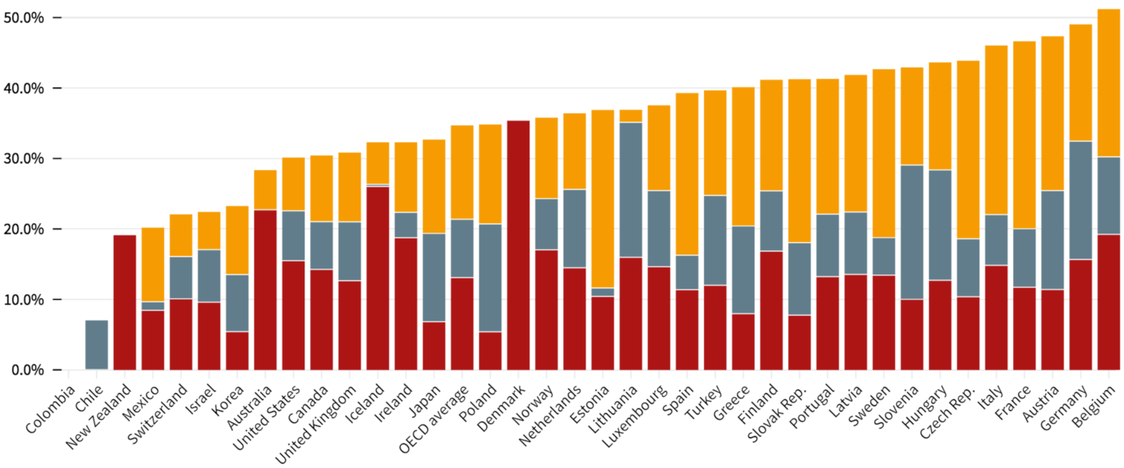
Online Appendix A Additional Figures and Tables

Figure A.1: Tax Wedge for Average Single Worker Across OECD Countries



Notes: The figure shows taxes as percentage of labor costs for the average single worker across OECD countries in 2020. The red bars refer to income tax, the gray bars to employee's social security contributions and the orange bars to employer's Social Security contributions. In Colombia, the single worker at the average wage level did not pay personal income taxes in 2020, and their contributions to pension, health, and employment risk insurances are considered to be non-tax compulsory payments (NTCPs) and therefore are not included as taxes in the Taxing Wages calculations. Source: Taxing Wages 2021 (which can be accessed at http://oe.cd/taxingwages).

Figure A.2: Polish Social Security Authority (ZUS) Annual Letter to those in NDC Scheme

ZUS

Informacja o stanie konta ubezpieczonego
w Zakładzie Ubezpieczeń Społecznych

III. Suma na Twoim koncie i subkoncie

1. Konto	294 601,34 zł
2. Subkonto	31 501,06 zł
Razem:	**326 102,40 zł**

IV. Składki należne i wpłacone (bez waloryzacji)

Subkonto:

1. Składki należne - czyli te, które wynikają z dokumentów przysłanych do ZUS	9 193,67 zł
2. Składki wpłacone na subkonto	9 193,67 zł

Otwarty fundusz emerytalny:

1. Składki należne - czyli te, które wynikają z dokumentów przysłanych do ZUS	18 400,19 zł
2. Składki odprowadzone do otwartego funduszu emerytalnego	18 400,19 zł

V. Hipotetyczna (prognozowana) wysokość Twojej emerytury

Twój wiek emerytalny to 65 lat

Emerytura obliczona na podstawie konta

Podajemy ją w dwóch wariantach:

Wiek, w którym przejdziesz na emeryturę	**Wariant I** Pracujesz do emerytury i składki wpływają średnio w tej samej wysokości co do tej pory	**Wariant II** W 2019 roku przestajesz pracować i do emerytury nie wpływają już nowe składki
65 lat	1 718,99 zł	1 348,91 zł

Ważne! Jeśli przekroczyłeś wiek emerytalny i nie masz jeszcze ustalonej emerytury, to jej prognozowaną wartość podajemy dla Twojego rzeczywistego wieku oraz dla kolejnych pięciu lat.

Emerytura obliczona na podstawie konta i subkonta

Podajemy ją w kolejnych wariantach:

Twój wiek emerytalny	**Wariant III** Pracujesz do emerytury i na konto i subkonto wpływają składki średnio w tej samej wysokości co do tej pory	**Wariant IV** W 2019 roku przestajesz pracować i do emerytury nie wpływają już nowe składki na konto i subkonto
65 lat	1 964,96 zł	1 493,14 zł

Ważne! Pamiętaj, że na 10 lat przed Twoim wiekiem emerytalnym środki z OFE będą co miesiąc wpłacane na Twoje subkonto w ZUS. Przy prognozie emerytury nie uwzględniliśmy tego, co masz jeszcze w OFE.

Co dają Ci ubezpieczenia społeczne już teraz

Ubezpieczenia społeczne poza emerytalnym obejmują także:

- ubezpieczenie chorobowe,
- ubezpieczenie wypadkowe,
- ubezpieczenia rentowe.

Ważne! Dzięki nim możesz uzyskać jednorazowe, okresowe lub stałe świadczenia w razie choroby, urodzenia dziecka i rodzicielstwa, wypadku przy pracy, niepełnosprawności, niezdolności do pracy.

Na Platformie Usług Elektronicznych na www.zus.pl możesz sprawdzić, jakim ubezpieczeniom podlegasz.

Świadczenia, które Ci przysługują, jeśli masz ubezpieczenie chorobowe

Zasiłek chorobowy w razie niezdolności do pracy z powodu choroby

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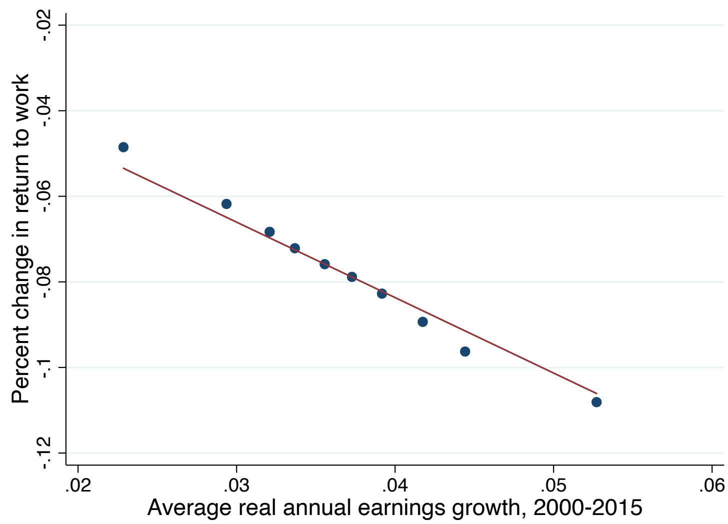
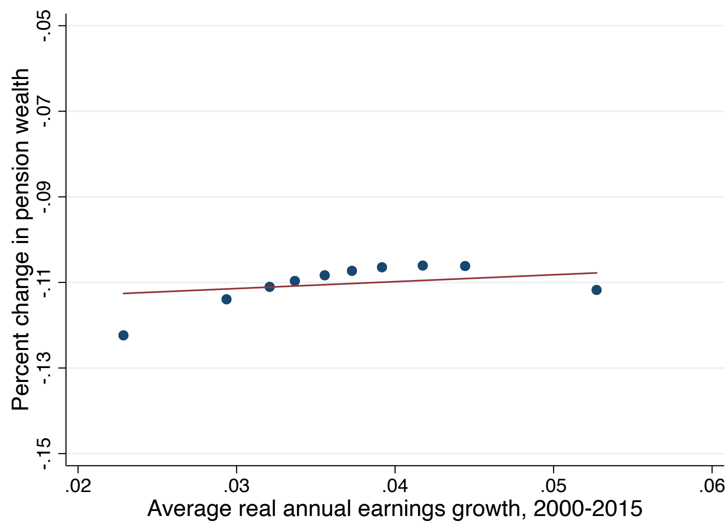
Notes: An example of the annual letter sent to all individuals in the NDC system after the 1999 reform. It states the total accumulated funds in the notional account, the retirement age of the individual, and the anticipated pension at age 65 under two scenarios: 1) working until retirement age at current earnings level and 2) stopping work in the current year and not making further contributions to the NDC account.

Figure A.3: The Percent Change in Work Incentives and Pension Wealth Across Locations



(a) Percent change in net return to work by the earnings growth in the local area



(b) Pecrent change in pension wealth by the earnings growth in the local area

Notes: This figure shows the non-parametric bin-scattered relationship between the percent change in net return and the average annual earnings growth (panel A) and between the percent change in pension wealth and the average annual earnings growth (panel B) across 2000 local areas. The annual earnings growth for each locations is calculated between 2000-2013 and we subtract the average annual earnings growth in Poland. We group the 2000 administrative local areas to 10 equally sized bins based on their annual earnings growth and we compute the annual earnings growth in the given bin (x-axis). The average percent change in incentives is shown (y-axis) in Panel (a), while the average percent change in pension wealth is shown in Panel (b).

Table A.1: Employment Rate for Men at Various Ages in the Administrative Data, Labor Force Survey and Household Budget Survey, 2000-2002.

	(1)	(2)	(3)	(4)	(5)
	Non-Agricultural Empl./Pop.		Total Empl./Pop.		Unempl./Pop.
	Admin. Data	LFS	LFS	HBS	LFS
1. Age 51 (cohorts: 1949-1951)	0.51	0.52	0.65	0.66	0.11
Number of Observations	890,620	5,141	5,141	2,299	5,054
2. Age 51-54 (cohorts: 1948-1949)	0.49	0.48	0.60	0.61	0.10
Number of Observations	1,669,539	9,485	9,485	4,254	9,410
3. Age 21-64 (cohorts: all)	0.56	0.56	0.68	0.68	0.12
Number of Observations	11,662,286	64,143	64,143	30,959	63,539
4. Age 50-54 (cohorts: all)	0.50	0.52	0.65	0.63	0.09
Number of Observations	3,907,140	7,771	7,771	10,811	7,678

Notes: This table compares the estimated employment rate for men in our administrative data with the employment rates in representative household surveys using the years between 2000 and 2002. Row 1 reports the employment to population rate for those who were 51 years old between 2000 and 2002, row 2 for those who were between 51 and 54 years old and born around the discontinuity (the 1948 and 1949 cohorts) and row 3 for those who were between age 21 and 64. We focus on non-agricultural employment as we do not observe agricultural employment in the administrative data. Note that agricultural workers belong to a separate pension system and are unaffected by the pension reform. Column (1) reports total non-agricultural employment divided by the total population for all males. Column (2) reports the same using the Labor Force Survey (LFS), the largest household study in Poland that provides the official measures of employment and unemployment. Columns (3) and (4) calculate total employment (including agricultural workers) divided by the total population in the LFS and Household Budget Survey (HBS) for the different age groups.

Table A.2: The Effect of the Pension Reform on Employment And Wages, Robustness to Bandwidth Choice of the Local-Linear Regression

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Change in employment probability						
High-growth	-0.0174***	-0.0263**	-0.0208***	-0.0153***	-0.0155***	-0.0209***
N = 545,435	(0.0050)	(0.0130)	(0.0067)	(0.0041)	(0.0036)	(0.0058)
Low-growth	0.0027	0.0085	0.0032	0.0001	0.0004	0.0040
N = 818,487	(0.0041)	(0.0106)	(0.0055)	(0.0034)	(0.0029)	(0.0061)
Difference (High-Low)	-0.0201***	-0.0348***	-0.0240***	-0.0154***	-0.0159***	-0.0249***
	(0.0065)	(0.0168)	(0.0087)	(0.0053)	(0.0046)	(0.0084)
Panel B: Change in log wage						
High-growth	0.0119	0.0867*	0.0093	0.0073	-0.0012	0.0118
N = 545,435	(0.0174)	(0.0459)	(0.0233)	(0.0144)	(0.0125)	(0.0251)
Low-growth	0.0029	0.0117	0.0063	-0.0093	-0.0119	0.0135
N = 818,487	(0.0145)	(0.0378)	(0.0194)	(0.0120)	(0.0105)	(0.0260)
Difference (High-Low)	0.0090	0.0750	0.0030	0.0166	0.0107	-0.0017
	(0.0226)	(0.0595)	(0.0303)	(0.0187)	(0.0163)	(0.0361)
Sample	Donut	Donut	Donut	Donut	Donut	Donut
$f(z_i)$	local-linear	local-linear	local-linear	local-linear	local-linear	local-linear
net-of-placebo	no	no	no	no	no	no
Bandwidth	150	50	100	200	250	Calonico et al.

Notes: This table shows robustness of the local-linear regression estimate (shown in Column 3 in Table 1) for various choices of the bandwidth, measured in days, on each side of the discontinuity. We show the estimated change in employment (panel A) and log wage (measured as earned income of workers) for those in work (panel B) at the reform discontinuity. Each cell in the table shows the β coefficient of the RDD specification in equation (15). The rows show the estimated employment change for different regions. The first and second row show the estimated effect in high and low-growth regions, respectively. High-growth regions are regions with above median earnings growth rate between 2000 and 2013, while low-growth regions have below median growth. The third row shows the difference between the high and low-growth regions. In each column we report a kernel-weighted local linear regression, where we set the bandwidth at different levels. In Column (1) we set the bandwidth at 150 days as in Table 1. In Columns 2-5 we apply values of bandwidth between 50 and 250 days. Column (6) chooses bandwidth according to the methodology in Calonico et al. (2014), and it is 87 days for the low-growth and 120 days for the high-growth regions. In each column we apply the donut hole RDD specification where we exclude those born between December 16th and January 5th. We report robust standard errors in parentheses following the recommendation in Calonico et al. (2014). Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.3: The Effect of the Pension Reform on Employment And Wages, Robustness to Donut Size

	(1)	(2)	(3)	(4)
Panel A: Change in employment probability				
High-growth	-0.0149***	-0.0105***	-0.0145***	-0.0073
N = 545,435	(0.0026)	(0.0037)	(0.0031)	(0.0044)
Low-growth	-0.0018	0.0014	-0.0027	0.0022
N = 818,487	(0.0023)	(0.0030)	(0.0025)	(0.0036)
Difference (High-Low)	-0.0131***	-0.0119***	-0.0119***	-0.095**
	(0.0035)	(0.0048)	(0.0040)	(0.0056)
Panel B: Change in log wage				
High-growth	-0.0055	0.0095	-0.0196*	-0.0007
N = 313,720	(0.0092)	(0.0130)	(0.0108)	(0.0153)
Low-growth	-0.0043	0.0176	-0.0210**	0.0215*
N = 439,545	(0.0077)	(0.0109)	(0.0091)	(0.0128)
Difference (High-Low)	-0.0012	-0.0081	0.0014	-0.0222
	(0.0120)	(0.0170)	(0.0141)	(0.0199)
Sample	Donut (base.)	Donut (base.)	Donut (Jan-Dec)	Donut (Jan-Dec)
$f(z_i)$	linear trend	local-linear	linear trend	local-linear
net-of-placebo	no	yes	no	yes

Notes: This table shows robustness to the change in the size of the donut in the benchmark regression specification (shown in Table 1). The table shows the estimated change in employment (panel A) and log wage (measured as earned income of workers) for those in work (panel B) at the reform discontinuity. Each cell in the table show the β coefficients of the RDD specification shown in equation (14) (Column 1 and 3) or in equation (15) (Column 2 and 4). The rows in Panel A show the estimated employment change for different regions. The first and second row show the estimated effect in high- and low-growth regions, respectively. High-growth regions are regions with above median earnings growth rate between 2000 and 2013, while low-growth regions have below median growth. The third row shows the difference between the high- and low-growth regions. In Column (1) and (2) we apply the benchmark donut hole RDD specification where we exclude those born between December 16th and January 5th. In Column (3) and (4) we apply a broader donut hole where we exclude everyone who was born in January or December. In Columns (1) and (3) we estimate a linear trend in birth date allowing for different slopes and intercepts at either side of the cutoff. In Column (2) and (4) we estimate a kernel-weighted local linear regressions, where we set the bandwidth at 150 days. Column (2) and (4) estimates the change at the reform discontinuity relative to the change at the placebo discontinuity as in equation (15). The placebo discontinuity is estimated between the 1949 and 1950 cohorts, both of which switched to the NDC system. We report robust standard errors in parentheses. For the local-linear regressions we calculate robust standard errors following Calonico et al. (2014). Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.4: Placebo Estimates on Employment and Wages

	(1)	(2)	(3)
	men	men	women
	1947-1948	1949-1950	1948-1949
Panel A: Change in employment probability			
High-growth	-0.0058	-0.0043	0.0043
	(0.0033)	(0.0026)	(0.0036)
N	395,819	647,006	1,349,940
Low-growth	-0.0018	-0.0004	-0.0000
	(0.0027)	(0.0021)	(0.0029)
N	590,418	977,555	2,002,716
Difference (High-Low)	-0.0040	-0.0039	0.0043
	(0.0043)	(0.0033)	(0.046)
Panel B: Change in log wage			
High-growth	-0.013	-0.016	0.004
	(0.011)	(0.009)	(0.013)
N	290,184	314,948	598,753
Low-growth	-0.007	-0.022*	0.016
	(0.010)	(0.008)	(0.011)
N	281,750	445,816	859,847
Difference (High-Low)	-0.001	-0.008	-0.012
	(0.015)	(0.012)	(0.017)
Sample	Donut	Donut	Donut
$f(z_i)$	linear trend	linear trend	linear trend
net-of-placebo	no	no	yes

Notes: This table shows the estimated change in employment (panel A) and log wage (measured as earned income of workers) for those in work (panel B) at three "placebo" discontinuities. Each cell in the table shows the β coefficients of the RDD specification shown in equation (14). Column (1) shows the employment and wage change between two cohorts (those born in 1947 and 1948), neither of whom were impacted by the reform, Column (2) shows between two cohorts (born in 1949 and in 1950) who were both impacted by the reform, while Column (3) shows the employment and wage change for women between two cohorts (those born in 1948 and 1949, net of placebo), who were much less affected by the reform at the net discontinuity. We estimate a linear trend in birth date allowing for different slopes and intercepts at either side of the cutoff. We also apply the donut hole RDD specification where we exclude those born between December 16th and January 5th. We report robust standard errors in parentheses. Significance levels are: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A.5: The Effect of the Pension Reform on Employment And Wages, by Employment and Self-Employment

	(1)	(2)	(3)	(4)	(5)
Panel A: Change in employment probability					
High-growth	-0.0204***	-0.0156***	-0.0175***	-0.0098***	0.0005
N = 545,435	(0.0024)	(0.0026)	(0.0050)	(0.0037)	(0.0018)
Low-growth	0.0013	0.0048	0.0038	0.0056*	-0.0033
N = 818,487	(0.0020)	(0.0021)	(0.0040)	(0.0030)	(0.0015)
Difference (High-Low)	-0.0217***	-0.0204***	-0.0213***	-0.0154***	0.0038
	(0.0031)	(0.0033)	(0.0064)	(0.0048)	(0.0023)
Panel B: Change in log wage					
High-growth	-0.014*	-0.016*	-0.011	-0.001	0.061
N = 313,720	(0.008)	(0.009)	(0.016)	(0.012)	(0.042)
Low-growth	-0.014**	-0.017**	-0.005	0.009	0.027
N = 439,545	(0.007)	(0.007)	(0.014)	(0.010)	(0.035)
Difference (High-Low)	0.000	0.000	-0.006	0.009	0.035
	(0.010)	(0.011)	(0.021)	(0.016)	(0.054)
Sample	Full	Donut	Donut	Donut	Donut
$f(z_i)$	linear trend	linear trend	local linear	linear trend	linear trend
net-of-placebo	no	no	no	yes	yes
Type of employment	Empl.	Empl.	Empl.	Empl.	Self-empl.

Notes: This table shows the estimated change in employment (panel A) and log wage (measured as earned income of workers) for those in work (panel B) at the reform discontinuity by category of employment. Columns 1-4 shows the estimated employment change when the outcome variable is 1 only if the worker is in employment (and not in self-employment). In column 5, the outcome variable is 1 if the worker is in self-employment. Each cell in the table shows the β coefficient of the RDD specification shown in equation (14) (Columns 1-3) or in equation (15) (Column 4). The rows show the estimated employment change for different regions. The first and second row show the estimated effect in high and low-growth regions, respectively. High-growth regions are regions with above median earnings growth rate between 2000 and 2013, while low-growth regions have below median growth. The third row shows the difference between the high and low-growth regions. In Column (1) we use the full dataset. In Columns (2)-(4) we apply the donut hole RDD specification where we exclude those born between December 16th and January 5th. In Columns (1), (2) and (4) we estimate a linear trend in birth date allowing for different slopes and intercepts at either side of the cutoff. Column (3) estimates a kernel-weighted local linear regression, where we set the bandwidth at 150 days. Column (4) estimates the change in employment at the reform discontinuity relative to the change at the placebo discontinuity as in equation (15). The placebo discontinuity is estimated between the 1949 and 1950 cohorts, both of which switched to the NDC system. We report robust standard errors in parentheses. For the local-linear regression we calculate robust standard errors following Calonico et al. (2014). Significance levels are: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Online Appendix B Household Survey Data

Beyond our administrative data, we use two additional data sources: the Polish Household Budget Survey (HBS) and the Polish Labor Force Survey (LFS). Both of these data sources are large representative household surveys. However, they are many times smaller than our administrative data and have too few observations from each cohort for us to apply the RDD empirical strategy to study the labor supply responses to the NDC reform.

The HBS includes a rotating panel where a household is interviewed in two consecutive years. This allows us to observe individuals' transitions between unemployment and employment across years, where unemployment is measured as receipt of unemployment benefits. Moreover, the HBS has detailed information about the type of income individuals receive. We make use of this to estimate the fraction of individuals who receive retirement pensions before the full or early retirement ages, and who are therefore in excluded sectors and special occupations not affected by the pension reform.

The LFS is a large survey studying employment outcomes in the Polish population. Since the LFS captures all types of employment, including agricultural labor which does not appear in our administrative data, we are able to estimate employment rates with and without agricultural workers (see Appendix Table A.1). The data also contain some information on tenure, firm size and the type of employment contract for individuals in work. We exploit this information to estimate whether an individual was eligible for old age unemployment benefit(s) following the 2004 reform (see Online Appendix F).

Online Appendix C Calculation of the Net Return to Work

C.1 Calculating the change in net return to work from switching from DB to NDC

In this section we provide a detailed description of how we calculate the net return to work. The percent change in net return to work (which is also shown in equation (3)) is:

$$\frac{\Delta nrw_t}{nrw_t^{DB}} = \frac{d \cdot (E_t[\Delta PV_{it}^{NDC}] - E_t[\Delta PV_{it}^{DB}])}{E_t[(1-\tau(\tau^{pi}, \tau^{ss})) \cdot w_{it} - u_{it}] + d \cdot E_t[\Delta PV_{it}^{DB}]}. \tag{C.1}$$

We calculate $E_t[(1 - \tau(\tau^{pi}, \tau^{ss})) \cdot w_{it} - u_{it}]$ as follows. Poland has a flat income tax rate that has changed only slightly since before the reform we study, and so we set $\tau^{pi} = 0.19$. There is a higher marginal tax rate for those making approximately 2.5 × average earnings. However, at a similar earnings level the individual hits the cap on social security contributions, making the tax function effectively linear. Income taxes apply to income net of social security contributions (paid by the employees). As a result, the after-tax income if working is:

$$w_{it}(1 - \tau(\tau^{pi}, \tau^{ss})) = w_{it}(1 - \tau^{pi}(1 - \tau^{ss}) - \tau^{ss}). \tag{C.2}$$

We calculate average after-tax wages of workers in equation (C.2) using our administrative data in the years between 2000 and 2002. The average out of work benefit, $E_t[u_{it}]$, is calculated as follows. Those working last period are eligible for an unemployment benefit for the first six months of unemployment, which is a flat taxable benefit equaling 40% of the average wage income of workers. After six months, the individual receives a flat untaxable welfare benefit equaling 30% of the average wage income of workers. Given that our model is an annual one, we assume that if they worked last period, the individual receives unemployment for 50% of the year and welfare for 50% of the year, so $u_{it} = [(1 - \tau^{pi}) \cdot 0.5 \cdot 0.4 \cdot \overline{w}_t] + [0.5 \cdot 0.3 \cdot \overline{w}_t]$. Those not working last period receive a welfare benefit of $u_{it} = [0.3 \cdot \overline{w}_t]$. The actual numbers of the tax formula that we use are presented in Table C.2.

We calculate the $E_t[\Delta PV_{it}^{NDC}]$ and $E_t[\Delta PV_{it}^{DB}]$ as follows. First, we simulate 2,000 life cycle earnings profiles following the procedure described in Section 4. In the first step, we simulate wages according to equation (11). This equation has a deterministic component capturing the age profile of wages and a stochastic component of AR(1) + MA(1) as specified in equations (12) and (13). In the second step, we simulate unemployment spells according to a Markov process. The parameter values of the benchmark simulation are shown in Table C.1. Table 3 shows that our estimated labor supply elasticity is robust to different parameter values for the wage process.

For each individual, we calculate the pension benefit at age 65 given their lifecycle earnings and the pension rules. To determine $b_{i65}^{\text{Employed}_t,NDC}$, we calculate the starting capital at age 50 and then apply the pension formulas described in equations (5) and (6). Panel C of Table C.2 shows the parameter values for the pension uprating rate r^{NDC} and life expectancy $E[T|t = 65]$ that we used for the calculations. We calculate $b_{i65}^{\text{Not Employed}_t,NDC}$ using individual i's life cycle profile but assuming they were not working at age t.

To calculate $b_{i65}^{\text{Employed}_t,DB}$, we apply the pension formulas described in equation (4). As before, we calculate $b_{i65}^{\text{Not Employed}_t,DB}$ by taking the life cycle profile but assuming that the individual is not working at age t. For both pension systems, we apply the minimum pension if someone's pension level is below that threshold (Panel B of Table C.2 shows the value of the minimum pension).

Once we have the difference in pension benefits if an individual works at age t, $b_{i65}^{\text{Employed}_t,k} - b_{i65}^{\text{Not Employed}_t,k}$, with $k \in \{DB, NDC\}$, we apply equation (9). The real pension uprating rate r^{index} and the real risk free interest rate r are shown in Part D of Table C.2. The survival rates $S_{s|t}$ at age t are calculated from the survival probabilities shown in Figure C.1. The figure shows at each age the probability of surviving one more year, s_t. Then we calculate survival rates as $S_{s|t} = \prod_{l=t}^{l=s} s_l$.

Once we calculate ΔPV_{it}^k for each individual, we take the average across individuals to obtain $E_t[\Delta PV_{it}^{NDC}]$ and $E_t[\Delta PV_{it}^{DB}]$.

Table C.1: Parameter Values Used for Simulating the Earnings Process

Parameter	Value		Source
Panel A: region-specific deterministic wage component			
	Low	High	
constant	-2.4688	-3.2599	Estimation of (11)
age	1.0433	1.1344	(dataset: administrative tax data)
age^2	-0.0328	-0.0370	
age^3	4.58E-04	5.34E-04	
age^4	-2.41E-06	-2.89E-06	
t	0.04338	0.0517	
Panel B: stochastic wage component			
ρ	0.9496		GMM estimation of (12) and (13)
θ	-0.2353		(dataset: administrative tax data)
σ^2_ε	0.0591		
σ^2_ξ	0.0276		
Panel C: unemployment process			
$Pr(UI_{it} = 1 \mid P_{it} = 1)$	0.0340		Estimation of Markov process
$Pr(P_{it} = 1 \mid UI_{it} = 1)$	0.4031		(dataset: HBS)

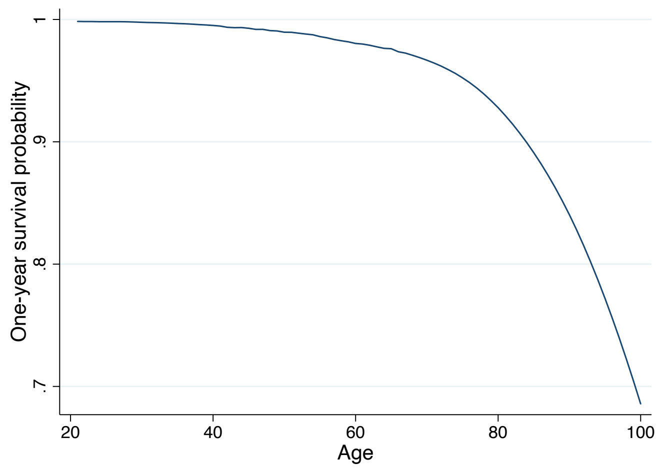
Notes: This table shows the parameter values used for simulating the lifecycle earnings profiles. Panel A shows the region-specific deterministic wage component of the wage process (see equation (11)). We estimate these values from the administrative tax data between 2000 and 2013. Panel B shows the parameter values of the stochastic components in the wage equation (see equations (12) and (13)). We estimate these values using a GMM estimator from the administrative tax data between 2000 and 2013. Panel C shows the parameter values of the unemployment process. These values are estimated from the Household Budget Survey (HBS), where we directly observe unemployment.

Table C.2: Paramater Values Used for Calculating the Net Return to Work

Parameter	Value	Source
Panel A: parameters of the tax function		
τ^{pi} (income tax)	0.19	Official tax
τ^{ss} in eq. (4) (soc. sec. worker cont. rate)	0.1871	and social security rates
τ^{ss} in eq. (6) (total pension cont. rates)	0.1952	
u_{it} (unemployment benefit and welfare,	$(1-\tau^{pi}) \cdot 0.5 \cdot 0.4 \cdot \bar{w}_t$	Official rates
working previous period)	$+0.5 \cdot 0.3 \cdot \bar{w}_t$	
u_{it} (welfare, not working previous period)	$0.3 \cdot \bar{w}_t$	
Panel B: parameters of the pension system		
r^{index} (pension uprating rate)	0.0116	Off. rates, (2000-20)
Minimum pension	$0.2 \times \bar{w}_{65}$	Off. rates &
		administrative tax data
Panel C: NDC-specific parameters		
r^{NDC} (NDC contribution uprating rate)	0.0381	Off. figures, (2000-17)
$E[T\|t=65]$ (life expectancy at age 65)	209.5 months	Off. life-tables
Panel D: discounting parameters		
r (risk-free rate)	0.0288	10-year gov. bonds (2000-19)
$S_{s\|t}$ (survival probability)	See Figure C.1	Off. life-tables

Notes: This table shows the parameter values used for calculating the net return to work defined in equation (1). Panel A shows the parameter values we used for the tax function. We take these values from the published tax and social security rates. Panel B shows the parameter values of the pension system. The uprating factor r^{index} is the average of the yearly values between 2000 and 2020 obtained from published government figures. The minimum pension is 20% of the average income at age 65. We calculate the average income at age 65 from the administrative tax data. Panel C shows the parameter values specific to the NDC pension scheme. The uprating rate, r^{NDC}, from equation (6) is calculated as the average of the yearly official uprating rates between 2000 and 2017. The life expectancy is obtained from the official life expectancy tables used by the government. Panel D shows the discounting parameters in equation (9). The risk free interest rate, r, is the average 10-year government bond interest rate between 2000 and 2019. The survival probabilities, $S_{s|t}$, are obtained from the official life expectancy tables used by the government.

Figure C.1: The Probability of Staying Alive One More Year at Each Age



Notes: This figure plots the annual survival probabilities (s_t) obtained from official life-tables for the years 2000-2016. At each age, the figure plots the probability of surviving one year for men in the 1949 cohort. After age 68, the probability is a forecast made in 2016. We use these probabilities to calculate the probability of staying alive at age s conditional on surviving until age t, $S_{s|t}$. These survival rates are then used to calculate the discount value of future pension benefits in equation (9).

Table C.3: Change in net return to work (%) under different parameterizations of deterministic component of wage process.

	(1)	(2)	(3)	(4)
1. High-growth	-9.59	-9.59	-11.17	-12.10
2. Low-growth	-8.93	-5.94	-5.94	-6.06
3. Difference (High-Low)	-0.66	-3.68	-5.23	-6.04
Differential shape of age-profile	Yes	Yes	Yes	Yes
Differential level		Yes	Yes	Yes
Differential shape of time-trend			Yes	Yes
Individual fixed-effects				Yes

Notes: This table shows the effect of the pension reform on the net return to work for different hypothetical parameterizations of the deterministic component of the wage process. Rows 1. and 2. show the effects for high and low growth regions, respectively, while the third row shows the difference between the high and low-growth regions. The purpose of columns (1)-(3) of this table is to illustrate what part of the wage process drives the difference in the change in the net return to work between the high and low-growth regions. Column (1) shows the net return to work in a scenario in which the high-growth and low-growth regions share the same trend rate of growth - assumed to be that estimated for the low-growth region in both cases - but have the different parameterizations of the age polynomial, which is set to their estimated values. The intercept of the low-growth wage process is adjusted such that individuals in the two regions have the same wages on average over the lifecycle. Column (2) shows the net return to work in which the high-growth and low-growth regions share the same trend rate of growth but have the estimated intercept and parameters of the age polynomial. Column (3) shows the net return to work in which the high-growth and low-growth regions differ in terms of time trend, the intercept, and parameters of the age polynomial, which are assigned their estimated values. This is also our baseline wage process. The table shows the parameters of the age polynomial play almost no role in driving the difference in the change in net return to work, but that the difference in the change in net return to work is driven partly by different levels of wage between high and low-growth regions, and partly by differences in the estimated time-trend parameters. Finally, column (4) shows the net return to work in which the high-growth and low-growth region parameters were estimated using an individual fixed-effects specification, where the level of fixed effects is chosen to match the average observed earnings of the 1948-1949 cohorts in 2000-2002.

Table C.4: Region-specific deterministic wage component parameters for different specifications of the wage regression.

Parameter	(1)	(2)	(3)	(4)
	Baseline		Individual FE	
constant	-2.4688	-3.2599	–	–
	(0.0626)	(0.0714)		
age	1.0433	1.1344	0.9362	0.9901
	(0.0066)	(0.0076)	(0.0080)	(0.0093)
age^2	-0.0328	-0.0370	-0.0286	-0.0309
	(0.0003)	(0.0003)	(0.0003)	(0.0004)
age^3	4.58E-04	5.34E-04	4.07E-04	4.51E-04
	(4.19e-06)	(4.80e-06)	(4.94e-06)	(5.70e-06)
age^4	-2.41E-06	-2.89E-06	-2.20e-06	-2.49e-06
	(2.51e-08)	(2.93e-08)	(2.87e-08)	(3.38e-08)
t	0.04338	0.0517	–	–
	(0.0001)	(0.0001)		
Region growth type	Low	High	Low	High
Implied annual wage growth	3.34	4.09	2.93	3.56
Difference (High-Low)	0.75		0.63	
Individual FE	No	No	Yes	Yes
N	6,692,578	4,887,578	6,689,495	4,885,520

Notes: This table shows estimates of the parameter values of the deterministic component of the wage process for different estimation methods. Columns (1) and (2) show the parameter estimates for the low and high-growth regions, respectively, under our baseline specification (see equation (11)), while columns (3) and (4) show the parameter estimates for the low and high-growth regions, respectively, from a fixed-effects regression. Here, the coefficient on the time trend is not identified separately from the coefficient on the first element of the age polynomial, and so only the latter is reported. The table also shows the real annual wage growth for the 1948-1949 cohorts between ages 21 and 64 implied by these parameter estimates. This shows that the implied annual wage growth is higher by a similar amount both under the levels and fixed effects specification, demonstrating that higher wage growth in high-growth regions is not driven by changes in the composition of the labor force with age. Standard errors are reported in parentheses.

Online Appendix D Employment Elasticity Calculations: Accounting for those Unaffected by the Reform

We are interested in the employment response to the NDC reform for those affected by the reform. However, some individuals at the reform discontinuity were unaffected by the reform because they were either in an excluded sector or special occupation, and thus remained in the DB scheme. In our benchmark elasticity formula (presented in Equation (2)) we abstract away from this issue. Here we discuss how the presence of unaffected workers affects the calculation of the employment elasticity.

There are two groups of workers unaffected by the reform. First, agricultural workers are unaffected by the reform and their employment is not observed in our administrative data. The indicator variable $A_{it} = 1$ denotes that someone is working in the agriculture sector. Besides agricultural workers, we also have individuals working in excluded occupations. While these workers' employment is observed in our administrative data, we do not observe whether someone is in an exempted occupation or not. We denote (non-agricultural) workers in excluded occupations with $E_{it} = 1$. The pension reform affects workers in the non-agricultural sector, $A_{it} = 0$, and in non-exempted occupations, $E_{it} = 0$.

The employment elasticity for the affected groups can be written as:

$$\eta = \frac{\frac{P_t^{NDC} - P_t^{DB}}{P_t^{DB}}}{\Delta nrw_t / nrw_t^{DB}} \tag{D.1}$$

where now $P_t^{NDC} = Pr(P_{it} = 1 | A_{it} = 0, E_{it} = 0, z_i < 50)$ is the probability of work among those now facing the NDC scheme, $P_t^{DB} = Pr(P_{it} = 1 | A_{it} = 0, E_{it} = 0, z_i > 50)$ the probability of work facing the DB scheme (but also not in an excluded occupation), P_{it} is a binary variable (working or not working) and so we can express its (conditional) expected value as a conditional probability, $E[P_{it} | A_{it} = 0, E_{it} = 0, z_i] = Pr(P_{it} | A_{it} = 0, E_{it} = 0, z_i)$, for $z_i \in \{z_i < 50, z_i > 50\}$. The numerator of equation (D.1) is thus the percentage change in employment conditional on being affected by the reform.

The baseline employment probability under the DB system conditional on being in sectors or in occupations affected by the reform, $Pr(P_{it} | A_{it} = 0, E_{it} = 0, z_i > 50)$, is the following:

$$Pr(P_{it} = 1|A_{it} = 0, E_{it} = 0, z_i > 50) = \frac{Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 0)|z_i > 50)}{Pr(A_{it} = 0 \cap E_{it} = 0|z_i > 50)}, \quad \text{(D.2)}$$

where $Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 0)|z_i > 50)$ shows the probability that individual i is employed at time t ($P_{it} = 1$) and is in a non-agricultural and non-exempted occupation ($A_{it} = 0 \cap E_{it} = 0$) and older than age 50.

Our regression discontinuity estimates in equation (14) identify the change in non-agricultural employment at the discontinuity, formally:

$$\beta = \Pr(P_{it} = 1 \cap A_{it} = 0|z_i < 50) - \Pr(P_{it} = 1 \cap A_{it} = 0|z_i > 50), \quad \text{(D.3)}$$

where β is the estimated parameter from the regression equation (14), $\Pr(P_{it} = 1 \cap A_{it} = 0|z_i < 50)$ is the probability of working in the non-agricultural sector for the younger cohorts (which contain both affected workers ushered into the new NDC pension system and exempted workers who stayed in the DB pension scheme) and $\Pr(P_{it} = 1 \cap A_{it} = 0|z_i > 50)$ is the probability of working in the non-agricultural sector for the older cohorts, all of whom stayed in the DB pension scheme. The change in non-agricultural employment at the discontinuity can be rewritten as

$$\begin{aligned}
&\Pr(P_{it} = 1 \cap A_{it} = 0|z_i < 50) - \Pr(P_{it} = 1 \cap A_{it} = 0|z_i > 50) = \\
&= \Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 0)|z_i < 50) + \Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 1)|z_i < 50) - \\
&\quad - [Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 0)|z_i > 50) + \Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 1)|z_i > 50)] \\
&= \Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 0)|z_i < 50) - \Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 0)|z_i > 50) \\
&= [Pr(P_{it} = 1|A_{it} = 0, E_{it} = 0, z_i < 50) - Pr(P_{it} = 1|A_{it} = 0, E_{it} = 0, z_i > 50)] \times \\
&\quad \times Pr(A_{it} = 0 \cap E_{it} = 0), \qquad \text{(D.4)}
\end{aligned}$$

where the second equality uses the fact that young workers stayed in the DB system only if they worked in an exempted occupation and so for them $\Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 1)|z_i < 50) = \Pr(P_{it} = 1 \cap (A_{it} = 0 \cap E_{it} = 1)|z_i > 50)$. The third equality uses the definition of conditional probability (similarly to Equation (D.2)) and that the probability of being in an exempt occupation or of being an agricultural worker is unlikely to differ at the discontinuity and so $Pr(A_{it} = 0 \cap E_{it} = 0|z_i < 50) = Pr(A_{it} = 0 \cap E_{it} = 0)Pr(A_{it} = 0 \cap E_{it} = 0|z_i > 50)$.

Inserting equations (D.4) and (D.2) into the percentage change in employment conditional on being in sectors or in occupations affected by the reform (the numerator of equation (D.1)) yields:

$$\frac{Pr(P_{it} = 1|A_{it} = 0, E_{it} = 0, z_i < 50) - Pr(P_{it} = 1|A_{it} = 0, E_{it} = 0, z_i > 50)}{Pr(P_{it}|A_{it} = 0, E_{it} = 0, z_i > 50)} =$$

$$= \frac{Pr(P_{it} = 1 \cap A_{it} = 0|z_i < 50) - Pr(P_{it} = 1 \cap A_{it} = 0)|z_i > 50)}{Pr(P_{it}|A_{it} = 0, E_{it} = 0, z_i > 50) \times Pr(A_{it} = 0 \cap E_{it} = 0)}$$

$$= \frac{Pr(P_{it} = 1 \cap A_{it} = 0|z_i < 50) - Pr(P_{it} = 1 \cap A_{it} = 0|z_i > 50)}{Pr(P_{it}^{DB} = 1 \cap A_{it} = 0 \cap E_{it} = 0|z_i > 50)}$$

$$= \frac{\beta}{Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 0|z_i > 50)}. \tag{D.5}$$

Equation (D.5) shows that to obtain the employment elasticity for the affected population, we need to divide the estimated percentage point change in non-agricultural employment around the discontinuity, β (which is what is recovered by our RDD estimator) by the fraction of the population working in non-agricultural and non-exempted occupations, $Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 0|z_i > 50)$. This latter object is not directly observed in the administrative data, as we do not know who is exempt because they work in a special occupation. We calculate this object by first using the Law of Total Probability and rearranging:

$$Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 0|z_i > 50) = \tag{D.6}$$
$$= Pr(P_{it} = 1 \cap A_{it} = 0|z_i > 50) - Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 1|z_i > 50).$$

The administrative data shows that the fraction of people working in the non-agricultural sector is $Pr(P_{it} = 1 \cap A_{it} = 0|z_i > 50)$= 49%.

We infer the fraction of the population that is working in the non-agricultural sector in an excluded occupation (and thus exempt from the reform, regardless of age), $Pr(P_{it} =$

$1 \cap A_{it} = 0 \cap E_{it} = 1|z_i > 50) = Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 1|z_i < 50)$, in the following way. Workers born in 1949 were exempt from the switch to the NDC system if they worked long enough in a special occupation (e.g. metal workers, teachers etc.) and claimed retirement benefits before 2008. Using the Household Budget Survey, we estimate that 11% of the 1949 cohort (who were 49 years old at the time of the reform) claimed retirement benefits by 2008. These are the individuals who were exempt from the pension reform since they would have otherwise been unable to collect benefits. We then determine what fraction of these individuals were employed over the 2000-2002 time period – the period used for estimating employment response to the policy change. We estimate that 6% of the younger cohort were already drawing retirement benefits and were not employed in 2002. We do not know if the remaining 5% who began drawing retirement benefits between 2002 and 2008 were employed or not in 2002. In the benchmark case, we assume that *none* of these workers were employed, meaning that $Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 1|z_i < 50) = 0$, and so we get $Pr(P_{it}^{DB} = 1 \cap A_{it} = 0\% \cap E_{it} = 0|z_i < 50) = 49\%$ according to equation (D.6). This leads to an estimated employment elasticity of 0.44 (see Table 2). As a robustness exercise, we assume that *all* individuals who began drawing retirement benefits between 2002 and 2008 were employed in 2002 and thus $Pr(P_{it}^{DB} = 1 \cap A_{it} = 0 \cap E_{it} = 1|z_i < 50) = 5\%$. In that case, $Pr(P_{it} = 1 \cap A_{it} = 0 \cap E_{it} = 0|z_i < 50) = 49\% - 5\% = 44\%$ and so the employment elasticity is 0.48 (see Panel E of Table 3).

Online Appendix E Number of Observations by Birth Date and the Covariance Balance Between Treated and Control Cohorts

Our empirical strategy exploits date of birth: individuals born before January 1st, 1949 stayed in the DB system, while younger individuals switched to NDC. Since their birth dates were determined many years before the policy change, individuals close to the discontunity could not have manipulated their eligibility in response to the policy.

In Panel (a) of Figure E.2 we plot the number of observations by birth month for the 1946-1953 cohorts in the years 2000-2002. Even though manipulation is not possible, there is a clear spike in reported births which occurs on the 1st of January of every year. Nevertheless, the spikes at January 1st were also present before the policy change, as demonstrated in Figure E.1, which shows the frequencies observed in the pre-reform year 1998. In fact, this spike at January 1st most likely reflects that many in these cohorts were born at home and self reported their date of birth, not that there was a higher coincidence of hospital births on the first day of the year. Since the cut-off enrollment at schools was 31st December/1st January, some parents strategically reported their children at the beginning of the calendar year so that their child would be among the oldest in the class when they started school. While this reporting behaviour took place 50 years before the pension reform was announced, the characteristics of these switchers may be correlated with the labor-market outcomes we care about.

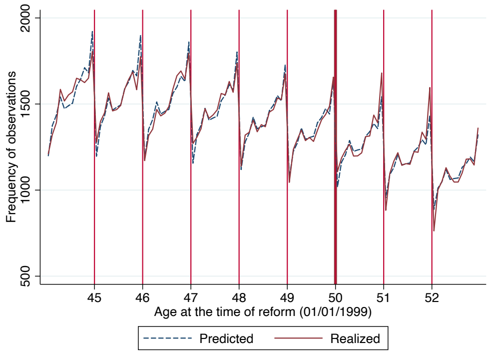
To alleviate this concern about the bunching at January 1st, we apply various donut hole RDD estimates throughout the paper. In particular, our baseline specification drops individuals who were born between December 17th and January 5th. We picked these thresholds visually; there is an excess of births between December 17-31, and an absence of births between January 1-5, but very little evidence of excess births or an absence of births outside of this range. For robustness we also apply a broader donut hole where we drop all individuals who were born in January and December (see Table A.3). Panels (d) and (e) of Figure E.2 and Figure E.1 show the number of observations for the baseline and the broader donut hole, respectively. The unusual January and December effects disappear for both definitions of donut and we observe a seasonal pattern in birth rates observed in other countries (see e.g. Buckles and Hungerman (2013)). There is also a time trend which reflects a post-World War 2 baby boom in Poland.

In panels b, d, and f of Figure E.2 and Figure E.1, we investigate whether there is an abnormal mass of observations at our reform discontinuity above the predictable pattern of monthly births and cohort trend. We regress the number of observations at each birth month on the month-of-birth dummies and a linear trend for the cohorts born between 1944 and 1953. We plot the residuals under each donut assumption. The residuals vary across birth months, but there is no unusual jump or drop in the number of observations between the 1948 and 1949 cohorts.

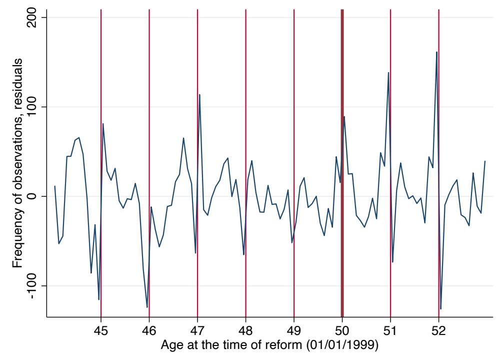
We also study whether covariates substantially differ between cohorts. Table E.1 shows the regression discontinuity estimates based on equation (14), where the outcome variables are various covariates. In panel A, we assess whether there is a change in rural/urban share and share of women. These are the only covariates that we observe in our administrative data. In panel B, we show the change in the region characteristics where individuals live. We present two characteristics: regional level log household income and employment rate in 1998. We measure these outcomes in 1998, before the reform took place. In Table E.2 we present the same estimates by region type for individual-level covariates.

Column (1) shows the difference in covariates for the 1948 cohort and the first treated cohorts (1949). Panel A shows that the rural share in the 1948 December cohort is slightly larger than the rural share for the January 1949 cohort, and the famale share is slightly lower. The 1948 December cohort has a lower employment rate in 1998 than the January 1st, 1949 cohort, although there is no differences in log household income. Nevertheless, these differences between the December and January cohorts are very similar to other cohorts, such as the 1949 and 1950 cohorts (see column 2). Reassuringly, when we estimate the discontinuity in covariates between the treated and untreated cohorts relative to two placebo cohorts (similarly to the estimates in the main text, see equation (15)), we find no significant differences in covariates (see column 3). This highlights that our net of placebo estimates pass the covariate balance tests for all outcomes in panels A and B. This can also be seen for individual-level covariates for low and high-growth regions separately in Table E.2.

Figure E.1: Frequencies by Month of Birth, Pre-reform Population Registry (1998)

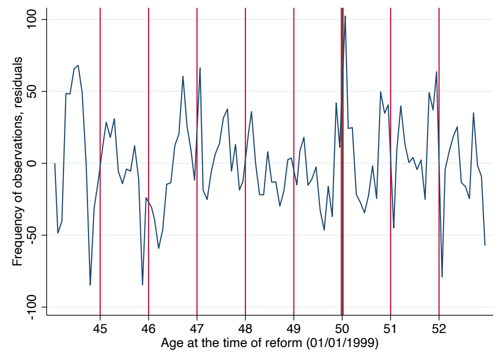


(a) No donut

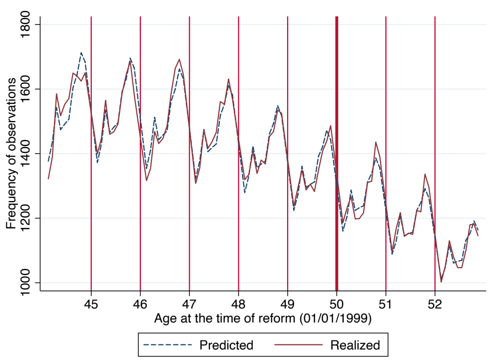


(b) No donut, residuals

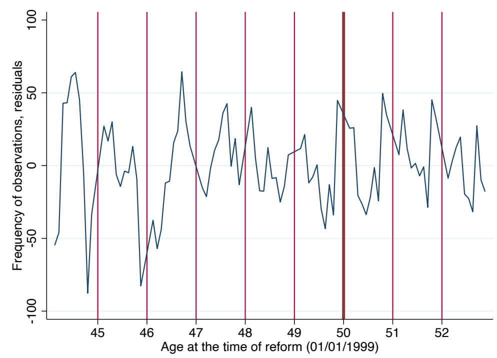
(c) Baseline donut



(d) Baseline donut, residuals



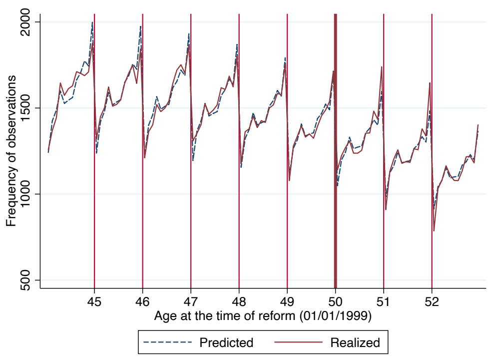
(e) Jan-Dec donut



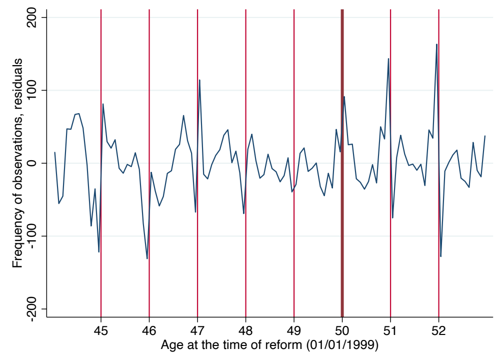
(f) Jan-Dec donut, residuals

Notes: This figure shows the frequencies by month of birth for the cohorts between 1944 and 1953. The frequencies are calculated using the population registry for 1998. We adjust the frequencies with the average number of days in each month. Panels a), c) and e) show the actual number of frequencies (red line) and the predicted one that is based on month of dummies and linear year trend (blue line). Panels (b), (d) and (f) show the difference between the predicted and the actual frequencies – the residuals from the prediction. Panels (a) and (b) show the actual data. Panels (c) and (d) show the frequencies when we drop individuals born between December 17th and January 5th (and adjust with the number of days remained in the month). Panels (e) and (f) show frequencies when we drop everybody born in January or December. Each red vertical line marks the December 31st/January 1st cohort threshold. The thick vertical red line shows the eligibility cut-off of the reform.

Figure E.2: Frequencies by Month of Birth, Post-reform Population Registry (2000-2002)

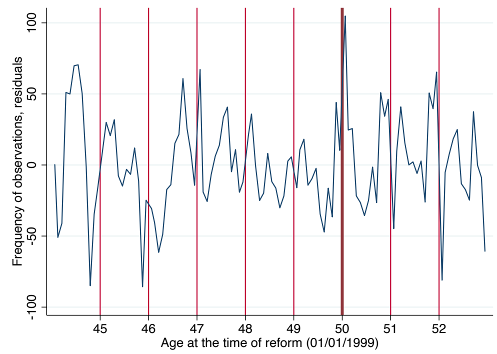


(a) No donut

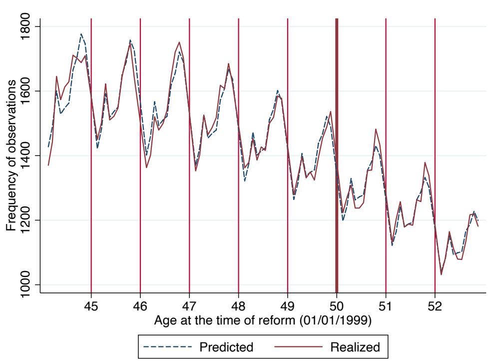


(b) No donut, residuals

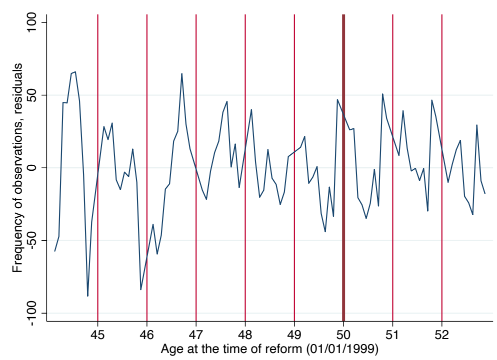
(c) Baseline donut



(d) Baseline donut, residuals



(e) Jan-Dec donut



(f) Jan-Dec donut, residuals

Notes: This figure shows the number of observations by month of birth for the cohorts between 1944 and 1953. The frequencies are calculated using the population registry between 2000-2002. We adjust the frequencies with the average number of days in each month. Panels a), c) and e) show the actual number of frequencies (red line) and the predicted one that is based on month of dummies and linear year trend (blue line). Panels (b), (d) and (f) show the difference between the predicted and the actual frequencies – the residuals from the prediction. Panels (a) and (b) show the actual data. Panels (c) and (d) show the frequencies when we drop individuals born between December 17th and January 5th (and adjust with the number of days remaining in the month). Panels (e) and (f) show frequencies when we drop everybody born in January or December. Each red vertical line marks the December 31st/January 1st cohort threshold. The thick vertical red line shows the eligibility cut-off of the reform.

Table E.1: Covariance Balance between Treatment and Control

	(1)	(2)	(3)
	Baseline RDD		Net-of-placebo RDD
Cohorts of interest	1948-1949	1949-1950	1948-1949
Panel A: individual-level covariates, overall			
Rural	0.0115***	0.0128***	0.0013
	(0.0014)	(0.0014)	(0.0020)
Female	-0.0078***	-0.0083***	0.0005
	(0.0012)	(0.0011)	(0.0016)
Panel B: regional-level covariates			
Log household income in 1998	-0.0076	0.0078	-0.0045
($\times$100)	(0.0319)	(0.0384)	(0.0462)
Employment in 1998 ($\times$100)	0.0905***	0.1699***	-0.0469*
	(0.0201)	(0.0198)	(0.0261)
N	1,438,545	1,499,039	2,937,584

Notes: This table shows covariance balance between the treated and control cohorts. For each covariate we assess whether there is a discontinuity in its value between birth cohorts. Column (1) shows the estimated discontinuity in the covariate between the 1948 and 1949 cohorts, while column 2 shows it for the 1949 and 1950 cohorts. We estimate the (linear trend) RDD specification described in equation (14) with the reported covariate as an outcome variable. In column (3) we present net-of-placebo estimates where we compare the estimated discontinuity between the 1948 and 1949 cohorts to the estimated discontinuity between the 1949 and 1950 cohorts. There, we estimate the (linear) RDD specification described in equation (15) with the covariate as an outcome variable. In Panel A, the covariate is whether the individual lives in a rural or urban area. In panel B, we use the characteristics of the region where the individual lives. We estimate the regional-level log household income and the regional-level employment rate in 1998, before the policy change. In each specification, we apply a "donut hole" by dropping individuals born between December 17th and January 5th. Robust standard errors are reported in parentheses. Significance levels are: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table E.2: Covariance Balance between Treatment and Control

	(1)	(2)	(3)
	Baseline RDD		Net-of-placebo RDD
Cohorts of interest	1948-1949	1949-1950	1948-1949
Panel A: individual-level covariates, low-growth regions			
Rural	0.0102***	0.0111***	-0.0009
	(0.0017)	(0.0016)	(0.0023)
Female	-0.0069***	-0.0102***	0.0033
	(0.0015)	(0.0015)	(0.0021)
Panel B: individual-level covariates, high-growth regions			
Rural	0.0140***	0.0155***	-0.0015
	(0.0024)	(0.0024)	(0.0034)
Female	-0.0091***	-0.0056*	-0.0035
	(0.0018)	(0.0018)	(0.0025)

Notes: This table shows covariance balance between the treated and control cohorts. For each covariate we assess whether there is a discontinuity in its value between birth cohorts. Column (1) shows the estimated discontinuity in the covariate between the 1948 and 1949 cohorts, while column 2 shows it for the 1949 and 1950 cohorts. We estimate the (linear trend) RDD specification described in equation (14) with the reported covariate as an outcome variable. In column (3) we present net-of-placebo estimates where we compare the estimated discontinuity between the 1948 and 1949 cohorts to the estimated discontinuity between the 1949 and 1950 cohorts. There, we estimate the (linear) RDD specification described in equation (15) with the covariate as an outcome variable. In Panel A, the covariate is whether the individual lives in a rural or urban area. In panel B, we use the characteristics of the region where the individual lives. We estimate the regional-level log household income and the regional-level employment rate in 1998, before the policy change. In each specification, we apply a "donut hole" by dropping individuals born between December 17th and January 5th. Robust standard errors are reported in parentheses. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Online Appendix F The Effect of Old Age Unemployment Benefit

F.1 Institutional Details and the Change in Net Return to Work

To study the employment response to contemporaneous work incentives, we study the employment response to a radical change in eligibility for an old age unemployment benefit program (OAUB). This program provided generous benefits to older individuals who were laid off from their jobs. The benefit entitled individuals to 80 percent of a hypothetical pension, with a minimum benefit of 120 percent of the unemployment benefit and a cap at 200 percent of the unemployment benefit. The benefit was stopped if the combined earnings from employment and the allowance were more than 200 percent of the unemployment benefit.[36]

On 30th April 2004 a reform raised the eligibility age from 55 to 60, effective starting 1st August 2004. Individuals could therefore take up the benefit if they reached age 55 by the 1st August 2004, and could demonstrate that they were laid off. This created a cohort-based discontinuity in access to this benefit, with individuals born before 1st August 1949 being potentially eligible for the benefit, and individuals born after not eligible.

The net return to work for individuals who were slightly older than 55 on 1st August 2004 and were thus eligible for the OAUB program can be calculated as:

$$nrw_{it}^{\text{OAUB}} = (1 - \tau(\tau^{pi}, \tau^{ss})) \cdot w_{it} - u_{it}^{\text{OAUB}} + E_t(PV_{it}^{\text{Employed}_t, NDC} - PV_{it}^{\text{Not employed}_t, NDC}). \tag{F.1}$$

where $(1-\tau(\tau^{pi}, \tau^{ss})) \cdot w_{it}$ is the after-tax income from work, u_{it}^{OAUB} is the value of old-age unemployment benefit, and $E_t(PV_{it}^{\text{Employed}_t, NDC} - PV_{it}^{\text{Not employed}_t, NDC})$ is the increase in the present-value of pensions as a result of working under the NDC rules. We apply the NDC rules here as the individuals who were slightly older than 55 at 1st August 2004, but younger than 55 at 31st of December 2004, were 49 years old at the time of the 1999 pension reform and hence were ushered into the NDC system.

[36] The Polish name of the program is "zasiłek przedemerytalny" (or "pre-retirement allowance" in English). This name reflects the tight link of these benefits to the DB pension benefit. In that sense the program has some features of early-retirement program. Nevertheless, the program is more similar to a standard unemployment insurance as an individual is required to be laid-off to be eligible for the program.

At the same time the net return to work for individuals who were younger than 55 at 1st of August and are not eligible for the OAUB is as follows :

$$nrw_{it}^{\text{NOAUB}} = (1 - \tau(\tau^{pi}, \tau^{ss})) \cdot w_{it} - u_{it}^{\text{NOAUB}} + E_t(PV_{it}^{\text{Employed}_t, DC} - PV_{it}^{\text{Not employed}_t, DC}). \tag{F.2}$$

where u_{it}^{NOAUB} is the combination of the standard welfare and unemployment programs that every individual in the society has access to. The change in return from work as a result of increasing the eligibility age of the OAUB program is therefore:

$$nrw_{it}^{\text{OAUB}} - nrw_{it}^{\text{NOAUB}} = -(u_{it}^{\text{OAUB}} - u_{it}^{\text{NOAUB}}). \tag{F.3}$$

Following our notation studying the impact of the pension reform (see Section 4), we denote nrw_t^{OAUB}, u_t^{OAUB} and u_t^{NOAUB} as the sample averages of $nrw_i t^{\text{OAUB}}$, u_{it}^{OAUB} and u_{it}^{NOAUB} at age t, respectively. We then define the employment elasticity as follows:

$$\eta^{Contemp} = \frac{(P_t^{\text{OAUB}} - P_t^{\text{NOAUB}})/P_t^{\text{OAUB}}}{-(u_t^{\text{OAUB}} - u_t^{\text{NOAUB}})/nrw_t^{\text{OAUB}}}. \tag{F.4}$$

where the numerator, $(P_t^{\text{OAUB}} - P_t^{\text{NOAUB}})/P_t^{\text{OAUB}}$, shows the employment impact of the OAUB program among those who were eligible. We will describe in the detail how we calculate this next.

F.2 Empirical Strategy and Results

We apply a regression discontinuity design for estimating the effect of the OAUB program. We estimate the following regression equation:

$$P_{it} = \alpha + \beta^{OAUB} \mathbf{1}\{z_i \geq 55\} + f(z_i) + \varepsilon_{it} \tag{F.5}$$

where P_{it} equals to 1 if individual i is employed at time period t and z_i is the age of the individual on 1st August 2004. Those individuals who were younger than 55 years old at the time of the reform, $\mathbf{1}\{z_i < 55\}$, were not eligible for the OAUB program, while those individuals who were older than 55 were eligible for the OAUB if they met certain non-age eligibility requirements described in greater detail below. As such, the regression coefficient β^{OAUB} captures the effect of having access to the OAUB program. We follow

Lee and Lemieux (2010) and estimate two separate regressions of $f(z_i)$ on each side of the cutoff point. We use a linear trend in the birth date.

A key assumption in such a regression discontinuity design is that there is no manipulation of the running variable z_i. Such a manipulation would induce bunching in the data. Figure F.1 highlights that there is no such bunching observed in the frequency distribution around the discontinuity.

In Table F.1 we report the estimated β^{OAUB} from the regression equation (F.5). We report estimates using data from all regions (first row), and separately for high (second row) and low earnings growth regions (third row). Column (1) shows estimates with linear trend, while columns (2) - (6) shows the estimates with local-linear estimation by applying various bandwidth choices. The results are very similar across specifications and all specifications. There is a 3.1-4.2 percentage point drop in employment across the specifications and the estimated change in employment in high and low growth regions are similar to each other.

In Column (7) we also implement a net of placebo exercise following a similar strategy as in the main analysis on the pension reform. In particular, we compare the estimated post 2004 employment differences between individuals who were born just before and after 1st August 1949, to the pre 2004 employment differences. The results are virtually the same, which highlights that there is no change in employment preceding the reform. This is shown in Table F.2 where we directly show the employment differences around the discontinuity in the years preceding the reform.

F.3 Calculation of the Employment Elasticity

Our aim is to calculate the employment elasticity as defined in equation (F.4). Our empirical exercise recovers the percentage point change in employment at the policy discontinuity. To recover the percentage change in employment caused by losing access to OAUB program, $(P_t^{\text{OAUB}} - P_t^{\text{NOAUB}})/P_t^{\text{OAUB}}$, we need to take into account that not everyone who was older than age 55 was eligible to the program. Denote $Elig_i = 1$ if the individual satisfies the non-age related program requirements, such as having a long enough working history, and involuntary job loss and $Elig_i = 0$ if the individual does not satisfy the requirements.

The regression in equation (F.5) identifies the following difference in employment:[37]

$$\beta^{OAUB} = Pr(P_{it} = 1|z_i < 55) - Pr(P_{it} = 1|z_i > 55)$$

Whereas the above equation identifies the effect over both eligible and ineligible individuals, our elasticity formula shows the percentage change in employment for the eligible population, formally:

$$\frac{P_t^{\text{OAUB}} - P_t^{\text{NOAUB}}}{P_t^{\text{OAUB}}} = \frac{Pr(P_{it} = 1|Elig_i = 1, z_i < 55) - Pr(P_{it} = 1|Elig = 1, z_i > 55)}{Pr(P_{it} = 1|Elig_i = 1, z_i > 55)}. \tag{F.6}$$

We can apply similar steps as in Online Appendix D to get the percentage change in employment for the eligible population. Non-age related eligibility (from layoff and tenure) is unlikely to vary much with age at the discontinuity so we assume $Pr(Elig_i|z_i < 55) = Pr(Elig_i|z_i > 55) = Pr(Elig_i)$ and so

$$\begin{aligned}
& Pr(P_{it} = 1|z_i < 55) - Pr(P_{it} = 1|z_i > 55) = \\
= \quad & \big(Pr(P_{it} = 1|Elig_i = 1, z_i < 55) - Pr(P_{it} = 1|Elig_i = 1, z_i > 55)\big) \times Pr(Elig_i = 1) - \\
& -\big(Pr(P_{it} = 1|Elig_i = 0, z_i < 55) - Pr(P_{it} = 1|Elig_i = 0, z_i > 55)\big) \times Pr(Elig_i = 0) \\
= \quad & (Pr(P_{it} = 1|Elig_i = 1, z_i < 55) - Pr(P_{it} = 1|Elig_i = 1, z_i > 55) \times Pr(Elig_i = 1)
\end{aligned} \tag{F.7}$$

where in the second equality we have used that there is no employment change around the discontinuity for non-eligible workers $Pr(P_{it} = 1|Elig_i = 0, z_i < 55) - Pr(P_{it}^{\text{NOAUB}} = 1|Elig_i = 0, z_i > 55) = 0$. We also have that

$$Pr(P_{it} = 1|Elig_i = 1, z_i > 55) = \frac{Pr(P_{it} = 1 \cap Elig_i = 1|z_i > 55)}{Pr(Elig_i = 1)} \tag{F.8}$$

and plugging the previous two equations into equation (F.6) implies that

$$\frac{P_t^{\text{OAUB}} - P_t^{\text{NOAUB}}}{P_t^{\text{OAUB}}} = \frac{Pr(P_{it} = 1|z_i < 55) - Pr(P_{it} = 1|z_i > 55)}{Pr(P_{it} = 1 \cap Elig = 1|z_i > 55)} = \frac{\beta^{\text{OAUB}}}{Pr(P_{it} = 1 \cap Elig = 1|z_i > 55)}$$

[37] For simplicity, we abstract away from the issue that in our administrative data we only observe non-agriculture workers. Our empirical exercise recovers only the elasticity for non-agricultural workers, but this is exactly what we need for comparing the employment responses to the contemporaneous change in incentives to the changes coming through the pension reform.

where the numerator is the percentage point change in employment at the discontinuity while the denominator is the fraction of the population that is working and eligible to the OAUB program. The denominator can be rewritten as

$$Pr(P_{it} = 1 \cap Elig_i = 1 | z_i > 55) = Pr(P_{it} = 1 | z_i > 55) \times Pr(Elig_i = 1 | z_i > 55, P_{it} = 1) \tag{F.9}$$

where $Pr(P_{it} = 1 | z_i > 55)$ is the employment rate to the right of the discontinuity, and $Pr(Elig_i = 1 | z_i > 55, P_{it} = 1)$ is the fraction of individuals who are working and eligible to the pension reform.

We can directly observe $Pr(P_{it} = 1 | z_i > 55)$ in our data, which is between 36-39%, depending the region. Nevertheless, we do not directly observe eligibility in our data, and so we need to infer $Pr(Elig_i = 1 | z_i > 55, P_{it} = 1)$ indirectly from the data. The key eligibility criteria was whether the worker has long enough previous employment history and the job separation was involuntary termination. In practice, involuntary job separations are not common in Poland. However, the key is whether someone can "engineer" a severance such that makes the worker eligible for old age unemployment benefit program.[38] This "engineering" is likely to be easier for workers at smaller firms with long tenure. We corroborate this conjecture by exploiting the Labor Force Survey (LFS) data where we observe job tenure and firm size. We estimate the employment response around the reform discontinuity by estimating separately the change in employment using equation (F.5) for four groups of workers: workers with short tenure (at or below 8 years) at large firms (more than 10 workers), workers with long tenure (longer than 8 years) at large firms, workers with short tenure at small firms (10 or less workers), and workers with long tenure at small firms.

We report the key estimates in column (2) in Table 4. In most of the groups there is only a limited change in employment, except for workers in small firms and with tenure of long duration. Since the fraction of individuals employed in small firms with long-tenure is around 41.6% (see column (1) in Table 4), we assume 40% is a lower bound for the fraction of workers who were eligible for the unemployment program. In that case applying our formula leads to an elasticity of 0.88 (or 0.96 in high earnings growth regions and 0.84 in low earnings growth regions).

[38] Employment laws in Poland make firings potentially costly for the employer, since they require severance payments and if the firing is not justified then they are legally responsible for compensation.

Nevertheless, it is also possible that some of the workers in the other categories can also “engineer” an involuntary separation. We infer an upper bound of the fraction of eligible population in each subgroup as follows. We assume that all of the individuals in the most responsive category of workers (with long tenure and in small firms) are eligible for OAUB. From column (3) of Table F.3, it can be seen that this category of workers experiences a change in employment of 28.4% as a result of the reform. We then assume that the ratio of the estimated percent change for each of the other groups to the change in the most affected group corresponds to the fraction of workers eligible in each employment group. For instance, since the short-tenure and large-firm group experience a 20% change in employment as a result of the reform, we infer that $20.0/28.4 = 70.4\%$ of individuals in this group are eligible for OAUB. And since workers in the short-tenure and large-firm group constitute 17.4% of the workforce, eligible workers in this group constitute 12.3% of the overall workforce. If we apply this exercise to each group and sum up to the total fraction of workers eligible, we arrive at an overall eligibility rate of 60.4%. This is our preferred eligibility rate, as it is likely that some fraction of all employment categories were eligible for the benefit. The corresponding elasticity for this eligibility rate is 0.58 (or 0.64 in high earnings growth regions and 0.56 in low-earnings growth regions).

F.4 Tables and Figures

Table F.1: Effect of Old Age Unemployment Benefit (OAUB) Reform on Employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. All regions	0.0371***	0.0376***	0.0340***	0.0326***	0.0374***	0.0337***	0.0370***
N = 790,783	(0.0022)	(0.0026)	(0.0032)	(0.0033)	(0.0024)	(0.0053)	(0.0060)
2. High-growth	0.0418***	0.0421***	0.0325***	0.0337***	0.0414***	0.0333***	0.0400***
N = 313,470	(0.0036)	(0.0042)	(0.0051)	(0.0053)	(0.0039)	(0.0084)	(0.0096)
3. Low-growth	0.0339***	0.0347***	0.0351***	0.0316***	0.0346***	0.0353***	0.0349***
N = 474,131	(0.0029)	(0.0033)	(0.0060)	(0.0043)	(0.0031)	(0.0064)	(0.0041)
Sample	full	full	full	full	full	full	full
$f(z_i)$	Linear trend	Local-Linear	Local-Linear	Local-Linear	Local-Linear	Local-Linear	Linear trend
Bandwith	–	150	50	100	200	Calonico et al.	–
net of placebo	no	no	no	no	no	no	yes

Notes: This table shows the estimated change in employment at the old age unemployment benefit program discontinuity. Each cell in the table shows the β^{OAUB} coefficients of the RDD specification shown in equation (F.5). The rows show the estimated employment change for different regions. The first row shows it for all regions, while the second and third rows show the estimated effect in high and low-growth regions, respectively. High-growth regions are regions with above median earnings growth rate between 2000 and 2013, while low-growth regions have below median growth. In all columns we use the full dataset (no donut hole applied). In columns (1), (7) we estimate a linear trend in birth date allowing for different slopes and intercepts at either side of the cutoff. Columns (2)-(6) apply a kernel-weighted local linear regressions with various bandwidth choices. Column (7) estimates the change in employment at the reform discontinuity relative to the change at the placebo discontinuity by applying an analogous empirical strategy to that described in equation (15). The placebo discontinuity is estimated for the 1949 cohort in 2001-2002, before the OAUB reform was announced. We report standard errors in parentheses. For the local-linear regression we calculate robust standard errors following Calonico et al. (2014). Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table F.2: Placebo Estimates on Employment Effect of the Old Age Unemployment Benefit (OAUB) Program

Income growth region	Placebo (2001-2003)
All regions	0.0001
N = 833,934	(0.0023)
High-growth	0.0018
N = 333,173	(0.0036)
Low-growth	0.0010
N = 499,872	(0.0029)
Sample	full
$f(z_i)$	Linear trend

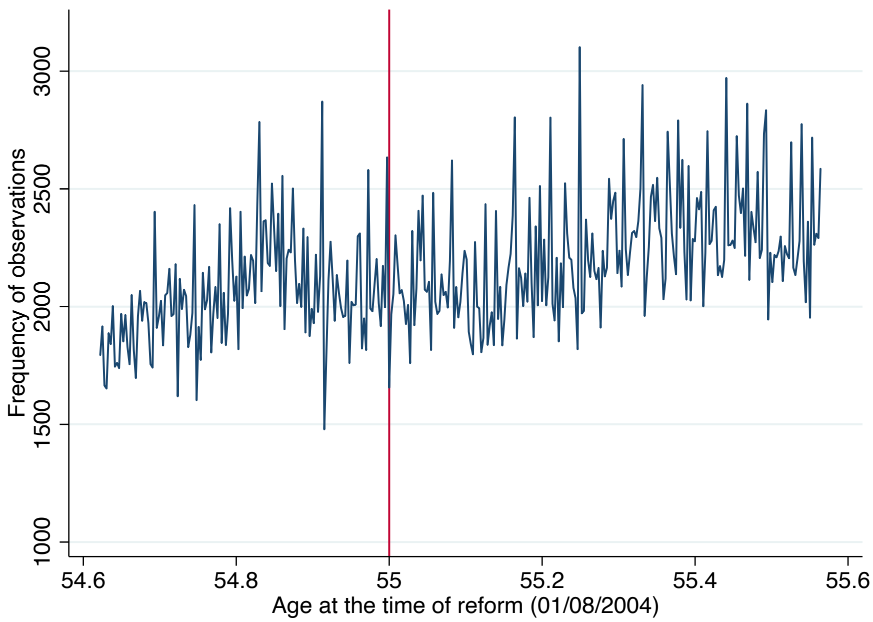
Notes: This table shows the estimated change in employment at the placebo discontinuity. We use the 1949 cohort in 2001-2003, before the OAUB reform was announced. We estimate a linear trend in birth date allowing for different slopes and intercepts at either side of the placebo cutoff. We report robust standard errors in parentheses. Significance levels are: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table F.3: Effects of Old Age Unemployment Benefit (OAUB) by Employment Type

	(1) Share of Workforce (%)	(2) RDD estimate	(3) Percent change (%)
Short tenure and large firm	17.42	0.0209	20.00
		(0.0154)	
Long tenure and large firm	32.58	0.0053	2.71
		(0.0238)	
Short tenure and small firm	8.39	0.0059	11.72
		(0.0125)	
Long tenure and small firm	41.61	0.0709***	28.40
		(0.0261)	
Number of observation		2,430	2,430

Notes: Column (1) shows the fraction of workforce in four employment categories: workers with short tenure (at or below 8 years) at large firms (more than 10 workers), workers with long tenure (longer than 8 years) at large firms, workers with short tenure at small firms (10 or less workers), and workers with long tenure at small firms. Column (2) reports the β^{OAUB} coefficients of the RDD specification shown in equation (F.5) estimating separately the employment discontinuity for each of the four categories. Each row corresponds to a separate regression with the outcome being employed in the particular employment category. For instance, in the 1st row, the outcome variable is equal to 1 if an individual is employed at a large firm with short tenure, and 0 otherwise. We use the Labor Force Survey for this analysis and the years for which we have month-of-birth information in the the data, namely 2004 (post-1st August) and 2005. We estimate a linear trend in birth date allowing for different slopes and intercepts at either side of the cutoff. Column (3) reports the corresponding percent change in employment in each employment category (dividing column 2 by column 1). Significance levels are: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Figure F.1: Frequencies by Day of Birth around the Old Age Unemployment Benefit (OAUB) Program Discontinuity



Notes: This figure shows the number of observations by day of birth for the cohort of those born in 1949. The frequencies are calculated using the population registry in the years 2005-2007. Individuals who were 55 or younger on 01/08/2004 were no longer eligible for the old age unemployment benefit. Individuals who were older than age 55 on 01/08/2004 could still take up the old age unemployment benefit. The reform discontinuity is marked with the red vertical line.

Online Appendix G Appendix to Lifecycle Model

G.1 Model Pension Systems

Our approach to modeling pension accrual closely follows the approach in the simulations in Section 4. To be consistent with our treatment of the net return to work in our simulations, we measure pension accrual as an increment to income, using an approach similar to the one in French and Jones (2011). Our approach here is different in one important regard. In our simulations we can allow pension wealth to depend on the entire history of wage and unemployment shocks, whereas in the dynamic model this would be computationally infeasible, and so we must approximate pension accrual given the model's state variables (and in particular, age, income and region).

We consider three scenarios when comparing DB and NDC systems. In the first scenario we consider DB and NDC systems which would apply to cohorts of individuals who work their entire careers under one of the two systems. We refer to these as the 'steady-state' DB and NDC pension systems. In the second we compare a steady state DB system to a composite system where everyone begins in the DB system, but some people transition into the NDC system at age 50, in a way similar to the impacted cohorts in our data. Finally, we consider 'steady state' DB and NDC systems where we construct the DB and NDC systems to be revenue-equivalent, allowing us to isolate the effect of work incentives. We now discuss each of these in turn.

G.1.1 Steady state pension systems

DB Pension Our approximated DB system has three components: (1) a universal payment to all individuals in retirement; (2) an increment to contemporaneous income received in periods in which an individual works; and (3) an increment to contemporaneous income received whether or not an individual works. Taking each in turn, the DB system comprises:

1. A universal payment to all those over the pension age, α_0^{DB}, which represents the universal component of the DB pension (the first term in the last bracket in equation (4)).

2. An increment to contemporaneous earnings in period t received if the agent chooses to work, which is proportional to earnings by a factor $\alpha_{1,t}^{DB}$ which varies by age and region (we suppress region subscripts here). This is estimated using our simulations in three steps:

   i) We first calculate the change in the present value of DB pensions as a result of choosing to work in a particular year for each simulated agent (in exactly the same manner as we do in Section 4).

   ii) We then take the ratio of the change in the present value to earnings at time t for each simulated agent.

   iii) Finally, we calculate the average of the resulting ratio over all simulated agents for each year t, to yield our measure of $\alpha_{1,t}^{DB}$ for all t.

3. Finally, under the DB system, unemployed individuals accumulated DB benefits by accumulating "contributory years" while on unemployment benefits – a period of 6 months in our model. To account for this, under the DB system, we assume individuals receive a contribution which is proportional (by a factor $\alpha_{2,t}^{DB}$) to the earnings that they would have received if they had chosen to work.

   We calculate this component as the change in the DB pension when being out of work and *not* receiving unemployment benefits, compared with being out of work and receiving unemployment benefits. This is estimated using our simulations as follows:

   i) We calculate what the increment to DB wealth would be if the agent worked under the (modeled) scenario where there is 6 months of unemployment benefits received when not working.

   ii) We calculate what the increment to DB wealth would be if the agent worked under the (counterfactual) scenario where there would be no unemployment benefit receipt for each individual in our simulations.

   iii) We take the difference of the objects calculated in (i) and (ii). We take this to be the increment to DB wealth which results in not working but receiving six months of unemployment insurance.

   iv) We express that quantity as a fraction of potential earnings at time t for each simulated agent (potential earnings are earnings for workers, and the earnings that those who do not work would receive if they worked).

v) We calculate the average of the resulting ratio over all simulated agents in our simulations for each year t to yield our measure of $\alpha_{2,t}^{DB}$ for all t.

The first of these three components enters the budget sets directly when an individual is retired, as shown in equation (G.15) in the next subsection. The second and third of these components enter through income during working life, which can be characterized as follows:

$$\begin{aligned} y_{it}^{DB} &= (1-\tau(\tau^{pi},\tau^{ss})+\alpha_{1,t}^{DB}+\alpha_{2,t}^{DB})w_{it} \quad \text{if} \quad P_{it}=1 \\ y_{it}^{DB} &= u+\alpha_{2,t}^{DB}w_{it} \quad \text{if} \quad P_{it}=0 \end{aligned} \tag{G.10}$$

where $\tau(.)$ gives tax due, u is an out-of-work welfare payment, and $\alpha_{1,t}^{DB}$ and $\alpha_{2,t}^{DB}$ are pension wealth accrual factors which individuals receive, respectively, if they work and whether they work or not. w_{it} are potential earnings. The calculation of $\alpha_{1,t}^{DB}$ and $\alpha_{2,t}^{DB}$ accounts for the taxation of pension wealth.

NDC Pension We calculate NDC wealth accrual in a similar fashion. There is no universal component to the pension, so the analogy to the DB universal component is $\alpha_0^{NDC}=0$. $\alpha_{1,t}^{NDC}$ is a factor which, when multiplied by earnings, gives an increment to income if the agent chooses to work. $\alpha_{2,t}^{NDC}$ is a factor which, when multiplied by (potential) earnings, gives the increment to income whether or not the agent chooses to work.

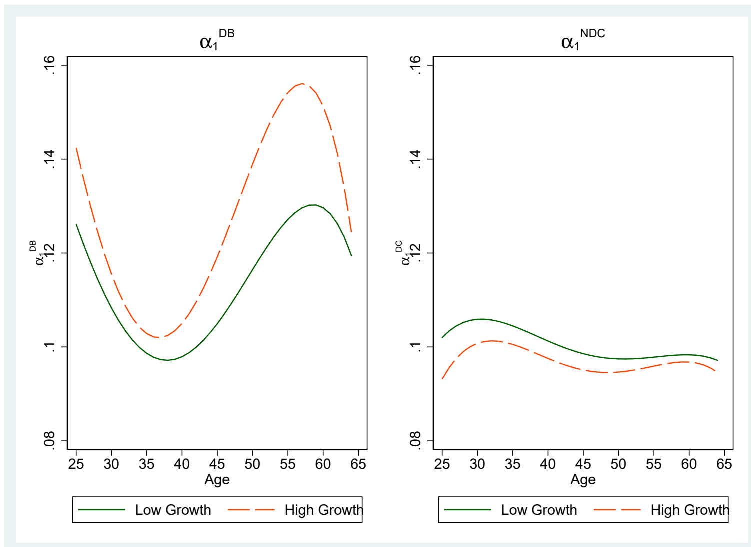
The form of income under the NDC system has the same form as that in equation G.10 but with $\alpha_{1,t}^{NDC}$ and $\alpha_{2,t}^{NDC}$ in the place of $\alpha_{1,t}^{DB}$ and $\alpha_{2,t}^{DB}$.

Summary The two steady-state pension systems can therefore be characterized by the following vectors of parameters:

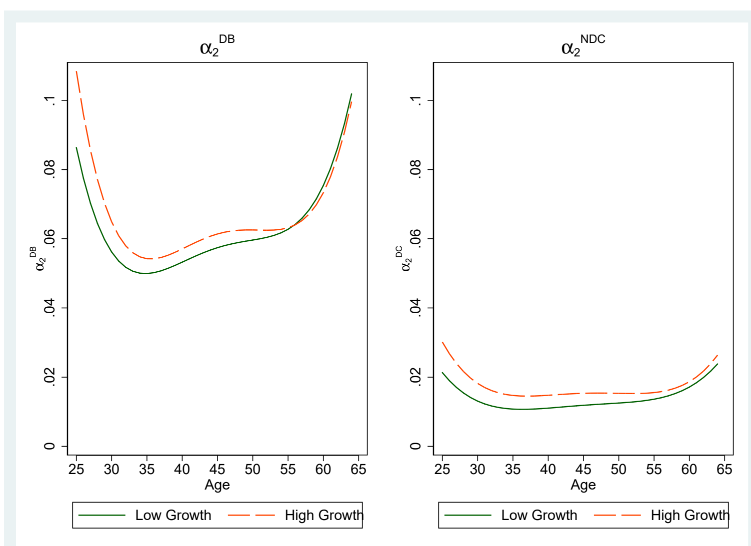
$$\left(\alpha_0^k,\{\alpha_{1,t}^k\}_{t=1}^T,\{\alpha_{2,t}^k\}_{t=1}^T\right), \tag{G.11}$$

where $k\in\{DB,NDC\}$ indexes pension systems. Figure G.2 illustrates the accrual factors $\{\alpha_{1,t}^k\}_{t=1}^T,\{\alpha_{2,t}^k\}_{t=1}^T$ for each of the two pension systems. Note that the return to work arising from the DB system $\{\alpha_{1,t}^{DB}\}_{t=1}^T$ (in the top left panel of the figure) is higher at all ages for those in high-growth regions than for those in low-growth regions. Later in the lifecycle, this predominantly occurs due to more frequent (and larger) recalculations of AIME for those in high-growth regions. Early in the lifecycle, this predominantly occurs due to the fact that the ultimate pension will be calculated based on an AIME that is large relative to contemporaneous earnings (a fact which is true for both types of individuals, but which is quantitatively more important for those in high-growth regions).

Figure G.2: Pension Accrual Parameters



(a) $\{\alpha^{DB}_{1,t}\}^T_{t=1}$ and $\{\alpha^{NDC}_{1,t}\}^T_{t=1}$



(b) $\{\alpha^{DB}_{2,t}\}^T_{t=1}$ and $\{\alpha^{NDC}_{2,t}\}^T_{t=1}$

G.1.2 Pension system for transition cohort

The systems described above characterize the pensions relevant when considering the behaviours of cohorts who lived their entire working lives under the DB and NDC regimes respectively. Our approach to estimating the causal impact of the reform at the cohort discontinuity in Section 6, however, involves comparing the behavior of a cohort who worked their entire career under the DB regime with a transition cohort who worked until age 50 under the DB regime before being switched to the NDC regime. We need to model the behavior of the latter cohort to obtain model predictions of the change in labor supply, which are used in estimation. To do this we model the pension system for that cohort as:

$$\left(\alpha_0^{trans}, \{\alpha_{1,t}^{trans}\}_{t=1}^{T}, \{\alpha_{2,t}^{trans}\}_{t=1}^{T}\right) \tag{G.12}$$

$$\alpha_0^{trans} = \varphi\, \alpha_0^{DB} \tag{G.13}$$

$$\begin{aligned} \alpha_{1,t}^{trans} &= \alpha_{1,t}^{DB} && t < 50 \\ \alpha_{2,t}^{trans} &= \alpha_{2,t}^{DB} && t < 50 \\ \\ \alpha_{1,t}^{trans} &= \alpha_{1,t}^{NDC} && t \geq 50 \\ \alpha_{2,t}^{trans} &= \alpha_{2,t}^{NDC} && t \geq 50 \end{aligned} \tag{G.14}$$

where the transition cohort, unlike those who spend their whole careers under the NDC regime, *do* receive a universal payment ($\alpha_0^{trans} = \varphi\ \alpha_0^{DB}$), which is unrelated to their earnings history and is lower, by a factor φ, than that received by those who stayed in the DB system. This comes through starting capital, the formula for which is outlined in equation (8). Using that formula, we estimate that $\varphi = 0.71$.[39]

In summary, the parameters of the pension accrual increments that are proportional

[39] That is, the transition cohort has a universal component of the pension worth 71% of that of the cohort who remained in the DB pension.

to earnings ($\alpha_{1,t}^{trans}, \alpha_{2,t}^{trans}$) are those of the DB scheme for up to age 50 (before the reform) and those of the NDC scheme from the age of 50 onwards.

G.1.3 Pension systems used in counterfactual exercise

Once the model is estimated, we use it to evaluate the likely effects on lifecycle labor supply of the changes in the net return to work implied by the reform. For this analysis (the results of which are illustrated in Figure 7), in order to isolate the changes in the net return to work from the changes induced by the fact that the payments became less generous overall, we construct two systems – one with NDC work incentives and one with DB work incentives – which are adjusted to yield the same government balance. We hold the two components which *do not* depend on work choices (α_0^k and $\{\alpha_{2,t}^k\}_{t=1}^T$) constant across systems, set at their levels in the DB system ($k = DB$). Pension accrual when working in the modelled NDC system is that of the new system ($\{\alpha_{1,t}^{NDC}\}_{t=1}^T$). Pension accrual when working in the modelled DB system is that prevailing in the old DB system scaled by a factor ϕ ($\{\phi\alpha_{1,t}^{DB}\}_{t=1}^T$). The value of ϕ is chosen such that the discounted value of the government balance (the sum of taxes and social security contributions, less welfare and pension payments) is the same in both cases.

Formally, the two pension systems we compare are a system with accrual in work following the NDC work incentives:

$$\left(\alpha_0^{DB}, \{\alpha_{\mathbf{1,t}}^{\mathbf{NDC}}\}_{t=1}^T, \{\alpha_{2,t}^{DB}\}_{t=1}^T\right),$$

and a modified DB system where the component that the agents get only if they work is scaled by a factor ϕ,

$$\left(\alpha_0^{DB}, \{\phi\alpha_{\mathbf{1,t}}^{\mathbf{DB}}\}_{t=1}^T, \{\alpha_{2,t}^{DB}\}_{t=1}^T\right).$$

We highlight in boldface the component that differs across these two systems. In our counterfactual analysis, ϕ is found to be 0.86 to obtain revenue neutrality.

G.2 Recursive Specification of the model

Equation G.15 gives the recursive specification of the agent's problem. Our vector of state variables is $\mathbf{X}_{it} = \{\text{region}_i, \nu_i, t, a_{it}, \text{offer}_{it}, w_{it}\}$. Two of these variables represent permanent heterogeneity, namely, region of residence $\in$ {low growth, high growth}, and agent's consumption weight (ν_i – their 'type'). The four which vary across the lifecycle are age (t), assets (a_{it}), the presence (or otherwise) of an employment offer (offer_{it}) and wages (w_{it}).

$$V_t(\mathbf{X}_{it}) = \max_{\{c_{it}, P_{it}\}} U(c_{it}, l_{it}; \nu_i) + \beta\Big(s_{t+1}\mathbb{E}_t V_{it+1}(\mathbf{X}_{it+1})\Big) \tag{G.15}$$

$$s.t. \begin{cases} a_{it+1} = (a_{it} + y_{it}^k - c_{it})(1+r) & \text{if } t < R \\ a_{it+1} = (a_{it} + \alpha_0^k - c_{it})(1+r) & \text{if } t \geq R \\ l_{it} = 1 - hP_{it} \\ a_{it+1} \geq 0 \end{cases}$$

where:

- c and P are the model's choice variables: consumption and participation
- $U(.)$ is the utility function, defined over consumption and leisure, given in equation (18)
- β is the discount factor
- s_{t+1} is the probability of surviving to period $t+1$, conditional on having survived to t
- the expectation operator integrates over future period wage distribution and employment offer probabilities
- R is the age at which agents must stop work (65)
- a is the level of assets held
- h is the share of the leisure endowment given up when an agent chooses to work

- y^k is income, inclusive of pension wealth accrual under the prevailing pension system k (as defined in equation G.10 for the $k = DB$ case)
- α_0^k is the universal component of the prevailing pension system (k)

G.3 Solution of the Model

The model outlined has no analytical solution and must be solved numerically. We do this using standard methods, which we summarize very briefly here. See the Appendix to Crawford and O'Dea (2020) for a more detailed description of the solution to a similar model.

We first select a discrete subset of the state space ($\mathbf{X}_t$). Of our six state variables, three are naturally discrete (region of residence, age, and employment offer). The other three are continuous variables (assets, wages and consumption weight) that need to be discretized. For assets, we form a grid of 50 points, spaced equally in log terms (so that more points are concentrated at the bottom of the grid where curvature will be greatest). For wages, which are distributed log-normally, we create a grid by dividing the distribution in each period into 20 equi-probable regions, with the grid being formed of the expected value in each of those regions. For preference types, we divide the Normal distribution into 10 equi-probable regions, with the grid being formed of the expected value in each of those regions. These three discretized sets of our continuous state variables, along with our naturally discrete state variables, form our discretized state space.

Solving the model involves solving the objective function at each point in the discretized state space starting in the final period of life T. The solution in this period yields the value function at each point in the discretized state space: $V_T(\mathbf{X}_T)$. Using this, the optimization problem for V_{T-1} and the problems for all earlier periods can be carried out iteratively. Linear interpolation is used to approximate the value function outside of the discrete subset of the state points we evaluate, and integration over wage shocks is carried out using the procedure in Tauchen (1986).

Solution of the model yields decision-rules for each of consumption and labor supply. These give optimal behavior at each point in the state space. Using these decision rules, random draws for earnings which follow the model's earnings process, and an initializing of the asset distribution (all households start with no assets), we can simulate behavior and obtain a simulated data set. Such a simulated data set for the model solved under actual policies can be used for estimation (see Section G.5 below). A simulated data set for a version solved under counterfactual policies can be used to assess what behavior would be under those policies (as in done in Figure 7).

G.4 Parameterization and Estimation

G.4.1 Parameterization

In our first step we set model features which can be identified external to the model or set with reference to the literature. This includes the interest rate and the survival probabilities. We use the same survival probabilities and the same interest rate used previously in the paper. We also set two preference parameters to values commonly used in the literature. One is the coefficient of relative risk aversion on utility, which is set at 4, a typical value for use in a non-separable utility function (see Auerbach and Kotlikoff (1987) or Conesa et al. (2009)), and the other is the discount rate, which we set equal to the interest rate ($\beta = \frac{1}{1+r}$). We normalize the leisure endowment to unity and assume that when agents work they forego 30% of their endowment (a standard value in the literature).

The parameters of the deterministic and AR(1) components of the earnings process are those in the simulation (see equation (11)).[40] The Markov process governing unemployment risk is also that in the simulation, discussed in Section 4 and with parameter values given in Table C.1.

G.5 Estimation

We estimate parameters using Indirect Inference. We choose parameters ($\chi = (\mu_\nu, \sigma_\nu^2)$) to minimize the following criterion function:

[40]The model does not include the MA(1) component process, which would involve the inclusion of another state variable. However, note from Panel C in Table 3, that our simulations are robust to changes in the earnings process and so this difference between the model and simulation is very unlikely to be consequential.

$$\hat{\chi} = \arg\min_{\chi} \ (\mathbf{m}(\chi) - \hat{\mathbf{m}})'\mathbf{W}(\mathbf{m}(\chi) - \hat{\mathbf{m}}), \tag{G.16}$$

where $\hat{\mathbf{m}}$ is the vector of moments we match, $\mathbf{m}(\chi)$ is a vector of the values of those moments implied by the model at parameter vector χ, and $\mathbf{W}$ is a weighting function for which we use the optimal weighting matrix - the inverse of the empirical variance-covariance matrix of our moment vector, normalized by the number of observations (so an element of $\mathbf{W}$ would be the variance of the estimated employment rate at age 50, for example). Standard errors are calculated using the formula:

$$(\hat{\chi} - \chi_0) \rightsquigarrow N(0, \mathbf{V}),$$

where optimal weighting implies

$$\mathbf{V} = (1 + \tau)(\mathbf{D}'\mathbf{W}^{-1}\mathbf{D})^{-1}$$

where $\mathbf{D} = \frac{\partial \mathbf{m}(\chi)}{\partial \chi'}\Big|_{\chi=\chi_0}$ is the gradient matrix of the population moment vector and τ is the number of observations per simulation. In practice $\mathbf{W}$ and $\mathbf{D}$ are replaced by estimated values: see French (2005) for details.

The estimates are given in panel B of Table 5. The estimate of mean consumption weight of approximately 0.485 sits at the mid-point of a range of papers that use utility functions similar to ours applied to data from other countries,[41] and the standard deviation in the consumption weight of 0.145 indicates a modest degree of heterogeneity in the population – implying that 95% of the population has a consumption weight of between 0.195 and 0.775.

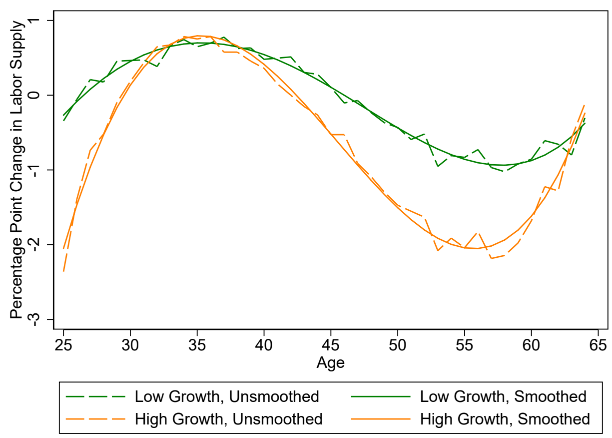
G.6 Counterfactual

The comparison of labor supply across the lifecycle summarized in Figure 7 compares a system with NDC work incentives with a system with DB work incentives designed to deliver an equivalent government balance to that prevailing under the NDC system. This is described in Section G.1.3

[41] Conesa et al. (2009) estimate a value 0.377, Nishiyama and Smetters (2007) have between 0.45 and 0.50, O'Dea (2019) estimates a range from 0.42 to 0.52, French and Jones (2011) estimate heterogeneous groups with an average in the population of 0.62.

The results in Figure 7 are smoothed using a fourth-order polynomial in age. To illustrate that there is very little difference between these smoothed profiles and the underlying unsmoothed profiles, Figure G.3 shows both together. The modest differences between the two figures are caused by approximation error. Even with fine grids and a large number of simulations, the object that we are analyzing – the difference between two labor supply averages – will be subject to modest approximation error.

Figure G.3: Effect of Switching to an NDC on Labor Supply Over the Lifecycle

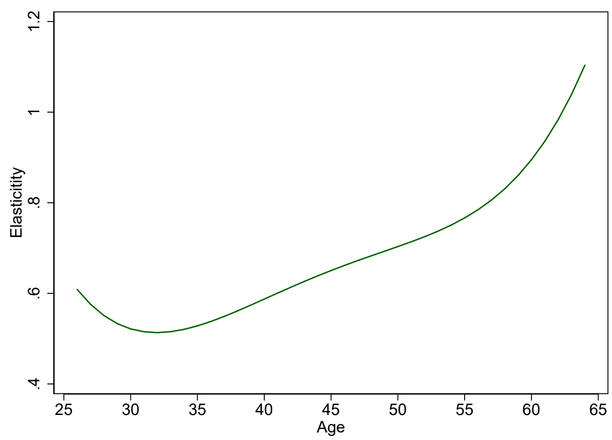


Notes: Percentage point change in labor supply at each age between the DB and NDC pension schemes. Profiles are smoothed using a polynomial of order 4. To isolate the reform effect on changing the net return to work from the effect operating through a reduction in the overall generosity of the pension system, we scale down the accruals in the DB system (proportionally) to ensure that the two pension systems are revenue- equivalent.

G.7 Elasticities

Figure G.4 gives our employment elasticities across the lifecycle. At any given age, these are calculated by perturbing wages by 20% at (only) that age, calculating the percentage change in the proportion in work and dividing it by labor supply at the unperturbed wage profile.

Figure G.4: Elasticities across the lifecyle



Notes: Elasticities are calculated by perturbing wages by 20% at each age, calculating the percentage change in the proportion in work and dividing it by labor supply at the unperturbed wage profile. Profile is smoothed using a polynomial of order 4.