Determinants and Implications of Sex-Based Public Pension Income Disparities: A Cross-Country Analysis

January 2022

Draft – Do not cite

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Abstract

Women eligible for their own old-age public pension benefits receive notably less than men in most European countries. The disparity is as high as 35% in some European countries. We examine the sources of this disparity using cross-country harmonized panel survey data with detailed work histories and country-period specific pension policy rules. Controlling for policies, claiming age, final earnings, and contribution years explains half of the sex-based pension differential across Italy, Spain, France and Germany. Our findings are consistent with earnings histories having a critical role in determining women's benefits, with policies rewarding longer earning histories worsening sex-based benefit differences. Recent pension reforms across Europe further tie benefits to earnings history, suggesting that sex-based pension disparities may increase without further reforms.

Keywords: Public pension, gender, gender equality, gender policy, old age policy

JEL codes: H55, J16, J18

Acknowledgements: Knapp and Lee acknowledge support from the from the National Institute on Aging (R01 AG030153).

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We used data from the 35th edition of the English Longitudinal Study of Ageing (ELSA), released July 2021. ELSA is the result of collaboration between University College London (UCL), the Institute for Fiscal Studies (IFS), and NatCen Social Research. Other academic collaborators based at the Universities of Cambridge, Exeter and East Anglia provided expert advice on specific modules. Funding for the first eight waves of ELSA has been provided by the US National Institute on Aging, and a consortium of British Government departments.

We used data from SHARE Waves 1, 2, 3, 4, 5, 6 release 7.1.0 as of June 2020 and SHARE Wave 7 release 7.1.1 as of December 2020. The SHARE data collection has been funded by the European Commission through the 5th framework programme (project QLK6-CT-2001-00360 in the thematic programme Quality of Life). Further support by the European Commission through the 6th framework programme (projects SHARE-I3, RII-CT-2006-062193, as an Integrated Infrastructure Initiative, COMPARE, CIT5-CT-2005-028857, as a project in Priority 7, Citizens and Governance in a Knowledge Based Society, and SHARE-LIFE (CIT4-CT2006-028812)) and through the 7th framework programme (SHARE-PREP (No 211909), SHARELEAP (No 227822) and M4 (No 261982)) is gratefully acknowledged. Substantial co-funding for add-ons such as the intensive training programme for SHARE interviewers came from the US National Institute on Aging (U01 AG09740-13S2, P01 AG005842, P01 AG08291, P30 AG12815, R21 AG025169, Y1-AG-4553-01, IAG BSR06-11 and OGHA 04-064). Substantial funding for the central coordination of SHARE came from the German Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung, BMBF). See http://www.shareproject.org/contact-organisation/funding.html for a full list of funding institutions.

We also used policy data compiled by the Gateway to Global Aging Data and the analysis data file from the Harmonized ELSA dataset and Codebook, Version G.2 and Harmonized SHARE dataset and Codebook, Version E.3 developed by the Gateway to Global Aging Data. The development of the Harmonized ELSA and the Harmonized SHARE was funded by the National Institute on Aging (R01 AG030153).

1. Introduction

One of the primary goals of old age social security systems is to provide guaranteed resources during the period of life where a person's ability to earn income through work may be limited. A long-standing issue in these social security systems is sex-based inequality: on average women are entitled to substantially less benefits than men. This disparity is partly driven by their design. These systems typically pay defined benefits based on contribution years and earnings while employed. Women have more periods out of the labor force due to caretaking of children or elders, leading to fewer contribution years and more limited earnings histories. Differences also arise from persistent consequences of these choices or sex-based discrimination, both can result in persistently lower wages and poor promotional opportunities for women.

In recent decades, old-age social security systems throughout Europe have undergone substantial changes that have reformed the design of the defined benefit systems or shifted away from them entirely towards either universal basic payments or notional defined contribution systems. Reforms that further link benefits paid to work and earnings history are likely to exacerbate sex-based differences.

In this paper we take a cross-country approach to analyzing the determinants and implications of sex-based pension income disparities. Limited policy variation within a country limits our understanding of the role pension design plays in determining these disparities and also limits identification of effective policies for addressing these disparities. We document sex-based differences in old-age public pension benefits using cross-country harmonized data on persons in old-age. We find significant differences. For example, in Germany, Italy, and France, women eligible for old-age pension benefits receive less than 65% of the benefits paid to men eligible for benefits. Sex-based differences in pension benefits are not consistent across

countries. Denmark and Switzerland exhibit near parity between the sexes. Controlling for differences in work history, the gap between men and women's benefits significantly narrows in some countries (e.g., France) but is largely unaffected in others (e.g., Spain). Using detailed life history we decompose sex-based differences in benefits paid into differences attributable to work history and earnings in Spain, Italy, France and Germany. We find that whether greater final earnings or additional contribution years are associated with substantial growth in pension benefits for women varies by country and is closes related to the design of their pension system. Despite controlling for differences in person-level work histories, earnings and country-specific pension policies, significant differences in benefits between the sexes remain. Based on these sources of sex-based benefit differences, we discuss implications of recent pension reforms and identify plausible policies that are (or are not) likely to be effective at closing these disparities.

2. Data

A necessary input into a cross-country study on disparities in pension income is data that can address lifecycle differences in experiences, including work and family history, that might influence benefit entitlements. Ideally, administrative data from multiple countries could be collected and analyzed, but privacy considerations usually prevent data sharing by country pension systems, limiting researchers' ability to combine them in a single analysis. The next best alternative is survey data. The ideal survey data would be longitudinal to take advantage of time-varying policies and enable investigating the sensitivity of findings to concurrent events. Further, to facilitate cross-country comparisons, which can demonstrate the robustness of findings to alternative social, political, and cultural backgrounds, the survey design would be nationally representative and standardized prior to fielding and any residual cross-country differences would be harmonized after the survey. Finally, it would include information on household

circumstance to account for within household specialization over the life cycle that may explain differences in observed outcomes. Another necessary input is detailed information on institutional rules that can be used to determine old age public pension eligibility and benefit entitlement across time and country. Policy variation can help identify whether disparities in pension income arise from particular components of a pension system's design (e.g., contribution years) and inform whether particular policy features aimed are successful at relieving these disparities (e.g., credits for maternity).

Such survey and institutional policy data exist in the international Health and Retirement Studies. Building on survey data from the Survey of Health, Ageing and Retirement in Europe (SHARE), which began in 2004, and the English Longitudinal Survey of Ageing (ELSA), which began in 2002, the Gateway to Global Aging Data (g2aging.org) team have compiled institutional rules on old-age entitlements and constructed harmonized variables, capturing institutional differences. We use these survey and policy resources to examine cross-country differences in old age public pension income between men and women.[4] SHARE and ELSA follow ex ante standardization of survey design, including (1) biennial interviews with respondents and their spouses; (2) a multidisciplinary questionnaire design that elicits a wealth of information about health, retirement, demographics, and other topics; and (3) regular refreshment samples to keep the sample representative of the older population.[5] Additionally, these files

[4] Gateway to Global Aging Data (2020), produced by the Program on Global Aging, Health & Policy, University of Southern California, with funding from the National Institute on Aging (R01 AG030153)

[5] SHARE Waves 1, 2, 3, 4, 5, 6, 7 and 8 (DOIs: 10.6103/SHARE.w1.710, 10.6103/SHARE.w2.710, 10.6103/SHARE.w3.710, 10.6103/SHARE.w4.710, 10.6103/SHARE.w5.710, 10.6103/SHARE.w6.710, 10.6103/SHARE.w7.711, 10.6103/SHARE.w8cabeta.001), see Börsch-Supan et al. (2013) for methodological details. The SHARE data collection has been funded by the European Commission through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARELIFE: CIT4-CT-2006-028812), FP7 (SHARE-PREP: GA N°211909, SHARE-LEAP: GA N°227822, SHARE M4: GA N°261982, DASISH: GA N°283646) and Horizon 2020 (SHARE-DEV3: GA N°676536, SHARE-COHESION: GA N°870628, SERISS: GA N°654221, SSHOC: GA N°823782) and by DG Employment, Social Affairs & Inclusion. Additional funding from the German Ministry of Education and Research, the Max Planck Society for the

include life history interviews administered in Wave 3 for SHARE (2007-8) and ELSA (2006) and again in Wave 7 (2016-17) for SHARE countries and respondents that did not participate in the survey at the third interview.[6] Ex-post harmonization by the Gateway to Global Aging Data project ensures that remaining differences in definitions of data elements are addressed.

3. Determinants of sex-based disparities in public pension income

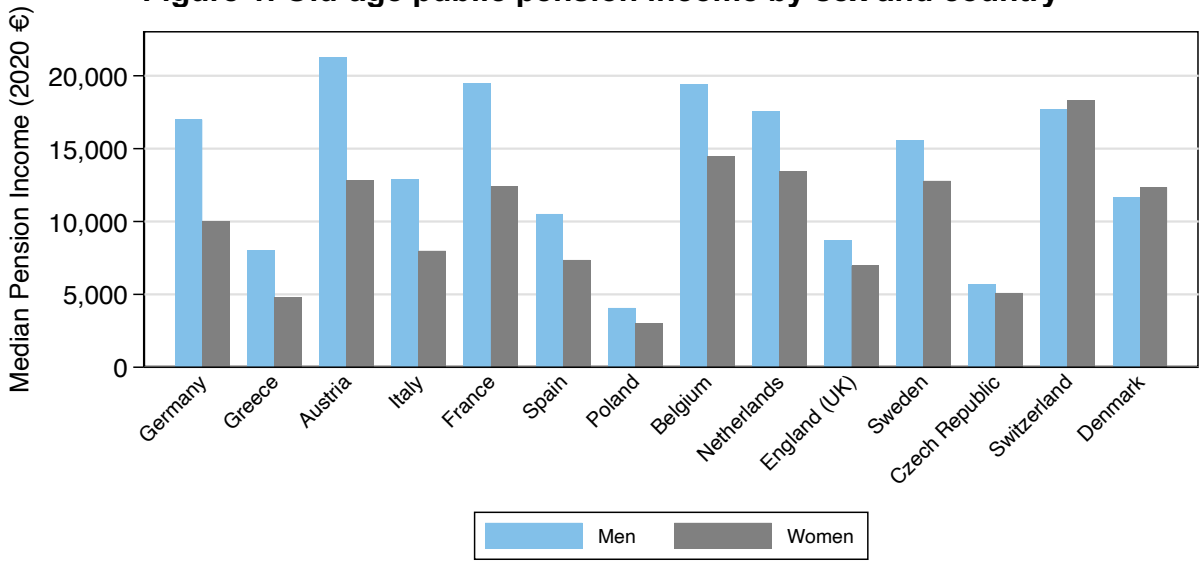
Sex-based disparities in public pension income across countries have been noted in a number of studies (for example, see Ginn, Street and Arber 2001; Fultz, Ruck and Steinhilber 2003; James, Cox Edwards, and Wong 2003; OECD 2021). James, Cox Edwards, and Wong (2003) highlight five factors contributing to gender differences in pension benefits: labor force participation, wages, sex-based retirement age policies, longevity, and widowhood. Barrientos (1998) also highlights the role of household division of labor — including responsibilities at home, breaks from the labor force and hour, and mobility constraints, in determining labor market participation as well as occupational choice.

Figure 1 demonstrates substantial differences in pension benefits by sex among married European men and women as reported in SHARE (2004-2017) and ELSA (2002-2018). Countries in Figure 1 are ordered from the largest to smallest percentage difference in women's benefits relative to men's benefits. Some countries have pronounced differences, as in the case of Germany, Greece, Austria, Italy and France where women's benefits relative to men's are 65% or less. Other countries, such as Switzerland and Denmark, exhibit near parity between the sexes.

Advancement of Science, the U.S. National Institute on Aging (U01_AG09740-13S2, P01_AG005842, P01_AG08291, P30_AG12815, R21_AG025169, Y1-AG-4553-01, IAG_BSR06-11, OGHA_04-064, HHSN271201300071C) and from various national funding sources is gratefully acknowledged (see www.share-project.org).

[6] Additionally, this paper uses data from the generated Job Episodes Panel (DOI: 10.6103/SHARE.jep.710), see Brugiavini et al. (2019) for methodological details. The Job Episodes Panel release 7.1.0 is based on SHARE Waves 3 and 7 (DOIs: 10.6103/SHARE.w3.710, 10.6103/SHARE.w7.710).

Figure 1. Old-age public pension income by sex and country



Notes: Estimates are conditional on observing individuals at age 70 or older to avoid censoring on pension income level. Income depicted in 2020 euros. Values are computed by first taking the median of non-zero, inflation-adjusted annual after-tax pension income reported by individuals across interviews and then taking the median by sex and country.

OECD (2021) documents similar disparities in retirement income (i.e., a measure that also includes income from public old-age social assistance and private or individual pensions). Relative to OECD (2021), our income disparities tend to be smaller because they are limited to old-age public pension benefits.

To understand the determinant of sex-based disparities, we focus on old-age public pensions because they are the primary instrument that governments have for insuring income in old age among individuals working in the country's private sector. Additionally, they are generally compulsory and independent of specific employers. We focus on currently married men and women as married and unmarried individuals are likely to have significantly different lifecycle choices and outcomes that determine their pension entitlements. This group represents a strong majority of individuals at this age, typically from 69% - 82% of the near-retirement population

(age 50-59) and 66% - 80% of typical pension eligibility ages (ages 60-69).[7] Most of these marriages are long marriages of more than 20 years for those age 50-59 and more than 30 years for those age 60-69.

Formulas for public pension benefits depend on contribution and earnings histories and do not typically vary by sex.[8] Each country's defined public pension benefit for person *i* in retirement is determined by a variant of

$$B_i \quad = \quad CY_i \times AIC_i \times RM_i \times CAA_i \qquad (1)$$

where CY_i is *i*'s cumulative contribution years, AIC_i is *i*'s final average indexed contributions based on earned income, RM_i is *i*'s replacement multiplier per contribution year based on the country benefit rules in place at the time he or she starts benefits, and CAA_i is *i*'s claiming age adjustment for starting benefits before or after the age/contribution year combination required for full benefits. Since equation (1) does not depend on sex, we can leverage these benefit structures to understand what factors correlate with, and may potentially explain, the observed differences between men and women. In some cases, benefit eligibility (distinct from the benefit formula in equation (1)) does vary by sex. That variation may have indirect effects on the level of benefits, which will increase women's benefits relative to men's (e.g., in Italy women can access unreduced benefits at a younger age).

The major pathways in equation (1) by which sex-based benefit disparities are likely to occur are contribution years, average income, and the claiming age penalty. The replacement multiplier is not a likely pathway because it is either constant or progressive, which would tend to favor

[7] Based on Gateway to Global Aging Data (2021) weighted estimates of a country's 2014 sample with a spouse by 10-year age group (2012 for the Netherlands as a 2014 estimate is not available). The range of married individuals has increased since 2004 (first SHARE survey) for ages 60-69, likely due to decreased mortality leading to fewer widows.

[8] Eligibility for full benefits based on sex does vary by country, but the computation of benefits at the normal retirement age does not.

women, who often have lower earnings. Sex-based pension differences may arise through the claiming age penalty because preferences to retire may differ by sex. However, those preference-driven differences are not the focus of this paper. We focus on contribution years and average income because they are likely to absorb the consequences of breaks for child bearing and rearing, which can result in sex-based benefit disparities.

This research is in progress, so we present findings for a few countries for which complete information on historical pension policy has been collected. We intend to add additional countries that have traditional defined benefit pension systems described by equation (1) but where the gaps between men and women are smaller (e.g., Czech Republic or Poland). For the rest of our analysis, we present findings focusing on Italy, Spain, France, and Germany. These countries all have typical defined benefit pensions through most of the observed period.

3.1. Contribution years

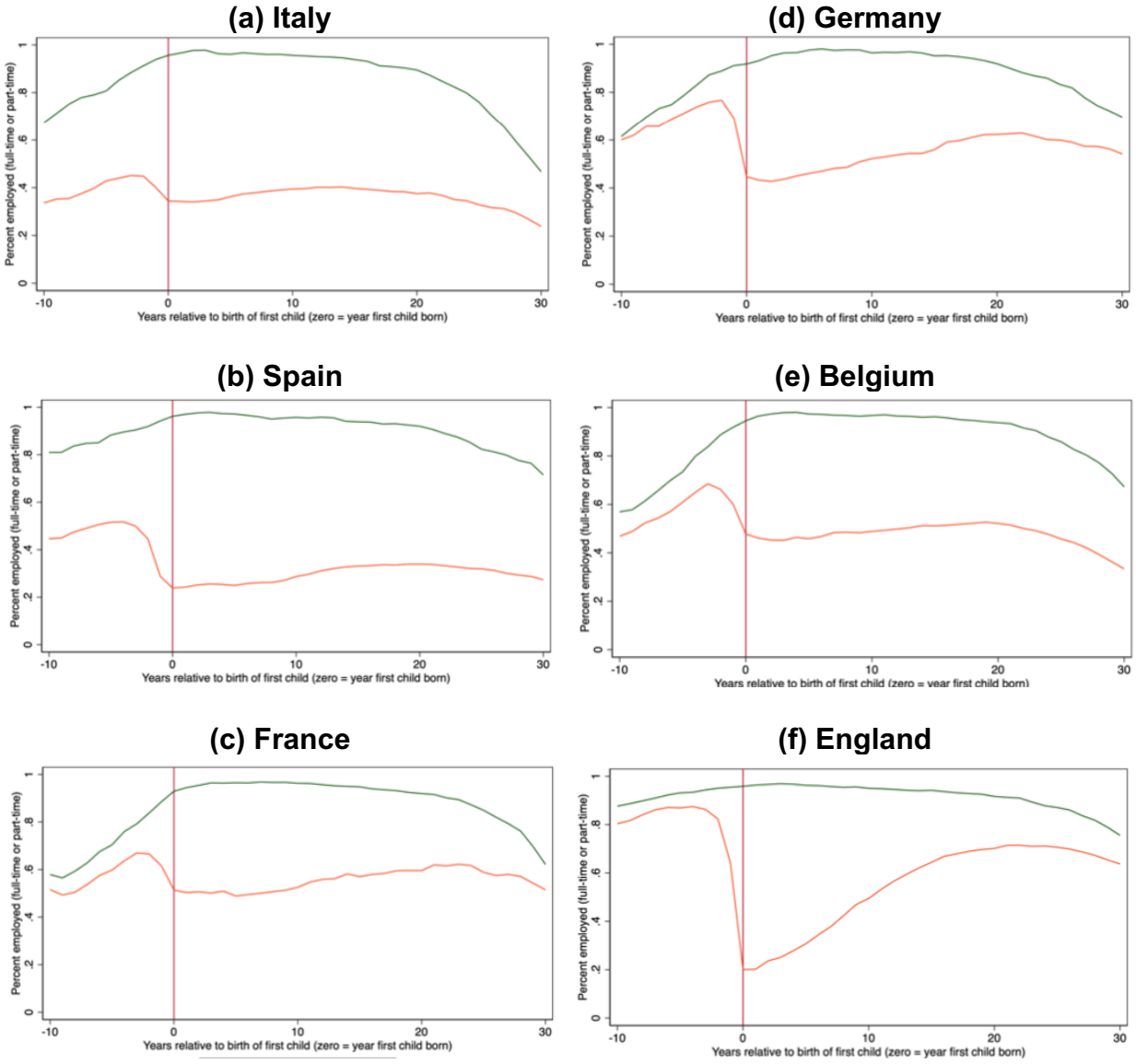
Contribution years are likely to be a critical determinant of differences in pension benefits as women are more likely to take breaks from work to have and raise children while young and to care for parents later in life. These breaks from work can have persistent effects above and beyond the break itself if finding work after these breaks is difficult and if the type of work available is short-term or has limited career potential.

Using life histories, we are able to document sex-based difference in employment around key life-cycle events such as the birth of a child or marriage. Figure 2 documents these patterns in Italy, France, Spain, Germany, Belgium, and England. The fraction working is increasing prior to the birth of the first child for both men and women, reflecting initial entry into the labor force. During this period, we see women are less likely to work than men, but this gap is notably smaller in France, Germany, Belgium and England than it is in Italy or Spain where 50% or less

of women in these cohorts work before childbirth. This pattern exists prior to marriage as well. The fraction of women not working highlights the confounding role that unobserved preference for work can have in creating pension disparities.

A consistent cross-country pattern is that the paths for men and women diverge around the birth of a first child, with the share of men working continuing to increase and the share of women exhibiting a sharp decrease. In all six countries, more than 1 in 5 women continue to work without a substantial break. The fraction of women that stop work varies substantially by country with France and Italy exhibiting similar declines, but England and Spain exhibiting much larger declines (approximately 75% and 50% compared to the fraction working 2 years before their first childbirth). In the 20 years following the first child birth, we observe a gradual increase in the fraction of women working but it never returns to pre-child birth levels. In England, France and Germany, a greater fraction of women eventually returns to employment. These patterns highlight that challenges mothers face in returning to the labor force after childbirth may vary by country as well as mothers' preference for work after childbirth. As noted earlier, this could be a longer break than intended if finding work after these breaks is difficult or inconsistent. However, it may also represent an intentional choice driven by competing demands and intra household specialization where a couple decides to have one person focus on market income while another focuses on home production (Becker, 1991).

Figure 2: Work histories relative to birth of first child



Notes: Author's calculations using SHARELIFE and ELSA Life History.

If pension disparities are driven primarily by a greater share of women or households whose preference is for household specialization, then that could have very different consequences for old-age social security policy then if it is a byproduct of persistent effects of childbearing or sex-based discrimination, as policymakers may be more likely to want to ameliorate differences driven by those latter factors.

There are several policies in place aimed at addressing the *direct* consequences that having and caring for children have on contribution years for women.[9] These policies include:

(a) reduced required contribution years for women for full benefit eligibility (e.g., Belgium, Poland, UK), although having children is not typically required

(b) fewer required contribution years for reduced benefit eligibility (e.g., Estonia)

(c) maternity or caretaking credits for contribution years toward benefit eligibility (e.g., Austria, France, Germany, Italy, Poland, Spain), although these credits may be limited based on a child's age or by an overall cap

(d) transfer of pension rights from earner to carer (e.g., Austria)

These adjustments are intended to either increase the number of contribution years such that it becomes easier for a person to satisfy benefit eligibility requirements or to lower those requirements. Often those aimed at lowering requirements are sex-based and not conditional on having children, with the exception of Home Responsibilities Protection, which was a policy used in the UK prior to 2010 that reduced required contributions based on periods out of the labor force for caretaking (Bozio, Crawford and Tetlow, 2010). The main mechanism used by most countries is to credit contribution years, which increases lifetime benefits for mothers who take breaks from work and who, after accounting for those credits, contribute a sufficient number of years to qualify for benefits.

3.2. Average indexed contributions based on salary

The measure of lifecycle earnings used to compute benefit levels is another critical driver of disparities in pension benefits. The average indexed contributions are typically the average over

[9] Monticone, Ruzik and Skiba (2008) provide a detailed review of European policies effecting women in the mid-2000s.

a long period of time of earnings (up to a maximum annual level for social security contributions) that have been indexed to a present value. If this period for mothers is more likely to include years when they took a break from work or reduced hours worked for childcare responsibilities, then their average will be lower.

Unfortunately, SHARE life histories do not collect detailed earning per year – such data is typically only available through administrative data systems. However, respondents do report their final pay prior to retirement at their main job, so we are able to partially control for differences in selection into jobs with higher or lower income which may be associated with having children. We consistently observe across the countries in Figure 3 that married men have greater indexed income in their last main job before retirement (accounting for the maximum earnings cap applicable in each country, which diminishes this difference).

There are three main policy mechanisms that could address differences in average indexed contributions arising from breaks for child bearing and rearing. These policies are:

(a) using fewer years in the assessment of the average

(b) taking the best years over the lifecycle rather than a continuous period

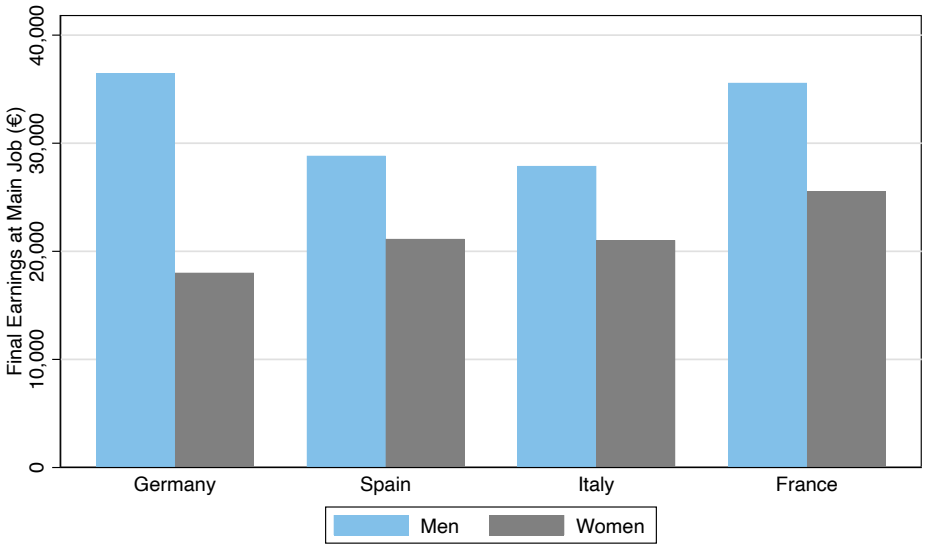
(c) replace missed earning periods with an alternative measure of earnings, such as the period prior to the break from employment

Variation exists across countries and over time in the number of years and whether consecutive or best contribution years are used to compute the average indexed contributions, but there are no examples of countries adjusting those factors based on sex, number of children or periods out of the labor force for dependent care.

In countries where credits are given for child birth or dependent care, an assumption must be made about how earnings during these periods will be treated for the computation of average

indexed contributions. In Italy, earnings are credited for 5 months with public funds for mothers working before child birth and having at least 5 years of contributions, and up to 10 months of parental leave credit is paid by the government after a 2001 reform (Gazzetta Ufficiale, 1971, 2001). Earnings are credited the average earnings for a year of uninterrupted work. In Spain, up to one year of labor leave is considered a contribution period in the first 3 years of a child's life at a rate commensurate with the minimum benefit basis (Monticone, Ruzik and Skiba, 2008). In France, the general and supplementary systems provide credits for maternity and for childrearing and, alternatively, "parental education leave" may allow for additional extensions beyond covered maternity leave depending on whether the employer continues to make contributions for the employee during this leave (L'Assurance Retraite, 2021; Arcco-Agirc, 2021). For the general scheme in France, the use of "best years" in the computation of the final benefit may eliminate periods out of the labor force for childcare from the computation of pension benefits (Legislation.cnav.fr, 2021). In Germany, the parent in charge of caregiving is treated as if they had the average income of pension contributors during the first year of their child's life (3 years for children born after 1992). Germany also has provisions for supplementary earning credits for childrearing periods for children under age 10 that depend on whether the carer works and, if they do not work, how many children they care for (Monticone, Ruzik and Skiba, 2008).

Figure 3. Final earnings in main job



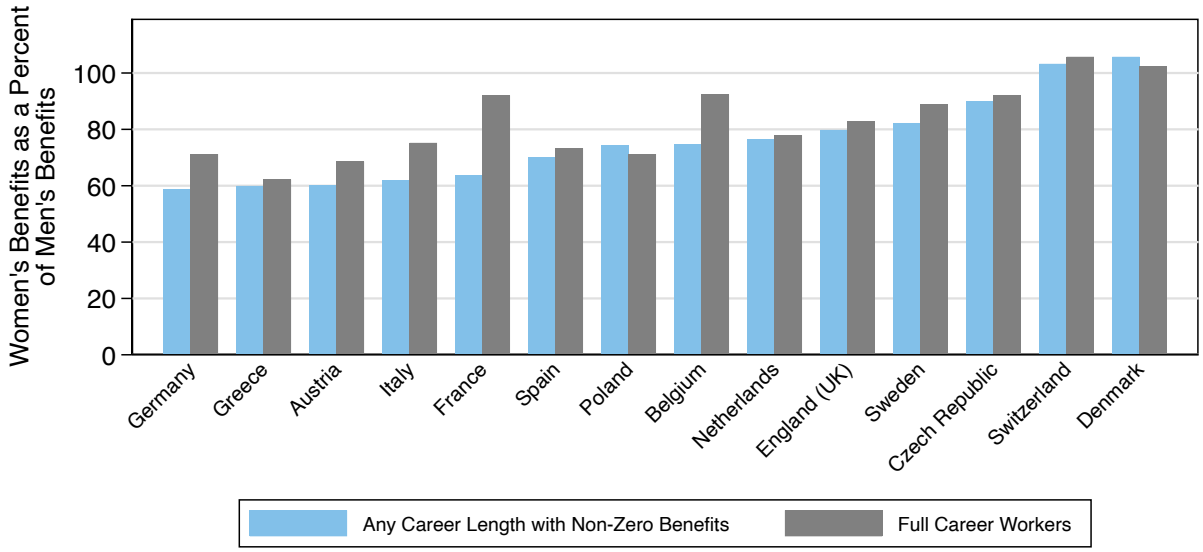
Notes: Authors calculations using changes in OECD's average annual wages for indexation of earnings. Reported values account for the maximum earnings cap applicable in each country, which diminishes this difference between men, who are more often subject to the cap, and women.

3.3. Summary

If the disparity in pension income is attributable to women taking breaks from work for childcare and the direct effect that has on contribution years and average contributions, then controlling for work history should reduce or eliminate the difference. In Figure 4 we compare how the percentage of pension income received by women changes when accounting for differences in work history. The first column by country corresponds to the ratios of women's to men's income in Figure 1. The second column by country restricts our estimate of pension income to only workers who had long careers, which we define as working more than 80% of the time between ages 20 and 55. This substantially narrows the gap for some countries – For example, France, where the ratio of women's to men's pension not accounting for work history was 64%, now becomes 92%. However, this is not true for all countries. Spain's ratio only narrows from 70% to 73% and Italy's narrows from 62% to 75%, suggesting there is still

substantial unexplained differences after controlling for differences in work history that are attributable to differences in average income, the claiming age adjustment, or residual factors associated with sex. The findings depicted in Figure 4 suggest that, if narrowing the gap is a policy objective, then the policy approach is likely to differ by country.

Figure 4: Women's old-age public pension income as a percent of men's income by career length and country



Note: Full career workers are defined as persons working at least 80% of the time between age 20 and 55. Estimates are conditional on observing individuals at age 70 or older to avoid censoring on pension income level.

4. Model

To understand the determinants of sex-based pension disparities, we account for differences in individual characteristics and life course events by incorporating respondent information on the components of pension benefits, such as contribution years and earnings. We estimate each respondent's pension benefits using the standard cross-country formulation for defined benefits in equation (1) and account for differences in country tax rates. We also account for additional factors of interest including sex, children, and country.

We begin with a very simple model that conditions reported post-tax benefits (B_i, our main outcome) on gender (Model 1) to highlight the average disparity across countries in our sample. We then incorporate expected pension benefits using an estimated amount that incorporates the information in equation (1) and a conversion of pre- to post-tax benefits since SHARE collects after-tax benefits (Model 2). This second model accounts for person-level differences in work history and final income as well as pension design. The coefficient on women reflects the disparity that persists after accounting for individual characteristics. Model 3 adapts the second model by introducing country-level differences. As noted in the previous sections, countries differ in their pension policy and how breaks from employment are credited. Equation (2) summarizes Model 3's specification for respondent *i*'s after-tax pension benefit after retirement:

$$\begin{aligned} \ln B_i \quad = \quad & \beta_0 + \beta_1 Female_i + \beta_2 \ln\left(TAX_i \times \hat{B}_i\right) + \boldsymbol{\beta}_3 Country_i \\ & + \boldsymbol{\beta}_4 Female_i \times Country_i + \varepsilon_{it} \end{aligned} \quad (2)$$

where,

- $Female_i$ is an indicator for whether individual *i* is female,
- $\hat{B}_i$ is an estimate of *i*'s pension benefits based on equation (1),
- TAX_i is a conversion factor reflecting an estimated ratio of pre- to post-tax benefit levels paid in *i*'s country in 2004,[10]
- $Country_{it}$ is an indicator for individual *i*'s country (baseline: Italy).

After accounting for person and country-level differences, we would expect that differences in pension benefits across the sexes would largely disappear. To the degree that they do not, the difference could be attributable to differences in the number of children a person raised. This is

[10] We use the rates computed by Bertoni et al. (2016). As of this draft, this is the best available conversion available for each of the countries in our sample. This assumes these rates remain constant over the observable period. In future versions, we intend to extend this methodology to allow conversions across the entire SHARE interview period.

explored in Model 4, where we account for the full interaction of gender and country with the number of children.

The above specifications have the advantage of clarifying whether sex-based disparities in pension benefits can be explained by differences in observable characteristics in SHARE. If the measures we used were exactly matched to the inputs of each country's pension benefit formula and there was no response error, then we would expect no residual difference by gender since none of these countries explicitly design their benefits to be different by sex. However, we have survey data, which may exhibit response error. We also have limited information on past earnings. Our measure for average indexed contributions (i.e., lifetime earnings accounting for plan-based contribution maximums) is based on last reported income. As indexed earnings tend to increase over the lifecycle, this assumption means our measure for average indexed contributions and expected benefits over are likely overestimates. Splitting apart the expected benefit in equation (2) into its determinants presented in equation (1) allows us to parse what factors are pivotal to closing the benefit differences between sexes in each country using observed variation in the SHARE data. We estimate the following formula for annual benefits (B_{it}) paid to individual *i* at time *t* net of tax in their first survey after being retired for at least one year:

$$\begin{aligned} \ln B_i \quad = \quad & \beta_0 + \beta_1 Female_i + \beta_2 \ln \hat{B}_i + \boldsymbol{\beta}_3 Country_i + \boldsymbol{\beta}_4 Female_i \times Country_i \\ & + \boldsymbol{\beta}_5 Kids_i + \boldsymbol{\beta}_6 Female_i \times Kids_i + \boldsymbol{\beta}_7 Country_i \times Kids_i \\ & + \beta_8 \ln TAX_i + \beta_9 \ln RM_i + \beta_{10} \ln CY_i + \beta_{11} \ln AIC_i + \beta_{12} \ln CAP_i \\ & + \beta_{13} \ln EARN_i + \boldsymbol{\beta}_{14} Female_i \times (\ln CY_i, \ln AIC_i, \ln EARN_i) \\ & + \boldsymbol{\beta}_{15} Country_i \times (\ln CY_i, \ln AIC_i, \ln EARN_i) + \varepsilon_i \end{aligned} \tag{3}$$

where, in addition to the explanatory factors described in equation 2,

- $Kids_i$ is an indicator for how many children individual *i* has at period t (categorized as 0, 1-2, or 3+ children; baseline: 1-2 children),

- CY_i is the number of contribution years and is based on *i*'s reported years worked prior to period *t* up to any maximum number of contribution years applicable for full benefits,
- AIC_i is the average indexed earnings (capped by the maximum annual contribution in period *t*), which is approximated based on *i*'s last reported earnings indexed to period *t*,
- RM_i is the average replacement multiplier, which will be calculated based on policies in place in period *t* for person *i*,
- CAP_i is the claiming age penalty based on how early one claims their benefit, which will be computed based on estimated claiming age and a country's statutory retirement age conditional on *i*'s birth cohort and sex,
- $EARN_i$ is an individual's current earnings from work above any threshold for an earnings test and it is computed based on self-reported earnings in SHARE,
- $Female_i \times (\ln CY_i\,, \ln AIC_i\,, \ln EARN_i)$ is the bivariate interaction of the contribution years, average indexed contributions, and current earnings with being female, and
- $Country_i \times (\ln CY_i\,, \ln AIC_i\,, \ln EARN_i)$ is the bivariate interaction of the contribution years, average indexed contributions, and current earnings with each country indicator.

Bolded coefficients in equation (3) correspond to vectors of multiple coefficients associated with the listed explanatory factors when they are comprised of multiple categories and/or interactions.

If reported pension benefits accurately reflect the design of each country's pension system and there is neither measurement error in the components of pension benefits nor systemic differences by gender or children, then we would expect $\beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = 1$ and the remaining model parameters would be zero. However, we suspect there may be differences by gender and number of children even after conditioning on contribution history. Further, we expect that there will be measurement error as we have imperfect measures of AIC_{it} (it is based

on last observed earnings) and survey responses may be imprecise (e.g., in Appendix A we identify a number of respondents who report starting benefits in a year where they were unqualified according to the country's pension eligibility rules).

Our sample is based on respondents who completed a life history interview in SHARE interview waves 3 or 7. We restrict our sample to married individuals who have been receiving a public pension for at least one year (to ensure that we have a full year's benefits), started benefits after 1991 (our detailed policy data dates back to 1992), and where we are able to construct a measure for key components of their pension benefits. We also further exclude Italian respondents who have not residual claim to the legacy defined benefit plan and government workers in France who are eligible for a different pension system than private sector workers. Details of our sample construction are included in Appendix A. Details of individual country plans are summarized in Appendix B.

5. Findings

Table 1 presents summary statistics by country for the main measures in our sample. The reported annual benefit received is around 13,400€ in Italy, 11,900€ in Spain, 20,400€ in France, and 14,200€ in Germany. Countries vary in their average replacement multiplier per contribution year, from around 2.0 to 2.5 in Spain and Italy to 1.1 in Germany and France. All exhibit limited variability within country, reflecting limited progressivity of benefits with respect to earnings history. All countries exhibit an average of over 34 contribution years, but Germany has the greatest variance in contribution years arising from its pension point-based system where those with limited work history (i.e., 5 years) may still qualify for a small benefit. Average indexed contributions range from 28,000€ in Italy and Germany up to 36,600€ in France. Respondents in Spain and France are more like to exhibit a penalty for early claiming based on each country's

eligibility policy for full and reduced pensions (for greater detail on that and our estimates of retirement age and years worked, see Appendix B). Most respondents do not have earning above a country's earnings test threshold for receiving benefits, so the averages are less than 3,000€ with substantial variance. Beyond the factors that directly relate to the benefit paid, we find that over 93% of the sample have children and the fraction of women receiving benefits range from a low of 16% in Spain to 47% in Germany. Estimating equation (1) using our predicted values yields an average expected pension benefit that is within 5,000€ of the average pension benefit reported in Italy, France and Germany, while expected benefits are on average 9,600€ greater than reported benefits in Spain.

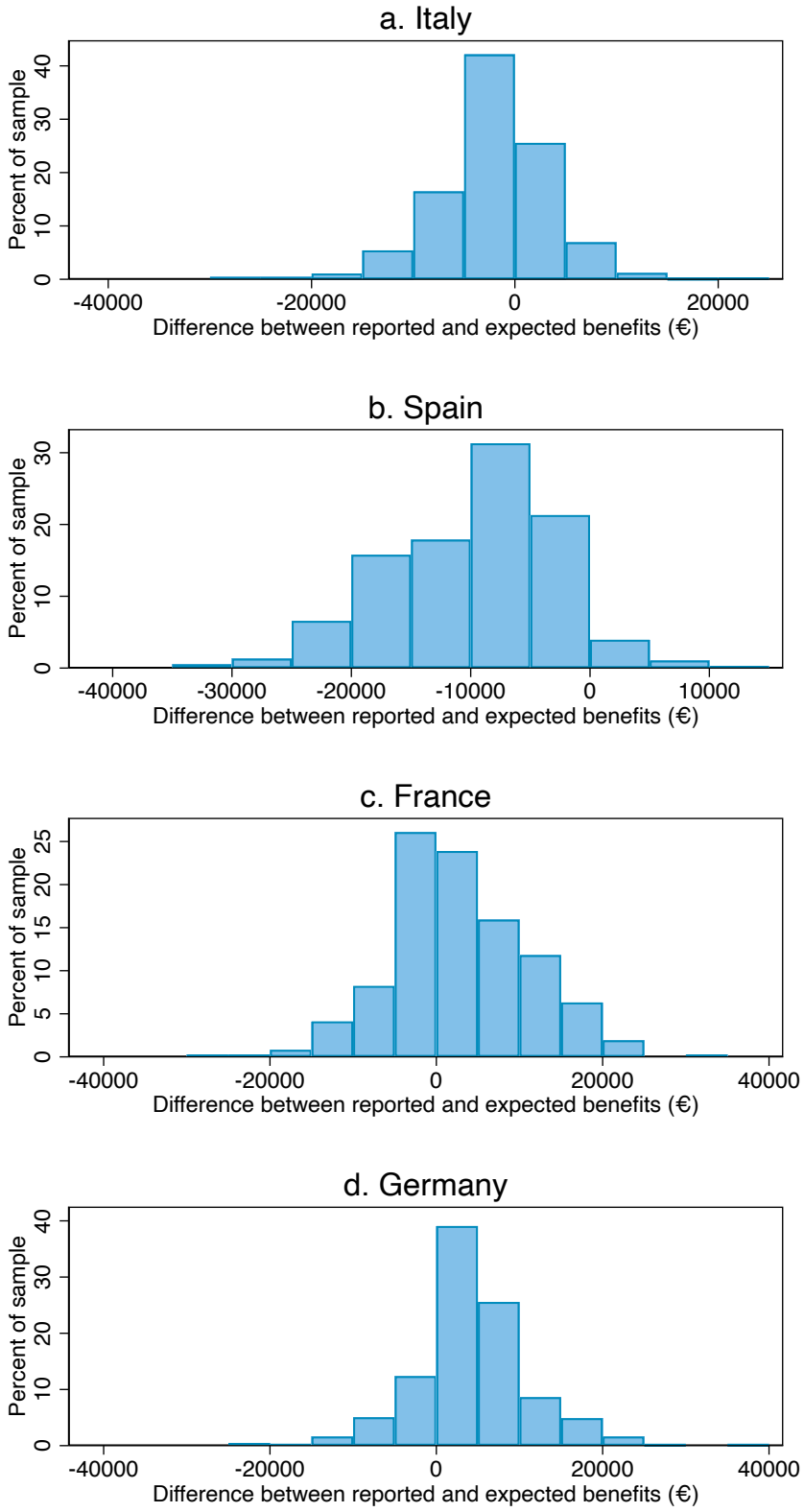
While Table 1 documents relatively small average differences in reported vs expected pension benefits, Figure 5 demonstrates that the distribution of differences between reported and expected pension benefits exhibit substantial within country variation. In Spain, the difference between reported and expected pension benefits is -5,200€, but in both cases the majority of pension benefit differences are within 5,000€ of each country's average difference. Overall, we interpret Figure 5 to suggest that our application of each country's pension benefit formula to the SHARE data provides a reasonable approximation of the reported benefit with the exception of Spain where it exhibits a systematic overestimate of the reported benefits. Systematic differences by country are captured in our model with a country-specific fixed effect.

Table 1: Summary statistics by country

	Italy		Spain		France		Germany	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Reported annual pension benefit	13,398 €	5,630	11,879 €	5,614	20,412 €	10,959	14,225 €	8,469
Replacement multiplier	0.020	0.0007	0.025	0.0006	0.011	0.0022	0.011	0.0003
Contribution years	36.4	4.1	34.7	3.0	38.3	3.6	39.2	7.8
Average indexed contributions	28,521 €	12,879	32,497 €	10,583	36,603 €	12,504	27,900 €	18,228
Claiming Age Adjustment	0.980	0.043	0.895	0.149	0.896	0.156	0.985	0.101
Earnings above threshold for earnings test	1,029 €	8,213	559 €	3,086	2,771 €	8,839	0 €	0
Number of children								
None	0.06	0.24	0.04	0.19	0.06	0.24	0.07	0.26
1-2 children	0.71	0.46	0.49	0.50	0.57	0.50	0.65	0.48
3+ children	0.23	0.42	0.47	0.50	0.37	0.48	0.27	0.44
Women	0.26	0.44	0.16	0.36	0.30	0.46	0.47	0.50
Expected annual pension benefit	15,337 €	5,624	21,530 €	6,851	17,101 €	6,512	9,679 €	6,066
Difference between reported and expected pension benefit	-1,939 €	5,701	-9,651 €	7,106	3,311 €	10,133	4,547 €	7,579
Age when reporting benefit	73.1	5.20	75.7	5.38	71.9	5.38	73.5	5.02
Birth year	1943	5.39	1940	5.63	1944	5.55	1942	5.23
Sample size	923		380		367		617	

Notes: Author's calculations using SHARE data. Expected annual pension benefit is estimated using equation (1) and may differ from pension benefits in SHARE. The difference in reported and expected pension benefits is computed by the reported annual pension benefits minus the expected annual pension benefits and then average over the sample in each country.

Figure 5: Difference between reported and expected pension benefits by country



Notes: Based on the final sample reported in Table 1.

The differences between reported pension benefits and our expected pension benefit measure may arise for a number of reasons related to mismeasurement. On the reported pension benefit side, the survey question asks individuals to report their typical payment after taxes and then proceeds to ask for the period the value was reported in (e.g., biweekly, monthly). This may lead to reporting error if the respondent provides a monthly value but does not account for the 13-month payment in Italy or the 13- and 14-month payments in Spain.[11] Additionally, values in SHARE after the first interview wave are reported after tax while benefits are based on before-tax dollars. While we make an effort to account for difference in tax rates, discrepancies may arise from variation in tax rates over time or before and after retirement. On the expected benefit side, differences may arise from our use of final earnings on the main job since we do not have good proxies for earnings history. Additionally, we base our measures for the claiming age adjustment and replacement multiplier on their reported number of years worked at the time of starting benefits, which may be subject to recall error.

Using the regression framework described in the previous section, Table 2 reports the average difference in after-tax pension benefits in our sample in Model 1 and then accounting for expected pension benefits in Model 2. Model 3 introduces country indicators aimed at capturing country-level differences not captured by our estimates of the expected pension benefit.

Model 1 reveals that women's average pension benefits are 29.0% lower in our sample. This difference does not account for differences in work histories and earnings levels that are influential in the determination of old-age benefit entitlements. We use reported years worked from SHARELIFE and final reported earnings in SHARE and country-specific old-age benefit

[11] Where 13-month and 14-month payment periods exist, the 13th month payment is an additional payment typically preceding the Christmas holiday and the 14th month payment is an additional payment typical preceding the summer time holiday season.

design to estimate person-level expected benefits. Accounting for expected benefits reduced sex-based pension disparities: women's pension benefits are 11.2% lower on average. This suggests that accounting for benefit design explains 61% of the observed disparity.

Table 2: Regression predicting reported benefits based on sex, estimated benefits, and country

	Model 1		Model 2		Model 3	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Indicator for Women	-0.290***	(0.0271)	-0.112***	(0.0280)	-0.107***	(0.0337)
[Marginal Effect]					[-0.140***]	(0.0270)
Expected annual pension benefit			0.298***	(0.0242)	0.413***	(0.0348)
Indicator for Germany					0.317***	(0.0348)
Indicator for Spain					-0.286***	(0.0356)
Indicator for France					0.314***	(0.0402)
Indicator for German Women					-0.0727	(0.0575)
Indicator for Spain Women					-0.105	(0.0884)
Indicator for French Women					0.0287	(0.0733)
Intercept	9.518***	(0.0139)	6.644***	(0.233)	5.470***	(0.335)
Sample size	2,287		2,287		2,287	
R-squared	0.051		0.144		0.266	

Notes: Baseline group is Italian men. Author's calculations using SHARE data. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Model 3 further allows for country-level differences, and finds meaningful differences across countries that may reflect country-specific error in measure pension benefits (as we expected in Spain), but we find no relationship between these country-specific errors and women.

Accounting for these country-specific differences does change the average difference in pension benefits computed using marginal effects: women earn 14% less on average.

If expected and reported benefits were accurate measures of true benefits, we would expect that a 1% increase in expected benefits would lead to a 1% increase in reported benefits (i.e., the coefficient on the expected annual pension benefit would be 1). Alternatively, if either or both expected and reported benefits were poor measures of true benefits, then our coefficient on the expected annual pension benefit would be zero and the model's intercept would be equal to the approximate mean of reported benefits. Model 2 in Table 2 tests this hypothesis and highlights that measurement error is significant. While additional expected pension benefits are associated with greater reported benefits, the relationship is significantly less than one. However, we can also reject that it is not fully independent of our measure expected benefits. Adding in country differences (Model 3) partly explain differences between reported benefits and our measure of expected benefits. However, the coefficient on the expected benefit is still significantly different from one, suggesting that our estimated measure of pension benefits and/or the reported measure of pension benefits still exhibits significant measurement error.

Table 3 presents Model 4, which adds the number of children and interactions with country and the indicator for women. In some countries, credits are given for maternity and/or paternity as well as childrearing. Exceptionally, France supplements benefits by 10% for parents of 3 or more children conditional on them raising the children from at least 9 years prior to their 16th birthday. Outside of pension design, we also expect children to require additional time that might substitute for time invested in developing work-related human capital, which may limit income growth over the lifecycle. Relative to having 1-2 children, the estimates in Table 3 suggest that not having children has no discernible relationship with pension benefits, but leads to a 10%

lower benefit on average for parents with 3+ children. For women, the direct effect of having children is to increase benefits by 11.2%, leading to a net effect of having 3 or more children that is not significant different from having 1 to 2 children. Therefore, it is only for men where the relationships between expected and predicted pension benefits is negatively influenced by having 3 or more children. There are limited significant relationships between the number of children and country. This is particular surprising in France, where there is the child supplement for having 3 or more children. This supplement was not included in our estimate of expected benefits as it is unique to France. It is possible the lack of a direct impact of having 3 or more children on the benefit level in France is indicative of successful policy design – that is the French child supplement is successful at offsetting the additional lifecycle demands of having many children. However, other countries do not exhibit a negative relationship between having 3 or more children and pension income, so we are doubtful that it is necessarily plan design.

For old-age beneficiaries with no children, there are few statistically significant relationships, with the exception of Germany and Spain, where there are substantial penalties for having no children. We caution against overinterpreting these relationships, as each of these countries has a small sample of married adults with no children. We suspect that the interaction of country and 3 or more children may be picking up on other country-specific characteristics that are not well captured in our model, such as higher tax rates for both members of a couple when the couple has high retirement incomes – an attribute that may not be captures well by our tax adjustment measure.

Table 3 again highlights that pension benefits for women are 14.9 percent lower than for men (estimated as a marginal effect to account for the average impact across the model's interactions with country and number of children). In this Table, we also estimate this difference by country

and find that it is notably larger in Spain and Germany (22 and 18 percent lower, respectively). The sex-based difference in pension benefits is smaller in Italy (12 percent) and France (9 percent). In France, the difference between men and women is insignificantly different from zero.

Table 3: Regression predicting reported benefits accounting for expected benefits and differences attributable to sex, country, and children

	Model 4	
	Coefficient	**Standard Error**
Indicator for Women	-0.147***	(0.0371)
Marginal effect by country		
Overall	-0.149***	(0.0280)
Italy	-0.118***	(0.0337)
Germany	-0.183***	(0.0501)
Spain	-0.221***	(0.0781)
France	-0.087	(0.0643)
Expected annual pension benefit	0.413***	(0.0354)
Country		
Germany	0.314***	(0.0404)
Spain	-0.256***	(0.0431)
France	0.320***	(0.0477)
Children		
0 children	0.0481	(0.0543)
3+ children	-0.104***	(0.0367)
Interactions		
Country x Women		
Germany	-0.0728	(0.0574)
Spain	-0.123	(0.0862)
France	0.0160	(0.0728)
Childen x Women		
0 children	0.113	(0.0857)
3+ children	0.112**	(0.0548)
Country x No children		
Germany	-0.137*	(0.0805)
Spain	-0.618***	(0.210)
France	0.0679	(0.135)
Country x 3+ children		
Germany	0.0568	(0.0615)
Spain	0.0416	(0.0627)
France	0.0126	(0.0727)
Constant	5.502***	(0.342)
Sample size	2,287	
R-squared	0.277	

Notes: Author's calculations using SHARE data. Baseline group is Italian men with 1-2 children. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Overall, accounting for expected benefits accounts for nearly half of the observable difference between men and women in our sample of SHARE old-age pension beneficiaries in Italy, Spain, France and Germany.[12] Focusing on the half of the difference that can be explained by expected benefits, we next want to understand whether there are particular components of the benefit that are more important for narrowing the benefit difference between men and women with similar expected benefits. Model 5, based on equation (3) replaces our expected benefit measure with the four key determinants of pension benefits ($CY_{it}, AIC_{it}, RM_{it}, CAP_{it}$) from equation 1 as well as our tax adjustment measure and a measure of income above the country-specific threshold for reducing benefits. Unlike previous model estimates reported in Tables 2 and 3, each of the determinants of pension benefits may now have their own independent relationship with the outcome. This flexibility enables us to identify the factors in each country that are most strongly associated with greater or less pension benefits. This greater flexibility comes at a cost because it also leaves out complex interactions, such as the higher average indexed earnings being related to having more contribution years. Given the size of equation (3), Table 4 reports only the marginal estimates conditional on the subsample of women overall and by each country.

Table 4 reveals for women across the four countries in our sample that contribution years and average indexed contributions lead to reductions in the pension gap with men. A 10% increase in contribution years typically lead to an increase in the after-tax pension benefit of 2.5% and a 10% increase in the final earnings is associated with a 1.8% increase in after-tax pension benefits. There are important differences by country.

[12] The overall marginal effect for women was -14.9% in Table 3. The difference in pension benefits between men and women in our sample was -29% in Table 1. Therefore 1-(14.9/29) = 49%

Only in France and Germany are contribution years statistically significant determinants of improved pension benefits. Both the German system and the French private-sector supplemental benefit system are pension point-based systems. These systems only provide benefits for years in which an individual contributes or is credited with benefits. Consequently, regular earnings over the lifecycle are the main determinant of benefit levels and one's final earnings are comparatively less important. In France, a 10% increase in contribution years is associated with a 9.2% increase in benefits and in Germany a 10% increase in contribution years is associated with a 4.2% increase in benefits. For Spain and Italy, these differences are insignificantly different from zero, as additional contribution years, conditional on reaching the maximum typically have limited benefit.

Only in Italy, Spain and France are final earnings (our indicator for average indexed contributions) significantly different from zero. In Spain and Italy, a 10% increase in final earnings lead to 1.9% increase in the final benefit, where is France, it leads to a 3.5% increase in final benefit. In Italy and Spain, the benefit is determined by recent indexed earnings (typically the last 5- 15 years), making final earnings, a particularly important determinant of pension benefits. In France's general system (not the supplementary system based on pension points), it is possible that final earnings are comparatively more important because they use the best 10-25 years of indexed earnings over a person's lifecycle, rather than the most recent. In Germany, greater final earnings are not strongly associated with greater pension benefits, likely reflecting that in a pension points scheme, the final year of earnings is treated no differently than any other potential earning year.

In Table 4, the coefficient on women remains significantly negative and has become more negative compared to Tables 2 and 3. This is to be expected as accounting for the individual

components of the pension benefit eliminates important interactions between pension components that may be correlated with sex (e.g., women have fewer work years which may lead to lower earnings). This change is most dramatic in Germany, where the difference in pension benefits for women in Table 3 was 18% and it is now 39% in Table 4. We attribute this large difference to Germany's pension point system which closely links earnings history to one's pension benefit. While Germany provides some pension point top-ups for low-income parents that continue to work, the strong linkage between earnings history and benefits in the German system provides limited compensation for mothers that bare the majority of the career opportunity cost of childrearing.

We briefly discuss the other factors in Table 4. The country indicators reveal that accounting for country specific differences independent of pension design elements (i.e., replace multiplier, benefit taxation, claiming age penalties, penalties for earnings and collecting pension benefits), there is little difference between the countries in our sample except France, which has greater benefits all else equal. A higher pre- to post-tax ratio (i.e., lower average tax rate) is associated with lower benefits, reflecting the progressive nature of most tax systems. The coefficient on the replacement multiplier is generally insignificantly different from zero reflecting limited within country variation in this measure. The claiming age adjustment reflects the percentage of the full benefits that are paid based on when the beneficiary started their benefit relative to the system's normal retirement age (e.g., early claimers get less than 100% of their benefit). The coefficient is strongly negative suggesting that early claiming is associated with greater benefits. We believe this represents more of the beneficiary's choice – those that can afford to claim early do. The earnings test, and number of children typically are not significant determinants of the final benefit, with some country-specific variation.

Table 4: Marginal Estimates from a regression predicting reported benefits accounting for interactions between pension benefit components and sex

Marginal estimates (Women only)	Overall		Italy		Spain		France		Germany	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Indicator for woman	-0.235***	(0.0277)	-0.136***	(0.0317)	-0.279***	(0.0855)	-0.0115	(0.0615)	-0.393***	(0.0522)
Indicator for Germany	0.0274	(0.118)	0.00740	(0.118)	-0.133	(0.191)	-0.215***	(0.0705)		
Indicator for Spain	0.0264	(0.119)	0.0150	(0.118)			-0.286	(0.202)	-0.0123	(0.197)
Indicator for Italy					-0.0458	(0.114)	-0.281**	(0.127)	-0.0562	(0.122)
Indicator for France	0.0882	(0.132)	0.102	(0.131)	-0.0146	(0.207)			-0.0415	(0.101)
Pre- to Post tax ratio (ln)	-2.795***	(0.441)	-2.795***	(0.441)	-2.795***	(0.441)	-2.795***	(0.441)	-2.795***	(0.441)
Replacement multiplier (ln)	-0.297	(0.194)	-0.297	(0.194)	-0.297	(0.194)	-0.297	(0.194)	-0.297	(0.194)
Contribution years (ln)	0.246**	(0.110)	-0.153	(0.164)	-0.279	(0.277)	0.924***	(0.278)	0.423***	(0.106)
Final Earnings (ln)	0.176***	(0.0669)	0.192**	(0.0798)	0.190*	(0.101)	0.348***	(0.125)	0.0932	(0.0572)
Claiming age adjustment (ln)	-0.578***	(0.124)	-0.578***	(0.124)	-0.578***	(0.124)	-0.578***	(0.124)	-0.578***	(0.124)
Earnings in excess of earning test (10,000 €)	0.0225	(0.0590)	0.0117	(0.0680)	-0.226**	(0.111)	0.207***	(0.0581)	0.207***	(0.0581)
Number of children (baseline: 1-2)										
None	0.0399	(0.0661)	0.130*	(0.0744)	-0.423**	(0.208)	0.181*	(0.106)	0.00683	(0.0798)
3+ children	0.0684	(0.0428)	0.0538	(0.0518)	0.0842	(0.0675)	0.0534	(0.0703)	0.0829	(0.0562)
Sample size	692		236		59		110		287	
R-squared	0.339									

Notes: Author's calculations using SHARE data. Baseline group is Italian men with 1-2 children. To compute marginal estimates by country, the model was re-estimated changing the baseline to the country of interest to ensure marginal estimates for country indicators reflected the correct baseline comparison. Standard errors for marginal estimates computed using delta method in parentheses. *** p<0.01, ** p<0.05, * p<0.1

6. Discussion

We are able to explain half of the public pension differences between men and women across Italy, Spain, France and Germany in our sample of married men and women that are observed transitioning from work to retirement in SHARE. The share of the difference that we can explain is based on survey responses regarding earnings and work history as well as country-specific pension benefit design. Investigating the mechanisms by which women in these countries can improve their pension benefits, we find that approaches differ based on a country's pension benefit design. In Italy and Spain, where the earnings-based component of pension benefits is based on the most recent 5 to 15 years (Italy) or 8 to 15 years (Spain) depending on birth year, we find increasing final earnings (or working additional years at the final earnings level) is most strongly associated with increasing benefits. For Germany, final earnings are not a meaningful determinant of one's benefits. As Germany's old-age benefit is based on accumulated pension points, the only approach meaningfully associated with increasing benefits is working longer. France, where sex-based differences in pension benefits are insignificant after accounting for expected benefits (see Table 2), offers an interesting blend of the other countries: It has a general old-age benefit system that is similar to Italy and Spain that uses slightly longer periods (10 to 25 years depending on birth year) but takes the best indexed earnings across the lifecycle, rather than the most recent. France's supplemental occupational pensions for private sector employees have points-based systems, similar to Germany. We find that women in France can meaningfully increase their pension benefits by either working longer or increasing earnings in their final years of work.

The share that we cannot explain is based on characteristics of women that are common across countries but more substantial in Spain and Germany and less in France. The unexplained

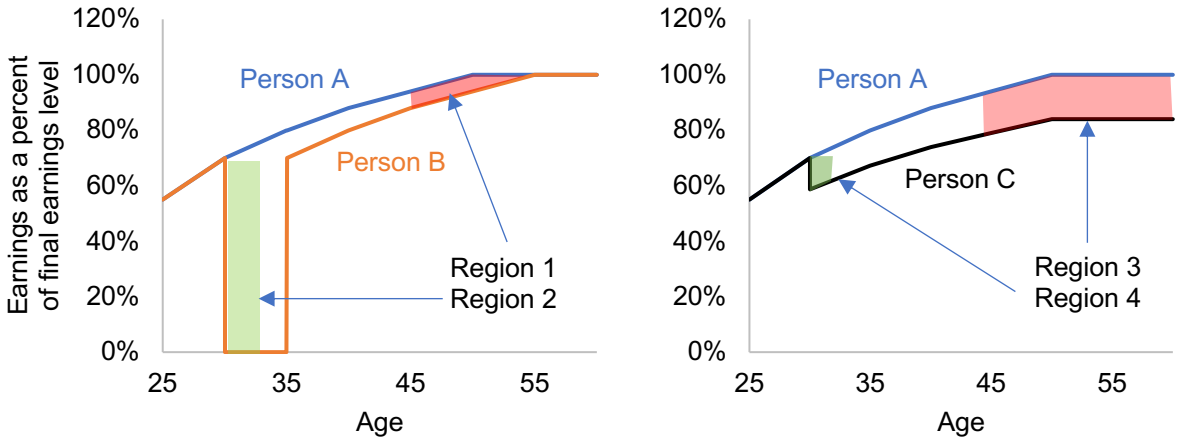
share may reflect factors that our data do not capture, such as differences in earnings histories or credits for childbearing and rearing. It may also reflect factors that even administrative data cannot capture, including persistent consequences of lifecycle choices and/or sex-based discrimination. Indeed, it is plausible that persistently lower wages and poor promotional opportunities for women in the workforce following childbirth may contribute to the remaining sex-based differences in pension benefits.

What can be explained by our estimate of pension benefits based on each country's pension benefit design may provide insight on determinants of the unexplained variation. We suspect that much of the unobserved variation by gender is attributable to differences in earning history given then nature of the work histories presented in Figure 2. In non-point-based pension benefit systems, adjusting the period used in computing the benefit reduces the consequences of taking breaks from work. Also, as in France, using the "best" years rather than the most recent can reduce the negative consequences of career interruptions. In points-based benefits systems, little can be done unless persistent gaps are filled in.

The strengths and weakness of these policy adjustments can be demonstrated with a simple illustrative example. Consider three identical people who, absent breaks or reductions in work effort would have the same earnings trajectory over their lifecycle. Person A in Figure 6 has an uninterrupted earnings history. Person B takes a break from employment for 5 years at age 30 to have and raise children. Person C permanently reduces her work effort by 16% after having children at age 30. If all work years are considered in the computation of benefits (as is the case in point-based systems) then Persons B and C will have average earnings that are 15% lower than Person A (and consequently a benefit difference of around 15%). This difference is

represented in Figure 6 as the area between Person A's lifecycle trajectory and above Person B or C's earnings trajectories.

Figure 6: Illustrative example of alternative earnings histories



Note: Illustrative example of alternative earnings histories where Person B takes a 5 year career interruption at age 30 and Person C permanently reduces work by 16% effect starting at age 30. Person B and C are designed to have an average earning history that is 15 percent less than Person A.

If the earnings opportunity cost of child bearing and rearing is protected as part of old-age insurance, then the old-age insurance system should be designed to eliminate this difference. Pension systems that use the most recent 15 years of earnings limit the difference to earnings since age 45 or the area represented by Region 1 for Person B and Region 3 for Person C. Notably this adjustment has reduced the difference in Person B's average earnings from 15% below Person A's average earnings to only 2% lower. However, this policy accentuates the difference for Person C – here the difference has increased slightly from 15% to 16%. This example illustrates that while more limited periods for computing average indexed earnings might improve the retirement circumstance of those that take short-term reductions, they are ineffective at reducing the opportunity cost of those whose earnings trajectories is permanently reduced.

As noted earlier, countries have introduced policies aimed at reduced the penalty for having and rearing children. We can again examine the likely efficacy of those using our simple example in Figure 6. Most of these policies offer credits for gaps or reductions in the period immediately following the birth of the child, but typically offer limited adjustments over the remaining part of childrearing period. In Figure 6, Regions 2 and 4 depict a pension credit equal to 3 years at a rate equal to the salary at childbirth (this would be generous based on the policies described in Section 3.2). For Person B who stops work, this credit is generous, whereas for Person C, such credit provides a limited top-up. In this example, such pension credit reduced the difference in average earnings from 15% to 8% for Person B and from 15% to 14% for Person C.

These examples highlight differences in policy pertaining to earnings history that have a substantial impact on old-age benefits should they stop or reduce work in relation to childbearing or rearing. Notably, most policies in place are targeted at short-term breaks from work and are poorly designed to compensate when earnings are permanently reduced. It is unknown if breaks from the labor force for childbearing and rearing look more like Person B or Person C. Future research may be able to separate women who exhibit these differing trajectories and use this distinction to determine if the choice between a break or reduction in effort, is pivotal in further explaining the difference in pension benefits between men and women. If it is, then a new set of policies may be required if closing this gap is a government objective.

The most pivotal pension design elements that can facilitate the closing of gaps include limited contribution years required for full benefits and average indexed earnings based on best work history rather than work history over one's entire life or recent work history. Our findings suggest that reforms promoting delayed claiming or longer work histories will likely widen the gap in pension benefits between men and women. Further, reforms prioritizing contribution years

and levels, such as the nominal defined contribution plans in Italy, will likely widen the pension gap between men and women even further by removing any elements in the benefit design that can enable persons to "catch up" in their 40s and 50s by establishing a significant work history after child care demands abate.

7. Conclusions

We have documented that sex-based pension disparities exist across most countries in Europe (Figure 1). We identify two major sources of these disparities: contribution years and the average income used to determine benefits. We find benefits disparities persist even amongst men and women who work most of their lives (Figure 4). Using detailed policy data for Italy, Spain, France and Germany we further control for differences in policy design that are sensitive to claiming age and final earnings. We find that, despite accounting for contribution years, final earnings and claiming age, women's reported benefits in these countries are 15% lower than men's reported benefits. These differences could arise from a number of sources. We believe a major contributor is delayed or reduced life-cycle earnings growth, which is consistent with our observed patterns, namely greater benefit growth for women from higher final earnings conditional on contribution years. Additionally, in systems based on pension points such as Germany, benefits are effectively based on a person's entire earnings history, making it very difficult to close the disparities in pension benefits between men and women as women bear the majority of the earnings opportunity cost over the lifecycle for childrearing.

The critical nature of lifecycle earnings in the determination of benefits is important for those concerned with sex-based pension disparities. Most pension reforms in Europe have shifted toward systems that make lifecycle earnings more relevant in the determination of final pension benefits, thereby reducing the insurance aspect of old-age insurance and shifting it more towards

a means of compulsory saving. Examples include nominal defined contribution plans (Italy and Poland), longer periods used in determined averages (France's universal pension and Spain), and point-based systems (France's occupational pensions and Germany). Our findings indicate that efforts to compensate mothers for time out of the workforce by crediting contribution years have not eliminated sex-based benefit gaps. This is likely due to differences in who works following childbearing. Our analysis of women's work histories across countries indicates there are three distinct groups of childbearing women: those who continuously work before and after childbearing, those who never work, and those who take a break from work following childbirth. The relative size of these three groups varies substantially by country. In Spain and Italy, the majority of women receiving benefits work a substantial amount of their career, limiting the potential benefits from such credits. In these countries, where differences in benefits persist, alternative policy mechanisms might be more successful at narrowing sex-based pension benefit gaps. For example, a targeted policy mechanism would be to reduce the number of years used in computing average earnings based on years of reduced or no work due to the demands for caretaking.

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Appendix A: Sample construction

Our initial sample is based on respondents to either the SHARE Wave 3 or 7 Life History interview from which we obtain the number of years worked and the wage of the respondent's main career job. Since our research question requires understanding the determinants of pension benefits for married persons, we apply several restrictions to remove records outside this scope or for whom information is incomplete. In this appendix, we document our sample selection. Table A1 provides the sample size after each sample restriction is applied.

Table A1. Country Sample Size by each Sample Criteria

	Spain	Italy	France	Germany
Completed Life History Survey	5,671	5,511	4,659	4,889
Sample restrictions				
Observed old-age pension income during core interview	2,943	3,271	3,251	2,936
At least two concurrent waves of old-age pension income or provided timing of retirement/claiming	2,896	3,146	3,216	2,876
Observed old-age pension income at least a full year after retiring/starting to claim	2,603	2,951	2,936	2,553
Married or partnered	2,057	2,366	1,987	2,104
Not Italian Class 3	2,057	2,149	1,987	2,014
Started receiving benefits in 1992 or later	1,715	1,716	1,657	1,795
Deemed to be eligibility for partial or full benefits at time of claiming	1,078	1,418	1,025	1,157
Have a zero or non-missing value for last wages	464	1,062	485	623
Reported receiving benefits from pension schemes different than CNAV or occupational schemes (ARRCO or AGIRC) or have missing information on whether they are East or West German	464	1,062	485	618
Have zero or extreme high expected pension benefits (those exceeding 100,000€)	464	1,045	485	617
Have extreme high last wages (those exceeding 80,000€)	464	1,027	480	617
Have last wages that qualify for a minimum pension	380	923	367	617

For the purposes of modeling reported old-age public pension income we must also observe the respondent during a core interview (SHARE interview waves 1, 2 and 4 to 7) receiving this

income, which reduces our sample by 40% as SHARE includes many individuals who have not started claiming. To ensure we observe a full year of pension receipt we require that the pension receipt observed is in reference to at least one full year after the respondent reported retiring or starting to claim or, in the case that the respondent did not provide the timing of their retirement or start of claiming, we use the 2nd report of pension income from the first two concurrent reports of receipt reported. These two requirements further reduce the sample by 11%. After determining the first report of full pension income, we then require that the sample only includes individuals who are married or partnered, eliminating 23% of our sample who are not married or partnered at that time. We also exclude any individuals in Italy who entered the workforce on or after January 1, 1996 because they would call under a different defined contribution plan, a 9% reduction in the Italian sample. Because we have pension benefit formulas and detailed policy only going back to 1992, we then drop anyone who started claiming benefits before 1992, a 16% further reduction. Looking at this sample there were a number of individuals who we observed claiming old-age pension payments but would not yet eligible to begin partial or full claiming using the pension rules we have documents, so we exclude these individuals from our analysis as we are not confident in our ability to appropriately calculate the determinants of their pension benefits. This leads to a further 32% reduction in the sample. This large reduction may be part attributable to alternative pathways to retirement that we do not model, such as disability and unemployment. We exclude any individual for whom we are not able to obtain a value of their wages during employment, whether from the life history survey or the core interview, a final further reduction of 44% but affecting the Spanish, French, and German samples more than the Italian samples. Additional exclusions for extreme values and country-specific issues, such as missing

information for computing benefits or minimum pensions where the computation differs from equation (1) lead to a final reduction of 13%.

Appendix B: Country-specific pension benefit rules

B.1. Italy

The Italian pension system, after the 1995 Dini Reform, has three different benefit classes for workers based on age and contribution years on December 31, 1995:

Class 1: DB plan - Individuals who had accrued at least 18 years of contributions on January 1, 1996

Class 2: Mix of the legacy DB plan (for contributions through 1996) and the new NDC plan (for contributions from 1996) - Individuals who had entered the workforce before January 1, 1996, but who had not accrued at least 18 years of contributions at that time

Class 3: New NDC plan only - Individuals who entered the workforce on or after January 1, 1996

The DB plan pays benefits based on a design similar to equation (1). The NDC plan pays a benefit based on salary-based contributions that earn a rate of return related to GDP growth and, at retirement, the accumulated notional capital is converted into an annuity taking account of average life expectancy at retirement. Benefit eligibility requirements and the computation of the benefit differ by class. For each class there are different eligibility tracks that have some combination of age and/or years of contribution requirement to receive pension benefits.

The 2011 Fornero reform made any new social security contributions for Class 1 persons go into the NDC system (Most of the beneficiaries we study fall under pre-Fornero reform and post-Dini reform rules. Below we present benefit rules in place during 1996-2011. See Knapp and

Rebellato (Forthcoming) for additional policy details for other time periods and relevant reference values.

Eligibility

Class 1

Eligibility Track V1**:** "Pensioni di Vecchiaia"

Age requirements: 65 years for men and 60 years for women, for all categories of workers.

Contribution requirements (paid or credited):

20 years (phased in, see Table 2), and 15 of these years must be accrued before 1992

OR

5 years of paid contributions and 70 years of age

Eligibility Track A1: "Pensioni di Anzianità"

Requirements before 2008

Contributions: 36-40 years of contributions (paid or credited) depending on year of initial eligibility

OR

35 years of contributions (paid or credited) and 52-62 years of age depending on year of initial eligibility

Requirements from 2008-2011

A worker must satisfy a quota rule and a minimum age. In 2009, the sum of a worker's age and contribution years (paid or credited) must be equal to or exceed 95 and the worker must be at least age 59.

Class 2

Eligibility Track V2: "Pensioni di Vecchiaia"

Age requirements: 65 years for men and 60 years for women, for all categories of workers.

Contribution requirements (paid or credited): 15-20 years depending on year of initial eligibility

Eligibility Track A2: "Pensioni di Anzianità"

Requirements before 2008

Contributions: 36-40 years of contributions (paid or credited) depending on year of initial eligibility

OR

35 years of contributions (paid or credited) and 52-62 years of age depending on year of initial eligibility

Requirements from 2008-2011

A worker must satisfy a quota rule and a minimum age. In 2009, the sum of a worker's age and contribution years (paid or credited) must be equal to or exceed 95 and the worker must be at least age 59.

Benefit

Conditional on satisfying at least one eligibility track within a benefit class, individuals receive benefit amounts according to the following, benefit class-specific, rules:

Class 1

Pension benefits are calculated based on a multiplier times final average earnings times the number of contribution years. The pension benefit cannot exceed 80 percent of final average earnings. The multiplier is progressive (i.e., high income earners have a lower income replacement rate). Specifically:

$$B_{DB,i,t} = r_t^A \times n_{i,t}^A \times AIC_{i,t}^A + r_t^B \times n_{i,t}^B \times AIC_{i,t}^B$$

where the average indexed contributions, $AIC_{i,t}^p$, are based on a common indexation but have different number of years considered depending on period p (p=A is before 1993 and p=B is on or after 1993 and consider 5 and 10 years, respectively for private sector wage workers), different replacement rates (r_t^A, r_t^B) depend on when the contributions were made and $AIC_{i,t}^p$ for period p, and $n_{i,t}^p$ corresponds to the number of contribution years in period p. Further, $n_{i,t}^A + n_{i,t}^B$ cannot exceed 40 years. Reframing the above equation, we can map it back to equation 1:

$$B_{\text{Italy(Class 1)},i,t} = B_{DB,i,t} = \overbrace{\left(r_t^A \times \frac{n_{i,t}^A}{n_{i,t}^A + n_{i,t}^B} + r_t^B \times \frac{n_{i,t}^B}{n_{i,t}^A + n_{i,t}^B}\right)}^{RM_{i,t}} \times \overbrace{\left(n_{i,t}^A + n_{i,t}^B\right)}^{CY_{i,t}} \times \underbrace{\left(AIC_{i,t}^A \times \frac{n_{i,t}^A}{n_{i,t}^A + n_{i,t}^B} + AIC_{i,t}^B \times \frac{n_{i,t}^B}{n_{i,t}^A + n_{i,t}^B}\right)}_{AIC_{i,t}}$$

The DB benefit may be reduced for claiming early under eligibility tracks A1 and A2. In these cases, individuals may claim up to 7-15 years early depending on policy year. Benefits are permanently reduced by 1% for the starting a year before achieving the required contribution years, an additional 2% per year for starting 2-9 years before achieving the required contribution, and an additional 3% per year for starting 10-15 years before achieving the required contribution.

Class 2

Benefits based on contributions prior to December 1995 are calculated using the DB formula for Class 1 (above) where period B is capped at 1995. Benefits based on contributions after December 1995 are calculated using the following NDC formula:

$$B_{NDC,i,t} = \beta_t \times \sum_{s=1996}^{t} \left(cr \times salary_{i,s} \times \left(\prod\nolimits_{m=s}^{t} \gamma_m\right)\right)$$

where β_t is an annuitization rate of accumulated NDC wealth based on age of retirement and the policy in place at year *t*, cr is the contribution rate on salary (fixed at 33% during this period), $salary_{i,t}$ is individual *i*'s salary at time *t*, and γ_t is the annual adjustment to contributions based on a 5-year moving average of the annual rates of growth of nominal GDP. This function can be transformed into the form in equation (1) by making a limited number of assumptions. As in the case of France's AGIRC and ARRCO benefit systems, suppose $AIC_{i,t}$ is the average of *i*'s indexed salary contributions paid over the length of their career at *t* ($CY_{i,t}$) based on indexing in calendar year *t* associated with the *k*th year of their career ($index_{t(k),t}$), then it can be formally represented as:

$$AIC_{i,t} = \frac{1}{CY_{i,t}} \sum_{k=0}^{CY_{i,t}} index_{t(k),t} \times salary_{i,t(k)}$$

Further, assume that cumulative annual adjustments are equal to the indexation of benefits (i.e., $index_{s,t} = \prod_{m=s}^{t} \gamma_m$), then the above formula for NDC benefits simplifies to:

$$B_{NDC,i,t} = \underbrace{\beta_t \times cr}_{RM_{i,t}} \times AIC_{i,t} \times CY_{i,t}$$

The replacement multiplier, average indexed contributions, and the claiming age penalty for class 2 worker used in estimating the model in section 4 are based on the weighted average of the time spent under the DB and NDC benefit systems:

$$B_{\text{Italy(Class 2)},i,t} = B_{DB,i,t} + B_{NDC,i,t} = \overbrace{\left(RM_{it}^{DB} \times \frac{CY_{i,t}^{DB}}{CY_{i,t}^{DB} + CY_{i,t}^{NDC}} + RM_{it}^{NDC} \times \frac{CY_{i,t}^{NDC}}{CY_{i,t}^{DB} + CY_{i,t}^{NDC}}\right)}^{RM_{i,t}} \times \underbrace{\left(CY_{i,t}^{DB} + CY_{i,t}^{NDC}\right)}_{CY_{i,t}} \times \underbrace{\left(AIC_{it}^{DB} \times \frac{CY_{i,t}^{DB}}{CY_{i,t}^{DB} + CY_{i,t}^{NDC}} + AIC_{it}^{NDC} \times \frac{CY_{i,t}^{NDC}}{CY_{i,t}^{DB} + CY_{i,t}^{NDC}}\right)}_{AIC_{i,t}}$$

B.2. Spain

The Spanish contributory public pension system (Pensión de Jubilación) is administered by the National Institute of Social Security (Instituto Nacional de la Seguridad Social - INSS). It provides a defined benefit based on contribution and earnings history. Most of the employees and autonomous workers in Spain are covered by this system.

The pension system provides a number of eligibility tracks based on typical old-age pension requirements – age and years of contribution – but also provides a number of alternative tracks based on reductions in work hours or job loss.

Eligibility

Eligibility Track 1 (Less than full contribution requirements)

Age requirements: Age 65 (rising gradually to 67 from 2013 to 2027) [13]

Contribution requirements: At least 15 contribution years including 2 contribution years in the last 8-15 years (depending on year benefits start).

Eligibility Track 2 (Full contribution requirements, available from 2012)

Age requirements: Age 65

[13] *Note*: The retirement age of 65 can be reduced for certain groups whose professional activity is arduous, toxic, dangerous or unhealthy; age 64 if employer replaces retiree with youth seeking first employment

Contribution requirements: 35 years and 3 months of contributions (rising gradually to 38 years and 6 months from 2013 to 2027).

Benefit

Pension benefits are calculated based on the retiree's regulatory base ("base reguladora") and multiplier based on years of contribution. The contribution base is defined as the gross monthly wage, including pro-rata bonuses and other forms of compensation. The regulatory base is 6/7th of the average of selected years that make up for the contribution base.

$$B_{SPAIN,i,t} = \frac{6}{7} \times AIC_{i,t} \times \left(0.5 + M_t^A \times n_{i,t}^A + M_t^B \times n_{i,t}^B\right)$$

where $n_{i,t}^A$ is the number of years contribution above 15 years but at or below threshold A (25 years before 2012) and $n_{i,t}^B$ is the number of years contribution above threshold A but at or below threshold B (35 years before 2012) and their respective multipliers. The last term in bracket should sum to 1 at the required contribution years for full benefits (i.e., 35 years before 2012). We transform this function into the form in equation 1 by dividing the term in parentheses by total contribution years.

$$B_{SPAIN,i,t} = \underbrace{\left(\frac{6}{7} \times \frac{\left(0.5 + M_t^A \times n_{i,t}^A + M_t^B \times n_{i,t}^B\right)}{15 + n_{i,t}^A + n_{i,t}^B}\right)}_{RM_{i,t}} \times \underbrace{\left(15 + n_{i,t}^A + n_{i,t}^B\right)}_{CY_{i,t}} \times AIC_{i,t}$$

Beneficiaries may claim their benefits as early as age 60 with a reduction in benefits before 2013, and then the minimum age is gradually rising to age 63. Penalties vary based on year and number of contributions years, but are in a range of 6.5% to 8% per year. Since 2003, the pension amount may exceed 100% for those who retire at age 65 or older with the benefit growing at the same rate as M_t^B.

B.3. France

For France's private sector workers, there are multiple public mandatory pension systems: a universal defined benefit pension that covers earnings up to a maximum income level and supplemental defined benefit pensions based on a worker's occupation that covers up to 8 times the maximum income level of the universal pension. The basic structure of the pension system has remained intact from 1992-2020, with major reforms during this period resulting in greater employer and employee contribution rates, increases in the required contribution quarters, introduction of incentives to delay retirement, increases in the retirement eligibility ages, and consolidation of the occupational pension systems.

In the private sector, there are two mandatory old-age benefit tiers:

- Tier 1 is Caisse nationale d'assurance vieillesse (CNAV), an earnings-related, defined-benefit public pension for private employees in manufacturing and services. CNAV also guarantees a minimum pension benefit (minimum contributif) for low-income pensioners.
- Tier 2 is composed of mandatory occupational schemes. These include Association des Régimes de Retraites Complémentaires (ARRCO) and l'Association Générale des Institutions de Retraite des Cadres (AGIRC). ARRCO offers benefits to all private sector workers below the social security threshold, and only to blue collar workers above the threshold. AGIRC covers only executives or managerial workers, for earnings above the social security threshold. Both AGIRC and ARRCO are point-based pay-as-you-go systems.

We limit our analysis to beneficiaries that worked in the private sector and so are most likely beneficiaries of these plans.

Eligibility

1. CNAV

There are two common eligibility tracks for full benefits and a number of less common eligibility tracks. Each eligibility track has its own contribution and eligibility age requirements. For CNAV, a contribution quarter is earned after contributing a fixed amount. In several French old-age benefit systems, particularly the public sector systems, quarters correspond to periods actually worked. This distinction is particularly important for part-year workers. We assume each year a worker was employed that they received 4 quarters. This will overstate the number of quarters for workers that did not earn enough to receive 4 quarters in a particular year.

Eligibility Track 1: Age only

Age requirements: Age 65 for persons born before July 1951 and gradually increasing to age 67 for persons born on or after 1955.

Contribution requirements: 1 contribution quarter

Eligibility Track 2: Age and experience

Age requirements: Age 60 for persons born before July 1951 and gradually increasing to age 62 for persons born on or after 1955.

Contribution requirements: 150 contribution quarters for workers born before 1934 and gradually rising to 172 quarters for workers born on or after 1973. Further revisions are made for more recent birth cohorts based on changes in mortality.

Other Eligibility Tracks for Full Benefits

- Long career option (Dispositif pour carrière longue)

  For those starting work before age 16, up to 2 years before the age requirement with 8 more quarters than required in eligibility track 2 (e.g., age 58 with 174 quarters of coverage if born in 1955 and entered workforce before age 18)

- Disability: Five years younger than the age requirement for eligibility track 2 provided the claimant is a worker with a permanent disability percentage of at least 50% with at least 1 contribution quarter
- Working mothers: Same as the age requirement for eligibility track 2 provided the claimant is a working mother with three or more children that contributed for 30 years and worked 5 of the last 15 years before retirement
- War veterans and victims: Same as the age requirement for eligibility track 2 with at least 1 contribution quarter

To claim CNAV, a worker must stop work with their "pre-retirement" firm for at least six months. We use eligibility tracks 1 and 2 to determine public pension eligibility.

2. **ARRCO and AGIRC**

These mandatory occupational pension systems are point-based: each year, an individual's contributions are converted to retirement pension points and added to the worker's account. There is no minimum duration of contributions to receive benefits. The mandatory occupation pension is awarded at the full rate to individuals who qualify for the full CNAV pension (see CNAV eligibility tracks 1 and 2) or age 65 for persons born before July 1951 and gradually increasing to age 67 for persons born on or after 1955.

Benefit

1. CNAV

The maximum benefit for CNAV is 50% of the insured's reference earnings. The insured reference earnings are computed based on annual earning up to a maximum threshold which

reflect the best 10-25 years of earnings indexed to the year of retirement depending on birth year. A 10% supplement is paid to persons who raised at least three children.

There is also a guaranteed minimum benefit to retirees who are entitled to a full pension. If an individual's pension rights fall below this minimum, their pension is brought up to the minimum (known as "minimum contributif"). Starting in 2012, the minimum pension benefit is reduced if total pension benefits exceed a maximum value.

The following formula provides details on how the benefit is computed if eligible for a full benefit and the horizontal brackets relate this function to equation (1):

$$B_{CNAV,i,t} = \underbrace{\frac{0.5}{CREF_{it}}}_{RM_{it}} \times \underbrace{AE_{i,t}}_{AIC_{it}} \times \underbrace{\min\{CREF_{it}, C_{it}\}}_{CY_{it}} \times (1 + CHILD_i)$$

where:

- $CREF_{it}$ are the reference years for benefit computation (varies based on time period t and individual i's birth year)
- AE_{it} is individual *i*'s reference earnings, calculated as the average of the worker's highest yearly wages capped by the Social Security ceiling and adjusted for inflation
- C_{it} is individual i's number of contribution years (including credits awarded for periods of unemployment, sick leave or maternity leave
- $CHILD_i$ is a child supplement equal to 10% if individual *i* raised 3 children for nine years each before their 16th birthdays

For individuals who do not qualify for full benefits via eligibility track 2 but have satisfied the applicable age requirement, they may claim their CNAV benefit early, but it is permanently reduced by a multiplier $CAP_i = (1 - rr_i \times early_i)$ where rr_i is a reduction rate based on individual *i*'s birth year and $early_i$ is the number of years individual *i* retired.

2. ARRCO and AGIRC

The amount depends on the number of points accrued during the insured person's career multiplied by the value of a point when the insured person retires. Each year, the number of points earned is the value of contributions divided by the cost of a pension point (known as a reference salary). At retirement, the accumulated number of points is converted into a pension benefit by multiplying them by the value of a pension point. Updating the cost and value of pension points is agreed between the social partners and is typically done on an annual basis. A supplement is paid to persons who raised children or have dependent children. The final benefit for these occupational schemes is equal to the sum of the ARRCO and AGIRC plans, where AGIRC is available only for managerial or executive workers. The following formula provides details on how the benefit is computed if eligible for a full benefit and the horizontal brackets relate this function to equation (1):

$$B_{p,i,t} \quad = \quad PPV_{p,t} \times \left(\sum_{s=\text{ career start year}}^{t} PP_{p,i,s} \right)$$

where $PPV_{p,t}$ is the pension point value in year *t* for pension plan *p* (where *p* = AGIRC or ARRCO) pension points and $PP_{p,i,t}$ are the pension points individual *i* accrued in period *t*. Pension point based plans can be converted into the framework in equation (1) with some simplifying assumptions. A pension point in ARRCO and AGIRC plans are determined based on a contribution rate ($cr_{p,t}$) based on plan *p* and time *t*, the employee's capped salary ($salary_{i,t}$) at time *t,* and a plan's reference salary ($ref_{p,t}$) at time *t*.[14] Therefore the benefit of a pension point plan, *p*, can be reframed as:

[14] Salary caps depend on pension plan and are either 3 times the CNAV salary threshold for ARRCO before 2018 or 8 times the CNAV salary threshold for AGIRC before 2018 and for the combined AGIRC-ARRCO plan from 2018.

$$B_{p,i,t} = PPV_{p,t} \times \left(\sum_{s=\text{career start year}}^{t} PP_{p,i,s} \right)$$
$$= PPV_{p,t} \times \left(\sum_{s=\text{career start year}}^{t} \frac{cr_{p,s} \times salary_{i,s}}{ref_{p,s}} \right)$$

Suppose $AIC_{i,t}$ is the average of *i*'s indexed salary contributions paid over the length of their career at *t* ($CY_{i,t}$) based on indexing in calendar year *t* associated with the *k*th year of their career ($index_{t(k),t}$), then it can be formally represented as:

$$AIC_{i,t} = \frac{1}{CY_{i,t}} \sum_{k=0}^{CY_{i,t}} cr_{p,t(k)} \times index_{t(k),t} \times salary_{i,t(k)}$$

and further assume the reference salary is constant in real terms (i.e., $ref_{p,t} = \overline{ref} / index_{s,t}$), then the above equation simplified to:

$$B_{p,i,t} = \underbrace{\frac{PPV_{p,t}}{\overline{ref}}}_{RM_{i,t}} \times AIC_{i,t} \times CY_{i,t}$$

where the first term is the equivalent of our replacement multiplier. To generate $AIC_{i,t}$, we also make a simplification of assuming the contribution rate is constant over the career and that indexation of salary caps are equal to growth in the CNAV salary caps.

Similar to CNAV, there is also a benefit supplement that depends on number of children and ranges from 5% to 24% depending on year a pension point was earned and plan.

ARRCO and AGIRC benefits can be started up to 10 years before eligibility for full benefits (e.g., age 50 for someone born before 1951). In this case, benefits would be permanently reduced by 57% of their value. AGIRC and ARRCO benefits are reduced based on the following claiming age penalty:

$$CAP_{i,t} = \begin{cases} 1 - (0.04 \times\ early_i), & 0 \leq early_i < 3 \\ 0.88 - (0.05 \times\ early_i), & 3 \leq early_i < 5 \\ 0.78 - (0.07 \times\ early_i), & 5 \leq early_i < 10 \end{cases}$$

where $early_i$ are the number of years before *i* would become eligible for full AGIRC or ARRCO benefits. See Knapp and Lee (Forthcoming) for additional policy details and relevant reference values.

All private sector workers are eligible for CNAV. Blue collar workers contribute only to ARRCO up to 3 times the social security threshold (8 times after 2018. Managerial and executive workers contribute to ARRCO up to the social security threshold, and contribute to AGIRC for earnings above the social security threshold up to 8 times that threshold. The combined benefit in France is then the sum of the three pension benefits:

$$B_{France,i,t} = B_{CNAV,i,t} + B_{ARRCO,i,t} + B_{AGIRC,i,t}$$

where the measures for the respective factors used in equation 1 are based on the weighted share of each benefit. For example, the over replacement multiplier is computed as:

$$RM_{i,t} = \frac{\hat{B}_{CNAV,i,t}}{\hat{B}_{France,i,t}} \times RM_{i,t}^{CNAV} + \frac{\hat{B}_{ARRCO,i,t}}{\hat{B}_{France,i,t}} \times RM_{i,t}^{ARRCO} + \frac{\hat{B}_{AGIRC,i,t}}{\hat{B}_{France,i,t}} \times RM_{i,t}^{AGIRC}$$

where we estimate the benefits (depicted above with a hat - $\hat{B}$) using equation 1.

B.4. Germany

Gesetzliche Rentenversicherung (GRV) is the German compulsory old-age public pension system. This system depends on current contributions to make current benefit payments (i.e., it is "pay as you go"). Pension benefits are based on a worker's accumulated pension points. A worker accrues pension points each year based on the ratio of their taxable earnings relative to the average earnings of all GRV-covered workers. For retirement income beyond GRV, individuals may also contribute to voluntary occupational pension systems (Betriebliche

Altersvorsorge) through their employers that supplement GRV or to voluntary private savings schemes. In 2002, a private saving scheme was introduced, known as the Riester Pension. The government subsequently offered subsidized matching contributions to Riester accounts. In 2005, an alternative government-subsidized saving scheme was introduced, known at the Rürup Pension, targeted at self-employed workers who are usually not eligible for the Riester Pension, although the Rürup Pension was not limited to self-employed. In this paper, we represent German old-age benefits through the GRV system's eligibility and benefit rules. We do not incorporate voluntary occupational pensions systems or the Riester and Rürup pensions.

Eligibility

GRV has six eligibility tracks that vary by year and birth cohort. An insured worker must satisfy at least one track's requirement to be eligible for full benefits. Contribution years in Germany include credits for periods of schooling after age 17, periods for childbearing and childrearing up to age 10 without contributions, and periods of unemployment.

- Eligibility Track 1: Regular old-age pension (Regelaltersrente)
    - Age requirement: age 65 for persons born before 1947 and gradually increasing to age 67 for persons born on or after 1963
    - Contribution requirement: 5 years
- Eligibility Track 2: Long-term insured persons (Altersrente für langjährig Versicherte)
    - Age requirement: 63 for persons born before 1937 and gradually increasing to age 67 for persons born on or after 1963
    - Contribution requirement: 35 years
- Eligibility Track 3: Severely disabled (Altersrente für schwerbehinderte Menschen)

    - Age requirement: 60 for persons born before 1941 and gradually increasing to age 65 for persons born on or after 1963
    - Contribution requirement: 35 years
    - Other requirements: Must qualify as severely disabled
- Eligibility Track 4: Women (Altersrente für Frauen)
    - Age requirement: 60 for women born before 1940 and gradually increasing to 65 for women born on or after December 1944
    - Contribution requirement: 15 years with at least 10 years of paid contributions since age 40
    - Other requirements (must satisfy all): Limited to women born before 1952
- Eligibility Track 5: Unemployed workers or workers in part-time employment (Altersrente wegen Arbeitslosigkeit oder nach Altersteilzeitarbeit)
    - Age requirement: 60 for persons born before 1937 and gradually increasing to 65 for workers born on or after December 1941
    - Contribution requirement: 15 years
    - Other requirements (must satisfy one condition):
        - Unemployed for 1 year after age 58 and 6 months
        - In part-time work for at least 24 months before age 60 and have at least 8 years of contributions during the 10 most recent years before retirement
- Eligibility Track 6 (available from 2012): Particularly long-term insured persons (Altersrente für besonders langjährig Versicherte)

    - Age requirement: 63 for persons born before 1953 and gradually increasing to age 65 based on birth year
    - Contribution requirement: 45 years

Eligibility for benefits at a reduced rate is available for a number of eligibility tracks. Benefits are reduced by 3.6% per year claimed before the full-eligibility condition associated with their qualifying eligibility track. The earliest eligibility conditions for starting benefits vary by eligibility track:

- Eligibility Track 1: Regular old-age pension – Early eligibility not available
- Eligibility Track 2: Long-term insured persons
    - Earliest eligibility age: 63
    - Must satisfy other requirements for full benefits
- Eligibility Track 3: Severely disabled
    - Earliest eligibility age: 60 for persons born before 1952 and gradually increasing to 63 for persons born after 1963
    - Must satisfy other requirements for full benefits
- Eligibility Track 4: Women
    - Earliest eligibility age: 60
    - Must satisfy other requirements for full benefits
- Eligibility Track 5: Unemployed workers or workers in part-time employment
    - Earliest eligibility age: 60 for workers born before 1946 and gradually increasing to age 63 for persons born on or after December 1948
    - Must satisfy other requirements for full benefits

- Eligibility Track 6: Particularly long-term insured persons – Early eligibility not available

For our analysis, we incorporate eligibility tracks 1, 2, 4, and 6 as appropriate. The sample restrictions described in Appendix A eliminate claimants from eligibility tracks 3 and 5 from our sample.

Benefit

GRV old-age pension benefits are based on a point system with insured individuals accruing points throughout their career. For each year of contribution an insured person receives pension points ($pp_{i,t}$), which reflect the employees' relative earnings position in year *t:*

$$pp_{i,t} = \frac{earnings_{i,t}}{avgearn_t}$$

where $earnings_{i,t}$ are individual i's earnings in contribution year t subject to a maximum earnings level and $avgearn_t$ are average nationwide earnings of all contributions in year t. A years' contribution at the level of average nationwide earnings results in one pension point.

The individual pension benefit on and after retirement is based on the cumulative pension points multiplied by the pension point value in that year. The pension point value is adjusted in relation to the gross wage growth. The unreduced benefit paid when a person qualifies for full (unreduced) benefits is computed as:

$$B_{GERMANY,i,t} = ppv_t \times \sum_{s=\text{first year of GRV contribution}}^{t} pp_{i,s}$$

where ppv_t is the value of a pension point in year t.

Eligible persons starting benefits early have their benefit permanently reduced by 0.3% per month (3.6% per year). Persons starting benefits after they have satisfied the requirements for

full benefits have their benefit permanently increased by 0.5% per month delayed (6.0% per year).

We convert the Germany pension system from pension points and values into the measures in equation 1 using the same approach as in the French supplementary occupational plans (ARRCO and AGIRC) in section B.3. See Knapp and Lee (Forthcoming) for additional policy details and relevant reference values for Germany.