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Is it worth raising the normal retirement age? A new model to estimate the employment effects

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ABSTRACT/RÉSUMÉ

Is it worth raising the normal retirement age? A new model to estimate the employment effects

Pension reforms, particularly those changing the normal retirement ages, are both crucial and controversial in ageing developed countries. This paper investigates the effects of such reforms on the labour market, focusing on the older-age employment rate. While existing cross-country estimates agree on a positive and significant effect of raising normal retirement ages, the estimated labour market effects are modest and usually much smaller than those derived from country-specific studies using micro data. This study attempts to reconcile these differences by introducing greater heterogeneity into the cross-country approach to better capture country-specific demographics and pension system characteristics, so that estimated effects are closer to those from single-country studies.

Starting from a standard cross-country panel error correction model, several empirical innovations are introduced to better capture the influence of the demographic composition of countries, the possibility to retire at earlier ages, and the importance of private pension funds and early exit pathways. These changes result in larger and more heterogeneous predicted effects of changes in the normal retirement ages on the older-age employment rate and average age of labour market exit across countries. This suggests a greater and varied impact of pension reforms on the labour market than previously estimated with pooled cross-country estimations, emphasising the importance of considering countries' demographic compositions and pension systems specificities when predicting the effects of pension reforms. The proposed model, distinguishing between minimum and normal retirement ages, allows for simulations on the effects of increasing normal retirement ages and narrowing the gap between normal and minimum retirement ages. In countries with the lowest older age employment rates, bridging these gaps could result in substantial increases in their employment rates.

JEL codes: J26, J21.

Keywords: normal retirement ages, employment rate, labour market policy, older workers

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Vaut-il la peine de relever l'âge normal de la retraite ? Un nouveau modèle pour estimer les effets sur l'emploi

Les réformes des retraites, en particulier celles modifiant les âges légaux de départ à la retraite, sont à la fois cruciales et controversées dans les pays développés vieillissants. Cette étude examine les effets de telles réformes sur le marché du travail, en se concentrant sur le taux d'emploi des travailleurs plus âgés. Alors que la plupart des modèles macroéconomiques multinationaux existants s'accordent sur un effet positif et significatif de l'augmentation des âges légaux de départ à la retraite, les impacts estimés sur les choix du marché du travail sont modestes et généralement bien inférieurs à ceux obtenus par des études spécifiques à chaque pays utilisant des données microéconomiques. Cette étude essaye de concilier ces différences en introduisant une plus grande hétérogénéité dans l'approche inter-pays, afin de mieux prendre en compte les caractéristiques démographiques et les systèmes de retraite propres à chaque pays, et ainsi obtenir des effets estimés plus proches de ceux des études spécifiques à chaque pays.

À partir d'un modèle standard à correction d'erreur (ECM) en panel multinational, plusieurs innovations empiriques sont introduites afin de mieux saisir l'influence de la composition démographique des pays, la possibilité de prendre une retraite anticipée et l'importance des fonds de pension privés et des possibilités de retraite anticipée. Ces changements conduisent à des effets prédits plus importants et plus hétérogènes des modifications des âges légaux de départ à la retraite sur le taux d'emploi des personnes plus âgés et l'âge effectif moyen de sortie du marché du travail dans différents pays. Cela suggère un impact plus important et varié des réformes des retraites sur le marché du travail que précédemment estimé dans les études transnationales, soulignant l'importance de prendre en compte la composition démographique et les spécificités des systèmes de retraite des pays lors de la prédiction des effets des réformes des retraites.

Le modèle proposé, qui distingue entre âges de départ à la retraite minimal et normal, permet de réaliser des simulations sur les effets de l'augmentation de l'âge normal de départ à la retraite et de la réduction de l'écart entre l'âge normal et l'âge minimal de départ à la retraite. Dans les pays ayant les taux d'emploi les plus faibles, réduire ces écarts pourrait entraîner des augmentations substantielles des taux d'emploi.

Codes JEL : J26, J21.

Mots-clés : âge légal de retraite, taux d'emploi, politique du marché du travail, travailleurs âgés

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Is it worth raising the normal retirement age? A new model to estimate the employment effects

By Hermes Morgavi[1]

1. Introduction and summary of results

1. Pension reforms, especially those increasing the normal retirement age, play an important and controversial role in many developed and ageing countries. The rising fiscal costs of public pensions and the strong opposition often faced by governments contemplating such interventions make evident the importance of reliable quantifications of their effects, especially on the labour market. Many empirical papers, using cross-country macro models, have estimated the impact of raising the normal retirement age on aggregate older-age employment. The estimates from such studies unequivocally point towards a positive and statistically significant effect on labour force participation and the employment rate. However, the magnitude of this effect is surprisingly modest when expressed in terms of average age of labour market exit: most studies suggest that a 1-year increase in the normal retirement age only raises the average age of labour market exit2 by 1-2½ months (see Table 1).

2. Empirical research using microdata from individual countries often suggests much stronger effects, for instance:

- (Mastrobuoni, 2009[1]), using U.S. microdata, finds that a 2-months increase in the normal retirement age raises the effective retirement age by approximately 1 month;
- (Fehr, Kallweit and Kindermann, 2012[2]) estimate that the 2007 pension reform in Germany, which increased the normal retirement age by 2 years, delayed retirement by an average of 9 to 12 months;
- (Hanel and Riphahn, 2012[3]) analysed a two-step pension reform in Switzerland that raised the normal retirement age for women from 62 to 63 in 2001 and then to 64 in 2005, finding that the combined reform delayed retirement entry by 7.7 months;
- (Lalive and Staubli, 2015[4]), using data from the Swiss social security database, found that the 1-year increase in the normal retirement age in 2001 delayed labour market exit by 7.9 months;

[1] The author is a member of the Macroeconomic Analysis Division of the OECD Economics Department. He would like to thank Christophe André for detailed and thoughtful comments on a previous draft, David Turner for his generous support and guidance in the drafting of this paper, as well as Veronica Humi for help with the editorial process.

[2] The average age of labour market exit is the average age of all persons withdrawing from the labour force in a given period, whether during any particular year or over any five-year period. The average age of labour market exit (AALME) is thus simply the sum of each year of age weighted by the proportion of all withdrawals from the labour force occurring at that year of age (see https://www.oecd.org/els/soc/Labour-Market-Exit-Age-Methodology.pdf).

- (Etgeton, 2018[5]), utilising the Biographical data of social insurance agencies in Germany, estimated that a 2-year increase in the normal retirement age implemented in 2012-13 would delay the average age of labour market exit by 8.4 months;
- (Morris, 2021[6]) estimated that the 1994 Australian pension reform, which raised the normal retirement age for women from 60 to 65, increased the average age of labour market exit by 9 months;
- (Fodor, Roehn and Hwang, 2022[7]) found that an increase in the minimum and normal retirement age in Slovakia would lead to a 7-month rise in the average age of labour market exit.

3. The results in (Turner and Morgavi, 2021[8]) show that, when heterogeneity across pension systems and demographics are adequately modelled, the cross-country panel estimates align more closely with the country-specific effects. However, that study relies on a database that is difficult to update3, being based on labour force participation that is identified by single year of age and is limited to a restricted group of mainly EU countries. The objective of this paper is to examine whether these results can be replicated at a more aggregate level; using a broader definition of the older age employment rate (defined on the population aged 55-74) as the dependent variable; and with a wider set of countries on a dataset which is both more up-to-date and can be readily updated in the future.

Table 1. The effect of raising the normal retirement age in previous OECD and IMF studies

The effect of raising the normal retirement age by 12 months

	Effect on average age of labour market exit (months)
(Blöndal and Scarpetta, 1999[9])	1.1 to 1.4
(Gal and Theising, 2015[10])	1.4
(Égert and Gal, 2017[11])	1.4
(Grigoli, Koczan and Tapalova, 2018[12])	2.3
(Geppert et al., 2019[13])	2.4
(Turner and Morgavi, 2021[8])	2.7-4.7

Note: The original studies reported their findings in terms of an effect on the employment rate or labour force participation rate. The figures reported here are the result of the author's calculations, which are detailed in (Turner and Morgavi, 2021[8]) and Annex B, and are made both to provide all estimations on a comparable basis and provide an estimate of the absolute effect on the average age of labour market exit to compare with an increase in the *normal* retirement age of 12 months. The calculations are based on estimated parameters reported in the respective studies, but also involve some additional assumptions. Hence, the figures in the table should be regarded as approximate, although they are robust to reasonable variations in these assumptions.
Source: Author's calculations described in Annex B.

4. The present work proposes several innovations to the empirical model used to quantify the effects of pension reforms. To give the sense of the importance of each modification, a standard cross-country panel error correction model (ECM) is estimated as a base model and innovations are introduced incrementally. The base model includes the normal retirement age as the main variable capturing the retirement policies as in most of the cross-country empirical papers, as well as a set of other labour market polices and control variables. According to the base model, a 1-year increase in the normal retirement age has an estimated effect on the employment rate of those aged 55-74, equal to 1.3 percentage points. This implies a median estimated effect on the average age of labour market exit of 3.2 months, from a 1-year

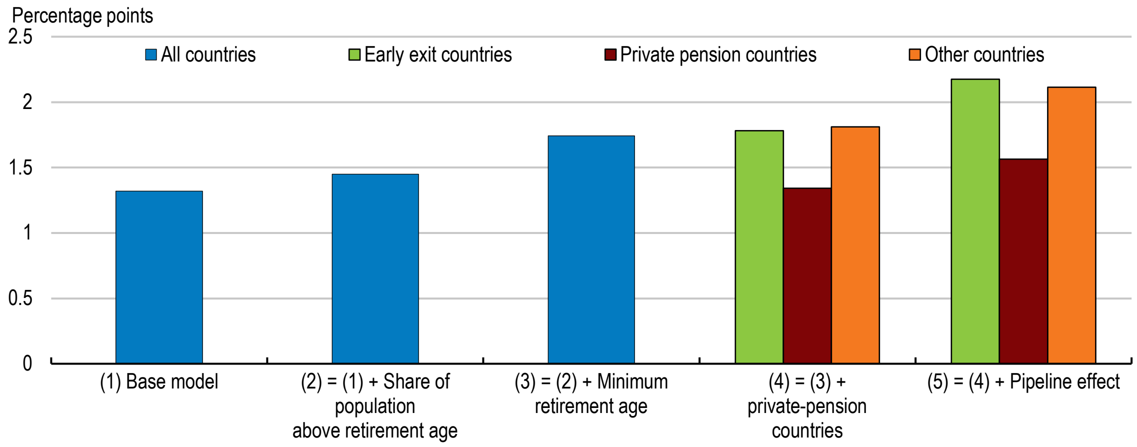
3 (Turner and Morgavi, 2021[8]), in fact, used a dataset collecting the labour market variables by education, sex and single year of age from the Eurostat Labour Force Surveys for the European countries, the Current Population Survey for the United States and the Statistics Canada Labour Force Survey for Canada. Most of the European countries instead provide data in 5-year age bands.

increase in the normal retirement age (see Annex B for the underlying calculation). The present work proceeds by incrementally introducing a number of features, some of which are inspired by (Geppert et al., 2019[13]) and (Turner and Morgavi, 2021[8]), to the base model. These additional features and their effects on quantifying the impact of an increase in normal retirement ages by 12 months are summarised below and in Figure 1, with further discussion in subsequent sections.

- To better capture the demographic composition of the labour force, the normal retirement age is replaced with the share of population above the normal retirement age. As a consequence, the estimated effect of an increase of the normal pension age on the older age employment rate for the median country is increased by 13 basis points, with a corresponding increase in the estimated effect on the average age of labour market exit by 0.3 months.
- Distinguishing between the normal retirement ages (the age at which workers are eligible for a full pension from a mandatory pension scheme) and the minimum retirement age (the age at which workers are eligible for a reduced pension from a mandatory pension scheme), raises the median policy effect on the employment rate by an additional 29 basis points and the corresponding effect on the average age of labour market exit by an additional 0.8 months.
- Following (Turner and Morgavi, 2021[8]), the model distinguishes countries where private pensions are important. These countries have a lower responsiveness to changes to the normal retirement age than other countries. This distinction further increases the estimated responsiveness of the other countries. The median effect on the employment rate for the countries where private pensions are predominant thus falls by 40 basis points and increases by 6 basis points in the other countries. The corresponding effect on the average age of labour market exit falls by 0.7 months in the countries where private pensions are predominant and increases by 0.8 months in the other countries.
- Finally, by distinguishing the countries where the effective retirement age is below the minimum retirement age, and including a “pipeline” effect to capture the effect of alternative early exit pathways (such as claiming social disability pensions, unemployment benefits, and other social welfare benefits or through voluntary early retirement programmes), that facilitate workers leaving the labour market 1 or 2 years before the minimum retirement age, the median policy response on the old age employment rate raises by a further 33 basis points, and the corresponding response on the average age of labour market exit by 0.9 months.

Figure 1. Model innovations give larger employment effects from raising the retirement age

Median effect on the employment rate of people aged 55-74 from raising the normal retirement age



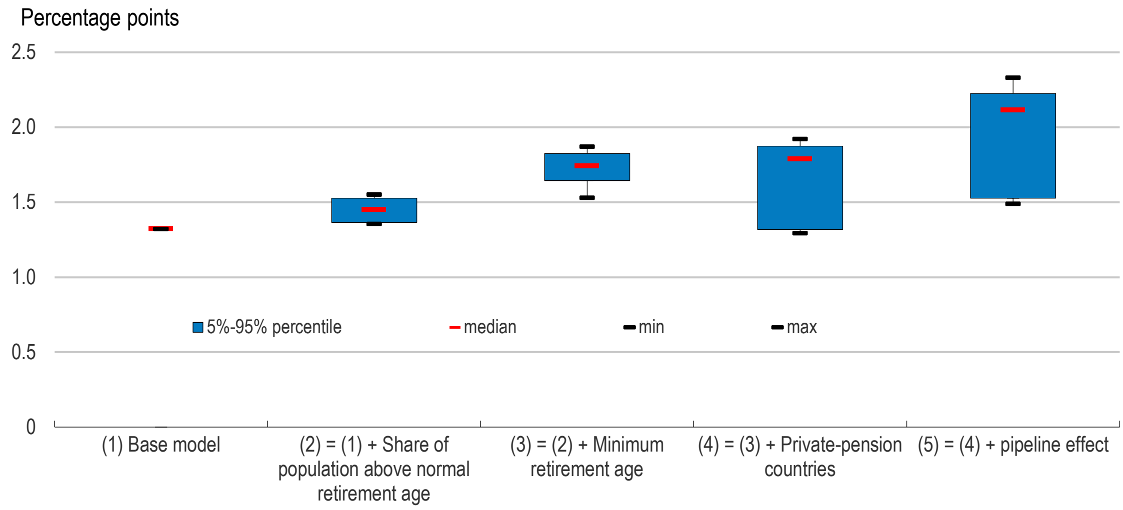
Note: The graph compares the effect on the old age employment rate of a raise of the normal retirement age by 1 year among the models expressed in percentage points. On the x-axis the modelling innovation introduced with respect to the previous model is shown. For the models including the effects of minimum retirement age and of the pipeline effects, these are also assumed to move by 1 year in line with the change in the normal retirement age. The effects are calculated using the data for year 2020 or latest year available to compute the long-term effects.
Source: Author's calculations.

5. In addition to a larger median effect of raising the normal retirement age, the revised model introduces greater heterogeneity of effects across countries, whereas the base model predicts the same effect on the employment rate across all countries (Figure 2):

- Using the share of population above the normal retirement age allows for different employment effects across countries, being large in countries with low retirement age or younger population. The employment rate effects thus have a cross-country range of 20 basis points and a corresponding range of effects on the average age of labour market exit of 2.2 months, 0.5 months more than the base model.
- Distinguishing between normal retirement ages and minimum retirement ages raises the cross-country range of the effects of increasing the normal retirement age on the older age employment rate 34 basis points and the range of the effects on the average age of labour market exit further increases to 2.6 months.
- Distinguishing the countries where private pensions are important, the range of the effects on the employment rate increases to 63 basis points, while the range of effects on the average age of labour market exit to 2.9 months.
- Finally, distinguishing the countries where the effective retirement age is below the minimum retirement age and including a pipeline effect, raises the range of the effect on the older age employment rate to 84 points and that of the average age of labour market exit to 3.5 months.

Figure 2. Model innovations give larger employment effects from raising the retirement age

Range of effects on employment rate of people aged 55-74, from raising the normal retirement age



Note: The graph compares the long-term effect on the old age employment rate of a raise of the normal retirement age by 1 year among the models expressed in percentage points. On the x-axis, for each model, the main innovation introduced with respect to the previous model is shown. For the models including the effects of minimum retirement age and of the pipeline effects, these are also assumed to move by 1 year. The red horizontal marks show the median of the distribution of the effects among the countries in the sample; the blue boxes show the distance between the fifth and the ninety-fifth percentile; and the whiskers show the minimum and the maximum values. The effects are calculated using the data for year 2020 or latest year available.
Source: Author's calculations.

6. So, to answer the question originally posed in the title of this paper, the innovations introduced by the present work produce much higher effects on the employment rate than implied by previous pooled country estimations, so that raising the normal retirement age is a much more worthwhile proposition for policymakers. The flexibility of the model better captures country-specificities of demography and pension systems, resulting in more heterogeneous predicted effects both across countries and through time. The model proposed, which distinguishes between minimum and normal retirement ages, enables simulations to be made on the impact of raising normal retirement ages and reducing the gap between normal and minimum retirement ages. In some countries with the lowest employment rates closing these gaps could lead to significant increases in employment rates. Few countries, instead, could seize substantial benefits by harmonising normal retirement ages between genders. Given the estimated adjustment horizon for changes in the retirement ages, it is crucial to anticipate the effects of demographic changes or implement automatic adjustment mechanisms for retirement ages. It is worth noticing that the present model focuses on the labour supply side but does not directly model the labour demand side from firms and the effect of fiscal incentives, because of lack of comparable data. Many authors have shown that the positive effects on employment are accompanied by an increase in the costs of social benefits for illness, disability, and unemployment, although to a lesser extent and on a temporary basis[4]. The possibility of active program substitution and its magnitude depends on the presence of early retirement pathways. The legislator, in defining optimal policies, will also need to take the possibility that these additional costs may materialise.

7. The remainder of the paper is organised as follows: section 2 presents the base model, which is used as a term of comparison to measure the effects of each innovation; sections 3 to 6 introduce each

[4] See, for example, (Duggan, Singleton and Song, 2007[38]), (Staubli and Zweimüller, 2013[37]), (Atalay and Barrett, 2015[39]), (Geyer and Welteke, 2019[40]).

innovation to the model and quantify the effects in term of goodness of fit, median effect on the older age employment rate of a 1-year increase in the normal retirement age, and heterogeneity of the estimated effects; section 7 compares the model predictions with those coming from country-specific estimates, section 8 shows how the model can be used for policy simulation and in particular to quantify the effects of minimum retirement age on old age employment rates; section 9 estimates the average adjustment period prior to the full realisation of the estimated long-term effects of policy changes; finally, section 10 concludes.

2. The base model

8. The base model that is the starting point of the present analysis uses the employment rate for those aged 55-74 as the dependent variable and the normal retirement age as the main policy instrument. The normal retirement age is calculated as the weighted average of the normal retirement ages for men and women, using the respective population shares as weights. The normal retirement age is here defined as the age at which an individual, who entered the labour market at age 25 and had a full career, becomes eligible for a full pension from all mandatory pension schemes.[5] The model is estimated using the two-steps Engle-Granger procedure, where the long-term relationship is estimated using the Dynamic OLS methodology with one lead and one lag and robust standard errors. The model can be written as follows:

$$ER_{c,t} = \alpha_c + \alpha_P \cdot RA_{c,t} + \sum_j \alpha_j X_{j,c,t} + \varepsilon_{c,t}$$
$$\Delta ER_{c,t} = \beta_c + \beta_t + \pi \cdot \hat{\varepsilon}_{c,t-1} + \beta_P \cdot \Delta RA_{c,t} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t} \qquad (1)$$

where:

- $RA_{c,t}$ is the normal retirement age of country c at time t,
- α_c and β_c are a set of country fixed effects;
- β_t are a set of time fixed effects;
- $X_{j,c,t}$ is a set of labour market policy variables and control variables also used to capture differences among countries in the labour and product market regulation (see Table 2). The labour and product market variables are the gross unemployment benefit replacement rate (UBGR); the detrended spending on active labour market policies per employed person, expressed as a share of GDP per capita (ALMP); the average tax wedge on the mean income; the excess coverage; the EPL indicator for regular contracts[6]; and the OECD indicator of product market competition on the network industries (ETCR).[7] In addition, the life expectancy at 65 and the prime age employment rate, defined on the age group 25-54, are also included as control variables. The first one captures the effect of health and longevity of the workforce and the long-term demographic trends. The latter captures overall trends in the labour markets; the impact of labour market policies not included in the model whose effects on

[5] The retirement ages are taken from the country notes of past editions of the OECD publication *Pensions at a Glance* for both men and women separately. For the base model, the two retirement ages are then aggregated using a weighted average, with the share of population by sex as weights.

[6] The OECD indicators of employment protection legislation (EPL) evaluate the regulations on the dismissal of workers on regular contracts and the hiring of workers on temporary contracts. For the present work the indicator for regular contracts is used. They cover both individual and collective dismissals.

[7] The OECD indicators of regulation in energy, transport and communications (ETCR) summarise regulatory provisions in seven sectors: telecoms, electricity, gas, post, rail, air passenger transport, and road freight.

older workers are not different than those for prime age workers; it also accounts for the importance of early career patterns, and of labour market attachment[8].

Table 2. Summary table of the variables

	Minimum	Median	Mean	Maximum	Variance
ER 55-74	13.3	32.0	32.7	57.5	93.8
UBGR	1.9	26.7	23.5	55.5	160.1
ALMP	2.3	27.7	31.2	97.5	458.4
Average tax wedge	1.9	31.0	30.0	48.3	85.1
Excess coverage	-4.7	20.7	29.6	87.3	711.1
EPL	0.1	2.3	2.1	4.6	0.9
ETCR	0.5	1.8	2.1	5.4	1.0
ER 25-54	58.4	80.2	79.0	88.6	29.0
LE 65	74.4	93.4	92.9	115.0	66.1

Note: ER 55-74 is the employment rate of people aged 55-74; UBGR is the gross unemployment benefit levels expressed in percentage of the previous gross earning; ALMP is the detrended active labour market policy spending on employment as a share of GDP per capita; Average tax wedge is the average tax wedge for a couple with 2 children and prime earner at 100% average wage; Excess coverage is the difference between the coverage of wage bargaining agreement and the share of covered workers who are represented by unions; EPL is the OECD Strictness of employment protection for regular contract from individual and collective dismissals; ETCR is the component on regulation of network industries of the OECD PMR indicator; ER 25-54 is the employment rate of people aged 25-54; LE 65 is the life expectancy at 65.
Source: For ER 55-74, OECD Employment database; for UBGR, OECD Social Protection and Well-being database; for ALMP, OECD Labour database; for Average tax wedge, OECD Tax statistics database; for Excess coverage, ICTWSS database; for EPL, OECD Labour database; for ETCR, OECD PMR indicator database; for ER 25-54, OECD Employment database; for LE 65, OECD Health database; and OECD Employment database.

9. To better compare the effects of each innovation, we kept the same set of policy and control variables constant for the long-term equation across all models. Only variables that were statistically significant in all the models were retained. Based on this criterion, the only variable included in the model was the EPL indicator. However, other labour market policies, which affect the prime age employment rate, were also included as control variables. Hence the inclusion of a labour market policy in the model is to be interpreted as the differential effect of this policy on the old age group employment rate, with respect to the prime age group. Thus, the estimated models suggest that the labour market policies affect the old age employment rate in a similar way as the prime age employment rate, except stricter EPL, which tends to favour older age employment age more. For the short-term equation, instead, a stepwise regression was performed to select the dependent variables. Only the pension policy variables were excluded from the stepwise procedure and were always included in the short-term equations.

3. Innovation 1: Introducing demographics

10. While the normal retirement age has been a common choice as a policy variable in empirical pooled-country studies on old-age labour market choices, it has limitations. This choice is equivalent to estimating the average effect among the countries in the sample or to assuming a uniform effect on the old-age employment rate, regardless of the current retirement age or the demographic composition[9].

11. A better alternative is to use the share of population age above the normal retirement age as a pension policy variable. This is estimated as the sum of the share of men whose age is above the normal

[8] For a description of the variables of the mode, see Annex A.

[9] For further discussion on the subject, see Annex A.

retirement age for men on the total population age 55-74 and the share of women whose age is similarly above the normal retirement age for women on the total population age 55-74. This approach addresses two aspects of the heterogeneity of pension systems: the differences in the normal retirement ages by sex, and the demographic compositions. It creates a direct link between normal retirement ages, demographic composition of the country and the aggregate employment rate.

12. Introducing the share of population above the retirement age as an alternative pension policy variable, the proposed model fits the data better than the base model (compare models (1) and (2) in Table 3), while the estimates for the common variables are similar. The estimated effects of an increase in the normal age of retirement in model (1) are equal to 1.32 percentage points for every country, independently of its age structure and of the initial pension age. The effect of the same policy change on the alternative model (2) can be readily computed if it is assumed that the population is equally distributed across all ages over the 55-74 cohort, so that exactly 5% of that cohort is a year (or less) older than the age of retirement. Then the effect of the increase in the normal age of retirement by one year is given by the product of the estimated coefficient and (-5%), or (-5) if, as in the present work, the shares are expressed in percentage. Based on model (2), this gives an effect of $-0.286 \cdot (-5) = 1.43$ percentage points, which is 11 basis points, or 8%, larger than the effect in the base model (1)[10].

13. The above comparison does not, however, do justice to the cross-country heterogeneity that this innovation introduces. Given the current variation in the demographic structure of the countries considered in the sample, the policy effect for 2020 is between 4 and 23 basis points higher than those obtained in the base model (1), so up to 17% higher. The effect is greatest in the Slovak Republic and smallest in Greece (see Figure 2). The normal retirement age in Slovakia is 62.7 for both men and women and 5.4% of the population between 55 and 74 are aged 63. If the normal retirement age is raised by 1 year this share of population would not be able to retire anymore at 63, while none of the other age classes are affected, with an estimated effect of $-0.286 \cdot (-5.4) = 1.55$ percentage points on the older age employment rate. The normal retirement age in Greece is 67 for both men and women, instead, and 4.7% of the population between 55 and 74 are aged 67. The estimates effect of raising the normal retirement age by 1 year on the older age employment rate is consequently equal to $-0.286 \cdot (-4.7) = 1.35$ percentage points. It is worth noticing that, given the linearity of the model, this effect does not depend on the observed employment rate.

[10] The estimated coefficient using the statutory retirement age as independent variable corresponds to the estimated average effect of a raise in the statutory retirement age, not considering the demographic composition of the countries. This back-on-the-envelope quantification can be considered an approximation of the average effect among the countries in the sample across time, considering the demographic composition of the countries. The difference between the two estimates gives a measure of the importance of considering the age and sex composition of the population.

Table 3. Long term equations explaining the older age employment rate

Dependent variable: employment rate of 55-74 age group

Explanatory variables	Variant equations				
	(1) Base model	(2) = (1) + % pop. above normal ret. age	(3) = (2) + Minimum retirement age	(4) = (3) + Private-pension countries	(5) = (4) + Pipeline effect
Labour and product market regulations					
EPL regular contracts	5.863**	6.283**	7.932**	8.138**	8.448**
Pension policies					
Normal retirement age	1.320**				
Pipeline effect					-0.087
% pop. above minimum ret. age			-0.098	-0.095	-0.132
% pop. above normal ret. age		-0.286**	-0.243**		
% pop. above normal ret. age (private pensions countries)				-0.172	-0.176
% pop. above normal ret. age (non- private pensions countries)				-0.256**	
% pop. above normal ret. age (early exit countries)					-0.265**
% pop. above normal ret. age (other countries)					-0.275***
Other variables					
ER 25-54	0.615***	0.608***	0.586***	0.583***	0.606***
Life expectancy 65+	0.561***	0.538***	0.506***	0.516***	0.493***
RMSE	2.66	2.60	2.61	2.60	2.60
Adjusted R^2	91.8%	92.2%	92.1%	92.1%	92.1%
Obs.	522	522	522	522	522
Countries	27	27	27	27	27
Time coverage	1992-2019	1992 - 2019	1992-2019	1992-2019	1992-2019

Note: The table shows the estimated coefficients of the long-term equation of the model. Model (1) corresponds to the base model. Model (2) is the same model as model (1) but instead of using the normal retirement age for pensions as pension policy variable, the share of population above the normal retirement age is used. Model (3) uses the database created by (Geppert et al., 2019[13]) integrated with the data from (OECD, 2021[14]) and (OECD, 2023[15]), which distinguish between minimum retirement age and normal retirement age. Model (4) introduces the distinction between countries where the private pension funds are important. Model (5) is equivalent to model (4), but the pipeline effect for early exit countries is added. The RMSE and the adjusted R^2 shown in the table refer to the long-term equation only and hence are computed excluding the lagged and leading variables used in the Dynamic OLS methodology to estimate it.
Source: Author's calculation.

4. Innovation 2: Distinguishing between the minimum and normal retirement age

14. Most countries' pension schemes allow workers to retire some years before the normal retirement age, with benefits often reduced for each year taken before the normal retirement age. Certain countries condition this possibility on a minimum number of years of past contributions, such as Austria, Germany, Greece, and Luxembourg. In some cases, such as in Belgium and Luxembourg, it is possible to retire early without penalties based on the length of contributions, while Germany and Portugal allow for early retirement without a penalty for early starters. In some countries like the Slovak Republic, early retirement is conditional on pension entitlements exceeding a given floor. Moreover, in some countries, like Czech Republic and Slovak Republic, early retirement is only possible within a given number of years before the normal retirement age (see (OECD, 2023[15])).

15. Providing an early retirement option within the old age pension system allows greater flexibility to account for differences in individual circumstances, including underlying health. However, such early retirement possibilities may have a negative impact on the older age employment rate. It also undermines the effects of increasing the normal retirement age if the raise is not accompanied by a correspondent raise in the minimum retirement age.

16. Taking advantage of the database put in place by (Geppert et al., 2019[13]), it is possible to refine the estimates and isolate the effects of the early retirement possibilities. Analysing the retirement conditions of the OECD countries, they built a database where the minimum retirement ages and the normal retirement ages are collected for the countries of the European Union plus Japan, United States, Switzerland, and Canada for the period 1990 to 2017. This database was updated with the last data available from (OECD, 2021[14]) and (OECD, 2023[15]). The definition used of normal retirement age, and accepted in the present work, is the age at which an individual, who entered the labour market at age 25 and had a full career, becomes eligible for a full pension from all mandatory pension schemes. The minimum retirement age, instead, is the age at which an individual, who entered the labour market at age 25 and had a full career, becomes eligible for a reduced pension from a mandatory pension scheme at an earlier age than the normal one[11]. In many countries a significant fall in the employment rate at these earlier ages can be observed, especially for lower-educated individuals[12].

17. Distinguishing both ages, adds the variable "*Share of population above the minimum retirement age*" as well as "*Share of population above the normal retirement age*". Model (3) in Table 3 and Figure 2 shows that the presence of such possibilities to retire before the normal retirement age dampens the employment rate of older-aged workers. Moreover, isolating the effect of the minimum retirement age, the median estimated effect of a rise of the normal retirement age by 1 year, assuming both the minimum and normal retirement ages move in parallel, is slightly higher by around 30 basis points and the range of estimates rises by 15 basis points with respect to the previous model, varying between 1.53 and 1.87 percentage points.

5. Innovation 3: Distinguishing countries with important private pension funds

18. The importance of private pension funds reduces the relevance of the public normal retirement age in favour of the rules and the incentives set by the private pension funds. Private pension funds often allow individuals to customise their retirement planning based on their financial situation preferences. Some private pension funds offer incentives for delaying retirement, such as increased benefits or bonuses. This can incentivise working longer, even beyond the public normal retirement age, to maximise their private pension benefits. Workers with lower salaries may have little room for financial commitments such as contributions to voluntary private pension schemes and may be forced to withdraw funds from their private pension accounts to meet more pressing short-term financial challenges. As a result, individuals may prioritise the rules and incentives offered by private pension funds over the fixed public retirement age and sometimes may be forced by necessity to work even after the normal retirement age to achieve a dignified retirement.

[11] These variables are calculated based on the country notes of the past editions of Pensions at a glance for both men and women separately. For further discussion on the variables' definitions, see Annex A.

[12] (Manoli and Weber, 2016[43]) using Austrian administrative data on the 2000 and 2004 pension reform estimated that, a 1-year increase in the minimum retirement age led to a 4.8-months increase in the average job exiting age and a 6-months increase in the average retirement age.

19. Following the approach in (Turner and Morgavi, 2021[8]) it is possible to differentiate for countries where private pension funds are important (henceforth "private pension countries[13]"). They find that these groups of countries are less responsive to changes in the normal retirement age. For the present work, countries are considered as having an important voluntary private pension system (private pension countries) if voluntary private pensions cover a large share of the working population and the replacement rate from such schemes is at least 60% of that in the public mandatory pension scheme.

20. The estimated parameters confirm the lower responsiveness of the private pension countries. The estimated coefficient for private pension countries, in fact, is equal to -0.172, even if the parameter is not statistically significant, to be compared with -0.256 for the other countries, see model (4) in Table 3. Thus, a 1-year increase in the normal retirement age in the private pension countries raises the older age employment rate by 1.3 percentage points on the median country, compared to 1.8 for the other countries, see model (4) in Figure 1. Differentiating the effect of changes in the normal retirement age of private pension countries, slightly increases the estimated effects on the other countries. Consequently, the median estimated effect of a rise of the normal retirement age by 1 year on the older age employment rate is 4 basis points higher and the range of estimates is 29 basis points greater with respect to model (3), varying between 1.29 and 1.92 percentage points.

6. Innovation 4: Distinguishing countries with alternative early exit pathways

21. The concept of early exit pathways, as developed by (Kohli and Rein, 1991[16]), refers to institutional arrangements linked to managing the transition between work exit and entry into the regular old-age pension system. Early exit pathways, shaped by economic challenges like high unemployment in the late 1970s and early 1980s, take the form of early retirement pensions, disability benefits, and extended unemployment benefits. These pathways provide easily accessible and relatively generous benefits, influencing older workers to withdraw from the labour market. Despite the initial economic rationale fading, early exit pathways persisted, becoming ingrained in workers' and employers' expectations, decoupled from the business cycle, often serving as pull factors for older workers to withdraw from the labour market, by offering easily accessible and relatively generous benefits.

22. The economic literature identified eight pathways from work to early exit including social disability pensions, voluntary early retirement programmes, unemployment benefits, and social welfare benefits in several countries, like Austria, Germany, Norway, the Netherlands, Denmark, Finland, Italy, Spain, and quantified the effects of early exit pathways and their undermining effects on older age labour force participation[14].

23. In the countries where alternative early exit pathways are important, the labour force participation falls already 1 or 2 years before the minimum retirement age (a so-called "pipeline effect"), especially for lower-educated individuals. This is captured in the model by the inclusion of an additional variable, called "pipeline effect", which is defined as the share of population whose age is greater than one year below the minimum retirement age and who also have a "low education" background[15]. The importance of the early

[13] For the purposes of the current estimation work, countries are characterised as having an important voluntary private pension system if voluntary private pensions cover a large share of the working population and the replacement rate from such schemes is at least 60% of that in the public mandatory pension scheme. Using data from Tables 5.3 and 9.1 in (OECD, 2019[31]), this includes Canada, Ireland, Israel, Japan, Mexico, the United Kingdom, and the United States.

[14] See, for example, (Larsen and Pedersen, 2008[33]), (Kyyrä, 2014[32]), (Riekhoff, Kuitto and Palomäki, 2020[35]), (Yashiro et al., 2021[36]), and (Riphahn and Schrader, 2022[34]) among the others.

[15] (Staubli, 2011[42]) show that tighter eligibility criteria to the Austrian disability insurance program induced an increase in employment of 1.6 to 3.4 percentage points and important spillover effects into the unemployment and sickness

exit pathways undermines the importance of the normal retirement ages for individuals' labour market choices.

24. For the present work, countries are considered as having important early exit pathways if their effective retirement age is below its minimum retirement age in the current year and in the 4 previous ones. Model (5) distinguishes early exit countries and captures the effect of the presence of the pipeline effect for those countries. The estimated parameters confirm the lower responsiveness of the early exit countries and the presence of a pipeline effect, even if restricted to the first year before the minimum retirement age and for the low-educated individuals only[16]. Isolating the pipeline effect increases the estimated minimum retirement and normal retirement effects. Consequently, the median estimated effect of a rise of the normal retirement age by 1 year on the older age employment rate is 33 basis points higher and the range of estimates is 52 basis points greater with respect to model (4), varying between 1.49 and 2.35 percentage points.

7. Comparison with single-country estimates

25. This section compares the estimated effects of historical pension reforms or of pension reform proposals, using the presented model, with quantifications from single-country studies analysing the same policy changes.

26. Discrepancies might be expected due to the ability of single-country studies to more accurately account for the unique characteristics of each nation's pension system, other relevant policies, demographics, and economic conditions. Additionally, the use of microdata in these studies allows for a more granular analysis that cannot be captured by macro-level models. The possibility of micro-level models to include a wide range of variables, such as employment history, income distribution, health status, and retirement intentions, contributes to a more comprehensive understanding of how pension reforms impact different segments of the population.

27. Nevertheless, despite the differing methodologies, the estimated effects from the two approaches are remarkably similar, with the panel estimates of reform effects being within 20% of the country-specific estimates in 5 out of the 7 cases considered (Table 4). Macro-models often fail to capture the complexity and the many differences among the countries pension systems and for this reason are frequently considered inferior to studies using micro data. However, the innovations proposed in the present study, by better capturing country-specific demographics and pension system characteristics, show that cross-country macro estimations can give results that are comparable to those derived from micro-level data. This approach can be particularly advantageous in situations where micro data are scarce or difficult to obtain, as it allows for meaningful analysis of retirement policies across different countries without requiring extensive individual-level data. This is particularly important in broad comparative studies or where access to granular data is limited.

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insurance program. (Borghans, Gielen and Luttmer, 2014[41]) show that more stringent criteria for accessing the disability insurance benefits induced in the Netherlands an increase in the employment rate by 2.9 percentage points and, at the same time, an increase in other social assistance programmes.

[16] (Staubli and Zweimüller, 2013[37]), using the social security data for Austria, estimate that the gradual rise in the minimum retirement age from 55 to 58.25 for women and from 60 to 62 for men between 2001 and 2010 resulted in in an increase in the employment rate by 9.75 percentage points for men and 11 percentage points for women. They also estimated that, at the same time, unemployment increased by 12.5 percentage points among men and by 11.8 percentage points among women.

Table 4. The predictions of the model are consistent with those of single-country studies

	(1)	(2)	(3)	(4)	(5)
Study	Country	Year of reform[1]	Increase in normal retirement age (months)	Effect on average effective age of retirement (months)	
				Original study	Proposed model
(Mastrobuoni, 2009[1])	USA	2000	2	1	0.6
(Fehr, Kallweit and Kindermann, 2012[2])	DEU	2008	24	9-12	8.4
(Hanel and Riphahn, 2012[3])	CHE	2001 & 2005	12	2.3-5.4	4.2-4.3
(Lalive and Staubli, 2015[4])	CHE	2001	12	7.9	4.2
(Etgeton, 2018[5])	DEU	2012	24	8.4	8.1
(Fodor, Roehn and Hwang, 2022[7])	SVK	2020	7	7	5.7

Note: 1. The year refers to the year of the pension reform analysed or to the year of reference of the quantification.
2. The quantification using the proposed model is made by estimating the effect of a 1-year increase in the country's normal retirement age for the specified year, using the estimates from model (5) in Table 3 and the data on the demographic composition in the estimation sample for the specific year. The estimated impact for a 1-year increase was subsequently rescaled to the actual change.
Source: Author's calculations.

8. The effect of changing the gap between minimum and full normal retirement ages

28. The quantifications considered above compute the effects on the older age employment rate of raising the normal retirement age by 1 year, assuming that the minimum retirement age also increases in tandem by 1 year. However, the experience of past OECD pension reforms demonstrates that this is not always the case and that reforms sometimes increase the gap between the two pension ages[17]. The proposed model in section 6, by distinguishing between the normal age of retirement and a minimum age of retirement, enables to simulate the effects of closing the gap between these two ages rather than raising them both concomitantly. The presence of minimum retirement ages gives more freedom for the workers to choose to forego a part of their pension and retire at an earlier age than the normal age at which they are eligible for a full pension. If the reduced pension is correctly calibrated to account for the longer retirement period, no additional financial pressure is exerted on the pension system. Greater choice allows for differences in individual circumstances, in particular health, with potentially positive effects on wellbeing. This may be the case in occupations where the decline in physical or cognitive abilities of older workers pose a risk to themselves or others, such as those in public security and safety services or manual occupations characterised by challenging working conditions that, over extended periods, could lead to adverse health outcomes. However, as pointed out in (OECD, 2023[15]), these cases can primarily be dealt with by policies outside the realm of old-age pensions such as health and safety regulations; reskilling and

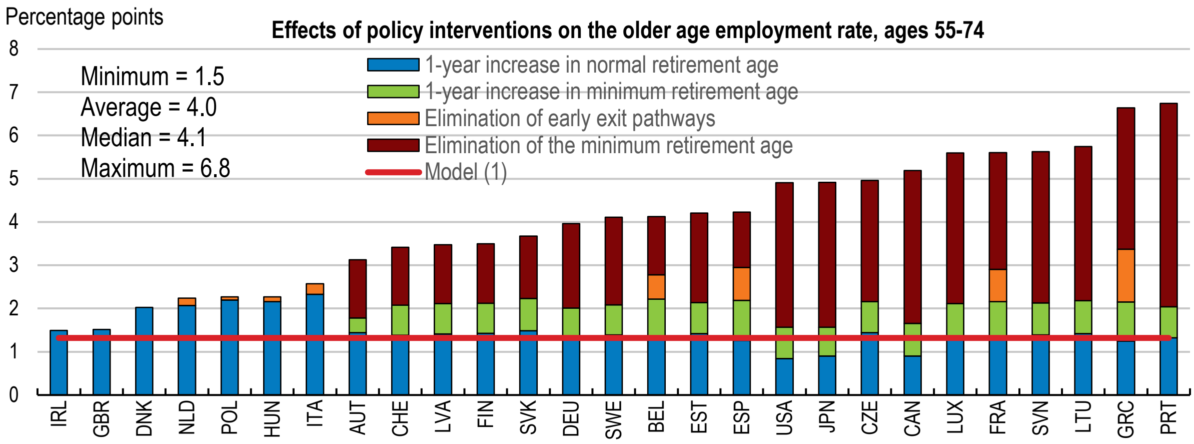
[17] For example, in Belgium the normal retirement age for women in the period 1998-2007 was raised 5 times from 60 to 65 while the minimum retirement age remained constant at 60; in Switzerland the normal retirement age for women was raised twice, in 2001 and 2005 while the minimum retirement age remained constant at 62; In Czech republic, the normal retirement age was for both men and women raised twice, in 2019 and 2020 while the minimum retirement age remained constant; in Germany the normal retirement age for both men and women was raised in 2018 while the minimum retirement age remained constant; and in Portugal the normal retirement age for women was raised 3 time in the period 1994-8 while the minimum retirement age remained constant. Other countries instead raised the statutory retirement age while at the same time they lowered minimum retirement age: for example, Italy for male workers in 2012.

upskilling frameworks to facilitate career transitions; accessible, efficient and responsive long-term sickness benefits and disability insurances; and special pension schemes covering workers in hazardous or arduous jobs.

29. Four possible policy changes related to raises in the retirement ages are evaluated in Figure 3 using the final model (5), incorporating all the modelling innovations[18]:

1) A 1-year increase in the normal retirement age, keeping the minimum retirement age unchanged.
2) A 1-year increase in the minimum retirement age, keeping the full normal retirement age unchanged after the previous one-year increase. This effect is only relevant for countries that offer a minimum retirement age option. It further assumes the corresponding 'pipeline effect' introduced in section 6 also shifts by one year.
3) Elimination of the early exit pathway. This effect is positive only for the early exit countries.
4) Elimination of the minimum retirement ages, assuming that the minimum retirement age becomes equal to the normal retirement age. To better assess the scale of such effects the policy change is considered simultaneously with a 1-year increase in the normal retirement age and the elimination of the early exit pathways.

Figure 3. Policy simulations changing the gap between the minimum and normal retirement ages



Note: This graph shows the effects of a set of policy changes by country based on the estimated model (5) using the data for the year 2020: the effects of raising the normal retirement ages by 1 year (without any changes in the minimum retirement ages), raising the minimum retirement ages by 1 year and correspondingly moving the pipeline effect by one year; eliminating the early exit pathways, if present, for all the countries in the sample, based on the estimated model. The elimination of the early exit pathways is equivalent to moving the correspondent effect to the minimum retirement age, incorporating the 1-year increase in the minimum retirement age. The elimination of the minimum retirement age is equivalent to raising the minimum retirement age, and the correspondent pipeline effect, to be equal to the normal retirement age, incorporating the 1-year increase in the normal retirement age and the elimination of the early retirement pathways. The estimated effects are compared with those obtained in the base model.
Source: Author's calculations.

30. The results presented in Figure 3 show that the employment effect of raising the normal retirement age is much smaller if the minimum retirement age remains unchanged. The rise in the minimum retirement age impacts a younger, and therefore generally greater, share of the population. The elimination of early

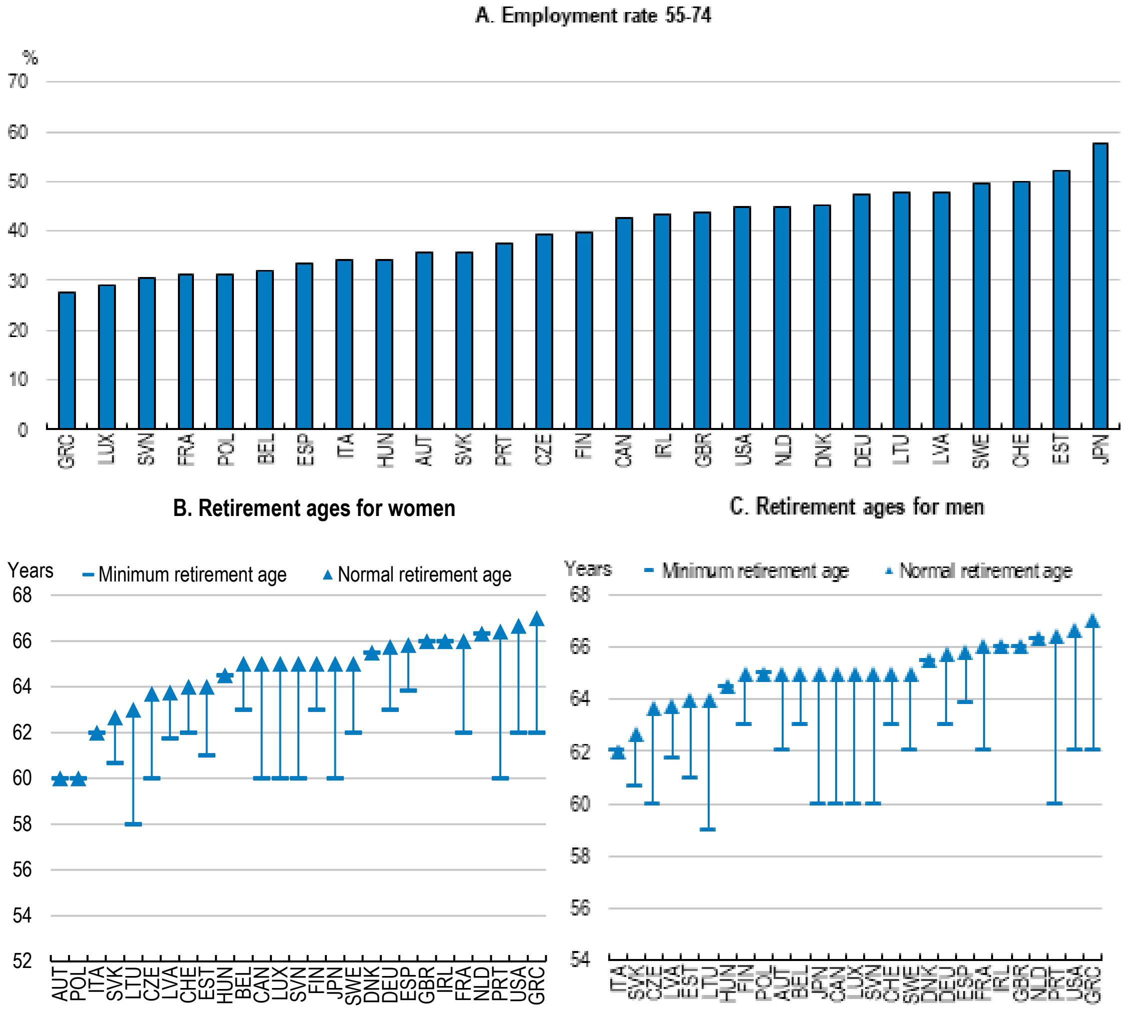
[18] The correspondent underlying model is described in Annex A while Figure A A.1 visualise the effects of the four reforms using the underlying model.

exit pathways ("pipeline" effects) can have substantial effects, as in the case of France, Spain, and Greece, which have a minimum retirement age between 2 and 5 years before the normal retirement age. Italy, the Netherlands, Poland, and Hungary instead did not have a distinct minimum retirement age in 2020, (so that the minimum retirement age is the same as the normal retirement age) hence, the elimination of the early exit pathway affects a much older, and therefore generally smaller, share of the population.

31. Many countries have recently (or are in the process of) reducing the distance between the two retirement ages, as for example, in Belgium, Spain, Finland, France, and Hungary (Figure 4, panels B and C). Some of the countries with the lowest older age employment rates have significant scope to reduce the distance between the normal and the minimum retirement age, including Greece, Luxembourg, Slovenia, and France (Figure 4, panel A). The normal retirement age of these countries is equal or above the median normal retirement age of the sample, but the possibility to retire early on a reduced pension likely undermines their old age employment rate. Other countries like Poland and Austria can instead reduce the differences in the normal retirement ages between men and women.

Figure 4. The countries with the lowest old age employment rate also have big retirement age gaps

Older age employment rate and retirement ages, year 2020



Source: OECD Employment database; and OECD Pension at a Glance database.

9. Adjustment horizon

32. The above quantifications refer to the long-term effects of a change in the retirement ages. Table 5, instead, shows the estimates of the short-term equations of the five models. The selection of the dependent variables was made performing a stepwise regression, separately for each model. The set of variables obtained is the same for all the models and the estimated parameters are very similar.

Table 5. Short-term equations

Comparative model analysis

Explanatory variables	Dependent variable: ΔER 55-74				
	(1) Base model	(2) = (1) + Share of population above retirement age	(3) = (2) + Minimum retirement age	(4) = (3) + Private-pension countries	(5) = (4) + Pipeline effect
EC-term	-0.042***	-0.047***	-0.052***	-0.053***	-0.054***
Tax-benefit and activation policies					
ΔALMP spending on employment (detrended), % of GDP per capita			0.056*	0.056*	
Wage setting institutions					
ΔExcess coverage	0.024**	0.023**	0.025**	0.024**	0.024*
Labour and product market regulations					
ΔETCR	0.555*	0.555*	0.593**	0.593**	0.552*
Pension policies					
ΔNormal retirement age	0.216**				
Δ% pop. above the statut. ret. age		-0.046***	-0.044**		
Δ% pop. above the statut. ret. age ^ private pensions				-0.028	-0.028
Δ% pop. above the statut. ret. age ^ early exit				-0.046**	-0.037
Δ% pop. above the statut. ret. age ^ other countries				-0.046**	-0.06**
Other variables					
ΔER 25-54	0.34***	0.34***	0.325***	0.326***	0.336***
ΔER 55-74(t-1)	0.230***	0.225***	0.215***	0.215***	0.222***
RMSE	0.705	0.702	0.699	0.699	0.701
Adjusted R^2	51.9%	52.3%	52.8%	52.8%	52.4%
Obs.	485	485	485	485	485
Countries	27	27	27	27	27
Time coverage	1993-2020	1993-2020	1993-2020	1993-2020	1993-2020

Note: The table shows the estimated coefficients of the short-term equation of the model. Model (1) corresponds to the base model. Model (2) is the same model as model (1) but instead of using the normal retirement age for pensions as pension policy variable, the share of population above the normal retirement age is used. Model (3) uses the database created by (Geppert et al., 2019[13]) integrated with the data from (OECD, 2021[14]), which distinguish between minimum retirement age and normal retirement age. Model (4) introduces the distinction between countries where the private pension funds are important. Model (5) is equivalent to model (4), but the pipeline effect for early exit countries is added. The RMSE and the adjusted R^2 shown in the table refer to the short-term equation only. The EC term is the estimated error correction term $\hat{\pi}$ from the short-term equation.
Source: Author's calculation.

33. The error correction term gives an idea of the adjustment period of the reform. The closer this parameter is to -1 the quicker the long-term effects of pension reform will realise in term of employment rate. The lagged dependent variable instead introduces a dynamic adjustment effect. This dynamic is fundamental for the evaluation of the effects of structural reforms, which, as in the case of pension reforms, require several years to fully deploy its effects, probably due to grandfathering options normally included in pension reforms. The estimated error correction terms range between -0.054 and -0.042 and the lagged dependent variable term varies between 0.21 and 0.22. Based on these estimates it is possible to compute the period necessary to approach to the long-term equilibrium. This means that, including the short-term effects and the dynamic adjustment, between 7 and 10 years are necessary to observe half of the expected long-term effects; between 15 and 23 years to observe 75% of the expected long-term effects; and between 26 and 40 years to observe 90% of the expected long-term effects.[19]

10. Conclusions

34. The employment rate at older age is affected, as for any other age group, by fiscal and activation policies, wage setting institutions and labour and product market regulations. What is peculiar of this age group is the importance of the pension policies in conjunction with the demographic dynamics. Pension policies specifically affect the population approaching the retirement ages. Predicting the effects of changes in the retirement ages requires a model that effectively integrates two key aspects of pension policies: retirement rules and demography. Neglecting either pension policies or demographic considerations leads to ineffective analysis.

35. The proposed model introduces several innovations to the base model. Replacing the normal retirement age with the share of population above the normal retirement age as the main pension policy variable allows for different effects of policy reforms among countries. This variable efficiently combines policy and demographic information and is closely linked to the policy instruments to allow for policy simulations. Given its foundation on a single age year model, the model can be easily generalised to incorporate specific dynamics like education, gender, presence of early exit pathways, etc. Distinguishing between minimum and normal retirement ages, allows to include the undermining effect of the presence of minimum retirement ages in the model. Accounting for pension systems specificities allows quantifying the undermining effect of alternative early exit pathways and the reduced responsiveness to changes to normal retirement ages due to the importance of private pension systems.

36. The models estimated using this approach better fit the data and provide predictions of the effects of pension reforms that are closer to the estimates coming from country-specific studies. The quantifications are different among countries, based on both the pension policies put in place by the government and the demography of the country. The innovations to the model introduced by the present work, summarised in Figure 2, go toward more diversification of the estimated effects and closer predicted effects to those estimated in single-country studies, compared to the base model. This results in a higher median effect, compared to the base model: the median estimated effect of an increase in the normal retirement ages on employment rate adopting model (5) is around 60% greater than the one estimated using the base model. The effects range between 1.49 and 2.35 percentage points, while it is the same for all countries in the base model, which estimates the average effect in the sample.

37. The proposed model, distinguishing between minimum and normal retirement ages, allows to make policy simulations on the effects of raising the normal retirement ages and of reducing the distance between the normal retirement age and the minimum retirement age. Some of the countries with the lowest

[19] The adjustment path following a 1-year increase in the statutory retirement ages is calculated assuming that the share of population whose age is equal to the statutory retirement age is equal to 5%. The results refer to a regular country (not a private pension nor an early exit one).

older age employment rate have relevant retirement age gaps. Reducing this gap can have significant effects on the employment rate. Other countries can instead benefit from reducing the differences in the normal retirement ages between men and women. The adjusting horizon for changes in the retirement ages is quite long, probably due to grandfathering options. For this reason, it is important to anticipate the effects of demographic changes or to include automatic adjustment mechanism for the retirement ages.

Annex A. The underlying model

The employment rate at age 55-74 can be written in the following way:

$$ER_{55-74} = \frac{Empl_{55-74}}{POP_{55-74}} = \frac{\sum_{a=55}^{74} Empl_a}{POP_{55-74}} = \frac{\sum_{a=55}^{74} ER_a \cdot POP_a}{POP_{55-74}} = \sum_{a=55}^{74} P_a \cdot ER_a \qquad (2)$$

where:

- $P_a = \frac{POP_a}{POP_{55-74}}$ is the share of population of age a on the total of population aged 55-74;
- $ER_a = \frac{E_a}{POP_a}$ is the employment rate at age a.

The present model is based on the one estimated by (Turner and Morgavi, 2021[8]) using single year age class data. The original model used the participation rate by age class while the present model uses the employment rate, as dependent variable. It assumes that there is a natural friction in the employment rate: the older is the worker the less likely he is to be working, independently of the retirement age. In the model proposed in the present work this assumption was dropped. It also assumes that the employment rate at the retirement ages falls by the same amount for all countries, independently of the retirement age. The employment rate for each country sex, age, year combination (c, s, a, t) can therefore be written as follows:

$$ER_{c,s,a,t} = \theta_c + \theta_t + \theta_r \cdot I(a \geq retirement\ age_{c,s,t}) + \sum_j \theta_j X_{j,c,t} \qquad (3)$$

where θ_c is a country fixed effect, θ_r is the retirement age effect, X_j are a set of control variable variables of interest and θ_j their associated coefficients. Consequently, the employment rate of population is assumed to remain constant at $\theta_c + \theta_t + \sum_j \theta_j X_{j,c,t}$ until the year before the retirement age when it falls by θ_r percentage points.

Aggregating equation (3) by age, becomes:

$$ER_{c,t} = \theta_c + \sum_s \theta_r \cdot P_{c,(a \geq retirement\ age_{c,s,t}),s,t} + \sum_j \theta_j X_{j,c,t}$$

Which is equivalent to the proposed model.

Grouping together the country and year fixed effects and the control variables $X_{j,c,t}$ in equation (3), which for a given country at a given year are constant, in the constant θ_0, the model can be rewritten in the following way:

$$ER_a = \theta_0 + \theta_r \cdot RET_a, \qquad where\ RET_a = \begin{cases} 1, & if\ a \geq retirement\ age \\ 0, & otherwise \end{cases}$$

Therefore, if the retirement age if equal to R_a

$$ER_{55} = \theta_0 + \theta_r \cdot 0$$

$$ER_{56} = \theta_0 + \theta_r \cdot 0$$

$$\vdots$$

$$ER_{R_a-1} = \theta_0 + \theta_r \cdot 0$$
$$ER_{R_a} = \theta_0 + \theta_r \cdot 1$$
$$ER_{R_a+1} = \theta_0 + \theta_r \cdot 1$$
$$\vdots$$
$$ER_{74} = \theta_0 + \theta_r \cdot 1$$

Hence

$$\begin{aligned} ER_{55-74}(R_a) &= \sum_{a=55}^{74} P_a \cdot ER_a = \sum_{a=55}^{74} P_a \cdot [\theta_0 + \theta_r \cdot RET_a] = \sum_{a=55}^{74} P_a \cdot \theta_0 + \theta_r \cdot \sum_{a=55}^{74} P_a \cdot RET_a \\ &= \theta_0 + \theta_r \cdot \sum_{a=R_a}^{74} P_a \end{aligned} \quad (4)$$

If, instead, the retirement age is raised to $R_a + 1$, it can be written:

$$ER_{55-74}(R_a + 1) = \theta_0 + \theta_r \cdot \sum_{a=R_{a+1}}^{74} P_a$$

The effect on the employment rate of the raise of the retirement age from R_a to $R_a + 1$ is

$$ER_{55-74}(R_a + 1) - ER_{55-74}(R_a) = \left(\theta_0 + \theta_r \cdot \sum_{a=R_{a+1}}^{74} P_a\right) - \left(\theta_0 + \theta_r \cdot \sum_{a=R_a}^{74} P_a\right) = -\theta_r \cdot P_{R_a}$$

The effect is equal to the parameter θ_r multiplied by the share of population at the initial retirement age P_{R_a}.

In the same way, it can be demonstrated that the effect of a 1-year change in the minimum and in the normal retirement age is given by:

$$ER_{55-74}(minR_a + 1, normR_a + 1) - ER_{55-74}(minR_a, normR_a) = -\theta_{minret} \cdot P_{minR_a} - \theta_{normret} \cdot P_{normR_a}$$

While the effect of increasing the normal retirement age by 1 year and the eliminating of the early exit pathways, that is letting the minimum retirement age be equal to the normal retirement age, can be quantified as follows:

$$\begin{aligned} &ER_{55-74}(minR_a + 1, normR_a + 1) - ER_{55-74}(minR_a, normR_a) \\ &\quad = -\theta_{pipeline} \cdot \sum_{a=minR_a-1}^{normR_a} P_a - \theta_{minret} \cdot \sum_{a=minR_a}^{normR_a} P_a - \theta_{normret} \cdot P_{normR_a} \end{aligned}$$

Figure A A.1 shows the effect of a pension reform on the employment rate by age, according to the underlying model. The employment rate is assumed to remain constant until the age year before the retirement ages. A first fall in the employment rate occurs the year before the minimum retirement age due to the pipeline effect, for the early exit countries only. This fall is equal to the pipeline effect $\theta_{pipeline}$. The second additional reduction in employment rate occurs at the minimum retirement age ($minret$), if present, and it is equal to the early retirement age effect, θ_{minret}. A share of the population prefers to renounce to part of the full pension to retire some years before the normal retirement age normal retirement rate ($normR_a$). At this age workers eligible for a full pension from all mandatory pension schemes. This fall is equal to the normal retirement age effect, $\theta_{normret}$.

If one assumes that all the population shares P_a are constant, formula (4) can be rewritten in the following way.

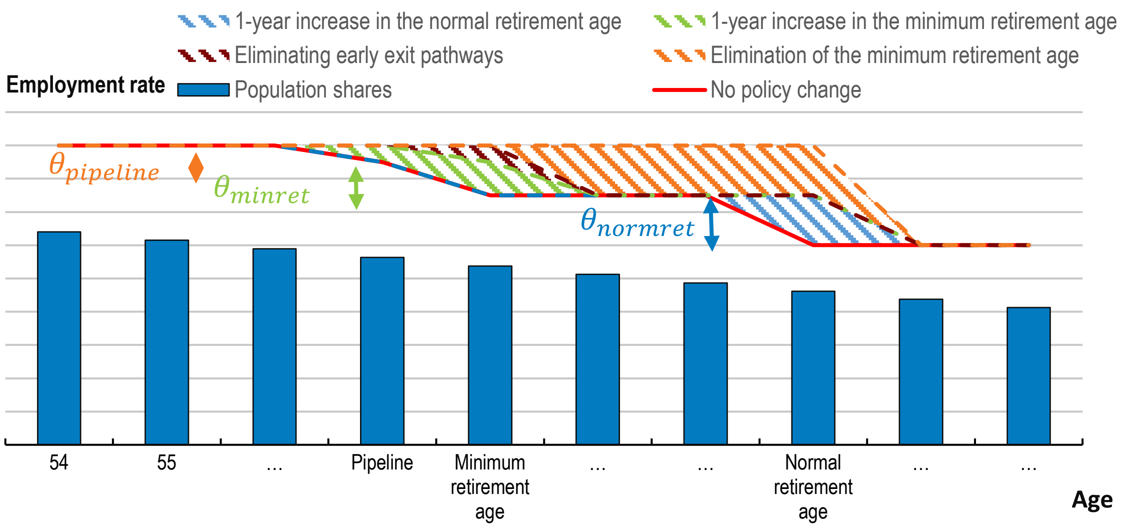
$$ER_{55-74}(R_a) = \theta_c + \theta_t + \theta_r \cdot \sum_{a=R_a}^{74} \frac{1}{20} = \theta_c + \theta_t + \theta_r \cdot \frac{74 - R_a}{20} \quad (5)$$

Hence

$$ER_{55-74}(R_{a+1}) - ER_{55-74}(R_a) = \left(\theta_c + \theta_t + \theta_r \cdot \frac{74 - R_{a+1}}{20}\right) - \left(\theta_c + \theta_t + \theta_r \frac{74 - R_a}{20}\right) = -\frac{\theta_r}{20} R_a \quad (6)$$

This shows that using the normal pension age in the regression model is equivalent to the proposed model, assuming that the population shares are constant and the parameter θ_r is -20 times the estimated parameter using the normal pension age variable, or $-1/5$ if, as it is the case in the present work, the shares are expressed in percentage.

Figure A A.1. Model visualisation



Note: The disaggregated model underlying model (5) is shown together with the effect of three possible pension reforms: a 1-year raise in the normal retirement age, a 1-year raise in the minimum retirement age, and the elimination of early exit pathways, consistent with the quantification in Figure 3. An increase of 1 year in the minimum and in the normal retirement age has an effect that is proportional to the population shares at those ages. The effect of eliminating the early exit pathways, that is to move the minimum retirement age to the normal retirement age, instead is proportional to the share of population whose age is included between the age year before the initial minimum retirement age and the final normal retirement age.

Annex B. Approximated effects on the average age of labour market exit

The employment rate at age 55-74 can be written in the following way:

$$ER_{55-74} = \frac{Empl_{55-74}}{POP_{55-74}} = \frac{\sum_a Empl_a}{POP_{55-74}} = \frac{\sum_a ER_a \cdot POP_a}{POP_{55-74}} = \sum_a ER_a \cdot P_a \tag{7}$$

If, as it implicit in the proposed model, changes in the retirement age affect the labour market choices of the population whose age is equal at the initial retirement age and assuming no changes in the age composition of the population, the effect on the employment rate of a change in the retirement ages is given by:

$$\Delta ER_{55-74} = \sum_{a=55}^{74} \Delta ER_a \cdot P_a = \Delta ER_{R_a} \cdot P_{R_a} \tag{8}$$

Ignoring deaths, assuming the age structure is stable, that nobody retires before age 55 and everyone retires by age 75, the average age of labour market exit can be calculated as[20]:

$$AALME = \sum_{a=55}^{74} a \cdot \frac{A_{a-1} \cdot P_{a-1} - A_a \cdot P_a}{A_{54} \cdot P_{54}}$$

where:

- $AALME$ is the average age of labour market exit;
- A_a is the participation rate at age a.

The effect of a change in the retirement age on the average age of labour market exit is:

$$AALME(R_a + 1) - AALME(R_a) = \Delta AALME = \sum_{a=55}^{74} a \cdot \frac{\Delta A_{a-1} \cdot P_{a-1} - \Delta A_a \cdot P_a}{A_{54} \cdot P_{54}} \tag{9}$$

Where the Δ express the difference between before and after the reform. Expanding the RHS of (9) gives:

$$\begin{aligned}\Delta AALME = &\frac{1}{A_{54} \cdot P_{54}} \\ &\cdot \left[(\Delta A_{54} \cdot P_{54} - \Delta A_{55} \cdot P_{55}) \cdot 55 + \cdots + \left(\Delta A_{R_a-1} \cdot P_{R_a-1} - \Delta A_{R_a} \cdot P_{R_a}\right) \cdot R_a \right. \\ &\left. + \left(\Delta A_{R_a} \cdot P_{R_a} - \Delta A_{R_{a+1}} \cdot P_{R_a+1}\right) \cdot \mathrm{R}_{a+1} + \cdots + (\Delta A_{73} \cdot P_{73} - \Delta A_{74} \cdot P_{74}) \cdot 74\right]\end{aligned} \tag{10}$$

If one assumes that there is no unemployment and therefore all the active population is employed, the formula above can be rewritten in the following way.

[20] See https://www.oecd.org/els/soc/Labour-Market-Exit-Age-Methodology.pdf.

$$\Delta AALME = \frac{1}{A_{54} \cdot P_{54}} \cdot \left[(\Delta ER_{54} \cdot P_{54} - \Delta ER_{55} \cdot P_{55}) \cdot 55 + \cdots + \left(\Delta ER_{R_a-1} \cdot P_{R_a-1} - \Delta ER_{R_a} \cdot P_{R_a}\right) \cdot R_a + \left(\Delta ER_{R_a} \cdot P_{R_a} - \Delta ER_{R_{a+1}} \cdot P_{R_a+1}\right) \cdot R_{a+1} + \cdots + (\Delta ER_{73} \cdot P_{73} - \Delta ER_{74} \cdot P_{74}) \cdot 74\right] \tag{11}$$

If, as above, one assumes that changes in the retirement age affect the labour market choices of the population whose age is equal at the initial retirement age and that no changes in the age composition of the population occur, the equation above can be written in the following way:

$$\begin{aligned}\Delta AALME &= \frac{1}{A_{54} \cdot P_{54}} \cdot \left[(0 \cdot P_{54} - 0 \cdot P_{55}) \cdot 55 + \cdots + \left(0 \cdot P_{R_a-1} + \Delta ER_{earR_a-1} P_{R_a}\right) \cdot R_a + \left(\Delta ER_{R_a} \cdot P_{R_a} - 0 \cdot P_{R_a+1}\right) \cdot (R_a + 1) + \cdots + (0 \cdot P_{73} - 0 \cdot P_{74}) \cdot 74\right] \\ &= \frac{1}{A_{54} \cdot P_{54}} \cdot \Delta ER_{R_a} \cdot (R_{a+1} - R_a) \cdot P_{R_a} = \frac{\Delta ER_{R_a}}{A_{54} \cdot P_{54}} \cdot P_{R_a} = \frac{\Delta ER_{55-74}}{A_{54} \cdot P_{54}}\end{aligned} \tag{12}$$

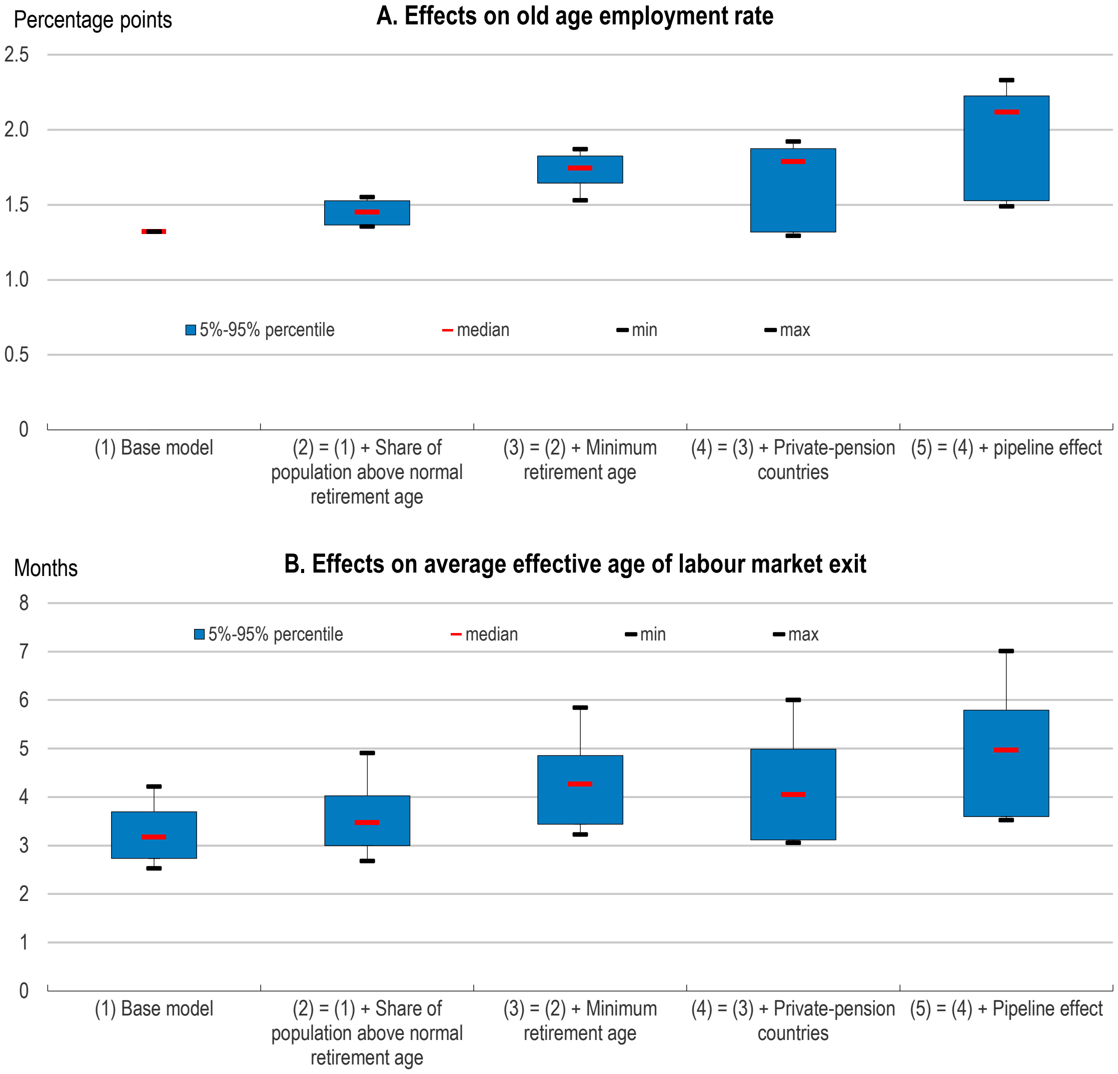
Following the same logic, it can be demonstrated that the same result is valid for all the models.

Equation (12) can thus be used to have an order of magnitude of the correspondent effects on the average age of labour market exit of a 1-year increase in the normal retirement age for each model. Given the strong assumptions they are based on the resulting estimated effects have no ambition of precision. They can however give an order of magnitude.

This formula was used for the computations in Table 1. Given the different set of countries included in the estimation samples of the different studies, the values of A_{54} and P_{54} are the correspondent OECD averages. The set of models in the present work are instead compared using the data of the estimation sample, which is the same for all the models. In the case of model (1) the effect on the employment rate is equal to 1.32 for all the countries. Hence the variability in entirely due to the variability in A_{54} and P_{54}. Thus, the estimated effects on the average age of labour market exit ranges between 2.53 and 4.22 months with a median of 3.17 months. The effects of pension reforms on the employment rate in the other models instead are more dispersed. The estimated effect on the average age of labour market exit is affected by the joint variation of A_{54}, P_{54} and the effects on the employment rate. The estimated effects on the average age of labour market exit consequent to model (2) range between 2.68 and 4.91 months, with a median of 3.47 months. The range of the estimated effects is thus 0.54 months greater than those consequent to the base model and the median is 0.30 months higher. The estimated effects on the average age of labour market exit consequent to model (3) range between 3.23 and 5.84 months, with a median of 4.26 months. The range of the estimated effects is thus 0.38 months greater than those consequent to model (2) and the median is 0.79 months higher. The estimated effects on the average age of labour market exit consequent to model (4) range between 3.06 and 6.00 months, with a median of 4.04 months. The range of the estimated effects is thus 0.33 months greater than those consequent to the base model and the median is 0.22 months lower. The estimated effects on the average age of labour market exit consequent to model (5) range between 3.52 and 7.14 months, with a median of 5.02 months. The range of the estimated effects is thus 0.67 months greater than those consequent to the base model and the median is 0.97 months lower. Figure A B. compares the models both in terms of the effects on the old age employment rate and on the average age of labour market exit.

Figure A B.1. Comparing the effects on ER-55-74 and on AALME under the proposed model

Compared effects of an increase in the normal retirement age



Note: The graph compares the long-term effect on the old age employment rate and on the average age of labour market exit of a raise of the normal retirement age by 1 year among the models expressed in percentage points and months, respectively. On the x-axis, for each model, the main innovation introduced with respect to the previous model is shown. For the models including the effects of minimum retirement age and of the pipeline effects, these are also assumed to move by 1 year. The red horizontal marks show the median of the distribution of the effects among the countries in the sample; the blue boxes show the distance between the fifth and the ninety-fifth percentile; and the whiskers show the minimum and the maximum values. The effects are calculated using the data for year 2020 or latest year available.
Source: Author's calculations.

Annex C. Robustness checks

1. Time coverage

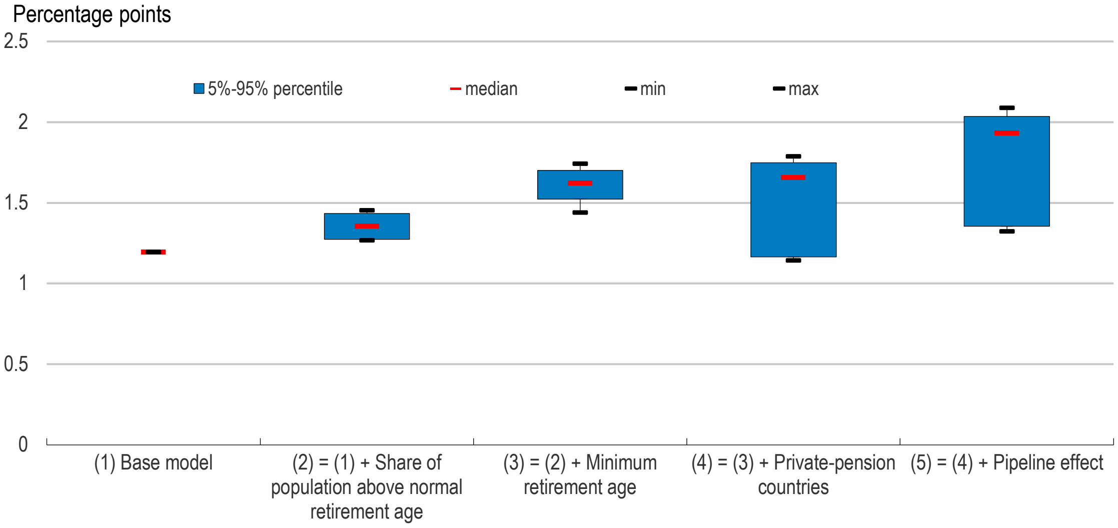
To obtain quantifications of pension reforms, the time coverage of the dependent variable was extended to 2020 by assuming that, after the last available year, their values remain constant at the last value assumed. Table A C.1 and Figure A C. show the estimates of the proposed model dropping this assumption. The estimated parameters on the original time sample are consistent with those in the full one.

Table A C.1. The estimates are robust to the extension of the estimation sample

Explanatory variables	Dependent variable: ER 55-74				
	(1) Base model	(2) = (1) + Share of population above retirement age	(3) = (2) + Minimum retirement age	(4) = (3) + private-pension countries	(5) = (4) + Pipeline effect
Labour and product market regulations					
EPL regular contracts	6.029**	6.402**	7.944**	8.187**	8.629**
Pension policies					
Normal retirement age	1.195**				
Pipeline effect					-0.079
% pop. above the minimum ret. Age			-0.083	-0.081	-0.118
% pop. above the normal ret. age		-0.268**	-0.234**	-0.245**	-0.261**
% pop. above the statut. ret. age ^ private pensions countries				0.089	0.106
Control variables					
ER 25-54	0.613***	0.603***	0.585***	0.579***	0.604***
Life expectancy 65+	0.559***	0.537***	0.511***	0.524***	0.504***
RMSE	2.65	2.55	2.54	2.54	2.55
Adjusted R^2	91.7%	92.3%	92.3%	92.3%	92.3%
Obs.	495	495	495	495	495
Countries	27	27	27	27	27
Time coverage	1992-2018	1992-2018	1992-2018	1992-2018	1992-2018
EC-term	-0.055***	-0.062***	-0.07***	-0.07***	-0.071***

Note: The table shows the estimated coefficients of the long-term equation of the model. Model (1) corresponds to the base model. Model (2) is the same model as model (1) but instead of using the normal retirement age for pensions as pension policy variable, the share of population above the normal retirement age is used. Model (3) uses the database created by (Geppert et al., 2019[13]) integrated with the data from (OECD, 2021[14]), which distinguish between minimum retirement age and normal retirement age. Model (4) introduces the distinction between countries where the private pension funds are important. Model (5) is equivalent to model (4), but the pipeline effect for early exit countries is added. The RMSE and the adjusted R^2 shown in the table refers to the long-term equation only and hence are computed excluding the lagged and leading variables used in the Dynamic OLS methodology to estimate it.
Source: Author's calculation.

Figure A C.1. The quantifications are robust to the extension of the estimation sample



Note: The graph compares the long-term effect on the old age employment rate and on the average age of labour market exit of a raise of the normal retirement age by 1 year among the models expressed in percentage points. On the x-axis, for each model, the main innovation introduced with respect to the previous model is shown. For the models including the effects of minimum retirement age and of the pipeline effects, these are also assumed to move by 1 year. The red horizontal marks show the median of the distribution of the effects among the countries in the sample; the blue boxes show the distance between the fifth and the ninety-fifth percentile; and the whiskers show the minimum and the maximum values. The effects are calculated using the data for year 2020 or latest year available.
Source: Author's calculations.

2. Generalised logit fractional regression

The employment rate can only assume values between 0 and 1. In these cases, fractional models such as logit or probit are often proposed to take into account the limits of the support of the dependent variable. There are good reasons to adopt these group of models and it is therefore worth comparing their performance to the linear model's. For this reason, Table A C. compares model (5) with its equivalent expressed in term of fractional regression using a generalised logit model, as shown in equation (13), (model (6)).

$$ER_{c,t} = \frac{1}{\left(1 + e^{-(\alpha_c + \alpha_r \cdot PSR_{c,t} + \sum_j \alpha_j X_{j,c,t})}\right)^R} + \varepsilon_{c,t}$$
$$\Delta ER_{c,t} = \beta_c + \beta_t + \pi \cdot \hat{\varepsilon}_{c,t} + \beta_r \cdot \Delta PSR_{c,t} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t} \qquad (13)$$

The generalised logistic function, proposed by (Richards, 1959[17]) as a generalisation of the logistic function[21], includes the logistic function as special case for $R = 1$. It captures the curvature effect, which amplifies or reduces the responsiveness of employment rate, depending on the current level of employment rate. Assuming a fractional model, the effects of policy changes are stronger in countries with a very low or very high employment rate and stronger for countries with an employment rate around the middle of the $[0,1]$ interval. This can be interpreted as a set of cultural or economical impediments that become stronger and stronger approaching towards the borders of the support. When the employment rate is at the centre of the support, a good part of the population can be in a situation in which small changes in the legislation can induce them to change their labour market decisions. The more the

[21] See Annex A section 15.Annex A

employment rate of a country approaches the borders of the support, the less and less people remain, who have not changed their behaviour. Those individuals are the ones who have stronger reasons to resist and therefore greater incentives are needed for them. Close to the limits of the support, changes in the retirement legislation cannot overtake the resistances of part of the population to change the labour market decisions.

More precisely, the marginal effect of an increase in the normal retirement rate that corresponds to a one percentage point reduction in the share of population above the retirement age has an effect equal to

$$\frac{\partial ER_{c,t}}{\partial PSR_{c,t}} = \alpha_r \cdot R \cdot ER\left(1 - ER^{\frac{1}{R}}\right)$$

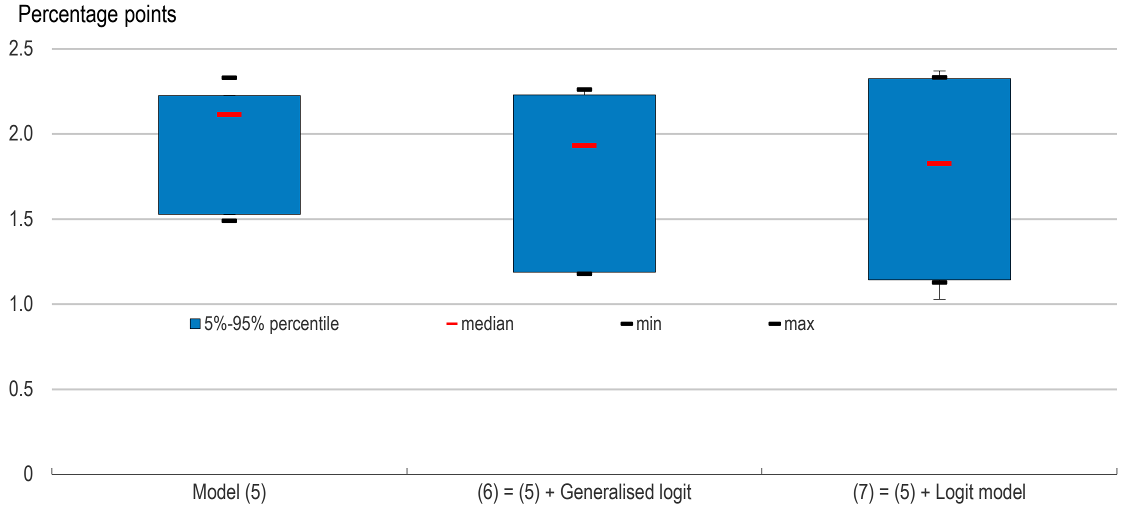
This is maximum when the employment rate is $ER^* = \left(\frac{R}{1+R}\right)^R$ and it gradually decreases around this value. The estimated parameter of R is equal to 2.013, which implies and ER^* equal to 44.4%. The estimate is not statistically significant from 1, which characterise the logistic model, whose ER^* is equal to 50%. Hence also the logistic model is estimated (model (7)).

Table A C.2. Estimates for fractional models

Explanatory variables	Dependent variable: ER 55-74		
	(5) = (4) + Pipeline effect	(6) = (5) + Generalised logit	(7) = (5) + Logit model
Labour and product market regulations			
EPL regular contracts	8.448**	0.251***	0.307***
Pension policies			
Pipeline effect	-0.087	-0.005**	-0.007***
% pop. above the minimum ret. Age	-0.132	-0.003**	-0.004**
% pop. above the normal ret. age			
% pop. above normal ret. age (private pensions countries)	-0.176	-0.005**	-0.005*
% pop. above normal ret. age (early exit countries)	-0.265**	-0.009***	-0.01***
% pop. above normal ret. age (other countries)	-0.275***	-0.011***	-0.014***
Control variables			
ER 25-54	0.606***	0.027***	0.034***
Life expectancy 65+	0.493***	0.017***	0.022***
R^2		2.013	
RMSE	2.60	2.69	2.70
Adjusted R^2	92.1%		
Obs.	522	594	594
Countries	27	27	27
Time coverage	1992-2019	1990-2020	1990-2020

Note: The table shows the estimated coefficients of the long-term equation of the model. Model (5) corresponds to model (5) in Table 3. Model (6) is equivalent to model (5) but expressed in fractional generalised logit form. Model (7) is equivalent to model (5) but expressed in fractional logit form. The RMSE shown in the table refers to the long-term equation only.
Source: Author's calculation.

Figure A C.2. Quantifications for fractional models

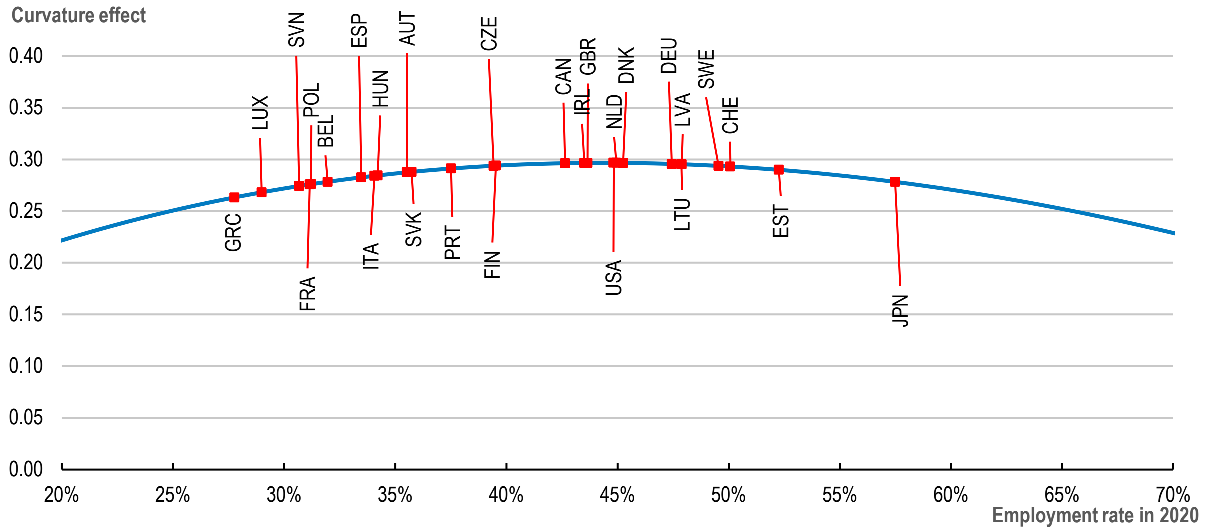


Note: The graph compares the long-term effect on the old age employment rate of a raise of the normal retirement age by 1 year among the models, expressed in percentage points. On the x-axis, for each model, the main innovation introduced with respect to the previous model is shown. The minimum retirement ages and the pipeline effects are also assumed to move by 1 year. The red horizontal marks show the median of the distribution of the effects among the countries in the sample; the blue boxes show the distance between the fifth and the ninety-fifth percentile; and the whiskers show the minimum and the maximum values. The effects are calculated using the data for year 2020 or latest year available.
Source: Author's calculations.

To have a better understanding of the curvature effect, Figure A C.3. shows the curvature effect calculated on the data for 2020 on the estimated model (6). The old-age employment rate of the countries in the sample in 2020 ranges between 27.8% (Greece) and 57.5% (Japan). The curvature effect of the logistic curve on the responsiveness of the employment rate to changes in the normal retirement ages ranges from 0.26 (Greece) to 0.30 (United States). This implies that a rise in the normal retirement ages in the United States has *coeteris paribus* a marginal effect 15% higher than in Greece.

The generalised logistic model worsens the goodness of fit. The median estimated effect of a rise of the normal retirement age by 1 year is 18 basis points lower, with respect to model (5), and the range of estimates is 24 basis points greater, varying between 1.18 and 2.26 percentage points. The logistic model also fits the data worse than Model (5). The median estimated effect of a rise of the normal retirement age by 1 year is 29 basis points lower, with respect to model (5), and the range of estimates is 36 basis points greater, varying between 1.13 and 2.33 percentage points.

Figure A C.3. The curvature effect of the generalised logistic model



Note: In the x-axis the employment rate for 2020 is shown. In the y-axis, the curvature effect is equal to $R \cdot ER\left(1 - ER^{\frac{1}{R}}\right)$.
Source: Author's calculations.

3. Non-linear error correction model

To better compare the estimates of the proposed model with the empirical results of the dominant literature, the linear error correction model was used for the short-term equation. This model assumes that the short-term dynamic of the dependent variable is influenced by the deviation from its long-run equilibrium; that the adjustments are proportional to the distance to the equilibrium; and that the speed of adjustment is constant. However, several authors proposed alternative error correction mechanism. (Granger, Terasvirta and Anderson, 1993[18]), (Dwyer, Locke and Yu, 1996[19]) and (van Dijk and Franses, 1997[20]) were among the first to propose non-linear error correction models mechanism such as smooth transition autoregressive (STAR) models, smooth transition error correction models (STECMs), a threshold error correction mechanism, etc.. These models found wide application in (Venetis, Paya and Peel, 2003[21]), (Béreau, Villavicencio and Mignon, 2010[22]), (Maugeri, 2010[23]) (Balcilar, Gupta and Shah, 2011[24]) and more recently by (Hambuckers and Kneib, 2021[25]) and (Chikhi and Diebolt, 2022[26]), among the others.

Table A C.3 compares the estimates of four non-linear error correction models and Figure A C. compares the correspondent convergence paths. In particular, the linear model is compared with the following ones:

- Quadratic:

$$\Delta ER_{c,t} = \beta_c + \beta_t + \boldsymbol{\pi} \cdot \left|\hat{\boldsymbol{\varepsilon}}_{c,t-1}\right| \cdot \hat{\boldsymbol{\varepsilon}}_{c,t-1} + \beta_P \cdot \Delta RA_{c,t} + \beta_d \cdot \Delta ER_{c,t-1} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t}$$

- Kernel

$$\Delta ER_{c,t} = \beta_c + \beta_t + \boldsymbol{\pi} \cdot \left[\mathbf{1} - \frac{\boldsymbol{\phi}(\hat{\boldsymbol{\varepsilon}}_{c,t-1}, \mathbf{0}, \boldsymbol{\sigma})}{\boldsymbol{\phi}(\mathbf{0}, \mathbf{0}, \boldsymbol{\sigma})}\right] \cdot \boldsymbol{sign}(\hat{\boldsymbol{\varepsilon}}_{c,t-1}) + \beta_P \cdot \Delta RA_{c,t} + \beta_d \cdot \Delta ER_{c,t-1} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t}$$

  Where $\phi(x, \mu, \sigma)$ is the normal density function of mean μ and standard deviation σ for the value x.

- Logit

$$\Delta ER_{c,t} = \beta_c + \beta_t + \boldsymbol{\pi} \cdot \frac{\mathbf{1}}{\mathbf{1} + \boldsymbol{exp}(\boldsymbol{\sigma} \cdot \hat{\boldsymbol{\varepsilon}}_{c,t-1} + \boldsymbol{\mu})} \cdot \hat{\boldsymbol{\varepsilon}}_{c,t-1} + \beta_P \cdot \Delta RA_{c,t} + \beta_d \cdot \Delta ER_{c,t-1} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t}$$

- Exponential

$$\Delta ER_{c,t} = \beta_c + \beta_t + [\mathbf{1} - \boldsymbol{exp}(\boldsymbol{\sigma} \cdot \hat{\boldsymbol{\varepsilon}}^2_{c,t-1})] \cdot \hat{\boldsymbol{\varepsilon}}_{c,t-1} + \beta_P \cdot \Delta RA_{c,t} + \beta_d \cdot \Delta ER_{c,t-1} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t}$$

The results show that, the speed of convergence to the long-term equilibrium varies substantially according to the model chosen. According to the kernel error correction model, including the short-term effect and the lagged dependent variable term, 3 years are necessary to observe half of the expected long-term effects; 7 years to observe 75% of the expected long-term effects; and 15 years to observe 90% of the expected long-term effects. On the other hand, according to the quadratic model 30 years are necessary to observe half of the expected long-term effects and more than 100 years are necessary to observe 75% or more of the expected long-term effects; according to the exponential model more than 100 years are necessary to observe 50% or more of the expected long-term effects. The adjustment path of the logit model is substantially equivalent to the linear model. The kernel model seems to fit better the data and therefore suggest that a shorter adjustment period can be expected, with respect to the linear error correction model.

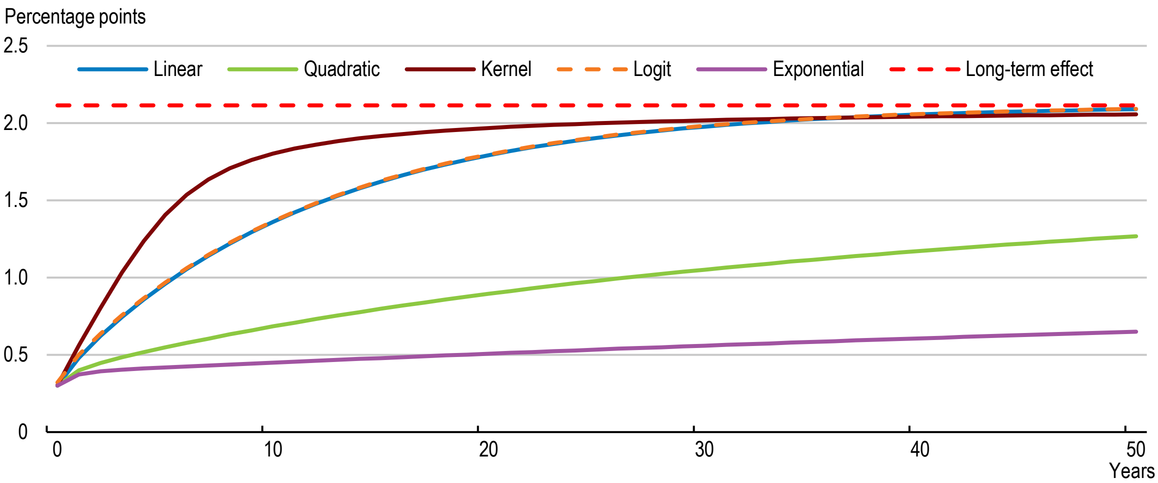
Table A C.3. The linear ECM compared with alternative non-linear ECM

Explanatory variables	Dependent variable: ΔER 55-74				
	Linear	Quadratic	Kernel	Logit	Exponential
π	-0.061***	-0.009***	-0.197***	-0.074	
μ				-1.881	
σ			0.617*	-0.175	0.00102**
Tax-benefit and activation policies					
ΔALMP spending on employment (detrended), % of GDP per capita			0.077*	0.086**	0.079*
Wage setting institutions					
ΔExcess coverage	0.024*	0.025*	0.025*	0.024*	0.027**
Pension policies					
Δ% pop. above the statut. ret. age ^ private pensions	-0.028	-0.032	-0.027	-0.033	-0.037
Δ% pop. above the statut. ret. age ^ early exit	-0.037	-0.039	-0.036*	-0.036*	-0.038***
Δ% pop. above the statut. ret. age ^ other countries	-0.06**	-0.06**	-0.06**	-0.064***	-0.06**
Other variables					
ΔER_{25-54}	0.336***	0.344***	0.334***	0.334***	0.35***
$\Delta ER_{55-74,t-1}$	0.222***	0.223***	0.156***	0.156***	0.153***
RMSE	0.701	0.709	0.684	0.686	0.694
Adjusted R-squared	52.4%	51.3%	68.3%	68.1%	52.9%
Obs.	485	485	504	504	504
Countries	27	27	27	27	27
Time coverage	1993-2020	1993-2020	1993-2020	1993-2020	1993-2020

Note: The comparison among the model is made assuming the same long-term model, notably model (5) of Table 3 and Figure 1. For the linear and the quadratic ECM, a stepwise regression was performed. The other models were estimated using the same set of dependent variables.
Source: Author's calculation.

Figure A C.4. Non-linear ECM may result in quicker convergence to long-term equilibrium

Path of convergence toward the long-term equilibrium according to alternative ECM



Note: The comparison among the model is made assuming the same long-term model, notably model (5) of Table 3 and Figure 1. These calculations include the estimated short-term effect for the regular countries, which are those not characterised neither by the importance of private pension countries, nor by the presence of early exit pathways, and assuming a share of people whose age is equal to the normal retirement age is equal to 5%.
Source: Author's calculation.

Annex A. Description of the variables

1. The dependent variable

The dependent variable of the models is the employment rate of people aged 55-74. This variable is obtained from the OECD Employment database as a ratio between the number of people employed at age 55-74 and the total population of the same age. Figure A A.1 shows the employment rate of people aged 55-74 for all the countries in the sample. The general tendency of the countries of the sample is a fall in the old-age employment rate in the 1970s and 1980s and an increase during the 1990s and 2000s. In the recent years instead the employment rate of people aged 55-74 remained constant or slightly declined for most of the countries in the sample.

2. Tax-benefit and activation policies variables

The unemployment benefit replacement rate is the gross unemployment benefit levels expressed in percentage of the previous gross earnings. The data are extracted from the OECD Social Protection and Well-being database. Figure A A.2 shows the observed values of the variable for all the countries in the sample.

The ALMP spending on employment is the total spending in active labour market policies as a share of GDP per capita. The data are extracted from the OECD Labour database. The policies included in this classification are: Public employment services and administration, Training, Employment incentives, Sheltered and supported employment and rehabilitation, Direct job creation, and Start-up incentives. The original data are detrended using an HP filter. Figure A A. shows the observed values of the variable for all the countries in the sample.

The tax wedge is the average tax wedge, couple with 2 children and prime earner at 100% average wage. It is defined as the ratio between the amount of taxes paid as a percentage of the corresponding total labour cost for the employers. The data are extracted from the OECD Tax statistics database. Figure A A.4 shows the observed values of the variable for all the countries in the sample.

3. Wage setting institutions variables

The excess coverage variable is defined as the difference between the coverage of wage bargaining agreement and the share of covered workers who are represented by unions. This variable is computed from the data in the ICTWSS database. Figure A A.5 shows the observed values of the variable for all the countries in the sample.

4. Labour and product market regulations

The EPL regular contracts variable is the OECD Strictness of employment protection for regular contract from individual and collective dismissals. The data are extracted from the OECD Labour database. Figure A A.7 shows the observed values of the variable for all the countries in the sample.

The ETCR variable is the component on regulation of network industries of the OECD PMR indicator. The data are extracted from the OECD PMR indicator database. Figure A A.8 shows the observed values of the variable for all the countries in the sample.

5. Demography and labour market

The employment rate of people aged 25-54 is obtained from the OECD Employment database as a ratio between the number of people employed at age 55-74 and the total population of the same age. The data are extracted from the OECD Employment database.

The life expectancy at 65 is the average of the life expectancy of men and women at 65, weighted with the share of men and women aged 65 on total population aged 65. The data on life expectancy at 65 are extracted from the OECD Health database. The data on population are extracted from the OECD Employment database.

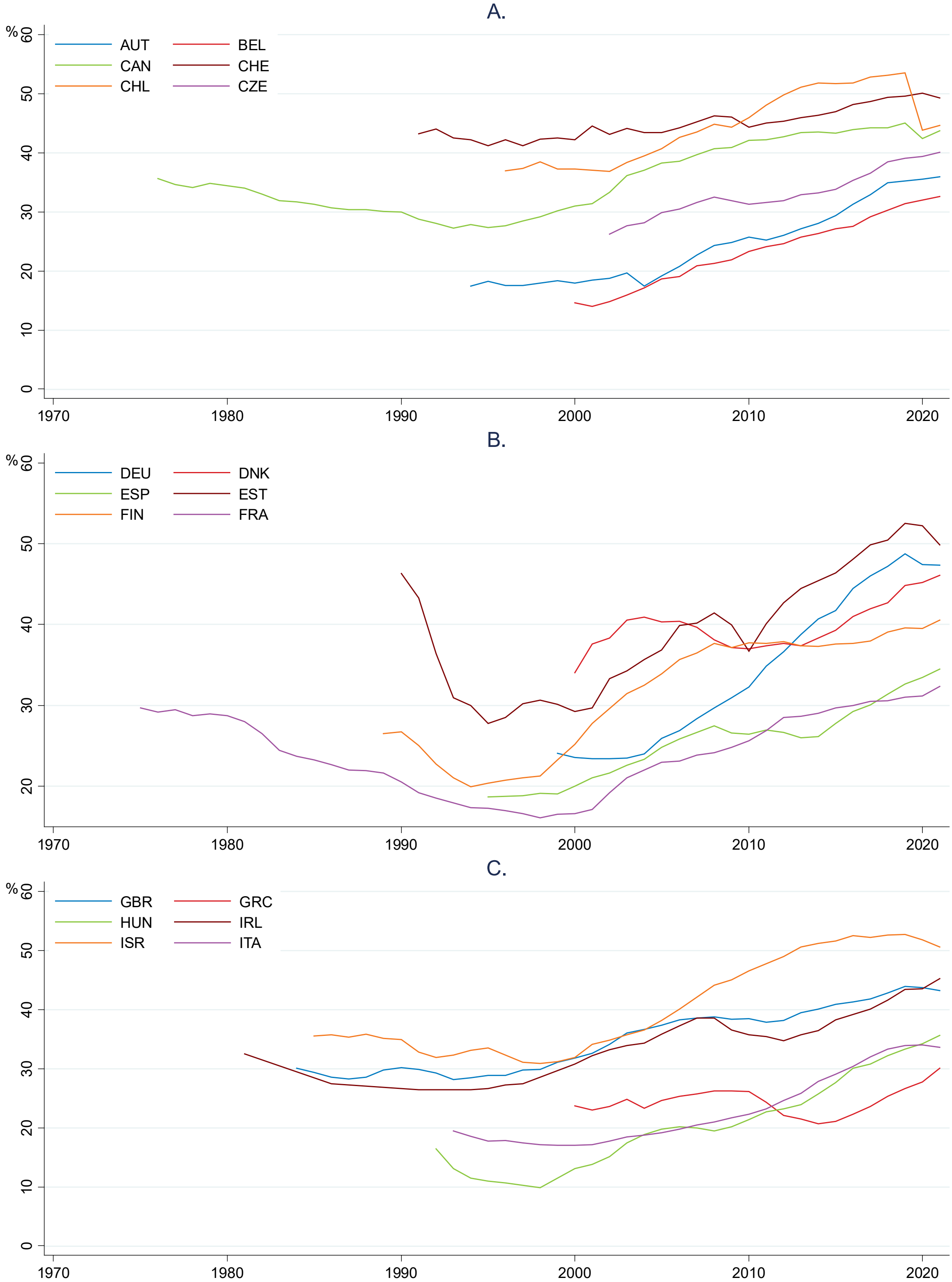
The normal retirement age is the age at which an individual who entered the labour market at age 25 and had a full career becomes eligible for a full pension from all mandatory pension schemes. This variable is calculated based on the country notes of the past editions of Pensions at a glance for both men and women separately. The aggregated variable used in the base model is computed as the weighted average of the two retirement ages, using the share of population by sex as weights. In (Égert and Gal, 2017[11]) instead the simple average of the two retirement ages is considered.

The share of population above the normal retirement age is computed, taking into account of the differences in the normal retirement age between men and women. It is equal to the number of men aged 55-74 above the normal retirement age for men and the number of women aged 55-74 above the normal retirement age for women expressed as a percentage of the total population aged 55-74. The source of the demographic data used for this variable and the following ones is the Wittgenstein Centre for Demography and Global Human Capital database. The series on population size by sex and education are available only with a frequency of 5 years and by 5-years age groups. To obtain annual data by single year of age a locally weighted regression was used on the original data.

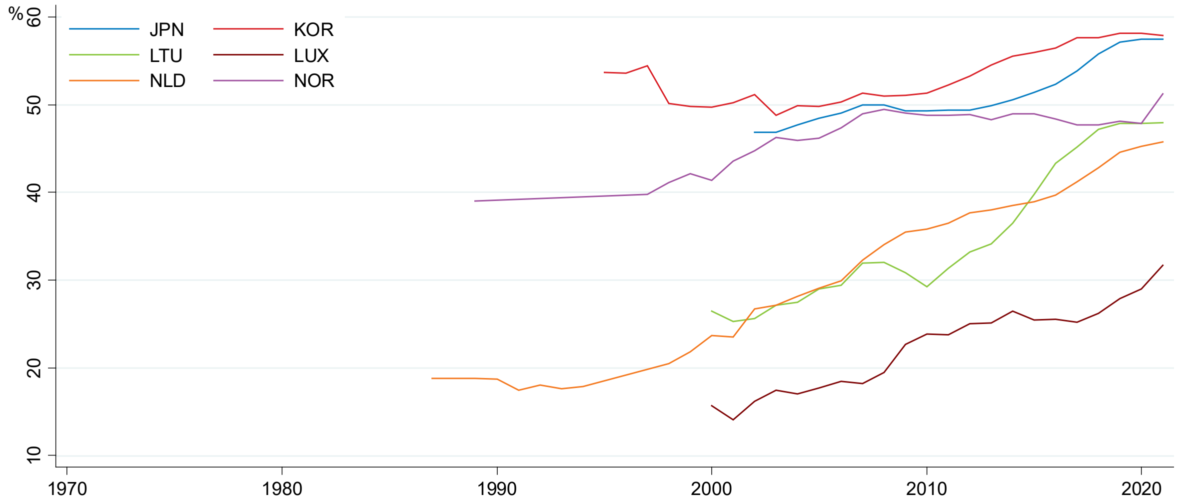
The minimum retirement age is the age at which an individual who entered the labour market at age 25 and had a full career becomes eligible for a (reduced) pension from a mandatory pension scheme. This variable is calculated based on the country notes of the past editions of Pensions at a glance for both men and women separately. Based on this variable, the share of population above the normal retirement age is computed, taking into account of the differences in the normal retirement age between men and women. It is equal to the number of men aged 55-74 above the minimum retirement age for men and the number of women aged 55-74 above the minimum retirement age for women expressed as a percentage of the total population aged 55-74.

Figure A A.9 compares the aggregate normal retirement age with the normal and minimum retirement ages for men and women for all the countries in the sample. Figure A A.10 compares the share of population above the normal age for pension with the shares of populations above the normal and minimum retirement age for men and women for all the countries in the sample.

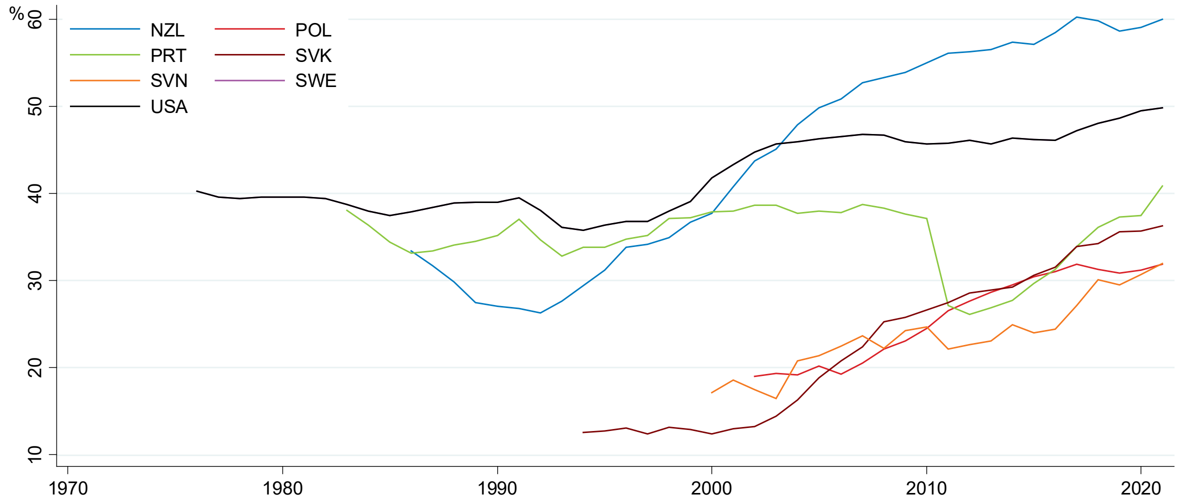
Figure A A.1. Employment rate 55-74



D.



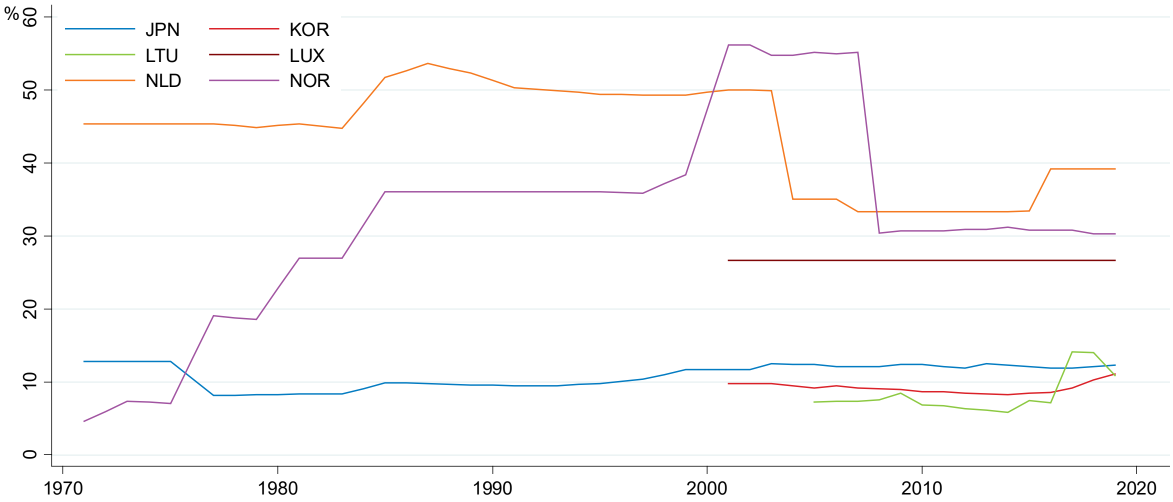
E.



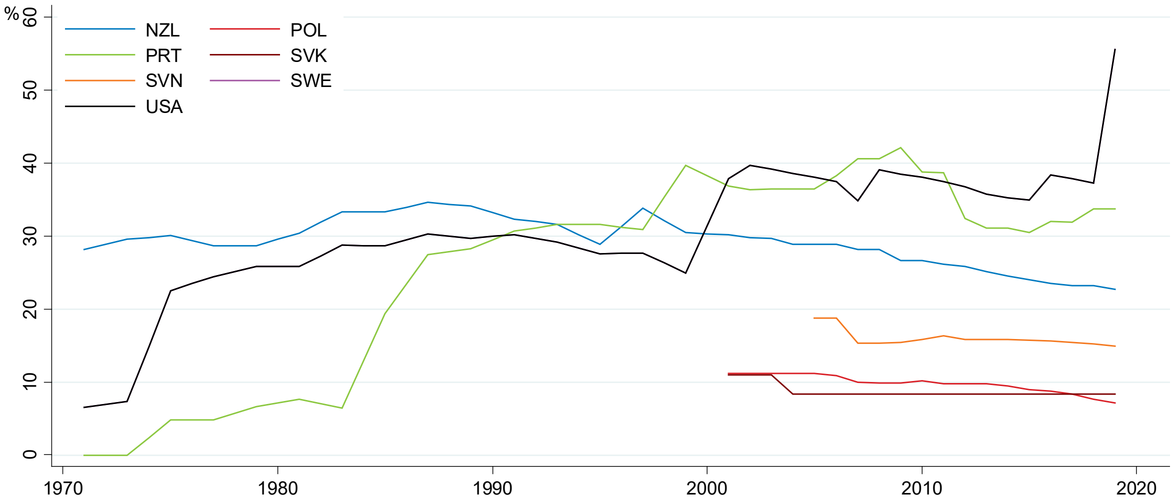
Source: OECD Employment database.

Figure A A.2. Unemployment benefit replacement rate

D.

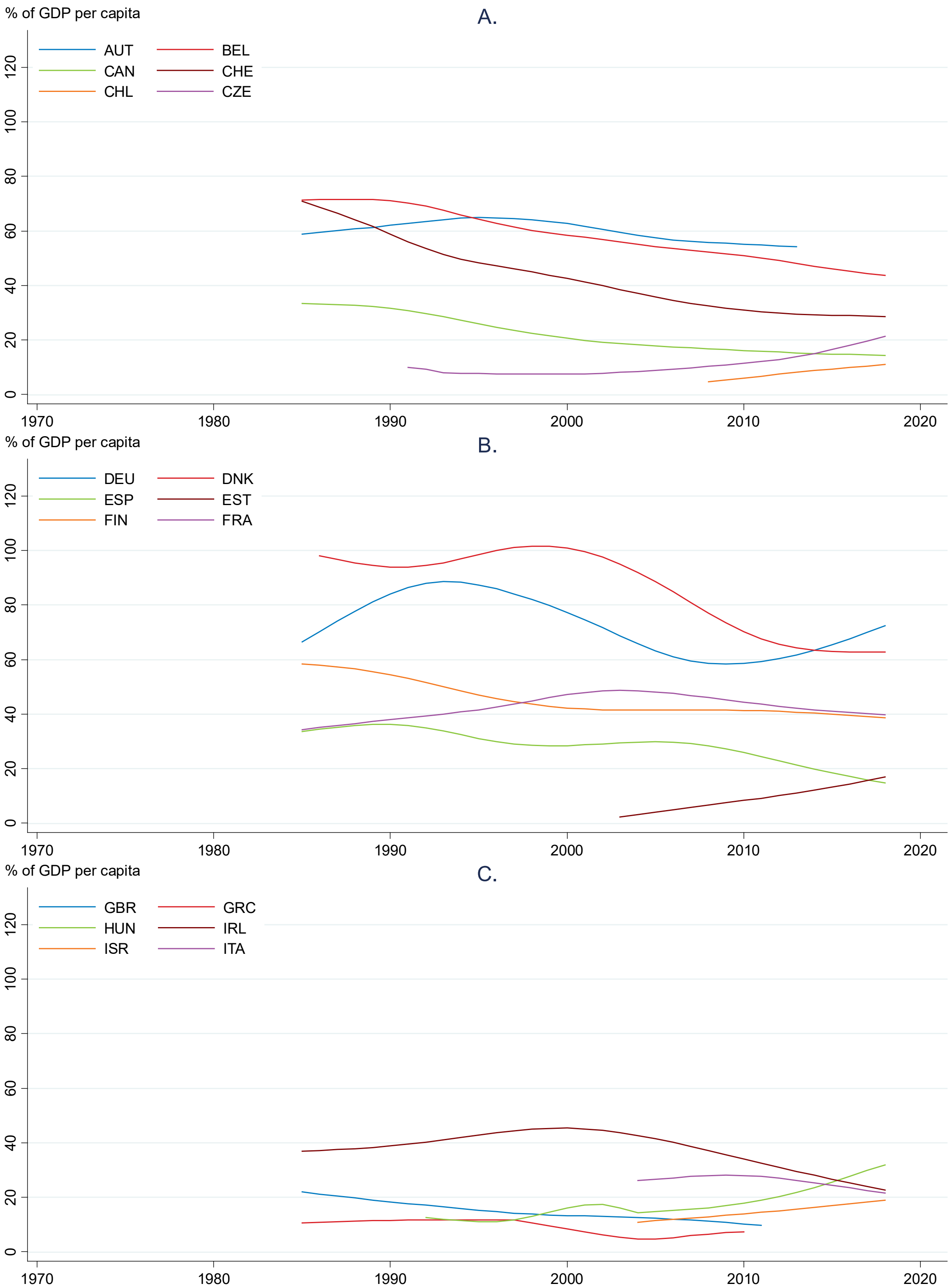


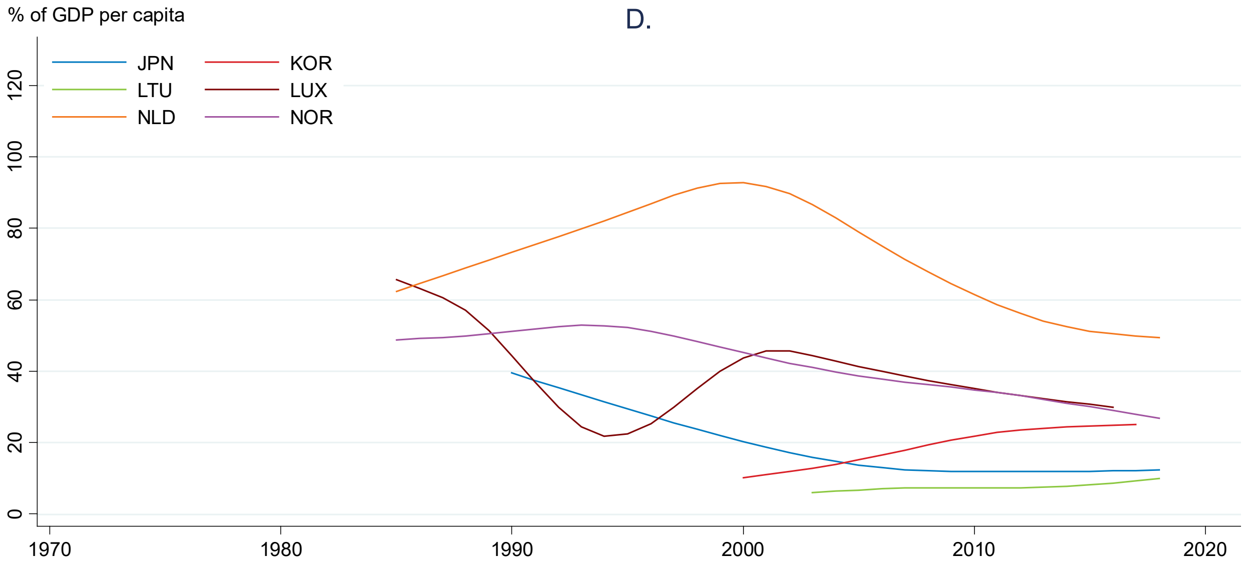
E.

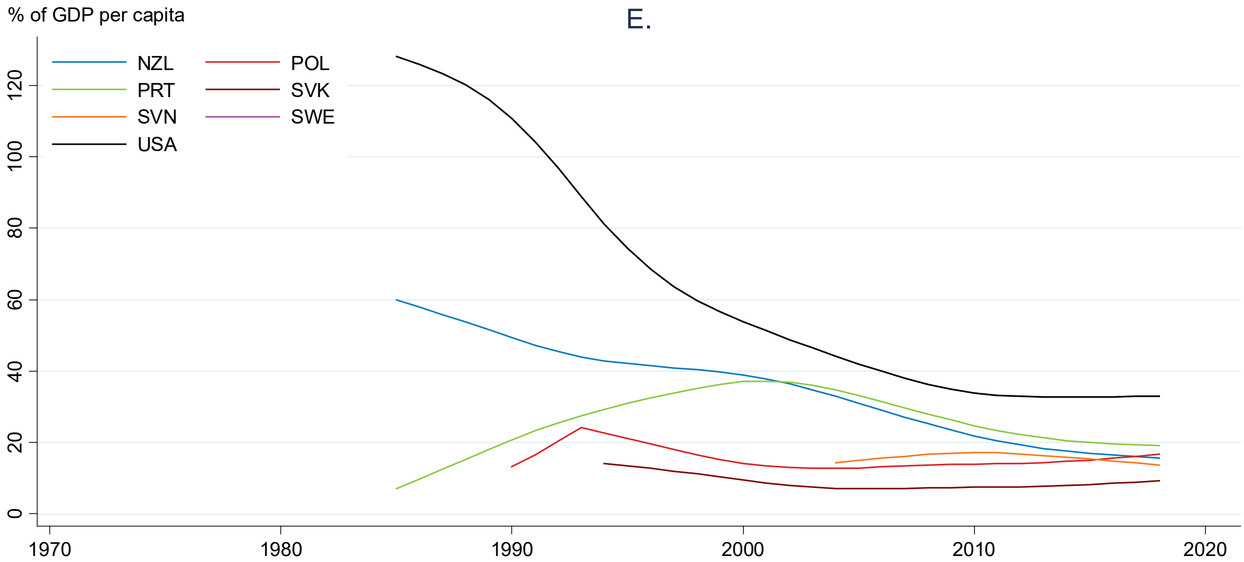


Source: OECD Social Protection and Well-being database.

Figure A A.3. ALMP spending on employment

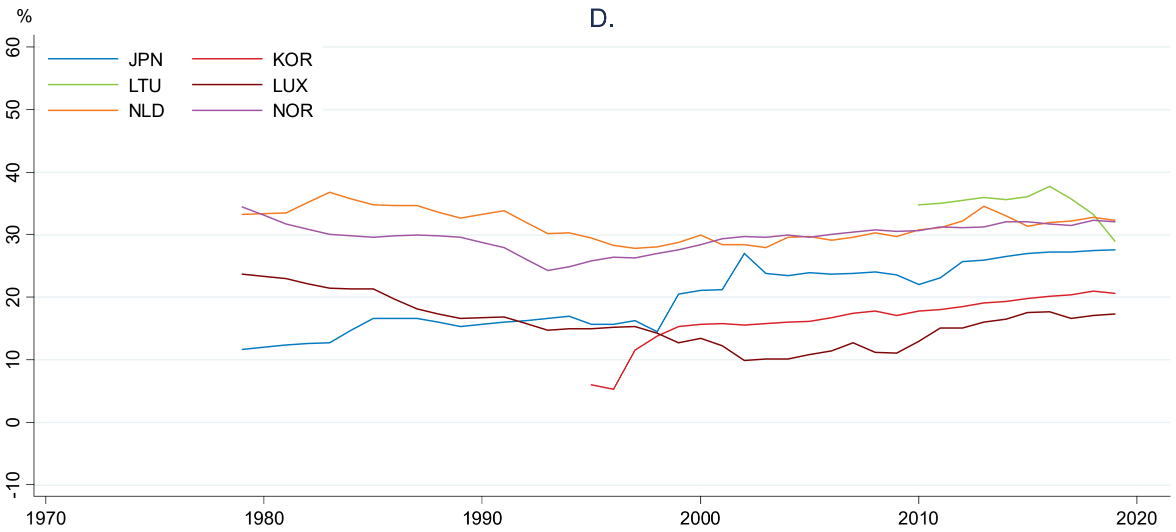


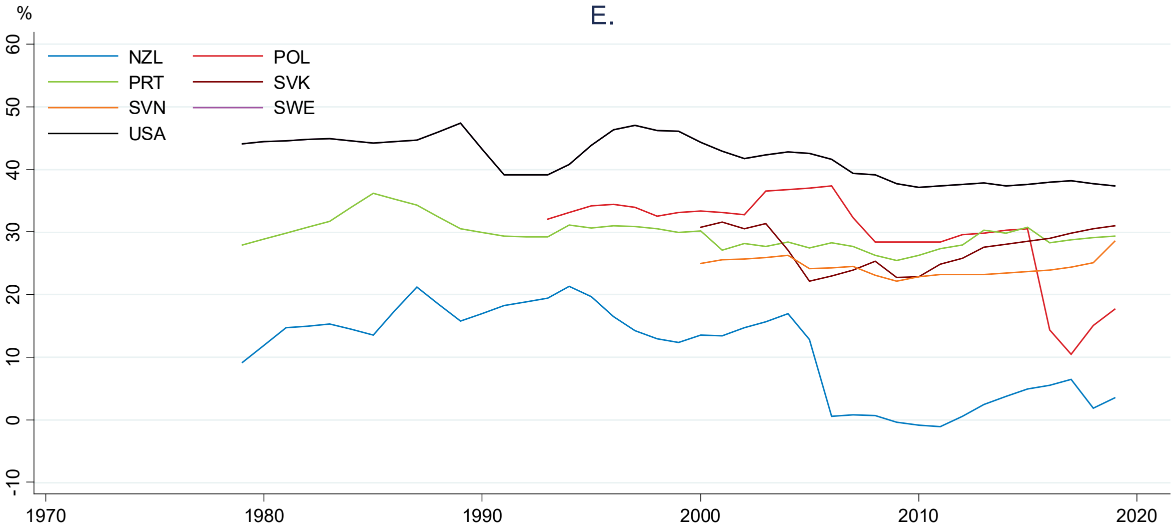




Source: OECD Social Protection and Well-being database.

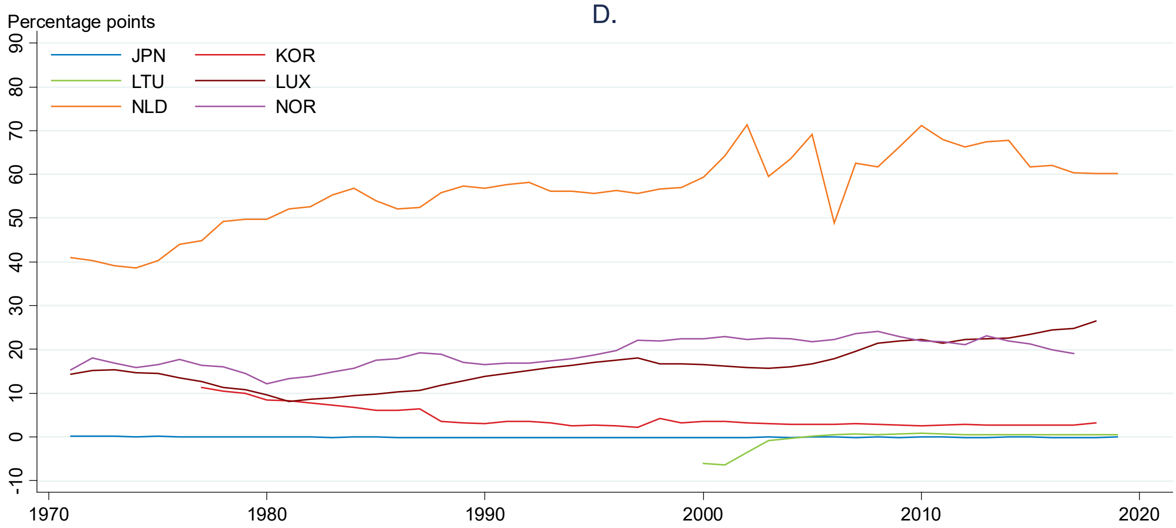
Figure A A.4. Tax wedge

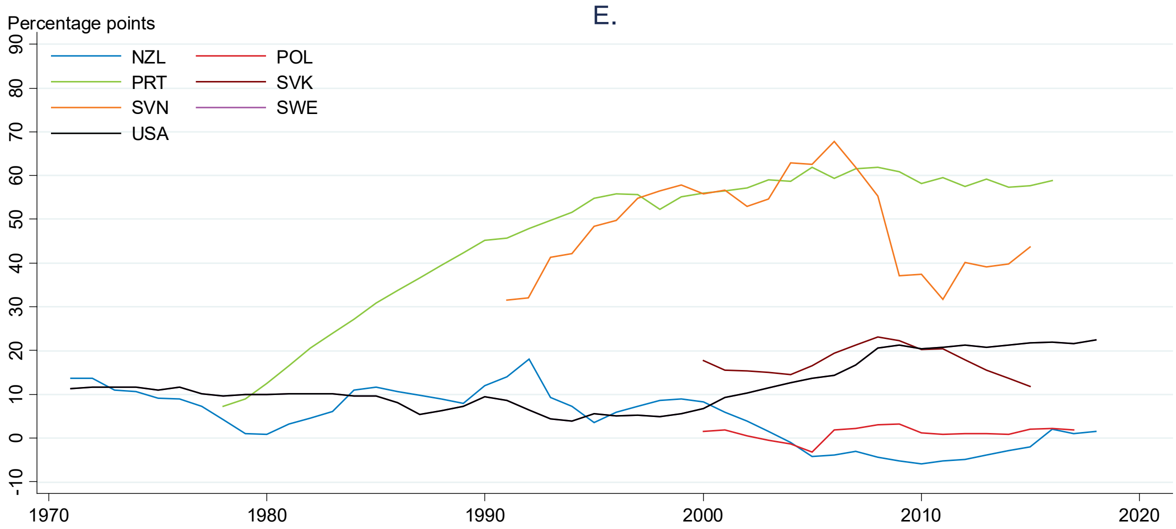




Source: OECD Social Protection and Well-being database.

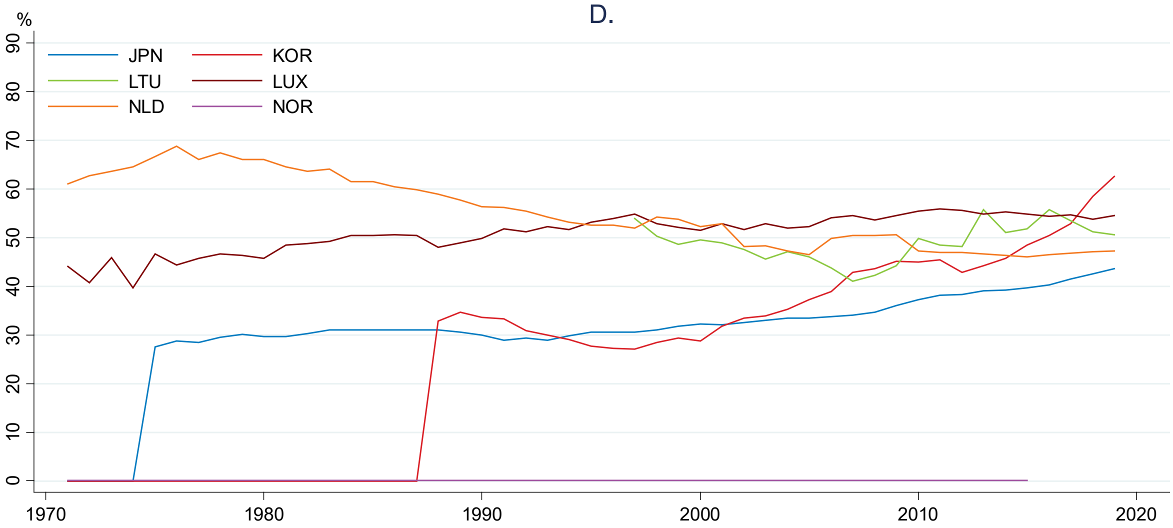
Figure A A.5. Excess coverage

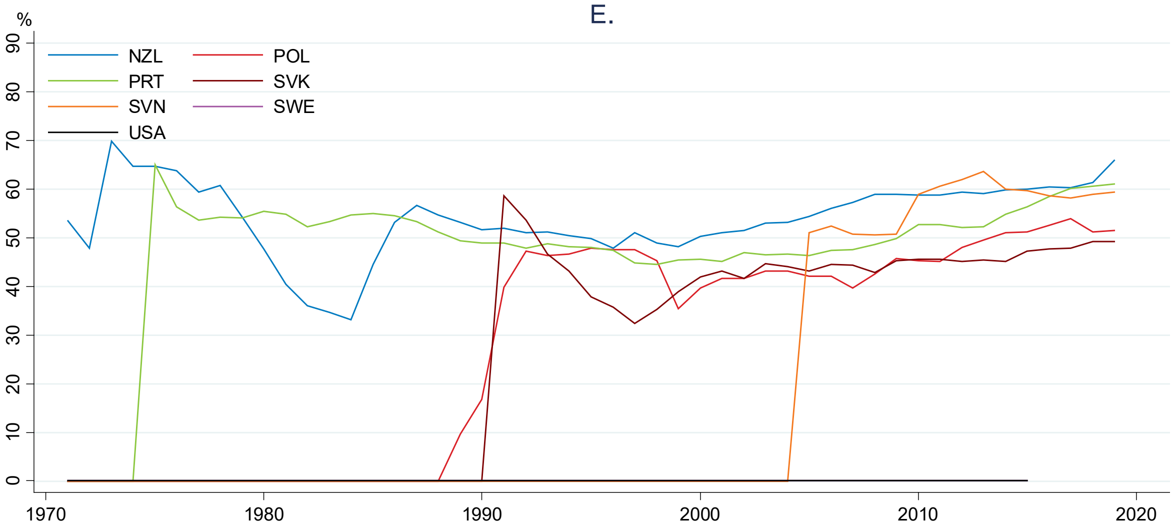




Source: ITCWSS; and OECD calculations.

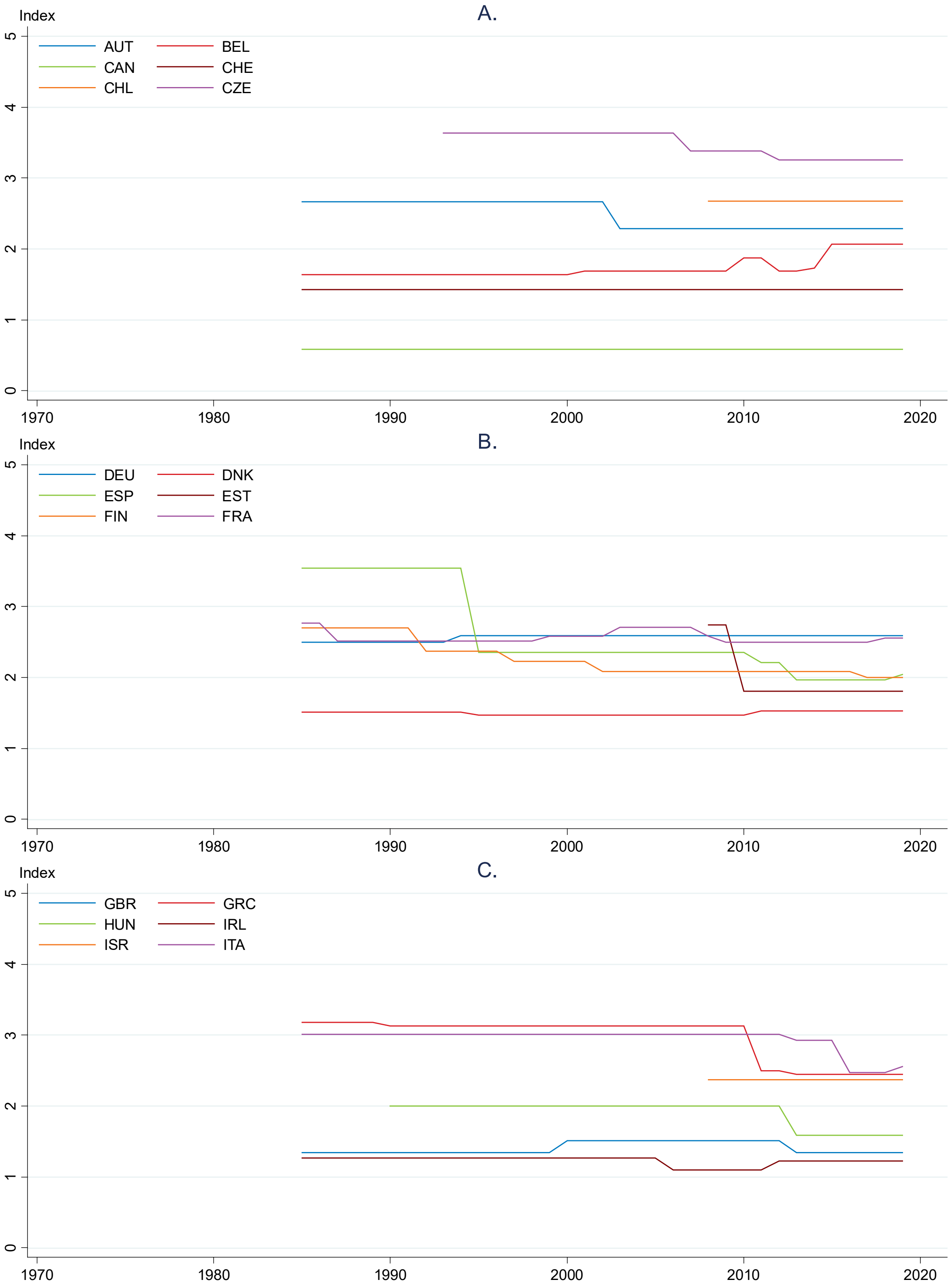
Figure A A.6. Minimum wage

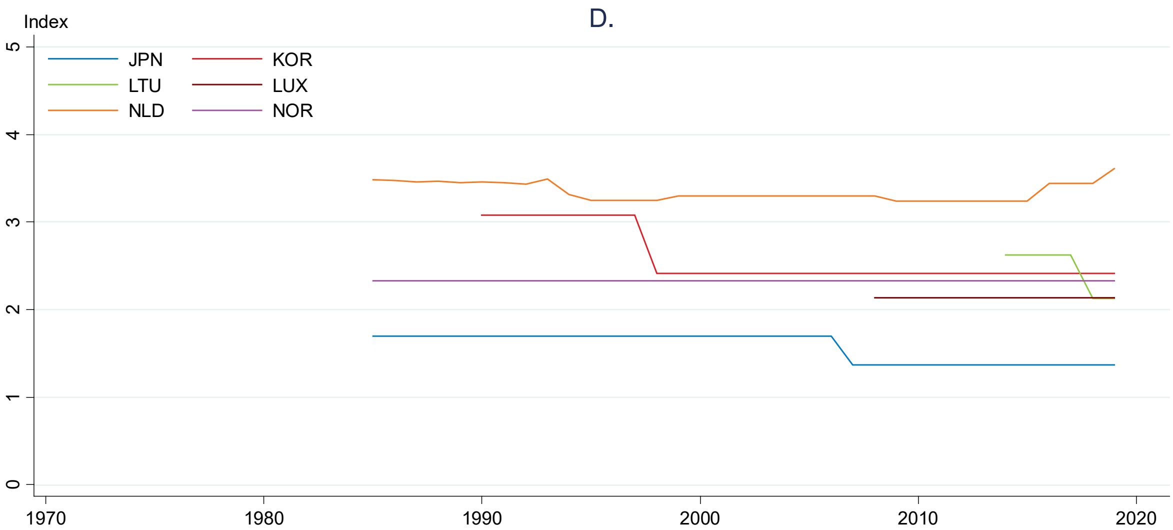


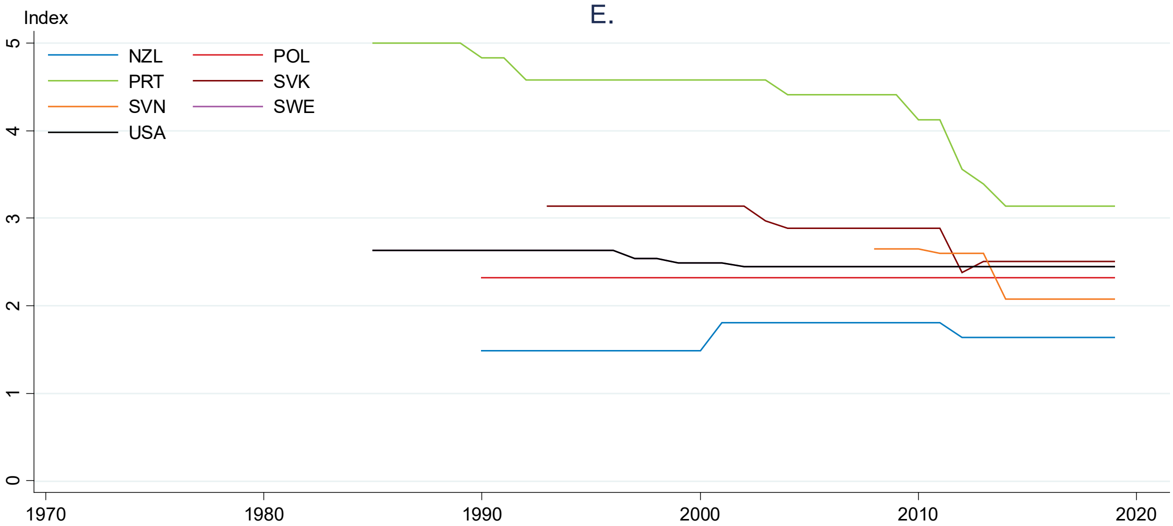


Note: For the countries, where there is no minimum wage, this variable is set to zero.
Source: OECD Labour database.

Figure A A.7. EPL regular contracts

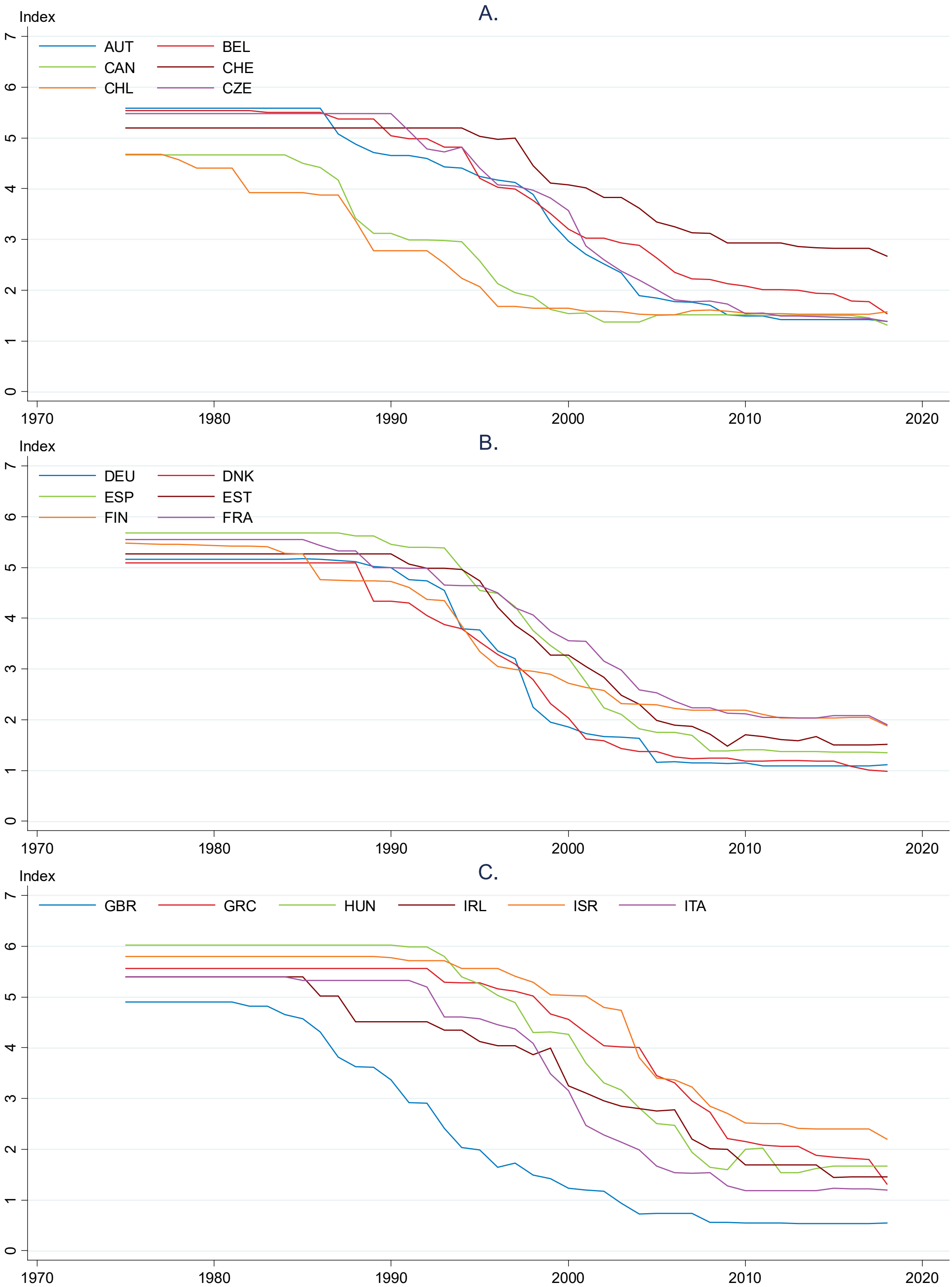


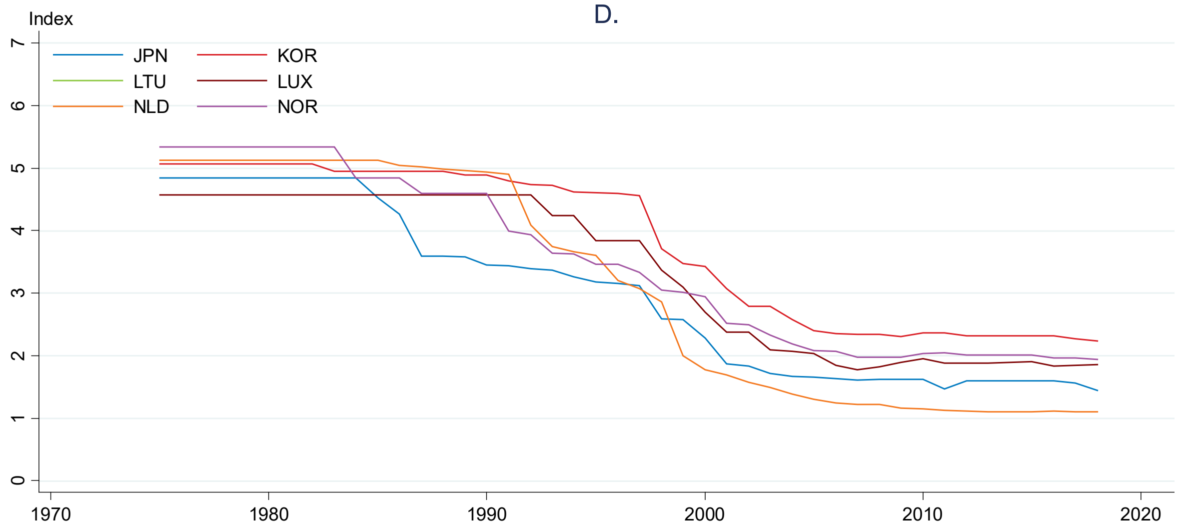


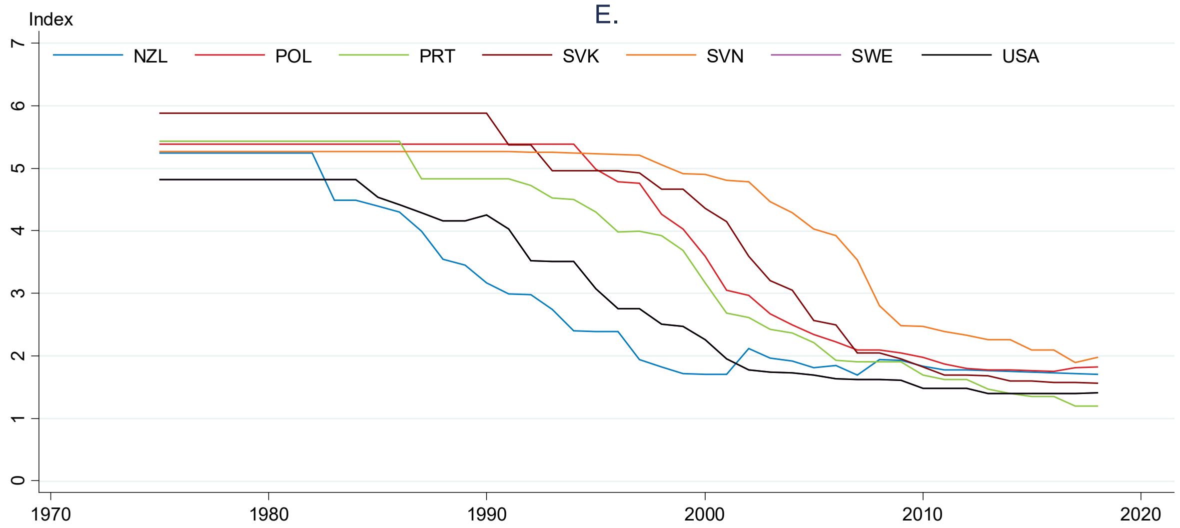


Source: OECD Labour database.

Figure A A.8. ETCR indicator of product market competition on the network industries

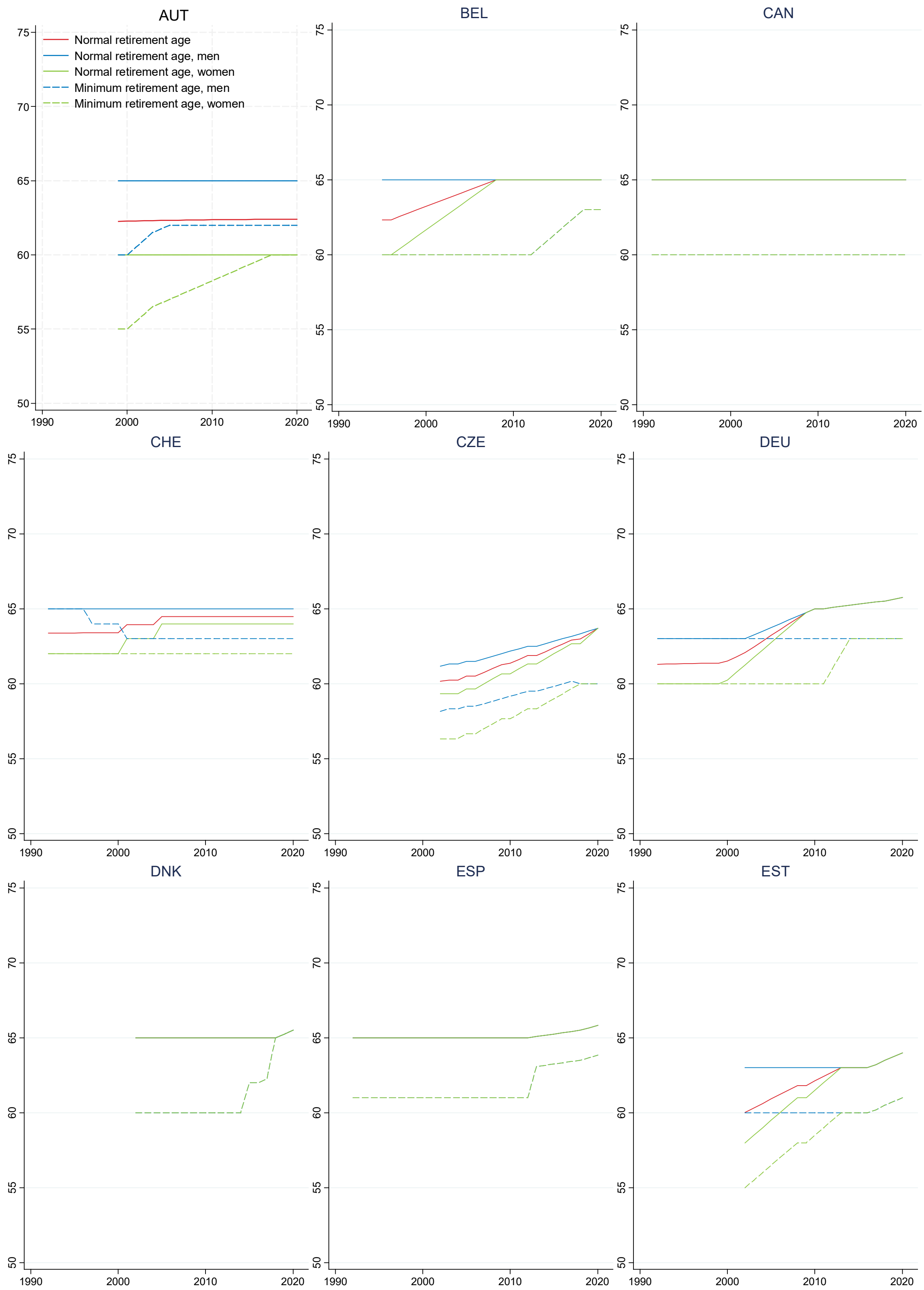


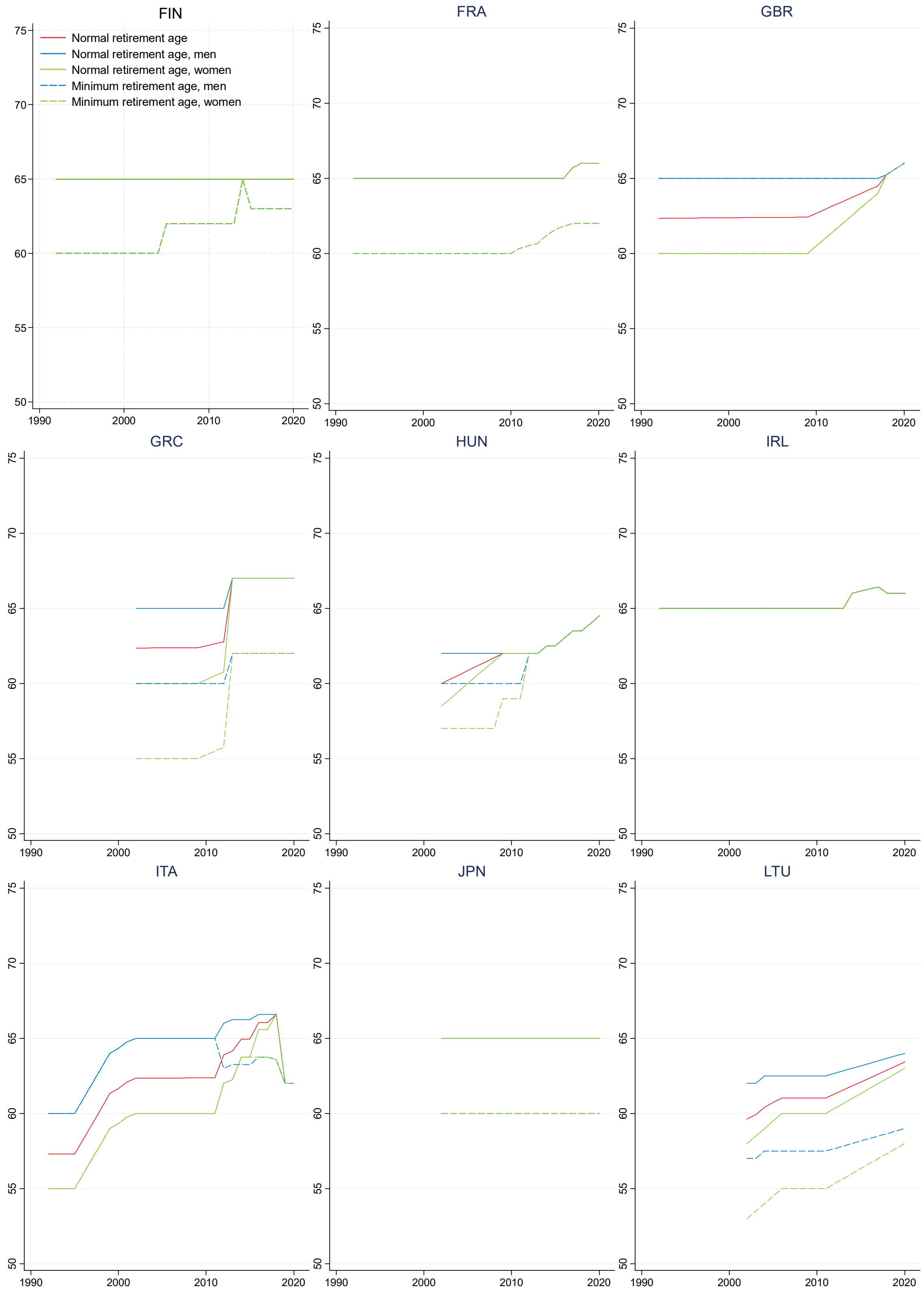


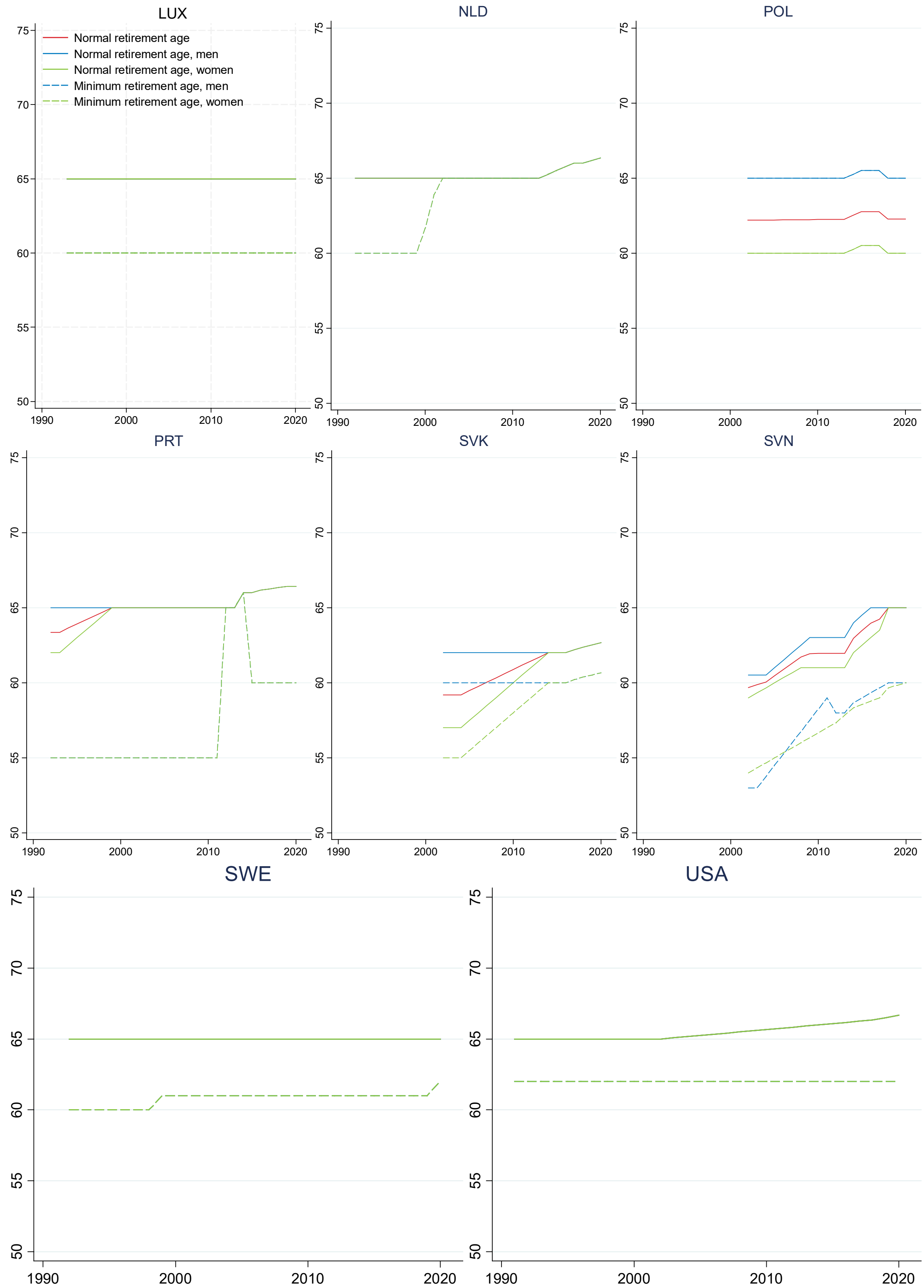


Source: OECD PMR database.

Figure A A.9. Retirement ages

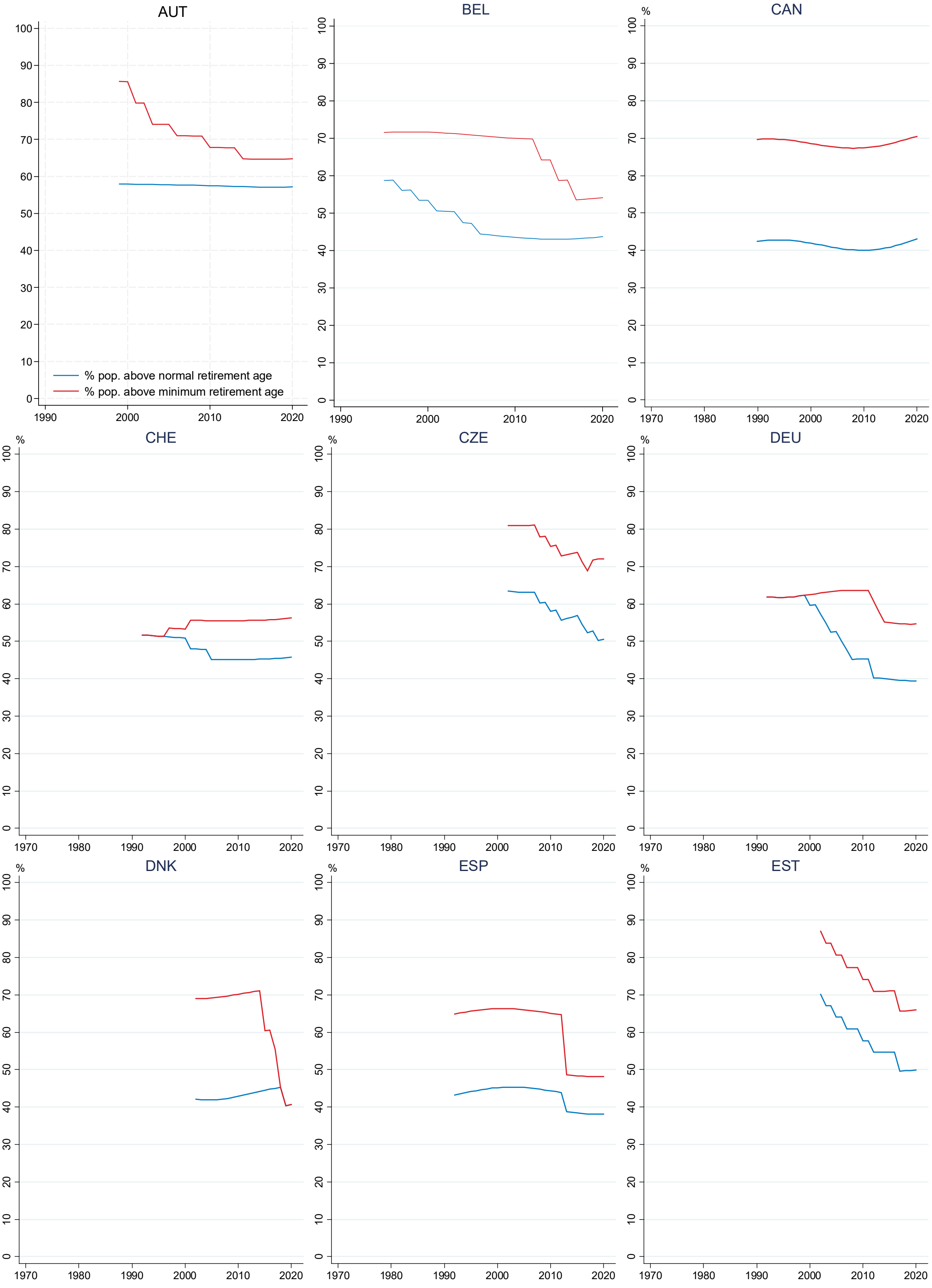


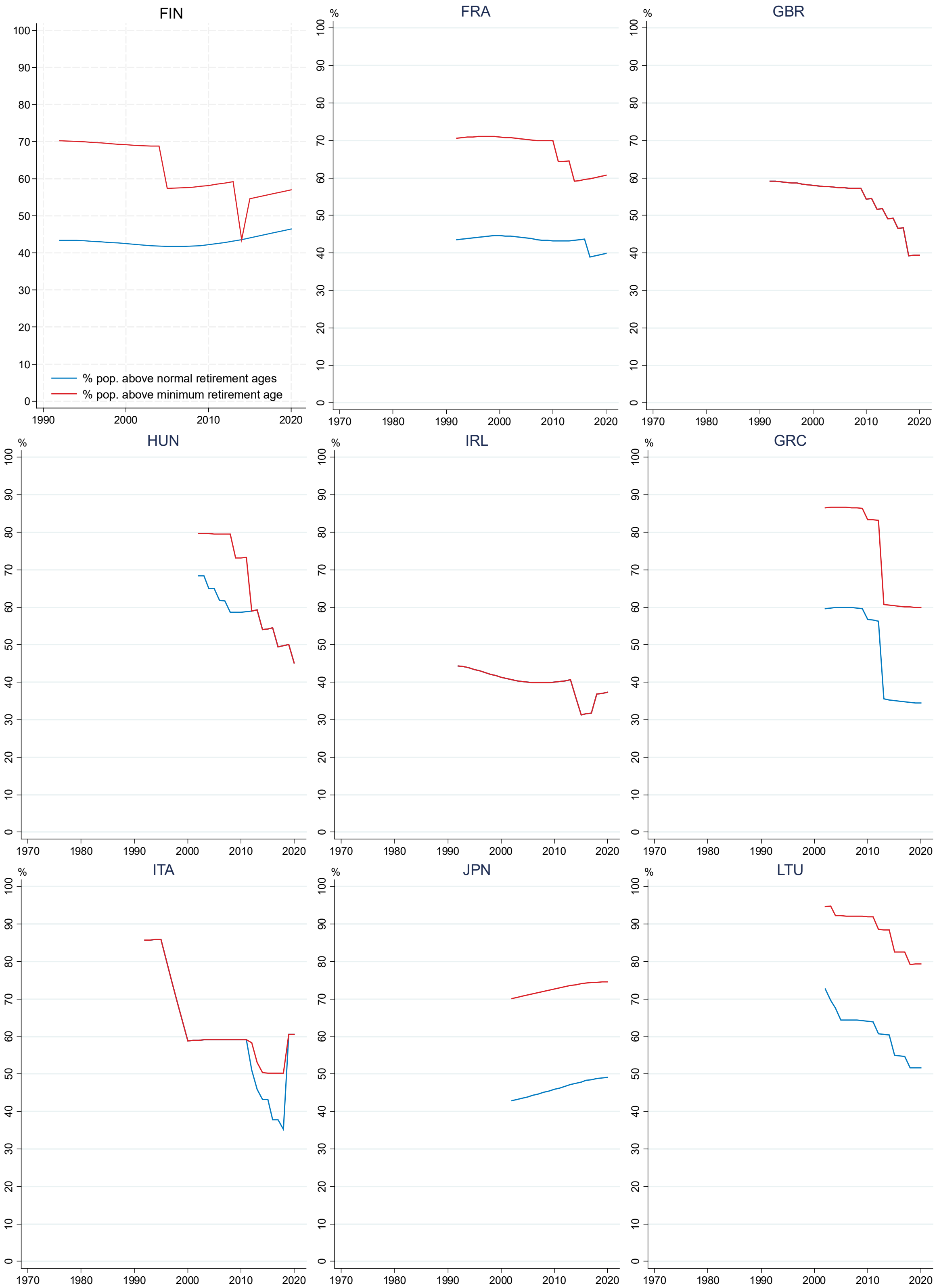

FIN
FRA
GBR
GRC
HUN
IRL
ITA
JPN
LTU
Normal retirement age
Normal retirement age, men
Normal retirement age, women
Minimum retirement age, men
Minimum retirement age, women
50
55
60
65
70
75
1990
2000
2010
2020

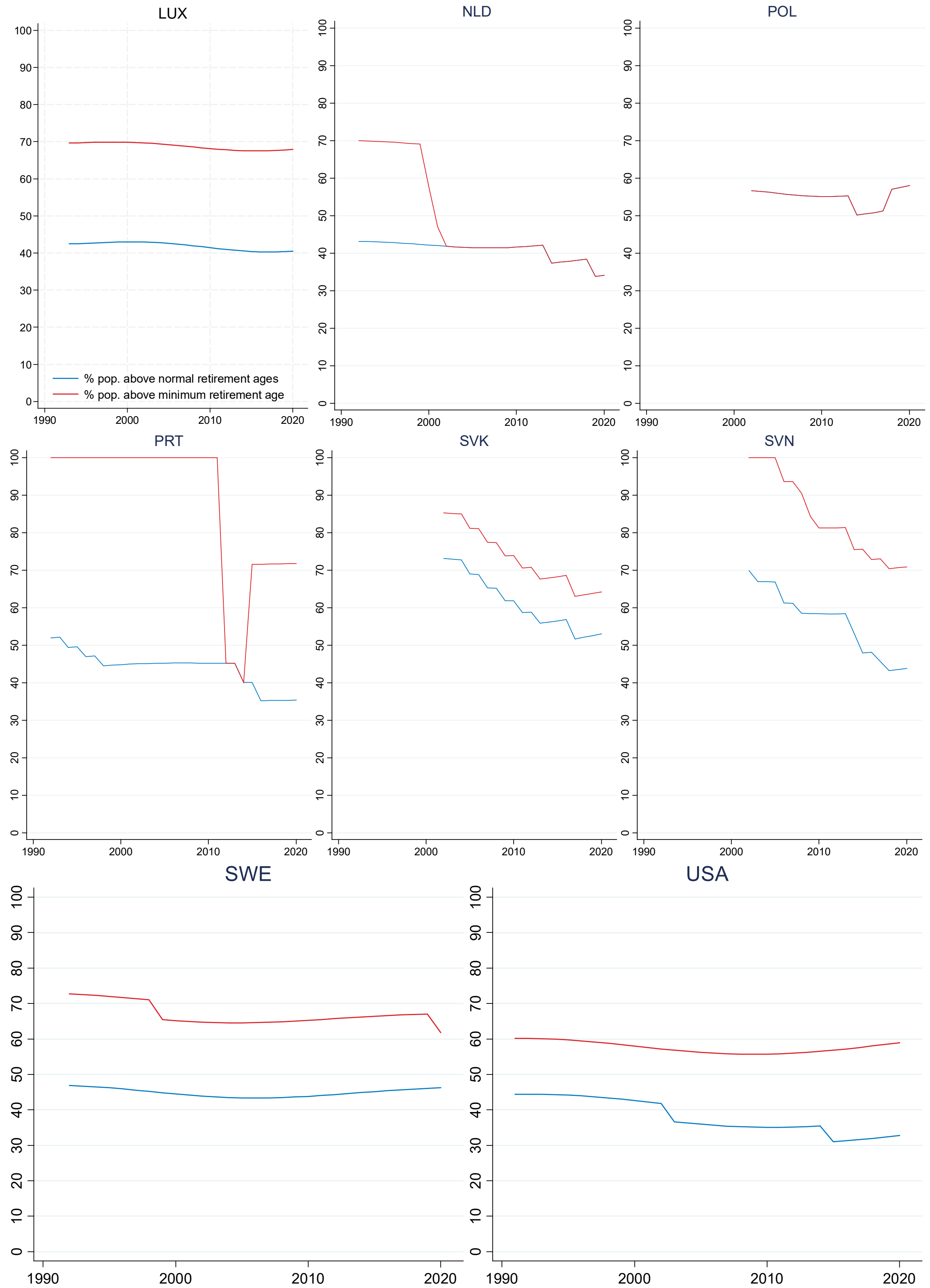


Source: (Geppert et al., 2019[13]); and author's calculations based on OECD Pension at a glance database.

Figure A A.10. Shares of population above the retirement ages




FIN
FRA
GBR
HUN
IRL
GRC
ITA
JPN
LTU
%
% pop. above normal retirement ages
% pop. above minimum retirement age



Source: Author's calculations based on (Geppert et al., 2019[13]); and OECD Pension at a glance database.

Annex A. Generalised logit function

The generalised logistic function was proposed by (Richards, 1959[17]) and is shown in Equation (14):

$$f(x) = A + \frac{K - A}{(C + Q \cdot e^{\boldsymbol{B} \cdot \boldsymbol{x}})^R} \tag{14}$$

where the parameters A, C, K and Q determine the left and right asymptotes, the vector $\boldsymbol{B}$ determines the impact of changes in the set of variables $\boldsymbol{x}$, and R, which is assumed greater than zero, determines the point at which the slope of the curve is the highest. The logit function is a particular case for $A = 0, C = 1, K = 1, Q = 1, R = 1$. To maintain the support of the old age employment rate bounded between 0 and 1, the following values were chosen for the parameters of the Richards' curve: $A = 0, C = 1, K = 1, Q = 1$. While the parameter R is to be estimated.

Consequently, the regression function becomes:

$$ER_{c,t} = \frac{1}{\left(1 + e^{-(\alpha_c + \alpha_{DC} \cdot DC_{c,t} + \alpha_r \cdot PSR_{c,s,t} + \sum_j \alpha_j X_{j,c,t})}\right)^R} + \varepsilon_{c,t}$$

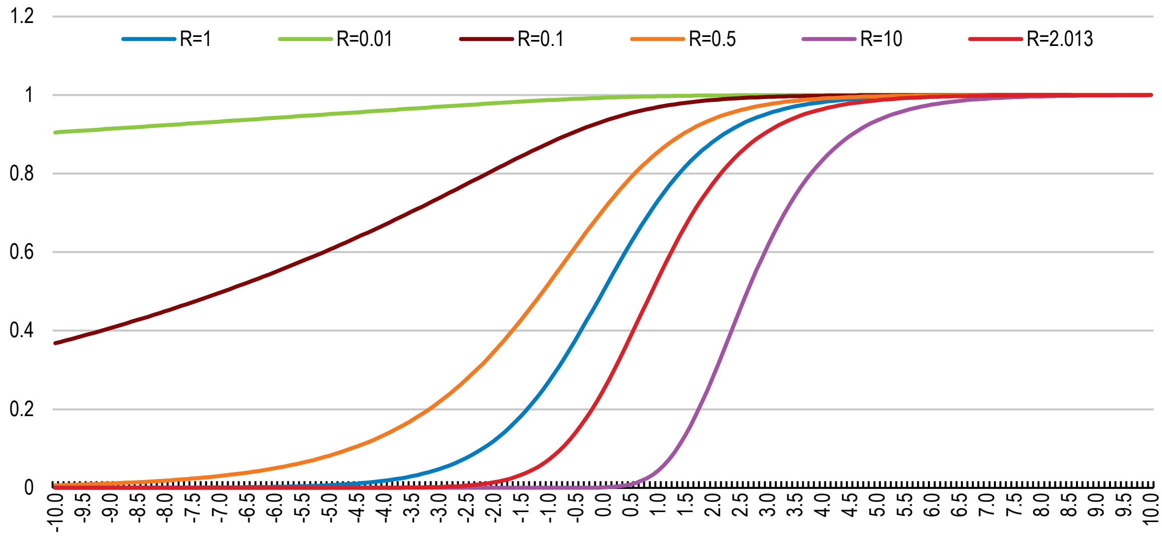
$$\Delta ER_{c,t} = \beta_c + \beta_t + \pi \cdot \hat{\varepsilon}_{c,t} + \beta_{DC} \cdot \Delta DC_{c,t} + \beta_r \cdot \Delta PSR_{c,s,t} + \sum_j \beta_j \cdot \Delta X_{j,c,t} + \eta_{c,t} \tag{15}$$

Adopting this functional form, the marginal effect of an increase in the normal retirement rate that corresponds to a one percentage point reduction in the share of population above the retirement age has an effect equal to

$$\frac{\partial ER_{c,t}}{\partial PSR_{c,t}} = \alpha_r \cdot R \cdot ER\left(1 - ER^{\frac{1}{R}}\right)$$

This is maximum when the employment rate is $ER^* = \left(\frac{R}{1+R}\right)^R$ and it gradually decreases around this value. The value of ER^* ranges between e and 1, depending on de value of R. Figure A A.1 shows the effect on the shape of the generalised logistic function varying the parameter R.

Figure A A.1. Effect of varying parameter R



Note The graph compares the shape of the generalised logit function for some selected values of R, among which the value $R = 1$, that is the ordinary logit function and $R = 2.013$, which is the estimated value of R in model (7) in Table A C.2.
Source: Author's calculations.

References

Atalay, K. and G. Barrett (2015), "The impact of age pension eligibility age on retirement and program dependence: Evidence from an Australian experiment", *Review of Economics and Statistics*, Vol. 97/1, pp. 71-87. [39]

Balcilar, M., R. Gupta and Z. Shah (2011), "An in-sample and out-of-sample empirical investigation of the nonlinearity in house prices of South Africa", *Economic Modelling*, Vol. 28/3, pp. 891-899, https://doi.org/10.1016/j.econmod.2010.11.005. [24]

Barnett, W. et al. (eds.) (1997), *Nonlinear Error-Correction Models for Interest Rates in the Netherlands*. [20]

Béreau, S., A. Villavicencio and V. Mignon (2010), "Nonlinear adjustment of the real exchange rate towards its equilibrium value: A panel smooth transition error correction modelling", *Economic Modelling*, Vol. 27/1, pp. 404-416, https://doi.org/10.1016/j.econmod.2009.10.007. [22]

Blöndal, S. and S. Scarpetta (1999), "The retirement decision in OECD countries", No. 202, OECD, https://www.oecd-ilibrary.org/economics/the-retirement-decision-in-oecd-countries_565174210530?crawler=true (accessed on 8 February 2021). [9]

Borghans, L., A. Gielen and E. Luttmer (2014), "Social Support Substitution and the Earnings Rebound: Evidence from a Regression Discontinuity in Disability Insurance Reform", *American Economic Journal: Economic Policy*, Vol. 6/4, pp. 34-70, https://doi.org/10.1257/pol.6.4.34. [41]

Börsch-Supan, A. and H. Jürges (2012), "Disability, Pension Reform and Early Retirement in Germany", in Wise, D. (ed.), *Social Security Programs and Retirement around the World: Historical Trends in Mortality and Health, Employment, and Disability Insurance Participation and Reforms*, University of Chicago Press, http://www.nber.org/books/wise11-1 (accessed on 6 January 2023). [30]

Chikhi, M. and C. Diebolt (2022), "Testing the weak form efficiency of the French ETF market with the LSTAR-ANLSTGARCH approach using a semiparametric estimation", *Eastern Journal of European Studies*, Vol. 13/1, pp. 228-253, https://doi.org/10.47743/ejes-2022-0111. [26]

Cribb, J. and C. Emmerson (2018), "Can't wait to get my pension: the effect of raising the female early retirement age on income, poverty and deprivation", *Journal of Pension Economics and Finance*, Vol. 18/3, pp. 450-472, https://doi.org/10.1017/s1474747218000057. [45]

Duggan, M., P. Singleton and J. Song (2007), “Aching to retire? The rise in the full retirement age and its impact on the social security disability rolls”, *Journal of Public Economics*, Vol. 91/7-8, pp. 1327-1350, https://doi.org/10.1016/j.jpubeco.2006.12.007. [38]

Duval, R. (2004), “Retirement Behaviour in OECD Countries: Impact of Old-Age Pension Schemes and other Social Transfer Programmes”, *OECD Economic Studies*, https://doi.org/10.1787/eco_studies-v2003-art8-en. [29]

Dwyer, G., P. Locke and W. Yu (1996), “Index Arbitrage and Nonlinear dynamics Between the S&P 500 Futures and Cash”, *Review of Financial Studies*, Vol. 9/1, pp. 301-332, https://doi.org/10.1093/rfs/9.1.301. [19]

Ebbinghaus, B. (2006), *Reforming Early Retirement in Europe, Japan and the USA*, Oxford Univ. Press. [28]

Égert, B. and P. Gal (2017), “The quantification of structural reforms in OECD countries : A new framework”, No. 1354, OECD Economics Department Working Papers, https://www.oecd-ilibrary.org/economics/the-quantification-of-structural-reforms-in-oecd-countries_2d887027-en (accessed on 10 November 2022). [11]

Etgeton, S. (2018), “The effect of pension reforms on old-age income inequality”, *Labour Economics*, Vol. 53, pp. 146-161, https://doi.org/10.1016/j.labeco.2018.05.006. [5]

Fehr, H., M. Kallweit and F. Kindermann (2012), “Pension reform with variable retirement age: a simulation analysis for Germany”, *Journal of Pension Economics and Finance*, Vol. 11/3, pp. 389-417, https://doi.org/10.1017/s1474747211000643. [2]

Fodor, J., O. Roehn and H. Hwang (2022), “Determinants of labour market exit of older workers in the Slovak Republic”, *OECD Economics Department Working Papers*, No. 1700, OECD Publishing, Paris, https://doi.org/10.1787/2161918e-en. [7]

Gal, P. and A. Theising (2015), “The macroeconomic impact of structural policies on labour market outcomes in OECD countries: A reassessment”, *OECD Economics Department Working Papers*, No. 1271, OECD Publishing, Paris, https://doi.org/10.1787/5jrqc6t8ktjf-en. [10]

Geppert, C. et al. (2019), “Labour supply of older people in advanced economies: the impact of changes to statutory retirement ages”, *Economics Department Working Papers*, No. 1554, OECD, https://www.oecd-ilibrary.org/economics/labour-supply-of-older-people-in-advance-economies-the-impact-of-changes-to-statutory-retirement-ages_b9f8d292-en (accessed on 27 August 2021). [13]

Geyer, J. and C. Welteke (2019), “Closing Routes to Retirement for Women”, *Journal of Human Resources*, Vol. 56/1, pp. 311-341, https://doi.org/10.3368/jhr.56.1.0717-8947r2. [40]

Grigoli, F., Z. Koczan and P. Tapalova (2018), “Drivers of Labor Force Participation in Advanced Economies: Macro and Micro Evidence”, *IMF Working Papers*, No. 18/150, IMF, https://www.imf.org/en/Publications/WP/Issues/2018/06/25/Drivers-of-Labor-Force-Participation-in-Advanced-Economies-Macro-and-Micro-Evidence-45977 (accessed on 10 November 2022). [12]

Hambuckers, J. and T. Kneib (2021), “Smooth-Transition Regression Models for Non-Stationary Extremes”, *Journal of Financial Econometrics*, Vol. 21/2, pp. 445-484, https://doi.org/10.1093/jjfinec/nbab005. [25]

Hanel, B. and R. Riphahn (2012), “The timing of retirement — New evidence from Swiss female workers”, *Labour Economics*, Vol. 19/5, pp. 718-728, https://doi.org/10.1016/j.labeco.2012.05.013. [3]

Kohli, M. et al. (eds.) (1991), *Time for retirement: Comparative studies of early exit from the labor force*, Cambridge University press. [16]

Kuitto, K. and J. Helmdag (2021), “Extending working lives: How policies shape retirement and labour market participation of older workers”, *Social Policy & Administration*, Vol. 55/3, pp. 423-439, https://doi.org/10.1111/spol.12717. [44]

Kyyrä, T. (2014), “Early Retirement Policy in the Presence of Competing Exit Pathways: Evidence from Pension Reforms in Finland”, *Economica*, Vol. 82/325, pp. 46-78, https://doi.org/10.1111/ecca.12100. [32]

Lalive, R. and S. Staubli (2015), “How does raising women’s full retirement age affect labor supply, income, and mortality?”, *NBER working paper, 18660, 17*. [4]

Larsen, M. and P. Pedersen (2008), “Pathways to early retirement in Denmark, 1984-2000”, *International Journal of Manpower*, Vol. 29/5, pp. 384-409, https://doi.org/10.1108/01437720810888544. [33]

Manoli, D. and A. Weber (2016), *The Effects of the Early Retirement Age on Retirement Decisions*, National Bureau of Economic Research, Cambridge, MA, https://doi.org/10.3386/w22561. [43]

Mastrobuoni, G. (2009), “Labor supply effects of the recent social security benefit cuts: Empirical estimates using cohort discontinuities”, *Journal of Public Economics*, Vol. 93/11-12, pp. 1224-1233, https://doi.org/10.1016/j.jpubeco.2009.07.009. [1]

Maugeri, N. (2010), *Money Illusion and Rational Expectations: New Evidence from Well Known Survey Data*, Università degli studi di Siena, http://repec.deps.unisi.it/quaderni/606.pdf. [23]

Morris, T. (2021), “The unequal burden of retirement reform: Evidence from Australia”, *Economic Inquiry*, Vol. 60/2, pp. 592-619, https://doi.org/10.1111/ecin.13034. [6]

OECD (2023), *Pensions at a Glance 2023: OECD and G20 Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/678055dd-en. [15]

OECD (2021), *Pensions at a Glance 2021: OECD and G20 Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/ca401ebd-en. [14]

OECD (2021), *Pensions at a Glance 2021: OECD and G20 Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/ca401ebd-en. [46]

OECD (2019), *Pension at a glance*. [31]

Richards, F. (1959), “A Flexible Growth Function for Empirical Use”, *Journal of Experimental Botany*, Vol. 10/2, pp. 290-301, https://doi.org/10.1093/jxb/10.2.290. [17]

Riekhoff, A., K. Kuitto and L. Palomäki (2020), “Substitution and spill-overs between early exit pathways in times of extending working lives in Europe”, *International Social Security Review*, Vol. 73/2, pp. 27-50, https://doi.org/10.1111/issr.12237. [35]

Riphahn, R. and R. Schrader (2022), “Reforms of an early retirement pathway in Germany and their labor market effects”, *Journal of Pension Economics and Finance*, Vol. 22/3, pp. 304-330, https://doi.org/10.1017/s1474747221000421. [34]

Staubli, S. (2011), “The impact of stricter criteria for disability insurance on labor force participation”, *Journal of Public Economics*, Vol. 95/9-10, pp. 1223-1235, https://doi.org/10.1016/j.jpubeco.2011.05.008. [42]

Staubli, S. and J. Zweimüller (2013), “Does raising the early retirement age increase employment of older workers?”, *Journal of Public Economics*, Vol. 108, pp. 17-32, https://doi.org/10.1016/j.jpubeco.2013.09.003. [37]

Turner, D. and H. Morgavi (2021), “Revisiting the effect of statutory pension ages on the Participation Rate”, *Public Sector Economics*, Vol. 45/2, pp. 257-282, https://doi.org/10.3326/PSE.45.2.4. [8]

Turner, D. and H. Morgavi (2020), “Revisiting the effect of statutory pension ages on the participation rate”*, Economics Department Working Papers*, No. 1616, OECD, https://www.oecd-ilibrary.org/economics/revisiting-the-effect-of-statutory-pension-ages-on-the-participation-rate_3f430e2b-en (accessed on 27 August 2021). [27]

Venetis, I., I. Paya and D. Peel (2003), “Re-examination of the predictability of economic activity using the yield spread: a nonlinear approach”, *International Review of Economics & Finance*, Vol. 12/2, pp. 187-206, https://doi.org/10.1016/s1059-0560(02)00147-8. [21]

Watson, J. (ed.) (1993), *Modeling Nonlinearity over the Business Cycle*, University of Chicago Press, http://www.nber.org/chapters/c7196. [18]

Yashiro, N. et al. (2021), “Technology, labour market institutions and early retirement: evidence from Finland”*, OECD Economics Department Working Papers*, No. 1659, OECD Publishing, Paris, https://doi.org/10.1787/3ea0c49b-en. [36]