consists of a fourth order polynomial in age, a linear time trend, region, and region interacted with the time trend. The time trend controls for aggregate wage growth. The regional time trends capture geographic variation in wage growth, that is relevant for when in the lifecycle an individual's top earnings years occur. We found that our estimated age profile and regional time trends are robust to controlling for a full set of time dummies, which would perfectly control for aggregate income.

It is noteworthy that we do not control for cohort effects in the regression above, since our goal is to measure income of an individual at a point in time relative to other members of the economy at the same point in time. Our goal is not to compare wages at different points in his life, which is what we obtain when we control for cohort but not time. As we noted previously, pension benefits are calculated using individual earnings relative to other members of the economy at a point in time.

The variable $\omega_{it} \sim N(0, \sigma_\omega^2)$ is iid and the stochastic component η_{it} evolves according to an AR(1) process:

$$\eta_{it} = \rho \eta_{i,t-1} + \varepsilon_{it}, \qquad \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2). \tag{13}$$

while the component ω_{it} evolves according to an MA(1) process:

$$\omega_{it} = \xi_{it} + \theta \xi_{i,t-1}, \qquad \xi_{it} \sim N(0, \sigma_\xi^2). \tag{14}$$

The parameters of the age polynomial and time trend are estimated from the administrative data for the years 2000-2013 for men between ages 21-64. We estimate $\rho, \theta, \sigma_\varepsilon^2, \sigma_\omega^2$ using a minimum distance estimator, matching the variance-covariance matrix of earnings. We estimate $\rho = .949$, $\theta = -.235$ and $\sigma_\varepsilon^2 = .059$, $\sigma_\xi^2 = .027$. [17] We construct $b_{i65}^{\text{Employed}_t,k}$ by simulating lifetime earnings, assuming that the individual is in the labor force in all periods and faces the unemployment risk estimated in the data. We construct $b_{i65}^{\text{Not employed}_t,k}$ by simulating lifetime earnings as before, but assuming that the individual is not working in period t. In our calculations we take into account all the details discussed in the institutional section including the starting capital and the minimum pension.

In order to exploit that variation in incentives depending on the shape of the earnings profile, we exploit the individual variation in earnings growth which depends on the wage trends in the local labor markets.[18] Specifically, we divide regions in the data into those with below and above-median earnings growth in the years 2000-2013. We then estimate the age and time-trend parameters in the earnings process above separately for the two types of regions.

In Figure 2, we plot the fraction of individuals in our simulations who are in one of their best-10 or best-20 years at a given age, for low and high-growth regions separately. It can be seen that at ages 51-54 individuals in high-growth regions were more likely to be experiencing one of their best years

[17] We also estimate a Markov process of unemployment spells from the Polish Household Budget Survey and incorporate the transition probabilities in our simulations.

[18] Unfortunately, we cannot use gender differences as the reform was phased in more gradually for women and we do not observe education in the administrative data.

than those in the low-growth regions. Accordingly, their incentives to work at these ages under the DB system will be greater in high-growth regions than in low-growth regions. By contrast, individuals in low-growth regions are more likely to have experienced one of their best years at younger ages, and so their incentives to augment their DB pension by working are correspondingly smaller.

Figure 3 shows the percentage change in net return to work (see equation 3 derived in Section 2) for an average individual in high-growth and low-growth regions between ages 50-54. In high-growth regions, where the best years are more likely to fall in that age range, we see a 4% reduction in the net return to work. On the other hand, in low-growth regions we see that the net return to work in fact increased by around 2% according to our simulations.

Nevertheless, our simulations also reveal that pension wealth dropped by around 18% at the discontinuity and the size of this drop was similar at low-growth and high-growth regions. To isolate the effect of incentives from this change in wealth, we will focus on the difference between high and low-growth regions. In the next section we will study whether the labor supply responses are in line with the changes in incentives. Later we will also explore whether the changes in incentives and the employment responses line up in a more disaggregated regional-level analysis.

5 Empirical strategy

To identify the effect of the reform on labor supply we exploit the sharp discontinuity created by the cohort-based nature of this reform. We apply a regression discontinuity design (RDD) where we compare individuals who were born a few weeks from each other, but face a different pension scheme from age 50. More specifically we follow Lee and Lemieux (2010) and estimate the following regression equation:

$$P_{it} = \alpha_t + \beta_t \cdot \mathbf{1}\{z_i < 50\} + f(z_i) + \varepsilon_{it} \tag{15}$$

where P_{it} equals to 1 if the individual i has positive earnings at time period t and z_i is the age of the individual on 1st January 1999 (when the reform was introduced). Those individuals who were younger than 50 years old at the time of the reform, $\mathbf{1}\{z_i < 50\}$, were ushered into the new NDC scheme, and so β_t assesses the impact of switching from the NDC to the DB pension scheme. In some specifications, we allow the coefficients in the RDD to vary for different years, hence the t subscripts for the regression coefficients. We follow Lee and Lemieux (2010) and estimate two separate regressions of $f(z_i)$ on each side of the cutoff point. We report estimates with linear regressions and with kernel-weighted local linear regressions using a triangular kernel.

In our RDD, the running variable is birth date which was determined many years before the policy change. Therefore, manipulation in the forcing variable is not possible. Still studying the histogram of the date of birth for the 1947-1950 cohorts reveals that there is a spike which occurs on the 1st of January of every year (Panel A of Figure 4). This is likely to reflect a reporting decision, where in the absence of hospital births in these years there was leeway for some parents to report the date of birth of their choosing. Since the 31st December/1st January cutoff is also the cutoff for enrollment in school, some parents strategically reported their children as being falsely born at the beginning of the calendar year so that their child would be among the oldest in the class when they started school. Although this behaviour is unrelated to the pension reform, some characteristics of these switchers may be correlated with the labor-market outcomes we care about.

To deal with this issue we also report estimates relative to the observed discontinuity in the placebo cohorts, where we see a similar spike on January 1st, but the reform should have no effect on behavior. Furthermore, we also report estimates where we exclude individuals born during the first 5 days of 1949 and the last two weeks of 1948. This is sometimes known as a "donut hole" regression-discontinuity design, and has been used in other instances of systematic bunching around the cutoff (see e.g. Almond and Doyle, 2011; Barreca et al., 2011).

A histogram where we exclude individuals immediately around the discontinuity is presented in Panel B of Figure 4. As we expect, the resulting distribution is smooth and stable across years.

6 Results

Extensive margin responses. We begin by showing our baseline RDD results for the employment response to the pension reform. In Figure 5 we show the average employment rates over the years 2000-2002 by each birth month around the reform discontinuity. In the figure, we line up birth cohorts by the age of the individual on January 1st 1999, at the time of the introduction of pension reform. Therefore, as we move along the x-axis we show employment to population rate of older cohorts. The red vertical line shows the threshold age/cohort for which the new rules applied. Cohorts that were younger than 50 years old on January 1st 1999 were ushered into the new NDC scheme, while older cohorts stayed in the old DB system.

We exclude individuals born right around the discontinuity so we apply a "donut hole" RDD. We also plot the lines of best fit for both the individuals below the age cutoff and those above the discontinuity, as well as the 95% confidence intervals. The downward slope of these lines in age reflects the tendency for employment rates to fall with age in the latter part of the life-cycle. As can be seen, employment rates for men aged 50 in Poland were around 50% in the period under consideration.

Since our simulations in Section 4 suggested that incentives changed differently for individuals in high-growth and low-growth regions, we report estimates separately for the high and the low earnings growth regions. Panel A shows around 1.5 percentage point or 3 percent drop in the employment rate as a result of switching to the NDC scheme (left to the vertical red line). This is in line with the 6 percent decrease in these individuals' net return to work (shown in Figure 3). Nevertheless, the change in employment might also reflect the 18% drop in pension wealth.

In Panel B of Figure 5, we also show the RDD result for the low-growth regions. In these regions, we do not find a significant difference between the DB and NDC cohorts. If anything, there is a slight increase in employment rate which is in line with the increase in net return to work shown in our simulations.

Panel A of Table 1 presents the corresponding RDD results based on equation 15. We report the estimates of β_t, which show the effect of being in the younger cohort that switched from DB to NDC. The estimated effects are reported for the high and the low-growth regions and we also calculate the difference between the two types of regions with the corresponding standard errors. The first column presents results from a specification including the whole sample of the two cohorts born around the reform discontinuity. The subsequent three columns show the "donut hole" RDD estimates where we drop individuals born in the 5 days immediately to the left of the age 50 discontinuity and those born in the 2 weeks immediately to the right of it. The differences between Column 1 and the donut hole RDD estimates are small, suggesting that our results are robust to including individuals bunching right around December 31st.

Columns 2-3 explore alternative assumptions on the functional form of the running variable, $f(z)$, which is estimated separately on both sides of the discontinuity. In Column 2 we estimate a linear specification, while in Column 3 we estimate a local linear polynomial, with a bandwidth of 150 days. In this latter specification we apply Calonico et al. (2014) to estimate bias-corrected robust confidence intervals. The estimates in the two specifications are very similar to each other. Moving from DB to NDC leads to a 1.4 (s.e. 0.2) percentage point decrease in employment at high-growth regions and a 0.3 (s.e. 0.4) percentage point increase in low-growth regions.

As we discussed above, the change in employment in high-growth and low-growth regions shows the combined effect of the wealth change and the change in net return (incentive effects). Nevertheless, since the change in pension wealth was similar in high and low-growth regions, the difference in employment change between high and low-growth regions reflects the change in incentives net of any wealth effect. The difference-in-differences estimate in the last row of Panel A suggests that high-growth regions experienced a 1.7 (s.e. 0.6) percentage point drop in employment relative to low-growth regions.

We conduct a series of placebo tests to ensure that our estimates capture the effect of the reform and not something else. Figure 6 plots employment rates around a placebo discontinuity in high and low-wage growth regions, in Panel A and Panel B respectively. For our baseline placebo, we select the cutoff between those aged 48 and 49 at the time of the reform (i.e. those born in the years 1949 and 1950), again in the years 2001-2003, such that they are observed at the same age as the treatment cohorts in 2000-2002. This is important to consider if there are any age effects. Similarly to the main estimates, we exclude individuals right at the discontinuity, i.e. it incorporates the "donut hole". It can be seen that there is no significant difference in employment rates at the placebo discontinuity. There might be a slightly higher employment rate for the older cohort in high-growth regions, but the difference is of an order of magnitude smaller than in the treatment case.

In Figure 7 we also plot a battery of placebo estimates for low and high-growth regions for the cohorts: 1946-1947, 1947-1948, 1949-1950, 1950-1951, alongside our treatment estimates. We also plot the 95% confidence interval for each estimate. We only use individuals observed to be in the age range 51-54, which is the same age range as our treatment cohorts in the years we consider. It can be seen that the treatment estimate for the high-growth regions is statistically significant and large, while all of the placebo estimates for high-growth regions are smaller and statistically insignificant.Out of the four placebo estimates, three are quantitatively much smaller than the treatment estimate, while the slightly larger placebo one in 1946-1947 is quite imprecisely estimated. This estimate is based only on one year of data, as the cohorts 1946-1947 are only observed at the ages 53-54 in one year, namely 2000. By 2001, the cohorts are already older than our treatment cohort and we therefore do not use them as a placebo.

The visual evidence in Figure 6 and Figure 7 is supported by the results in Table 2, which shows the regression results for our placebo tests for the two closest pairs of cohorts: the 1947-1948 and the 1949-1950 ones. We report coefficients for being in the younger of the two pair of cohorts. Estimating the placebo discontinuity for the low-growth regions, we find a 0.13 percentage points reduction for the 1947-1948 cohorts, and 0.14 for the 1949-1950 cohorts, which are in contrast to the small positive effect found around the policy discontinuity (see Table 1). For the high-growth regions, our estimates are again very similar for the 1947-1948 and 1949-1950 cohorts, with a 0.48 and 0.47 percentage reduction respectively predicted for the younger cohort (0.51 reduction if the two pairs of cohorts are combined), which is a whole percentage point smaller than the estimates for the treatment discontinuity. The difference-in-difference estimates between high and low-growth regions are also small and statistically insignificant. These pieces of evidence highlight that the main effects are only found between the cohorts where the policy discontinuity is present and we find no indication for a differential effect in other cohorts.

Nevertheless, in Column 4 of Table 1 we also present our main results relative to the placebo estimates. We use the "placebo" discontinuity between those aged 48 and 49 at the time of the reform. Our estimated impact of NDC on individuals is -1.0 (s.e. 0.3) percentage points in the high-growth regions and 0.3 (s.e. 0.4) percentage points in low-growth regions. The employment change is around 1.2 (s.e. 0.5) percentage points lower in high-growth regions than in low-growth regions. This is very similar to the simple RDD estimates in Column 2 (1.6 percentage points difference). We will use these more conservative estimates in the benchmark analysis when calculating extensive margin elasticities, and report robustness checks with the other estimates.

Intensive margin responses. In Panel B of Table 1, we present the RDD results for observed log-earnings among those reporting positive earnings. These are insignificant and small, and are similar to the placebo estimates in Panel B of Table 2. This suggests that the reform had a limited impact on the intensive margin response.

Implied elasticity. In Table 3 we present the components of the elasticity formula in equation (2) for the two types of regions. Row (1) and (2) show the effect of the reform on net return to work and on incentives. As we explained above, the reform impact on incentives depended on the local economic circumstances. In high-growth regions, working at ages 51-54 was important as the best years fell in that age range. That is why switching to NDC in fact lowered the net return to work by 5.97%. On the other hand, at low-growth regions the earnings at ages 51-54 were less important. The reform in fact increased the net return to work by 2.56%.

Row (2) shows the impact of the reform on pension wealth. As we discussed above, the reform had a relatively large unintended impact on pension wealth. Both the high and the low-growth regions experienced around a 19% reduction on their pension wealth. As a result, our estimates on employment change in high and low-growth regions show the combined effect of changes in pension wealth and changes in net incentives to work. Nevertheless, the difference in pension wealth change between high and low-growth regions is negligible (0.6%), while the difference in incentives still remains significant (8.52%). As a result, the difference-in-differences estimate identifies the effect of the reform on incentives net of wealth effect.

Row (3) in Table 3 reports the percentage change in employment as a result of the reform. We use our net-of-placebo estimates of the percentage point change in Column 4 of Table 1 and divide it by baseline employment rates found at the discontinuity for the older cohort still in the DB system.

Row (4) reports our estimates on the implied extensive margin elasticity for the baseline specification. We divide the employment changes (row 3) by the percentage changes in net return to work (row 1) as it is defined in equation 2. The implied extensive margin elasticity in the high and low-growth regions are 0.37 (s.e.) and 0.26 (s.e.), respectively. Nevertheless, these elasticities reflect the combined effect of the changes in incentives and the reform on the pension wealth.

In the last column we report the elasticity calculated based on the differential response in high and low-growth regions. The estimated elasticity is 0.33 (s.e. 0.09) and statistically significant. Since the differential change in pension wealth was negligible (0.6%), this elasticity estimate captures only the effect of changes in incentives.

The estimated elasticity is comparable to the existing estimates in the literature (see e.g. Chetty et al., 2013 for a review on the elasticity estimates in the literature). The extensive margin elasticity is not a structural parameter, but should be age varying, since older individuals are closer to the retirement margin (Blundell et al., 2016). Most relevant to our analysis are therefore studies which examine the extensive margin elasticities of older workers. For instance, Gruber and Wise (1999) find an elasticity of 0.23 for men aged 59, and Manoli and Weber (2016) an elasticity of 0.25 for workers aged 55-70.[19]

Robustness. Table 4 presents some robustness exercises for the benchmark estimates of the elasticity. Panel A reports the baseline difference-in-differences estimate of the implied elasticity shown in Table 3. Panel B shows the elasticity estimates for various empirical specifications estimating the employment changes caused by switching from DB to NDC reported in Table 1. As we saw in Table 1 the employment changes are slightly higher when we did not estimate them relative to the placebo estimates. In line with this, we find a slightly larger elasticities of around 0.45.

In Panel C we assess the robustness of the results to alternative assumptions made in calculating the changes in incentives and pension wealth. In particular, we explore how the implied elasticities change if we apply alternative earnings processes in our simulations. In the first row, we investigate using an earnings process applying the parametrization estimated in French (2005) using survey data

[19] In referring to our own estimates and those in the literature, we use the definition of an extensive margin elasticity used by Chetty et al. (2013), i.e. the elasticity of employment rates with respect to wages, defined as the percentage change in employment rates divided by the percentage change in net-of-tax wages. In our case, of course, the net-of-tax wage is augmented by the change in the net present value of pension benefits as a result of working, which we refer throughout the text as a net return to work.

from the U.S. While the change in pension wealth is very similar to our benchmark specification, French (2005) implies a slightly higher change in net return to work, and so it leads to a slightly lower implied elasticity estimate (0.22 instead of 0.33 in our benchmark). The second row in Panel C uses simulations where the estimated stochastic component of the wage is an AR(1) process with White Noise, estimated above half of the minimum wage. This specifications leads to an almost identical estimate of the implied elasticity. These estimates highlight that our main results are robust to alternative assumptions made in our simulation of incentives and pension wealth.

In Panel D of Table 4 we assess alternative values of the perception of present value in the formula calculating the change in net incentives (equation 3). In the benchmark analysis, we assume that $d = 1$ and so individuals fully incorporate the change in the net present value of pension entitlements. We explore how the implied elasticity varies when $d = 0.9$, $d = 0.75$, and $d = 0.5$. When the present value change is not fully incorporated, we find that the implied elasticity is somewhat larger. For instance, if a $1 change in present value of pension entitlements is translated to $0.5 of current income, then the implied elasticity is 0.58. As we explained above, this extensive elasticity would be at the higher end of the existing estimates in the literature, which suggests that the Polish seems to value highly the changes in the present discounted value of pension entitlements.

Elasticity estimates by finer regions. Our main estimates so far compared the employment change, the change in incentives and the change in pension wealth between high-growth and low-growth regions. In Figure 8 we assess the changes at at a finer regional level. We calculate pension incentives over 2000 small administrative regions in Poland. Panel A shows that the reform incentives are tightly linked to the growth rate at the local level: the higher the growth rate is, the more negative the change in net return to work is. We also show that the change in wealth is unrelated to the regional growth rate. In Figure 9 we estimate the RDD treatment effect (net-of-placebo) of switching to the NDC system separately for each bin and for each of the years 2000-2002 and plot these estimates against the percent change in net return to work. As it can be seen, there is a definite positive relationship between the change in work incentives as a result of the pension reform and the estimated effect of the reform on employment outcomes. The best fitting line is clearly upward sloping. The slope shows the relationship between the percentage change in employment and the percentage change in incentives and so it is an estimate of the extensive margin elasticity. We estimate that the slope is 0.45 (s.e. 0.25), which is very close to the benchmark 0.33 elasticity. The intercept shows the change in employment when the change to then net return to work is zero. As a result, the intercept shows the wealth effect of the policy. A 18% reduction in pension wealth at age 50 is equivalent to a roughly 6% decline in life-time wealth. Since we estimate that the intercept is 1.3% (s.e. 1.5%), our results imply that the wealth elasticity is -0.22 (s.e. 0.24). Even if this elasticity is quite imprecisely estimated, it is very close to the wealth effect estimated in lottery studies (for instance, Lindqvist et al. (2020) find a wealth elasticity of -0.17). The relatively small wealth effects also suggests that even a substantial cut in pension benefits will have limited impact on labor supply.

Overall, the finer regional-level analysis underscores our benchmark results. The employment changes are linked to the change in incentives, but not to the changes in wealth. The elasticity obtained at the finer regional level is very close to the elasticities obtained from comparing the response in high-growth regions relative to low-growth ones, though the estimates are more imprecise. This highlights that our difference-in-differences estimates are not sensitive to the specific cutoff used to define those regions.

Comparing Incentive Effects To Wealth Effects Finally, it is worth comparing the estimated incentive effects from tightening the link to the impact of cutting overall pension wealth. Both our noisy estimates on pension wealth responses, and the more precise estimates coming from assessing the impact of lotteries on labor supply, suggest that the potential impact of cutting pension benefits will be limited. We found that a 20% reduction of pension wealth led to only a 1.3% drop in employment. This implies that tightening the link between current contributions and future benefits might be a better way to alleviate the distortions than across-the-board cuts in pension benefits.

7 Conclusion

This paper shows that individuals' labor supply is responsive to changes in the way *current* social security contributions are linked to *future* pension benefits. We demonstrate this using the 1999 Polish pension reform, which switched from a defined benefit system to a (notional) defined contribution system. While the new NDC scheme improved incentives over most of the life cycle, for many of the individuals in our sample who were in their 50s the opposite was true. Under the DB scheme the benefit of working between age 51 and 54 was particularly strong for individuals living in high earning-growth regions and weaker in low-growth regions. In line with these changed work incentives, we find a change in employment that implies an employment elasticity with respect to the net return to work (which includes both the wage and the gain in expected pension benefits) of 0.33 (s.e. 0.09).

Our estimates, therefore, indicate that tightening the link between benefits and contributions throughout the life cycle in the NDC system can alleviate the tax burden of financing pensions. Tightening the link between benefits and contributions has been long advocated by pension experts, but so far there was only limited evidence that tightening this link stimulates labor supply. In fact, our estimates imply that the distortions caused by SSCs are substantially lower than those caused by personal income taxes if SSCs are tightly linked to future benefits. Thus, pension reforms are one way to alleviate the tax burden coming from aging populations. Nevertheless, it is worth emphasizing that tightening the link between current contributions and future benefits also increases inequality among pensioners. Balancing issues of efficiency with distributional concerns will be central for policymakers considering such reforms. We hope that our novel estimates of the potential efficiency gains from linking the pension benefits to future benefits will help to assess these trade-offs more precisely.

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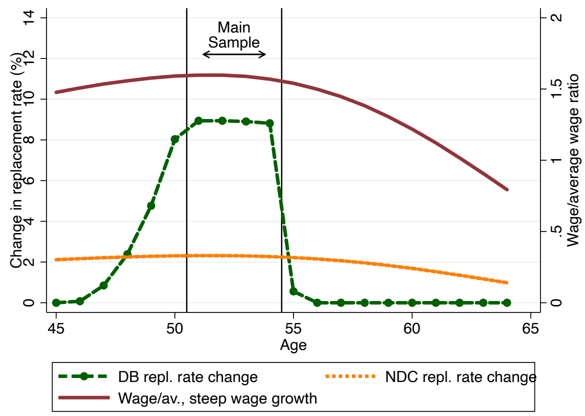
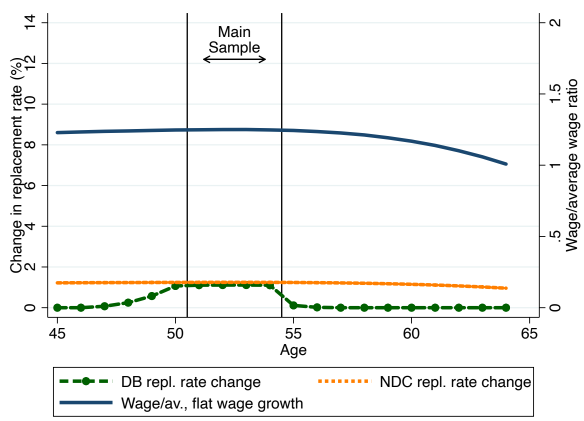
Figures

Figure 1: Incentives under the DB and the NDC Scheme for Different Wage Profiles

A. Hump Shaped Wage Profile

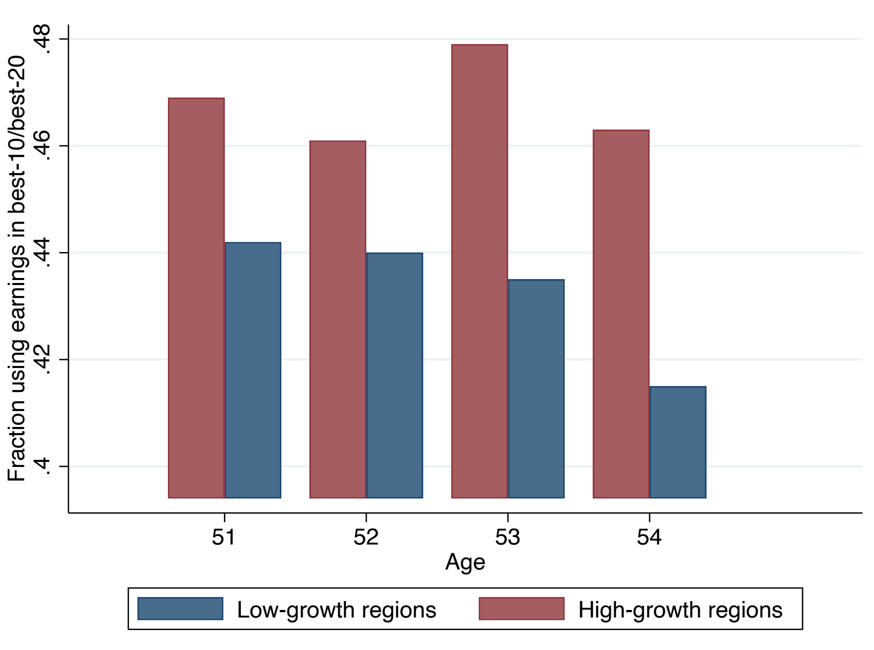


B. Flat Wage Profile



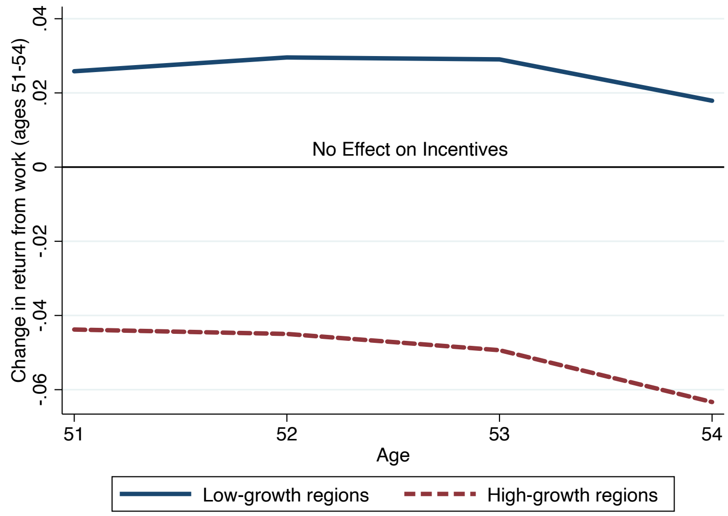
Notes: This figure shows incentives to work change over the life cycle for those facing the DB scheme and for those facing the NDC scheme). We highlight the change in incentives for two hypothetical individuals: one with a hump shaped wage profile (panel A) and one with flat wage profile (panel B). The solid lines (red on panel A and blue on panel B) show a hypothetical individual's annual earnings, y_{it}, relative to the economy's average annual earnings, $\bar{y}_t$ (values shown in the secondary). We express individual earnings in terms the economy's average annual earnings since this is what matters for $aime_i$ in the DB formula (see the text for details). Both panels show the percentage change in the replacement rate of pension benefits at age 65 coming from working at a given age, $(b_{65}^{\text{Employed}_t,k} - b_{65}^{\text{Not employed}_t,k})/y_{i,65}$, under the NDC and DB rules. In both panels we assume that individuals work until retirement age 65 except the age at which the change in employment status occurs.

Figure 2: Fraction of Individuals for whom Earnings at Given Age are Included in their Best Years



Notes: This figure shows the fraction of individuals for whom earnings at given age are included in their best-10 or best-20 years where the Average Indexed Monthly Earnings, *aime*, is calculated under the DB rules. To calculate the *aime* either of two periods is used: either the best 10 consecutive years out of the last 20 prior to retirement or the 20 best years taken from the whole insurance period. The blue bar shows the fraction at regions with low earnings growth, while the red is for regions with high earnings growth. The fraction of individuals is calculated based on our simulations in Section 4. We simulate earnings profiles for 1000 individuals whose wage profile is estimated from the administrative data. Low growth and high growth regions are assumed to have a common polynomial in age and variance of permanent wage shock, but different time-trends in wage growth. The individuals work until the retirement age 65 unless experiencing an unemployment shock driven by a Markov process described in the text.

Figure 3: Average Change in Pension Incentives by Regions

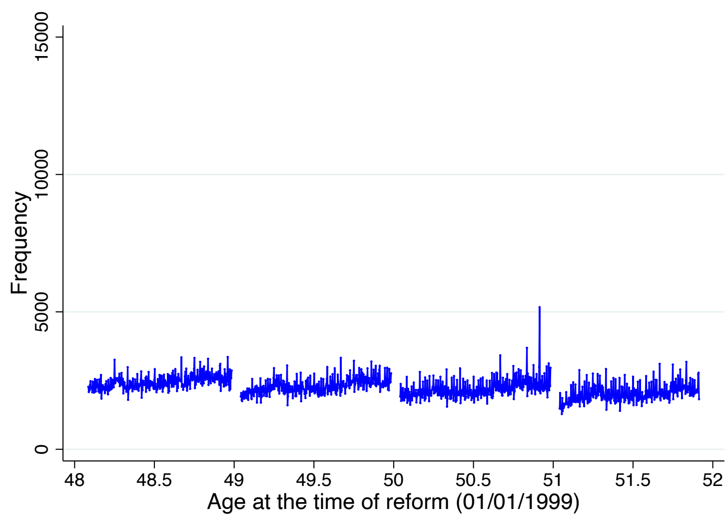


Notes: The graph plots the change in the average net return from working an extra year at a given age as a result of moving from the DB system (i.e. the 1948 cohort), to the NDC system (i.e. the 1949 cohort). The change is calculated using simulations for two groups of 1,000 simulated individuals from the 1948-1949 cohorts. As it is explained in Section 2, the change in net return from work reflects the change in the expected present discounted value of future pensions. The dashed line shows the measure for individuals in regions experiencing above-median earnings growth, while the solid line is for individuals experiencing below-median earnings growth. In the baseline, the individuals are assumed to work at all ages except the age under consideration, unless experiencing an unemployment shock driven by our estimated Markov unemployment process. The change in employment status involves working at the age under consideration.

Figure 4: Histogram of the Date of Birth

Panel A. Without donut hole.

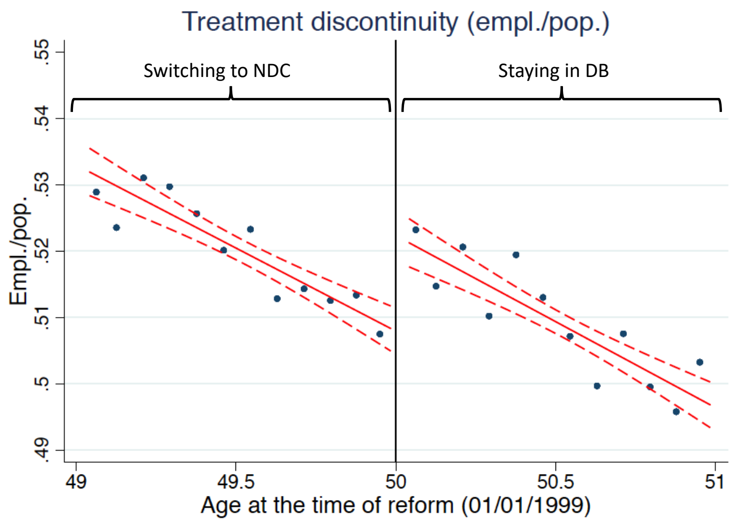
Panel B. With donut hole.



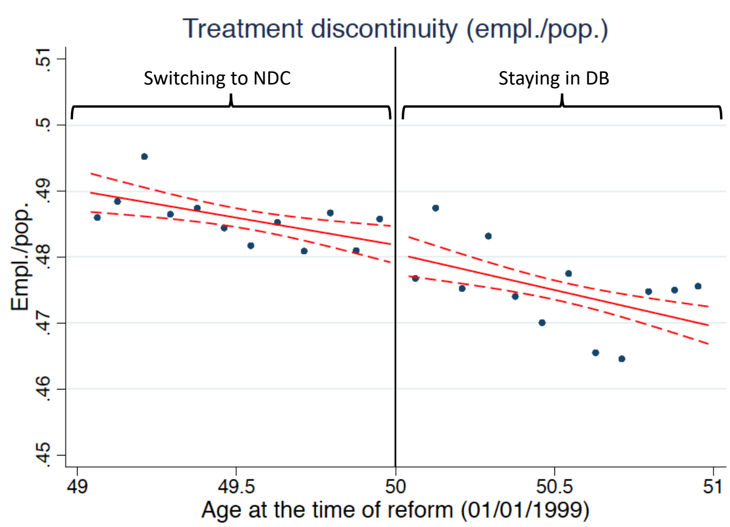
Notes: A histogram of individuals aged 48-52 on 1st January 1949 (born between 1947-1951) is shown. For instance, individuals aged precisely 48 at the time of the reform were those born on 31st December 1950, while those aged 49 were those born between on 31st December 1949, and so on. Panel A shows the raw histogram of people at each age measured to the nearest day. Panel B shows the same histogram excluding individuals born in the last two weeks of each year, or in the first 5 days of each year, i.e. with the “donut” included. Our discontinuity of interest is age 50 at the time of the reform, i.e. between those born on 31st Dec 1948 and 1st Jan 1949.

Figure 5: Effect of the Pension Reform on Employment by Regions

Panel A. RDD plot of employment in high-growth regions (2000-2002).



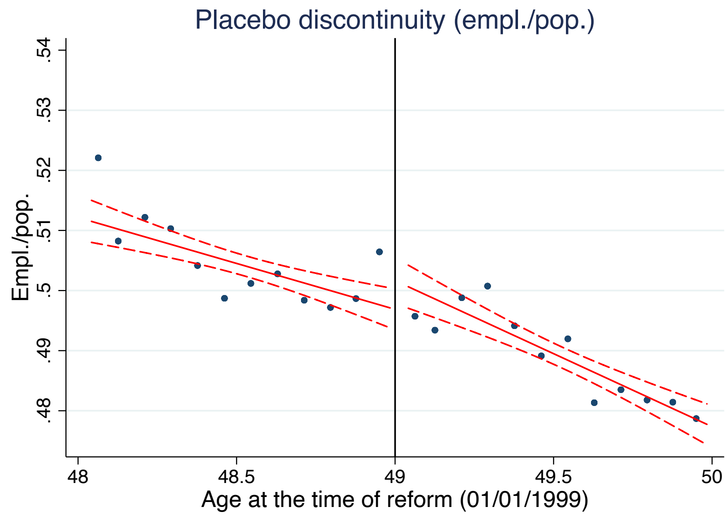
Panel B. RDD plot of employment in low-growth regions (2000-2002).



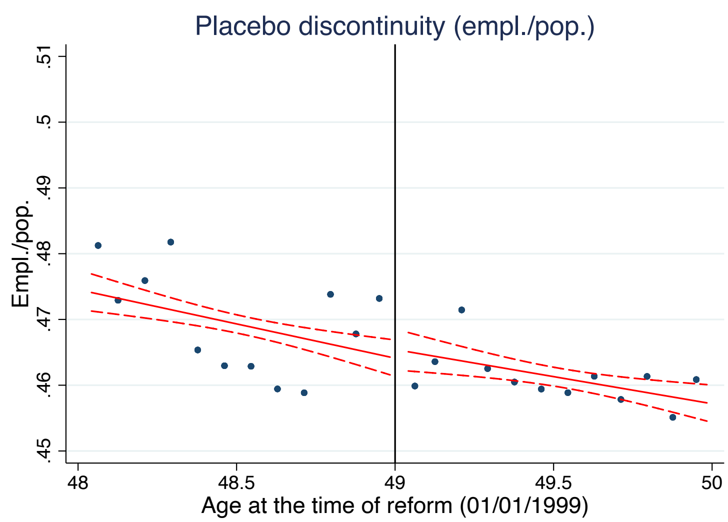
Notes: RDD plot showing the effect on employment in high-growth regions (panel A) and low-growth regions (panel B), for years 2000-2002. We plot the fraction of individuals who have positive earnings by month of birth in each year (measures as the age on 01/01/1999). Individuals younger than age 50 in 01/01/1999 are in the new NDC scheme, while older individuals are in the DB scheme. We exclude those born born on Jan 1-5 1949 and Dec 16-31 1948. The solid lines are OLS lines of best-fit, allowing for different slopes and intercepts on both sides of the cutoff. The 95 percent confidence intervals are also shown. Observations for the years 2000-2002 are pooled.

Figure 6: Placebo Estimates of the Employment Effects by Regions

Panel A. Placebo discontinuity in high growth regions (2001-2003).

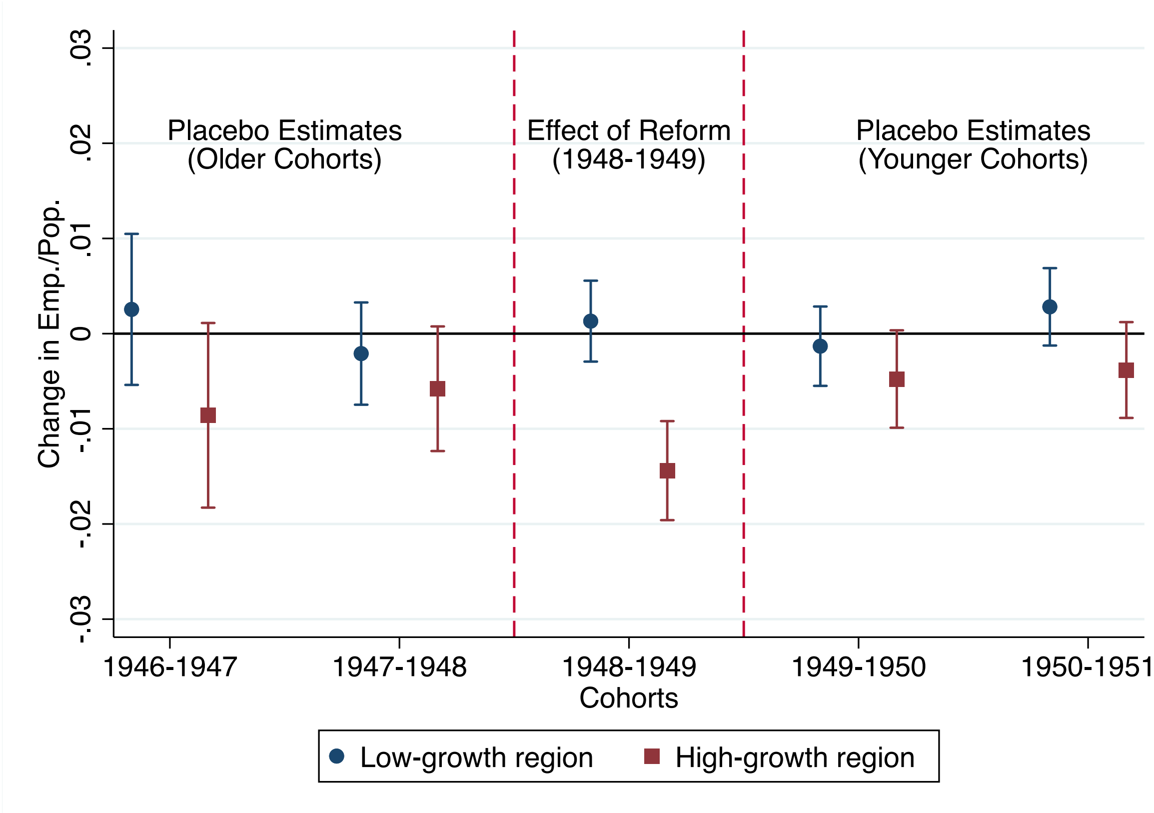


Panel B. Placebo discontinuity in low growth regions (2001-2003).



Notes: Employment rates for men in 2001-2003 at the placebo discontinuity for those aged 48 and 49 at the time of the reform (years of birth 1949-1950) in high-income growth regions (panel A) and low-income growth regions (panel B). The age of the individuals in these cohorts in the years 2001-2003 is the same as the age of the individuals in the cohorts 1948-1949 around the treatment discontinuity in the years 2000-2002. Otherwise, the plots are as in Figure 5.

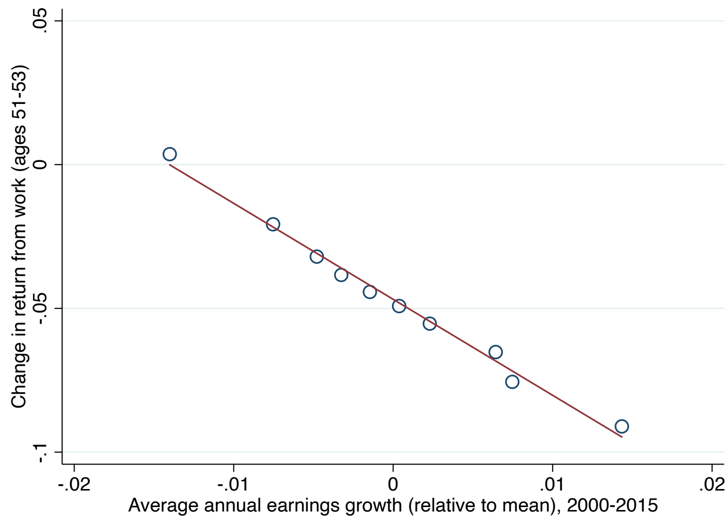
Figure 7: RDD Estimates of Employment Effect for Various Cohorts by Regions



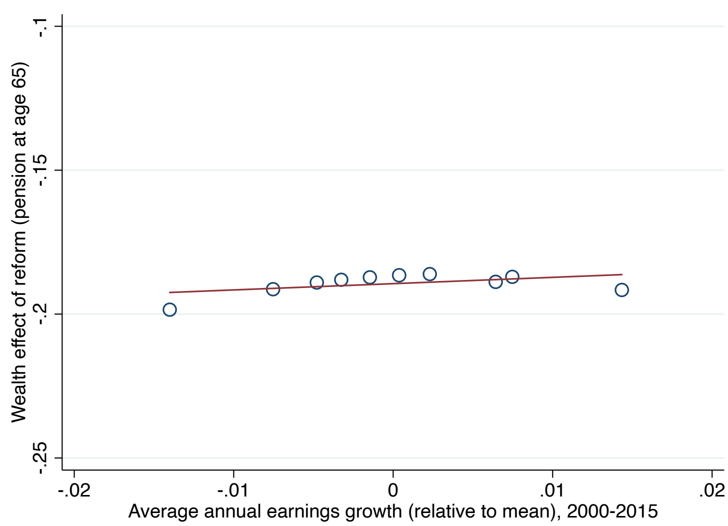
Notes: The figure depicts estimates of differences in employment between various cohorts obtained using the RDD design (see equation 15). The impact of the reform is estimated based on the 1948-1949 cohorts (individuals 50 and 51 years old on January 1st, 1999). The older placebo cohorts are shown to the left and the younger ones to the right. In each case, we estimate the donut RDD with a linear specification. The treatment effect and the younger cohort estimates use individuals in the 51-54 age range. Since we only have data from 2000 onwards, we use individuals aged 53-54 for the 1946-1947 cohorts and 52-54 for the 1947-1948 ones. The blue dots with the 95 percent confidence intervals show the estimates for low-growth regions, while the red squares show the estimates for high-growth regions.

Figure 8: Effect of the Reform on Net Return to Work and on Wealth by Region

Panel A. Reform effect on net return to work by the regional level earnings-growth

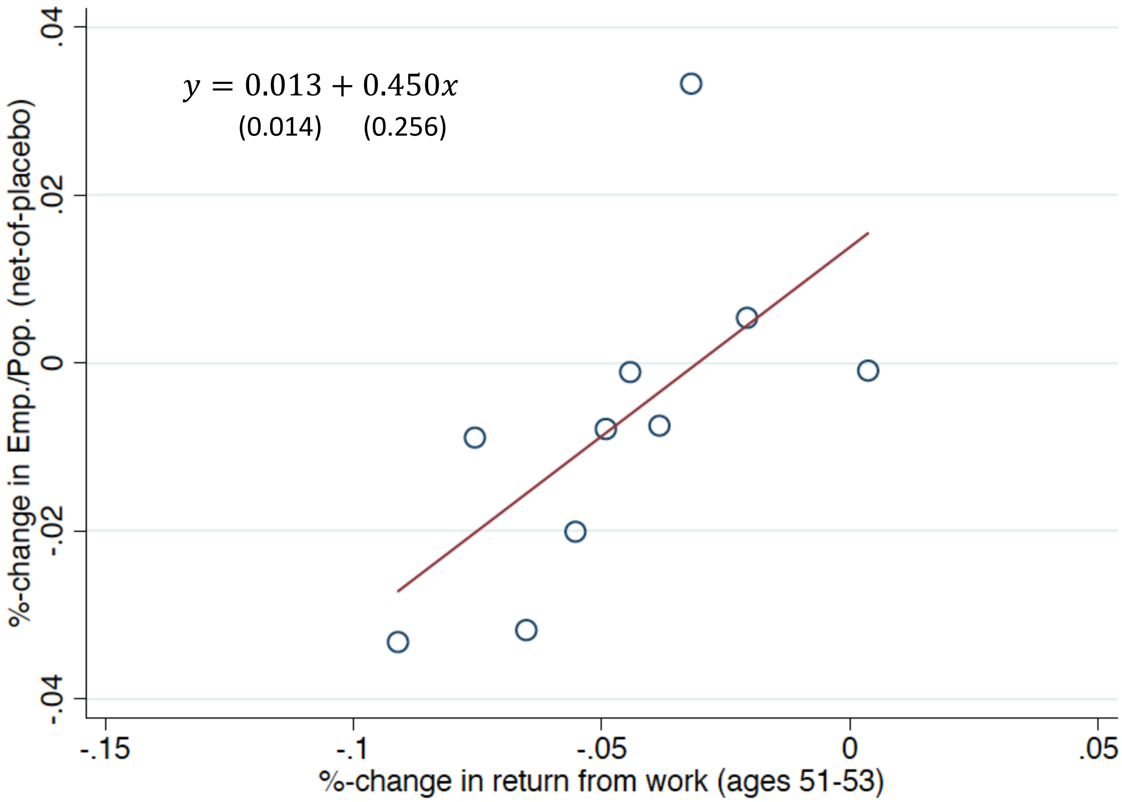


Panel B. Reform effect on wealth by the regional level earnings-growth



Notes: Binscatter plots of the relationship between average annual earnings growth in the regions (relative to average annual earnings growth) and the change in net return to work as a result of the reform (Panel A) and the wealth effect of the pension reform (Panel B). Regions have been grouped into deciles (using population weights) by the size of the change in net return to work at ages 51-53 as a result of the reform. We measure the wealth effect of the reform as the change in the size of the pension an individual receives at age 65.

Figure 9: RDD Estimates of Employment Effect of 1999 Reform and Change in Return to Work as a Result of the Move to the DC System (ages 51-53).



Notes: Binscatter plot of the relationship between the change in return to work as a result of the pension reform, and the estimated effect of the reform on employment. Regions have been grouped into deciles (using population weights) by the size of the change in net return to work at ages 51-53 as a result of the reform. The coefficient of the slope of the line of best fit is significant at the 5% level. The net-of-placebo estimates come from "donut hole" regressions for each individual region for the treatment group (those aged 50 at the time of the reform) minus the estimated employment effect for the placebo group (those aged 49 at the time of the reform).

Tables

Table 1: RDD Coefficient Estimates of Reform Effect (Cohorts 1948-1949)

Income growth region	Full sample	Donut RDD		
	Linear	Linear	Robust	Net-of-placebo
Panel A: Change in employment probability				
High-growth	-0.0188***	-0.0145***	-0.0144***	-0.0096***
N = 586,746	(0.0024)	(0.0027)	(0.0049)	(0.0037)
Low-growth	-0.0010	0.0014	0.0029	0.0026
N = 874,958	(0.0020)	(0.0022)	(0.0040)	(0.0030)
Diff-in-diff (High-Low)	-0.0178***	-0.0159***	-0.0173***	-0.0122***
	(0.0031)	(0.0035)	(0.0063)	(0.0048)
Panel B: Change in log-earned income (only workers)				
High-growth	-0.001	-0.005	-0.015	0.011
N = 313,720	(0.008)	(0.009)	(0.017)	(0.013)
Low-growth	-0.003	0.005	-0.004	0.018
N = 439,545	(0.007)	(0.008)	(0.007)	(0.011)
Diff-in-diff (High-Low)	0.002	-0.010	-0.019	-0.007
	(0.011)	(0.012)	(0.018)	(0.021)

Notes: Donut RDD excludes those born in Jan 1-5 1949 and Dec 16-31 1948. Triangular kernel and 150 BW used for robust estimation. The net-of-placebo estimates use the cohorts 1949 and 1950 to estimate the placebo discontinuity, with the discontinuity in the years 2001-2003 providing the placebo for the treatment discontinuity using the cohorts 1948-1949 in the years 2000-2002. For the net-of-placebo estimates, a donut exclusion is employed for both the placebo and the treatment estimates. The number of observations given is for the more restrictive Donut RDD specification. The final row reports the difference in estimated employment effects of the reform between the high-growth and low-growth regions. In panel B, the dependent variable is the logarithm of earned income, conditional on an individual receiving positive earned income in a given year. Standard errors in parentheses.

Table 2: RDD Coefficients for Placebo Estimates (Cohorts 1947-1948, 1949-1950)

Income growth region	1947-1948	1949-1950
Panel A: Change in employment probability		
High-growth	-0.0048*	-0.0047*
	(0.0027)	(0.0026)
N	586,746	647,453
Low-growth	-0.0013	-0.0015
	(0.0027)	(0.0021)
N	874,958	985,468
Diff-in-Diff (High-Low)	-0.0035	-0.0032
	(0.0038)	(0.0032)
Panel B: Change in log-earned income (only workers)		
High-growth	-0.012	-0.022
	(0.010)	(0.009)
N	290,184	336,404
Low-growth	-0.011	-0.014
	(0.008)	(0.007)
N	405,578	474,907
Diff-in-Diff (High-Low)	-0.001	-0.008
	(0.013)	(0.011)

Notes: All specifications are Donut RDD, which excludes those born in Jan 1-5 and Dec 16-31 in each cohort, and which uses the linear model in the forcing variable. The placebo estimates are all estimated in years 2000-2002.

Table 3: Elasticity Estimates

Region type	High-growth	Low-growth	Diff-in-diff (High-Low)
(1) Change in net return to work (%)	-5.97	2.56	-8.52
(2) Change in pension wealth (%)	-18.4	-19.0	0.06
(3) Change in employment (%)	-2.20	0.66	-2.85
	(0.76)	(0.85)	(0.80)
Implied elasticity (3) / (1)	0.37	0.26	0.33
	(0.13)	(0.33)	(0.09)

Notes: Implied elasticity is calculated using equation (2). The percent change in the net return to work as a result of the reform is calculated using the formula in equation (3), derived in Section 2, as well as the simulations presented in Section 4. To calculate the percentage change in employment, we use the net-of-placebo estimates in Table 1 and the observed employment rates at the discontinuity in the DB cohort. Standard errors in parentheses.

Table 4: Elasticity Estimates under Different Specifications

Region type	Change in net return to work (%)	Change in net wealth (%)	Change in empl. (%)	Implied elasticity
Panel A: Baseline				
Baseline	-8.52	-0.6	-2.85	0.33
			(0.80)	(0.09)
Panel B: Estimation methods				
Linear (full sample)	-8.52	-0.6	-4.05	0.48
			(0.52)	(0.06)
Linear (donut RDD)	-8.52	-0.6	-3.67	0.43
			(0.58)	(0.07)
Robust (donut RDD)	-8.52	-0.6	-4.03	0.47
			(1.06)	(0.12)
Panel C: Simulations of incentives				
AR(1) earnings (from French (2005))	-12.70	-0.4	-2.85	0.22
			(0.80)	(0.06)
AR(1) + WN earnings	-8.66	-0.4	-2.85	0.33
			(0.85)	(0.09)
Panel D: Perception of present value				
$d = 0.9$	-7.14	-0.6	-2.85	0.35
			(0.80)	(0.10)
$d = 0.75$	-5.91	-0.6	-2.85	0.42
			(0.80)	(0.12)
$d = 0.5$	-4.18	-0.6	-2.85	0.58
			(0.80)	(0.16)

Notes: All estimates in this table are in differences between high-growth regions and low-growth regions. In calculating the present value of pension benefits, realised indexation, uprating and interest rates were used. The estimation methods in Panel B are those listed in the first three columns of Table 1. In other Panels, the net-of-placebo estimates from Table 1 were used. The first row in Panel C is the elasticity calculated using simulations assuming an AR(1) process and the parameterization found in French (2005), estimated on earnings above minimum wage. The second row in Panel C uses simulations where the estimated stochastic component of the wage is an AR(1) process with White Noise, estimated above half of the minimum wage. In all other rows, we assume our baseline stochastic component, which is an AR(1)+MA(1) process estimated on administrative data. The coefficient d refers to the parameter which reflects the weighting of the present value of pension benefits in the current return from work in equation (1), where d is the weighting placed on future benefits. Standard errors in parentheses.